Special Topic Highlight: Disaster Resilience

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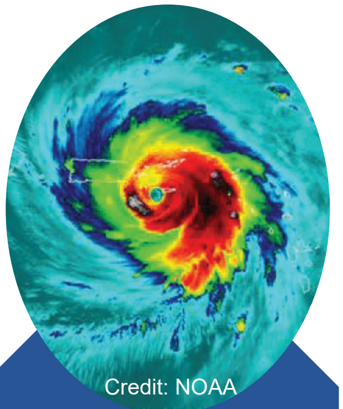
Engineering Laboratory

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

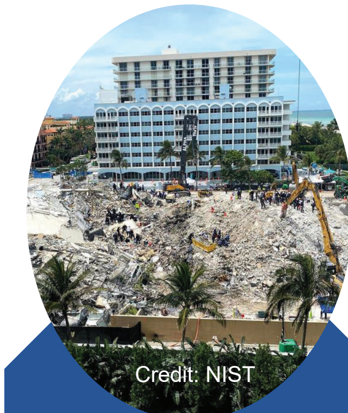
October 29, 2024

Engineering Lab Programmatic Goals


Credit: NOAA

Statutory Programs:

NEHRP
NWIRP
NCST


Credit: NIST

Disaster-resilient Buildings, Infrastructure, and Communities

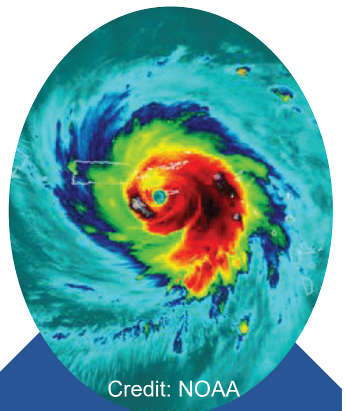

Credit: Beamie Young/NIST

Building Energy and Environment


Credit: NIST

Advanced Manufacturing, Automation, and Autonomous Systems

Disaster Resilience Goals



Statutory Programs:

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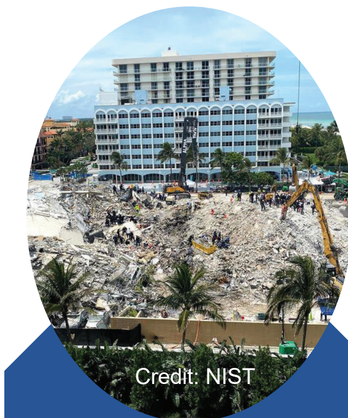

Disaster-resilient Buildings, Infrastructure, and Communities

Objective: **To reduce the risk and enhance the resilience of buildings, infrastructure, and communities to natural and manmade hazards through advances in measurement science**

- Community Resilience
- Earthquake Risk Reduction
- Engineered Materials
- Fire Risk Reduction – Buildings
- Fire Risk Reduction – Communities
- Structural Performance Under Multi-hazards
- Disaster and Failure Studies

Disaster Investigations

Mr. Jason Averill
Deputy Director, Engineering Laboratory

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Disaster Investigations

NIST

Earthquakes

1971

San Fernando, CA

Mexico City, Mexico
Loma Prieta, CA
Northridge, CA
Kobe, Japan
Kocaeli, Turkey

Maule, Chile
Christchurch, NZ

***Gaziantep, Türkiye**

2023

***Ongoing Studies**
● NCST Investigations

Hurricanes

1969

Camille, MS/LA

Alicia, Galveston, TX
Hugo, SC
Andrew, FL
Fran, NC
Mitch and Georges, LAC

Katrina and Rita, LA

***Matthew & Florence, NC**
Harvey, TX
● ***Maria, PR**

***Fiona, PR**
***Ian, FL**

2022

Construction & Building

1973

Skyline Plaza Apartments, VA
Willow Island Cooling Tower, WV
Kansas City Hyatt Regency, MO
Harbor Cay Condominium, FL
Riley Road Interchange, IN
L'Ambiance Plaza, CT
U.S. Embassy, Moscow, USSR
Ashland Oil Tank Collapse, PA
Murrah Federal Building, OK

