May 16, 2018
NCST Advisory
Committee Meeting

NCST Technical Investigation of Hurricane Maria's Impacts on Puerto Rico:

Overview of Preliminary Observations and Investigation Goals

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NIST

Long History of Disaster and Failure Studies at NIST

Earthquakes

San Fernando, CA (1971)

Mexico City, Mexico (1985)

Loma Prieta, CA (1989)

Northridge, CA (1994)

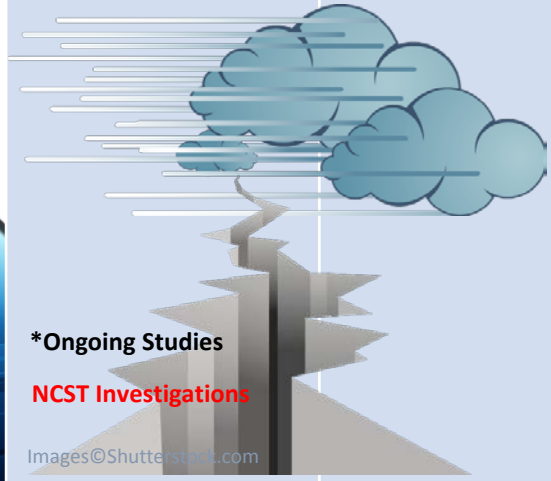
Kobe, Japan (1995)

Kocaeli, Turkey (1999)

Maule, Chile (2010)

Christchurch, NZ (2011)

***Puebla, Mexico (2017)**



***Ongoing Studies**

NCST Investigations

Hurricanes

Camille, MS/LA (1969)

Alicia, Galveston, TX (1983)

Hugo, SC (1989)

Andrew, FL (1992)

Fran, NC (1996)

Mitch and Georges, LAC (1998)

Katrina and Rita (2005)

***Matthew, NC (2016)**

***Harvey, TX (2017)**

***Maria, PR (2017)**

Construction & Building

Skyline Plaza Apartments, Bailey's Crossroads, VA (1973)

Willow Island Cooling Tower, WV (1978)

Kansas City Hyatt Regency, Kansas City, MO (1981)

Riley Road Interchange, East Chicago, IN (1982)

Harbor Cay Condominium, Cocoa Beach, FL (1981)

L'Ambiance Plaza, Hartford, CT (1987)

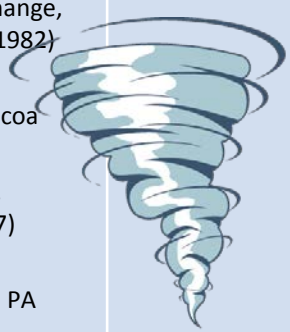
Ashland Oil Tank Collapse, Floreffe, PA (1988)

U.S. Embassy, Moscow, USSR (1987)

Murrah Federal Building, Oklahoma City, OK (1995)

World Trade Center Disaster, New York, NY (2001)

Dallas Cowboys Indoor Practice Facility, May 2009



Tornadoes

Jarrell, TX (1997)

Spencer, SD (1998)

Oklahoma City, OK (1999)

Joplin, MO (2011)

Moore OK (2013)

Fires

DuPont Plaza Hotel, San Juan PR (1986)

First Interstate Bank Building, Los Angeles, CA (1988)

Loma Prieta Earthquake, CA (1989)

Hillhaven Nursing Home (1989)

Pulaski Building, Washington, DC (1990)

Happyland Social Club, Bronx, NY (1990)

Oakland Hills, CA (1991)

Watts St, New York City (1994)

Northridge Earthquake, CA (1994)

Kobe, Japan (1995)

Vandalia St, New York City (1998)

Cherry Road, Washington, DC (1999)

Keokuk, IA (1999)

Houston, TX (2000)

Phoenix, AZ (2001)

Cook County Administration Building Fire (2003)

The Station Nightclub, RI (2003)

Charleston, SC, Sofa Super Store Fire (2007)

Witch Creek & Guejito, CA, WUI Fire (2007)

Amarillo, TX, WUI Fire (2011)

San Francisco, CA (2012)

***Fuse-47, MD (2017)**

Prioritizing DFS Field Activities

engineering laboratory

(1) What is the unique new knowledge that would be potentially gained from this study?

(2) What is the anticipated potential impact on standards, codes and practices?

(3) Do we have sufficient resources (people and funding) to support a study? If there is an existing study in the same hazard area, what is the impact on the current study?

(4) What is a current assessment of how site conditions would affect safety for a field deployment? Would current site conditions affect the timing of the field deployment?

(5) Is there a request for NIST to conduct a study by others (local, state, Federal)? If so, would NIST provide complementary expertise or would NIST have primary expertise?