● **World Trade Center Disaster, NY**

Cowboys Practice Facility, TX

● ***Champlain Towers South, FL**

2021

Tornadoes

1997

Jarrell, TX
Spencer, SD
Oklahoma City, OK

● **Joplin, MO**
Moore OK

2013

Fires

1986 DuPont Plaza Hotel, PR
First Interstate Bank Bldg, CA
Loma Prieta Earthquake, CA
Hillhaven Nursing Home
Pulaski Bldg, DC
Happyland Social Club, NY
Oakland Hills, CA
Watts St, NY
Northridge Earthquake, CA
Kobe, Japan
Vandalia St, NY
Cherry Road, DC
Keokuk, IA
Houston, TX
Phoenix, AZ
Cook County Admin Bldg Fire, IL
● **The Station Nightclub, RI**
Sofa Super Store, SC
Witch Creek & Guejito, CA
Amarillo, TX
San Francisco, CA
Gatlinburg, TN
Fuse-47, MD
2018 ***Camp Fire, CA**

Past NCST Investigations

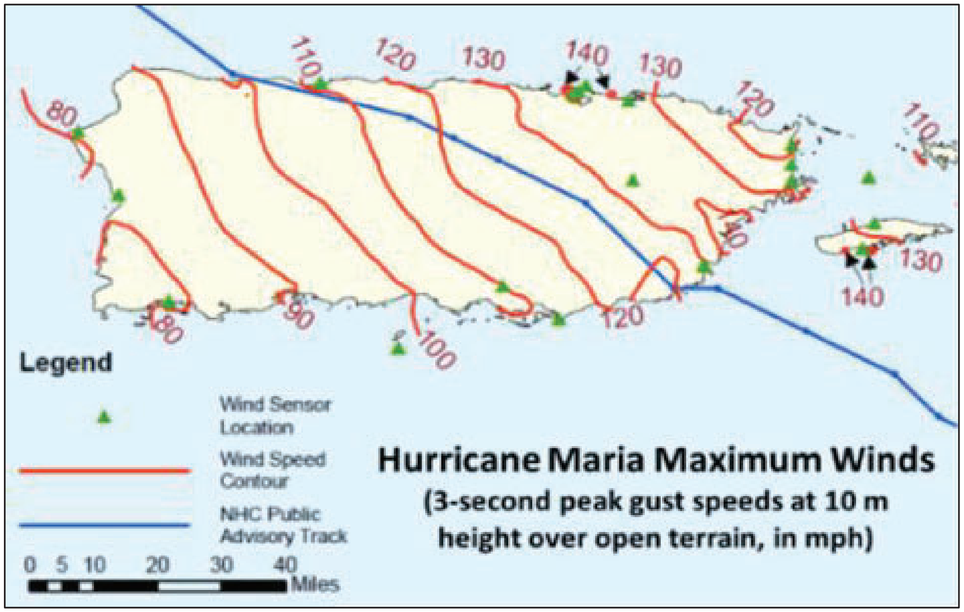
World Trade Center
2001 - 2005

Station Nightclub
2003 - 2005

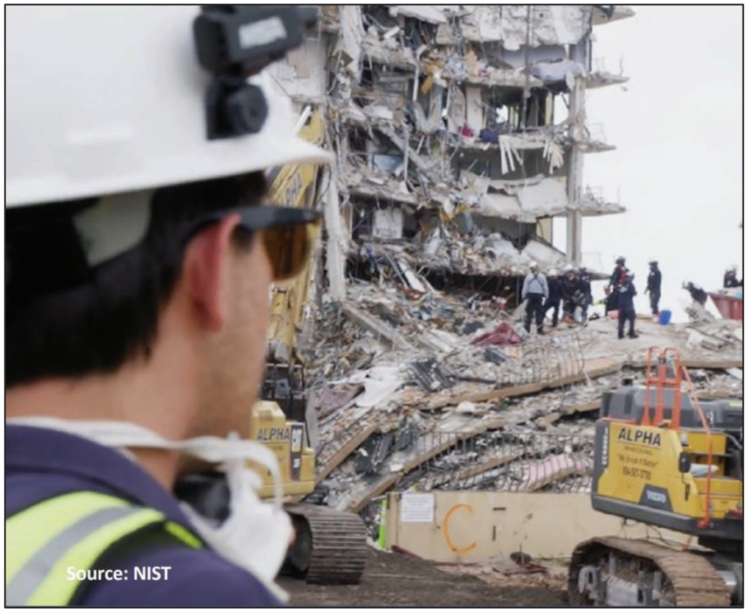
Joplin Tornado
2011 - 2014

Ongoing NCST Investigations

Hurricane Maria



Champlain Towers South



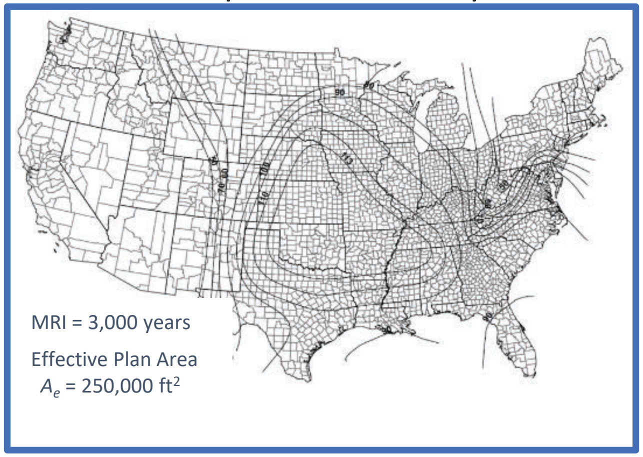
Impacts: Changes to Codes and Standards

DuPont Plaza Hotel Fire (1986)	Passage of Hotel-Motel Sprinkler Act
L'Ambiance Plaza (1987)	Improvements to OSHA safety and inspection requirements for lift-slab construction
Hurricane Andrew (1992)	Upgraded wind provisions adopted in HUD's Manufactured Home Construction and Safety Standards