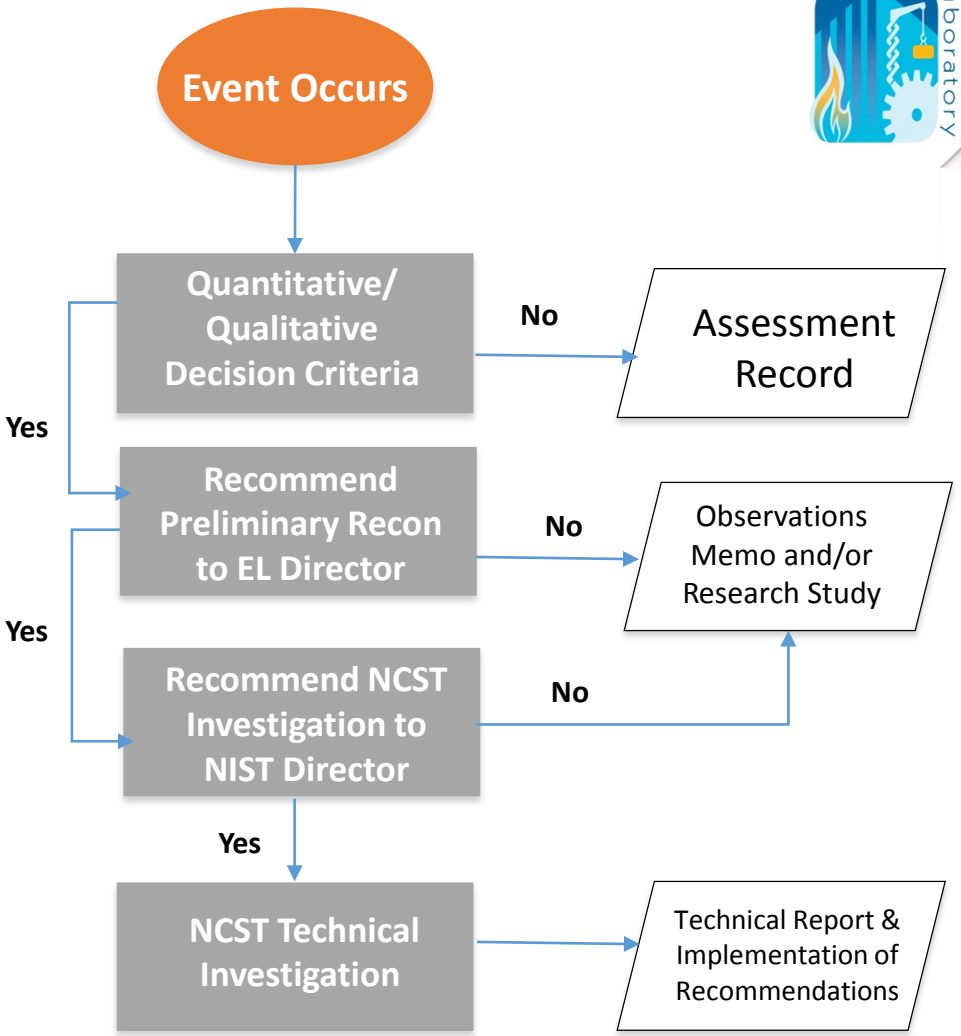
(6) Does NIST have primary authority? If so, would NIST collaborate with other agencies where NIST provides complementary expertise or would NIST have primary authority and/or expertise?

Quantifying Events and Process Flows

1.0 Event Consequence			
	Low	Medium	High
A. Mortality			
Facility context	0	1 to 2	>2
Community context[1]	0 to 3	4 to 9	>10
Regional context[2]	0 to 5	6 to 19	>20
B. Exposed Population			
Facility context	<100	100 to 499	≥500
Community context	<1 000	1 000 to 9 999	≥10 000
Regional context	<100 000	100 000 to 999 999	≥1 000 000
C. Hazard and/or Failure Intensity			
Earthquake	≤ MMI IV	MMI V to VII	≥MMI VIII
Hurricane at Landfall	≤Cat 3	Cat 4	Cat 5
Tornado	≤EF3	EF4	EF5
Coastal Inundation	< 3 ft	3 to 9 ft	≥ 10 ft
Fire Spread in Structures	Fire spread not beyond area of origin	Fire spread throughout a structure	Fire spread beyond structure of origin
Wildland Urban Interface Fire (WUI)	High Forest Service Fire Danger Rating	Very High Forest Service Fire Danger Rating	Extreme Forest Service Fire Danger Rating
Blast	< 99 lbs. TNT-equivalent	100 - 999 lbs. TNT-equivalent	> 1000 lbs. TNT-equivalent
Impact	< 1 x 10^6 ft lb/sec	1 x 10^6 to 1 x 10^7 ft lb/sec	> 1 x 10^7 ft lb/sec

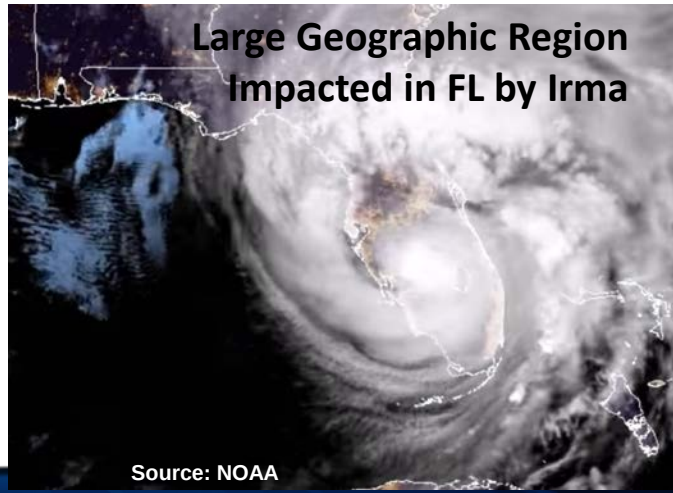
D. Physical Damage[1]			
Failure during Construction or in Service[2]	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
Engineered Building Systems[3]	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
Transportation & Utility Systems[4]	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
Non-Engineered Building Systems	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
Count x Weight:			
Event Consequence Score:			

2.0 Evacuation and Response[5]			
A. Evacuation	Normal evacuation	Moderate evacuation challenges	Severe evacuation challenges
B. Emergency Response	Normal operations	Moderate operational challenges	Severe operational challenges
Count x Weight:			
Evacuation and Response Score:			

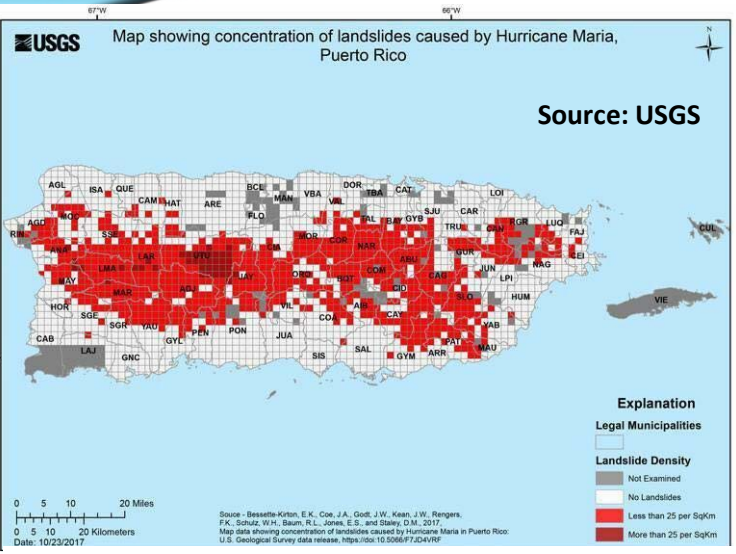


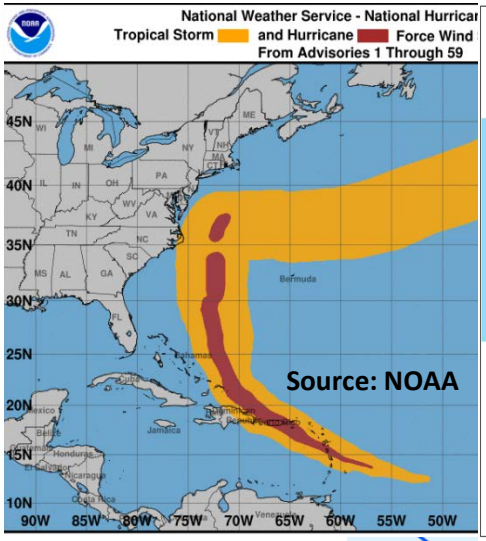
DFS Deploys to Record-Breaking Disaster Season