Northridge Earthquake (1994)	American Institute of Steel Construction adopted design guidelines for seismic rehabilitation of existing welded steel frame buildings
Jarrell, TX Tornado (1997)	NOAA's National Weather Service adopted the Enhanced Fujita (EF) Scale for estimating tornado intensity
World Trade Center (2001)	• 40 ICC code changes to International Building Code and International Fire Code • 10 NFPA code changes to Life Safety Code • 2 NFPA code changes to Uniform Fire Code
Station Nightclub Fire (2003)	NFPA Life Safety Code updates to sprinklers, festival seating, crowd management, egress inspection record-keeping
Joplin, MO Tornado (2011)*	• Tornado hazard map, tornado load design methodology and provisions included in ASCE 7 and the Florida Building Code • Scope of ICC 500 expanded to include shelters in existing public buildings

NIST Studies NCST Investigations *Implementation Ongoing

The Long Tail of NCST Recommendations
Joplin Tornado (2011)

Example tornado map



2024 Service to America Medal

- **Recommendation 3**: ASCE 7-22 includes a tornado hazard map; adopted into IBC 2024.
- **Recommendation 4**: A "Smart" Damage Indicator developed and will be proposed for new ASCE/SEI/AMS Standard for Wind Speed Estimation in Tornadoes
- **Recommendation 5/6**: ASCE 7-22 includes tornado load design methodology and load provisions
- **Recommendation 7a**: Expanded scope of ICC 500 to include shelters in existing buildings published in 2020