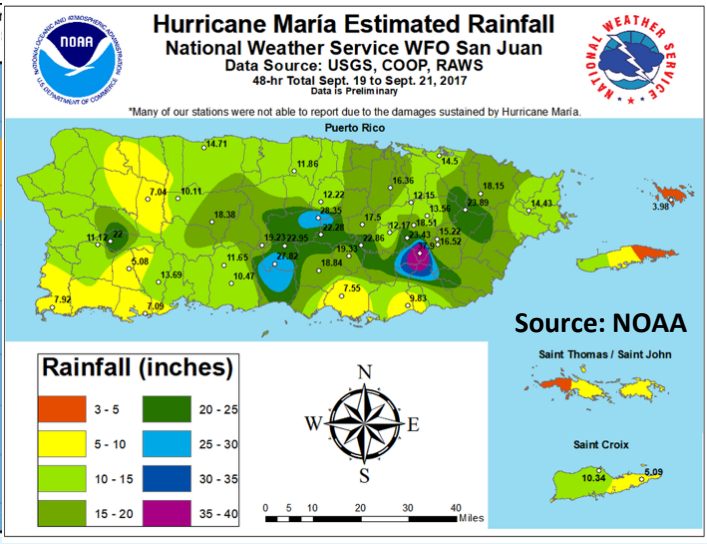
- **Preliminary Reconnaissance Deployments**
  - December 2017 Hurricane Maria (Puerto Rico)
  - October 2017 Northern California WUI Fires (Santa Rosa, CA)
  - September 2017 Hurricane Irma (Florida Keys and South Florida)
  - August 2017 Hurricane Harvey (Rockport and West Houston, TX)
- **Ongoing Non-NCST Studies**
  - FEMA collaboration of 2017 Hurricane Harvey (Rockport/Houston, TX)
  - CoE collaboration of 2016 Hurricane Matthew (Lumberton, NC)
  - Fuse-47 Apartment Complex Fire (College Park, MD)
- **NCST Established**
  - Director approves investigation of 2017 Hurricane Maria (Puerto Rico)



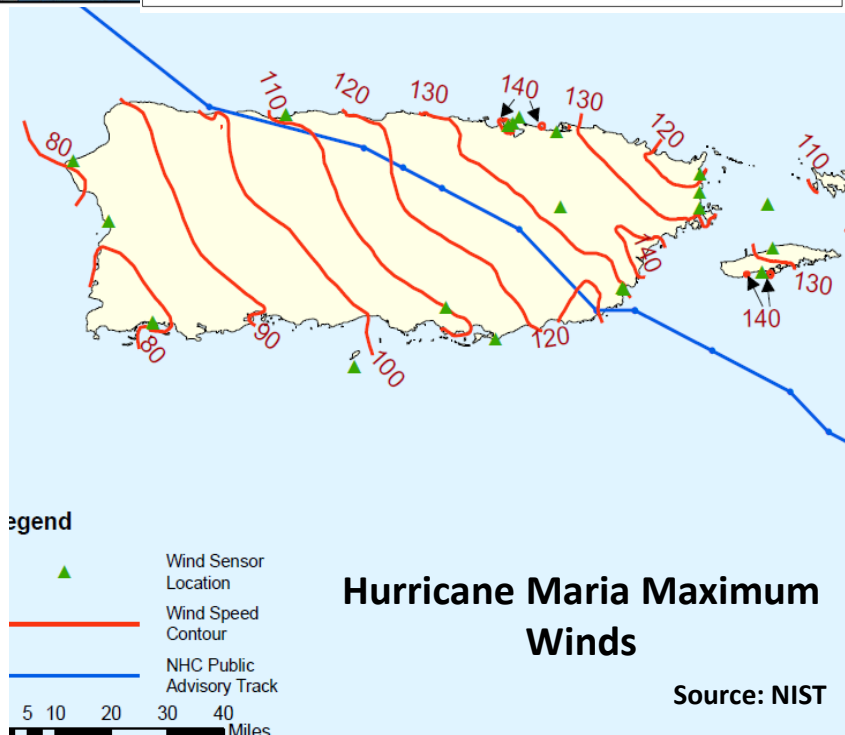
Hurricane Maria's Hazards in Puerto Rico







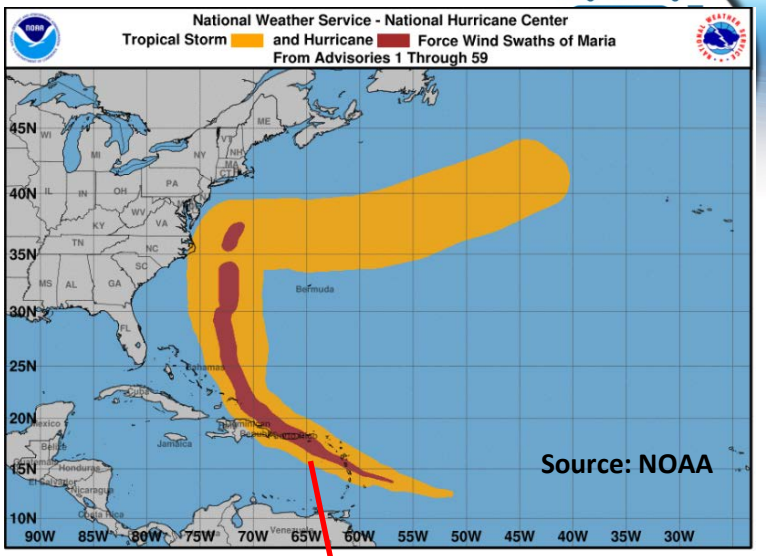
- **Winds:** Maria made landfall as a strong Cat 4 storm; the storm tracked diagonally across PR, with hurricane-force winds extending over the entire Commonwealth (~3.4 million people); maximum estimated peak wind gusts were 140+ mph (National Hurricane Center, NIST)
- **Storm Surge:** Surge produced inundation up to 9 ft along the southeastern coast of PR (National Hurricane Center)
- **Rain:** Extensive rainfall, with max 38" (NHC)
- **Landslides:** Many hundreds of landslides occurred throughout mountainous regions (USGS)

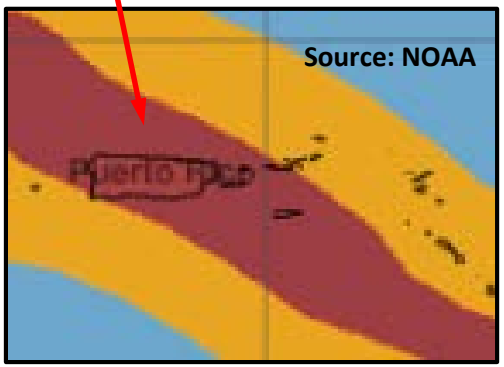


Hurricane Maria's Hazards in Puerto Rico

engineering

- TS Maria formed west of the Lesser Antilles on Sept 16*.
- Maria intensified to Category 5 status in two days, with sustained winds of 175 mph*.
- Hurricane Maria made landfall in Puerto Rico on Sept. 20 as a strong Category 4 storm*.
- Most intense hurricane to strike Puerto Rico since the Category 5 Okeechobee Hurricane of 1928**.
- Maria impacted Puerto Rico just 13 days after Hurricane Irma, which brought tropical storm-force winds to the entire Commonwealth***.





*Source: https://www.nhc.noaa.gov/archive/2017/MARIA.shtml; http://www.weather.gov/sju/maria2017
**Source: https://www.nhc.noaa.gov/outreach/history/#okee
***Source: https://www.nhc.noaa.gov/archive/2017/IRMA.shtml

C. Hazard and/or Failure Intensity			
Earthquake	≤ MMI IV	MMI V to VII	≥MMI VIII
Hurricane at Landfall	≤Cat 3	Cat 4	Cat 5

Population Exposure to Hurricane Maria's Hazard

- **Exposed Population:** The entire Commonwealth of Puerto Rico was exposed to Maria (total population is approximately 3.3 million).
- **Mortality:** As of December 9, 2017, 64 deaths** in Puerto Rico were attributed to Hurricane Maria.
  - 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.
  - The Governor of Puerto Rico announced a recount and review of certified deaths; George Washington's University's School of Public Health awarded the project on assessing excess deaths in PR related to Hurricane Maria.***

*Source: https://www.census.gov/quickfacts/PR
**Source: https://www.nytimes.com/interactive/2017/12/08/us/puerto-rico-hurricane-maria-death-toll.html
***Source: http://prfaa.pr.gov/governor-rossello-announces-the-george-washington-university-will-lead-efforts-to-review-the-death-count-associated-with-hurricane-maria-in-puerto-rico/

A. Mortality			
Facility context	0	1 to 2	>2
Community context[1]	0 to 3	4 to 9	>10
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B. Exposed Population			
Facility context	<100	100 to 499	≥500
Community context	<1 000	1 000 to 9 999	≥10 000
Regional context	<100 000	100 000 to 999 999	≥1 000 000

Hurricane Maria Preliminary Reconnaissance Team

Team 1 (NIST Deployed Team Member, embedded with FEMA)

- Marc Levitan (Structural Engineering)

Team 2 (NIST Deployed Team, shadowing FEMA)

- Erica Kuligowski (Sociology, Emergency Communication)
- Judy Mitrani-Reiser (Engineering, Resilience)
- Carmen Martinez (IT, Logistics)

Source: NIST


Source: NIST


Source: NIST

DFS uses NIST's Community Resilience Planning Guide (CRPG) to Structure Field Activities

Identify Important Social Dimensions to Prioritize in Maria Deployment

- **Family/Kinship**
- **Education**
- **Health**
- **Government**
- **Economy**
- **Media**
- **Community-based Organizations**