Fire Research

Dr. Matthew Hoehler
Chief, Fire Research Division

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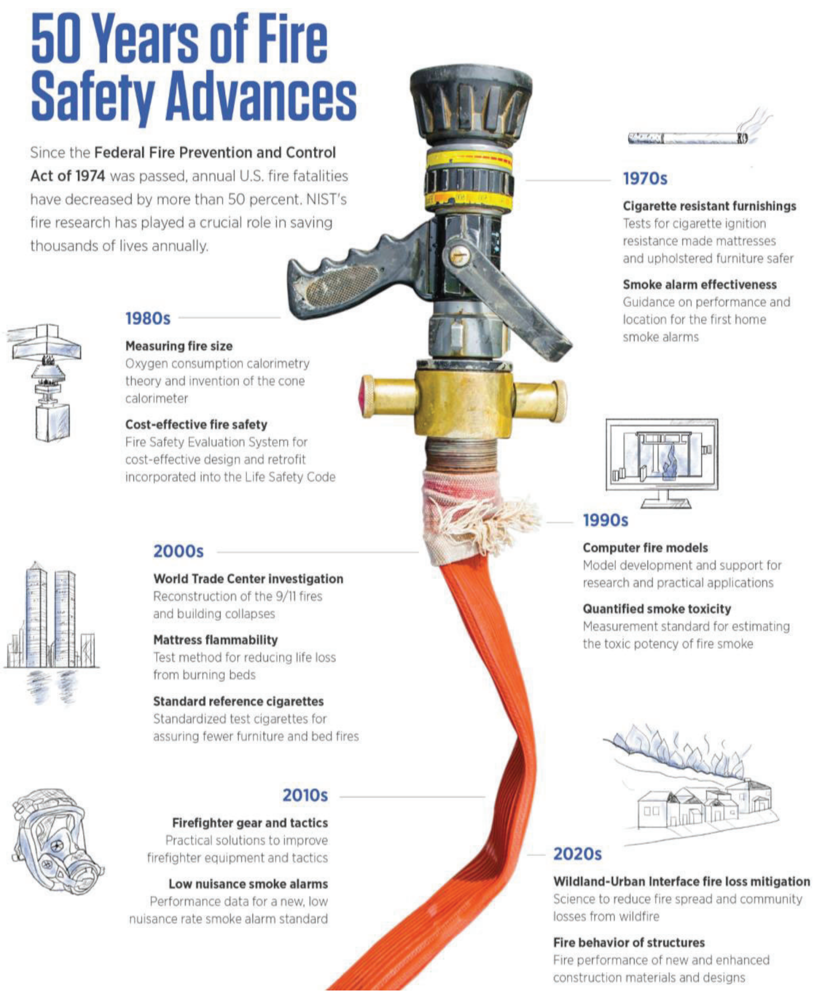
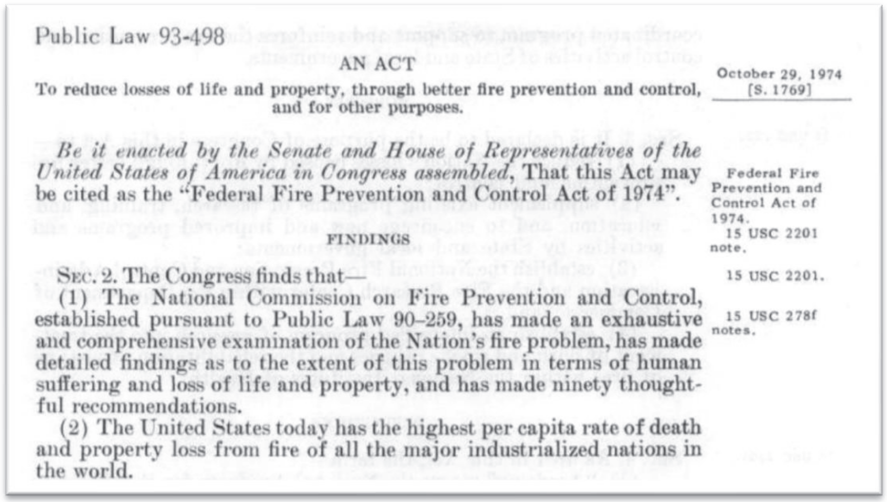
120 Years of Fire Research

NIST





Public Law 93-498

AN ACT

To reduce losses of life and property, through better fire prevention and control, and for other purposes.