DFS Collects Data Across Community Scales

Economy

MEP Center

↓

Chamber of Commerce

↓

Economy RSF

Health

Regional Hospitals

↓

Department of Health

↓

HSS RSF

Emergency Management

Zone EM Directors

↓

PREMA

↓

FEMA

Education

Regional Directors

↓

Department of Education

↓

HSS RSF

Other Sectors

Weather Service

Transportation & Public Works

Power

Aqueducts & Sewer Authority

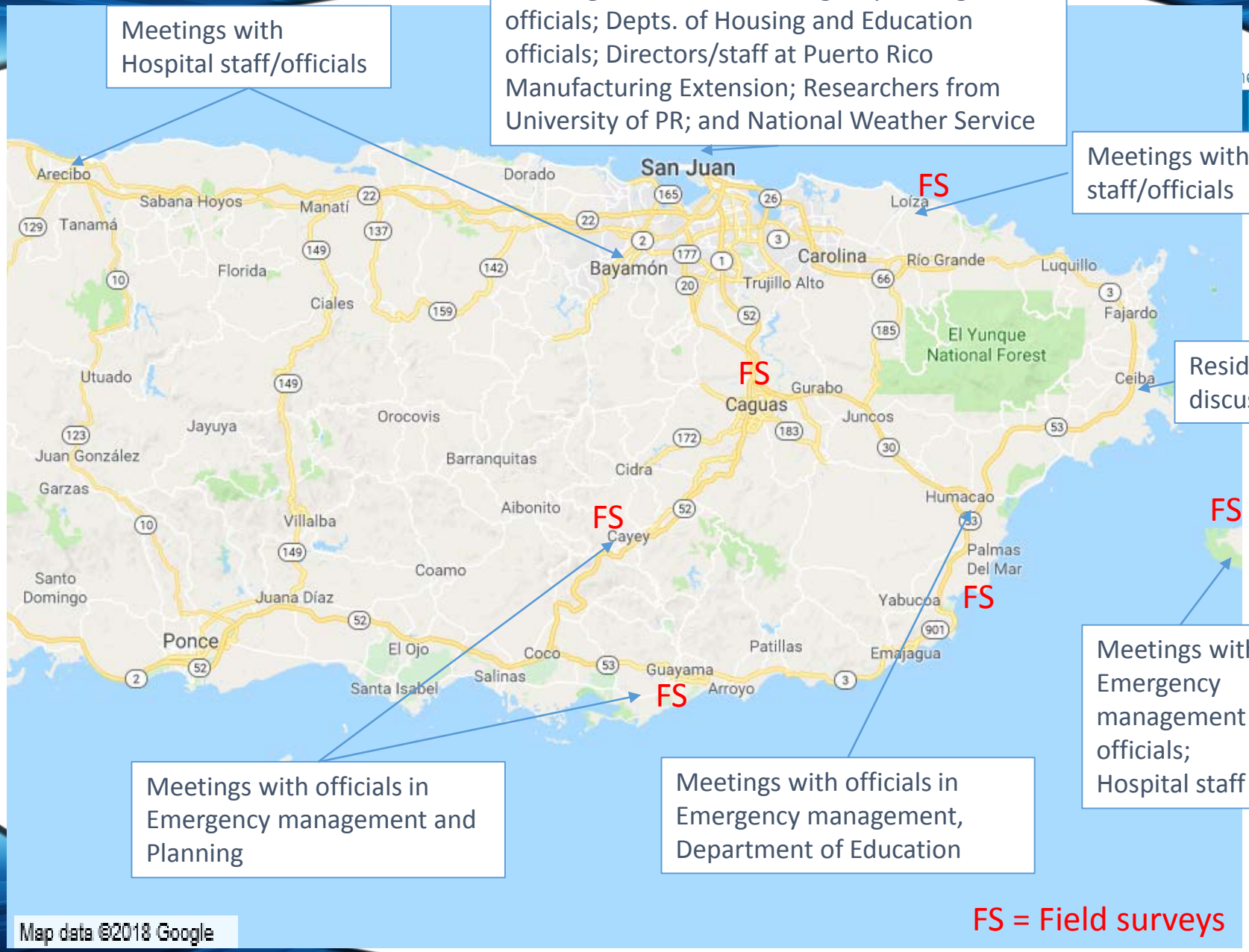
PROMESA

Academic Partners

Structural Engineering Faculty from UPR Mayaguez

Social Science Faculty from UPR Rio Piedras

Social Science Faculty from Michigan State University in the field


Meetings with Hospital staff/officials
Meetings with FEMA; Emergency management officials; Depts. of Housing and Education officials; Directors/staff at Puerto Rico Manufacturing Extension; Researchers from University of PR; and National Weather Service
Meetings with school staff/officials
Resident discussions
Meetings with Emergency management officials; Hospital staff
Meetings with officials in Emergency management and Planning
Meetings with officials in Emergency management, Department of Education
FS
FS = Field surveys
Arecibo
Sabana Hoyos
Manatí
Tanamá
Florida
Ciales
Dorado
San Juan
Bayamón
Loíza
Carolina
Río Grande
Luquillo
Trujillo Alto
Fajardo
El Yunque National Forest
Ceiba
Utuado
Gurabo
Caguas
Juncos
Jayuya
Orocovis
Juan González
Barranquitas
Cidra
Garzas
Aibonito
Humacao
Villalba
Cayey
Palmas Del Mar
Santo Domingo
Coamo
Juana Díaz
Yabucoa
Ponce
El Ojo
Coco
Patillas
Emajagua
Salinas
Guayama
Santa Isabel
Arroyo
Map data ©2018 Google