October 29, 1974
[S. 1769]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Federal Fire Prevention and Control Act of 1974".

Federal Fire Prevention and Control Act of 1974.
15 USC 2201 note.

FINDINGS

SEC. 2. The Congress finds that—

15 USC 2201.

(1) The National Commission on Fire Prevention and Control, established pursuant to Public Law 90-259, has made an exhaustive and comprehensive examination of the Nation's fire problem, has made detailed findings as to the extent of this problem in terms of human suffering and loss of life and property, and has made ninety thoughtful recommendations.

15 USC 278f notes.

(2) The United States today has the highest per capita rate of death and property loss from fire of all the major industrialized nations in the world.

Scan the QR code to learn more

www.nist.gov/fire/history

Fire Research Division Strategic Goals

NIST

- **Cultivate Worldclass Fire Expertise** Foster a culture that attracts, develops, and retains passionate, adaptable experts and support staff to address current and emerging fire safety challenges.

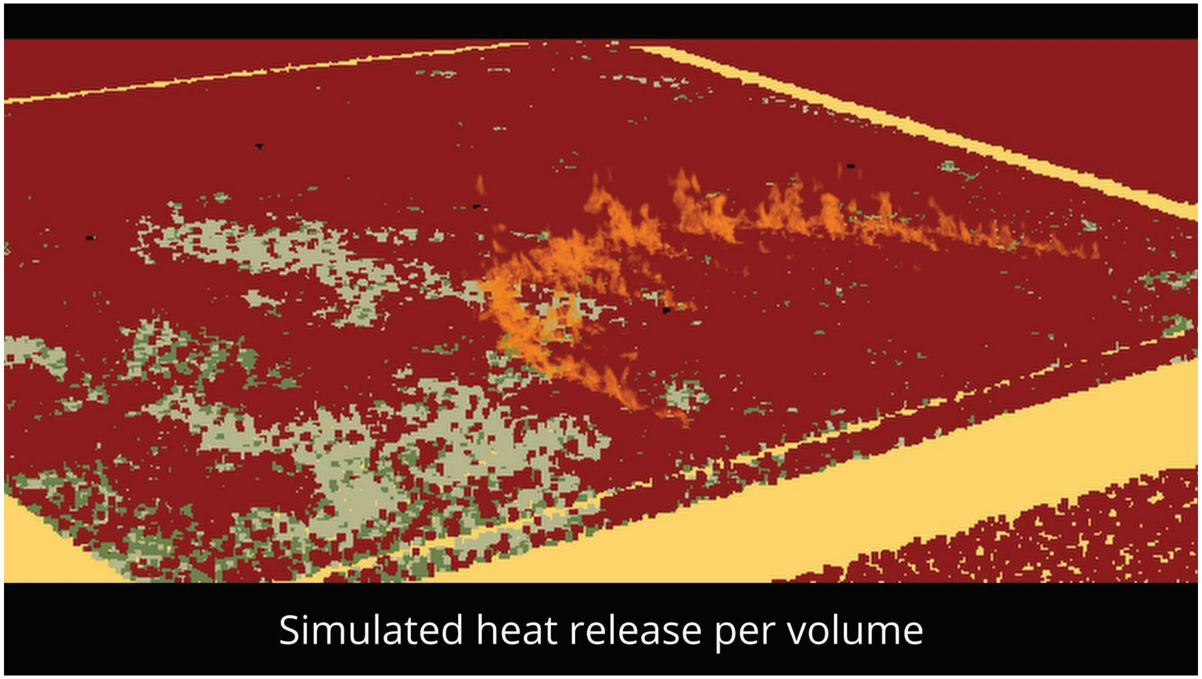
- **Advance Fire Measurement and Experimental Techniques** Lead in pioneering, standardizing, and applying conventional and cutting-edge measurement technologies and experimental techniques, ensuring quantifiable uncertainty to characterize fires up to community scales.