Building Damage Disrupts Daily Functions

Engineered Buildings:

- Minimal *structural* damage caused by wind hazards to reinforced-concrete and concrete- block buildings with concrete roofs (common construction)
- However, some roof failures, extensive wind damage to metal building systems, and wind damage to rooftop solar panels
- Many buildings with good structural performance still suffered *extensive nonstructural damage and loss of function* due to rainwater penetration of the building envelope

Non-engineered Buildings:

- Severe physical damage and loss of function

Building Damage Disrupts Daily Functions

D. Physical Damage[3]			
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Infrastructure Failures Challenge Emergency Response

Electric Power:

- Complete electrical outage across PR; cascading effects to other lifelines
- Extensive damage to generation, transmission and distribution systems

Communications:

- Near complete loss of digital communications across PR
- Extensive damage to tower- and building-mounted cellular equipment; damage to “hundreds of miles” of fiber optic cable (source: AT&T)

Infrastructure Failures Challenge Emergency Response

Emergency Response:

- Communication challenges between emergency officials, critical facilities, shelters, and with the public for extended periods of time
- Reliance on less efficient communication techniques (e.g., runners) used; redundancy gaps (e.g., few ham radios); overwhelming reliance on media

2.0 Evacuation and Response[7]			
A. Evacuation	Normal evacuation	Moderate evacuation challenges	Severe evacuation challenges
B. Emergency Response	Normal operations	Moderate operational challenges	Severe operational challenges
Count x Weight:	0 x 1 = 0	0 x 3 = 0	2 x 5 = 10
Evacuation and Response Score:	**10/2 = 5.0**		

Transportation & Utility Systems[6]	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function

NIST Director Establishes NCST

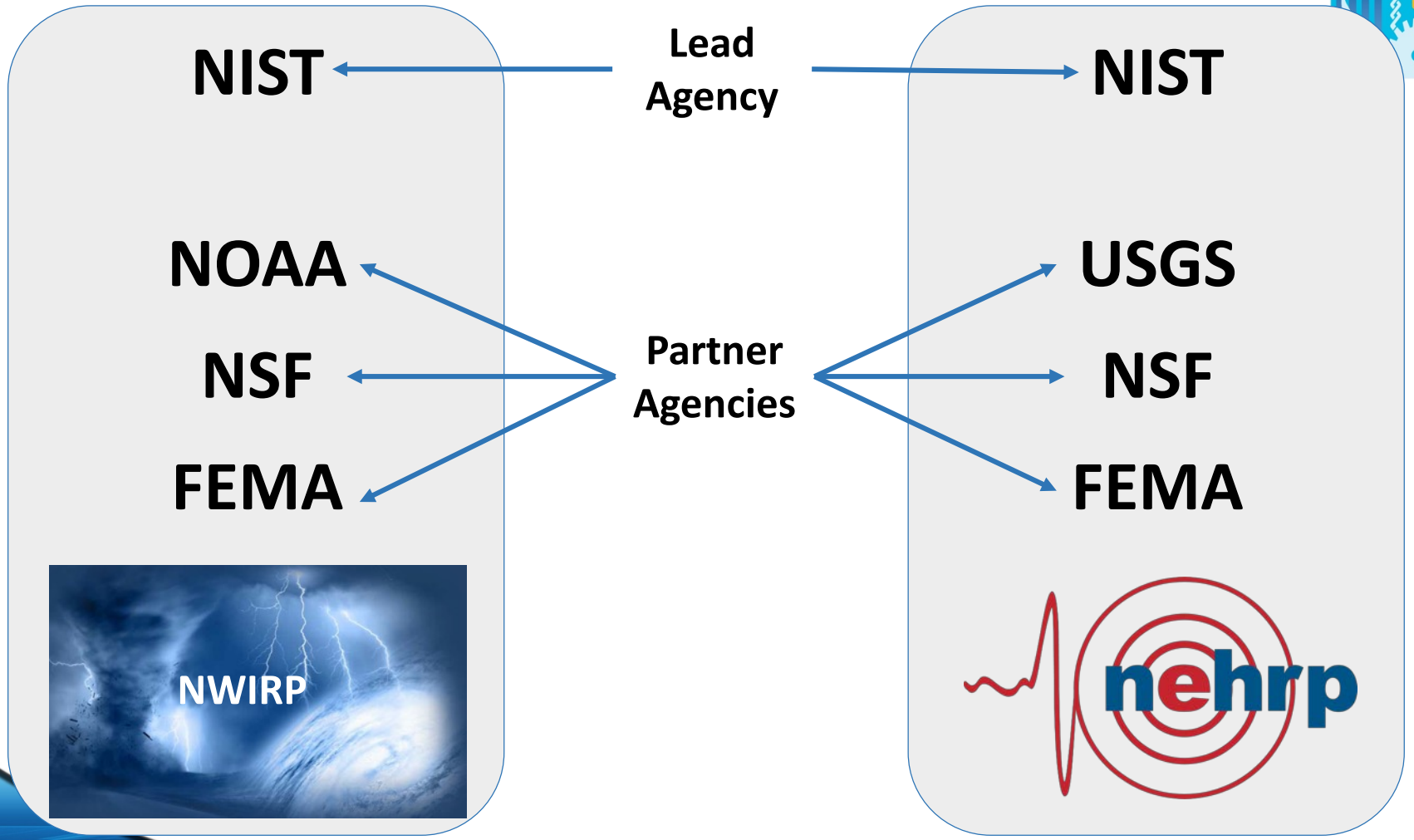
The NIST Director established a Team under the National Construction Safety Team (NCST) Act on February 21, 2018 to conduct a technical investigation of the effects of Hurricane Maria on the U.S. territory of Puerto Rico and characterize:

(1) *the wind environment and technical conditions associated with deaths and injuries;*

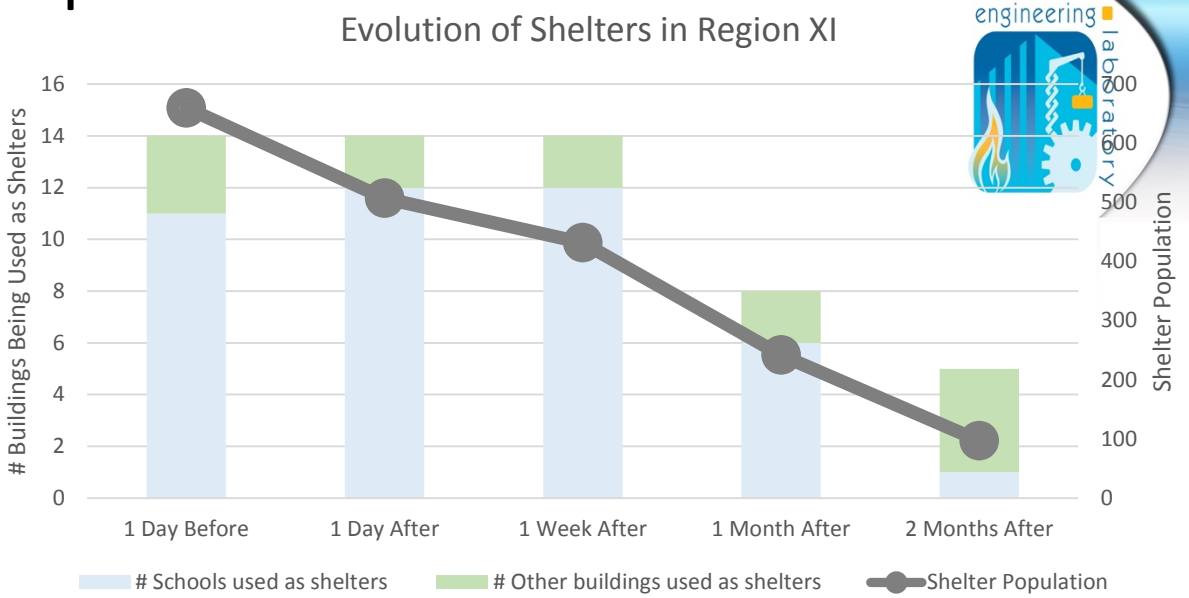
(2) *the performance of representative critical buildings, and designated safe areas in those buildings, including their dependence on lifelines; and*

(3) *the performance of emergency communications systems and the public's response to such communications.*

NIST Leads National Hazards Statutory Programs



Maria's Negative Impacts on Critical Social Functions



Education/schools:

- Shelter populations inhabiting schools months after the event, potentially delaying access to education
- Power losses/generator failures also delayed/disrupted education

Healthcare:

- Non-structural building damage/generator failures impacted delivery of healthcare
- Patients in multiple facilities had to be evacuated

Business and Supply Chain:

- Business closure data collected by NIST MEP Center show that food sector had largest impact
- Main reason for closures: power loss, building envelope damage, and road closures

Source: NIST

Questions?

Standardizing Disaster and Failure Studies

Statutory Arm

- Evaluate hazard events and failures against statutory criteria
- Federal Advisory Committee (NCSTAC)
- Field studies authorities
- Coordinate with agencies, academics, and others

Procedures Arm

- Field and safety protocols
- Human subjects (IRB, PRA)
- Equipment - data collection and personnel safety
- Data preservation
- IT security
- Media releases

Research Arm

- Disaster metrology
- Collaborate across NIST
- Coordinate with
- NIST CR CoE
- NIST grant awardees
- Federal agencies
- Research centers
- Outreach/committee work