- **Drive Innovation in Fire Science, Engineering, and Model Development** Excel in fundamental and applied science and engineering to characterize fire behavior and its impacts on people, property, and the environment. Develop and maintain fire models and simulation software for research, fire protection engineering, and fire reconstruction.

- **Deliver Fire Data & Promote the Development of Codes and Standards** Provide trusted, rigorously documented data to advance fire safety. Collaborate with standards development organizations to advance the development of codes and standards.

Image credit: Isaac Leventon / NIST

The Changing Fire Landscape



Video credit: Eric Mueller / NIST

Scale: 100 m x 100 m

1 New materials pose challenging fire scenarios

2 Fire risks of electrification

3 Increased wildland-urban interface fire hazard

4 Computational demand

The NIST Approach to WUI Fire Studies

Witch and Guejito Fires 2007 San Diego, CA	Tanglewood Complex 2011 Amarillo, TX	Waldo Canyon Fire 2012 Colorado Springs, CO	Camp Fire 2018 Paradise, CA
• Timeline reconstruction • Structure ignition pathways • Defensive actions • Exposure quantification • Effectiveness of mitigation • Methodology for future deployments	• Detailed reconstruction of fire behavior and timeline • Advanced field data collection methods • Damage assessments • Neighborhood case studies • Parcel-level attributes	• Timeline reconstruction • Fire behavior and spread in WUI interface • Detailed assessment of defensive actions	• Timeline reconstruction • Fire spread in WUI intermix • Burnovers • Damage assessments • Notification, evacuation, traffic, temporary refuge areas, rescues • Link between timelines of evacuation and fire

Source: E. Link (2024) The NIST Wildland-Urban Interface Fire Case Study Approach and Outlook. NIST Technical Note NIST TN 2296.

Temporary Fire Refuge Areas (TFRA)

a factsheet for first responders and community leaders

Local Logos

DRAFT

How to identify TFRAs. First, identify existing areas throughout the community. Areas that may be suitable include cul-de-sacs, parks, golf courses, ballfields, parking lots, or cleared undeveloped parcels. Consider ease of access and proximity to population and egress arteries. TFRA locations should enable rapid access by nearby residents.

⚠ TFRAs are not Safety Zones ⚠

Attributes of TFRAs.

- ☑ large area clear of combustibles
- ☑ readily accessible by surrounding neighborhood
- ☑ multiple access pathways
- ☑ space to accommodate vehicles
- ☑ near fire hydrants

- ⚠ nearby sites with high-energy fuels (e.g., propane/gas/chemical facilities or storage)
- ⚠ access through high fuel load areas
- ⚠ locked gates
- ⚠ topographic features such as chimneys and steep slopes

Placement and sizing of TFRAs. A distributed network of TFRAs is necessary to limit travel distance and enhance access. The density of TFRAs depends on community population and access. Pre-existing locations may need to be supplemented by creation of new areas suitable as TFRAs (such as a new park) to meet local needs. TFRAs can be as small as a cul-de-sac or as large as several acres (parking lots or parks). Local conditions (e.g., fuels & population density) will dictate how many TFRAs are needed and how large they need to be.

Signage and maps for TRAs. A sample sign is shown in the image on the right. Communities must ensure that information on the signs is consistent with local notification and evacuation plans. Large TFRAs and TFRAs with multiple access points will require more than one sign.

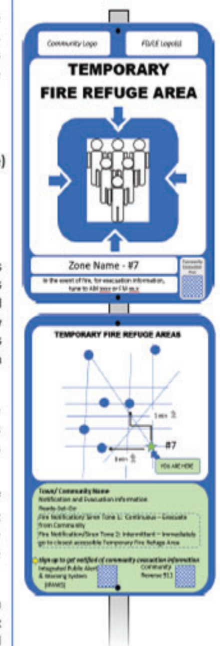
Integrating TFRAs into evacuation plans. While the use of TFRAs is more hazardous than evacuation from the fire area, the establishment of TFRAs must be incorporated into the community evacuation plan. Advance planning, including identification, signage, and community education are necessary steps to make TFRAs an effective evacuation option.

Educating the community. Community leaders must inform citizens of the local notification and evacuation plans. Emergency managers must understand that the role of TFRAs is to identify areas of potential refuge and reduced fire exposures for use as a last resort. The following groups should be informed about notification and evacuation plans well before a fire incident:

- emergency managers
- first responders
- public works
- neighboring jurisdictions
- residents
- commuters & tourists
- schools & health care
- entities managing TFRA spaces

First Responders should…

1. Monitor TFRAs for presence of civilians.
2. Facilitate evacuation of civilians from TFRAs as conditions allow. This may be accomplished by escorting convoys of vehicles, providing transportation, or telling civilians specific directions of when and which route to follow.
3. Periodically revisit TFRAs to ensure all civilians are safely evacuated.



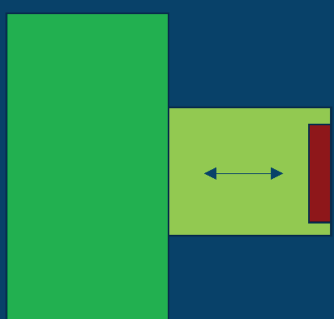
The image above shows a sign that can be posted at community-designated TFRAs. The upper sign identifies the area as a TFRA and includes a name and identification number. Local radio frequencies used to broadcast fire information can be included, along with a QR code to the evacuation plan. The lower sign shows a map of nearby TFRAs and may include additional information about emergency alerts, such as sirens or reverse-911.

A Community Perspective

NIST

Early Experiments

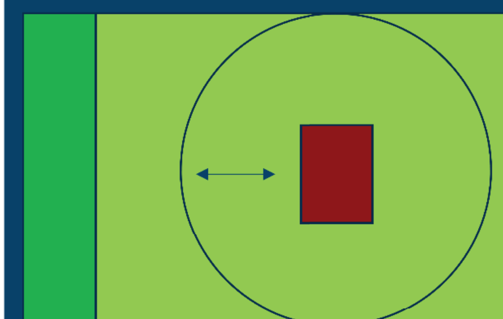
- Limited exposure to structure coupling
- Limited ambient wind
- No ember hardening



"House in the woods"

Early Building Codes (2008-2020)

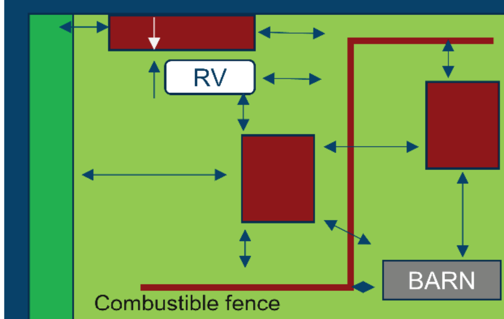
- Defensible Space
- Some exposure to structure coupling
- Some ember hardening



"Parcel and zones"

Structure / Parcel / Community HMM (2022)

- **Goal: Stand alone structures**
- Comprehensive exposure to structure coupling for fire and embers
- Multiparcel fuels
- Housing density (H, M, L)
- Community hardening



"Multiparcel spatial analysis"

Graphic credit: Alex Maranghides / NIST

Protect your community from Wildfire

HMM

Hazard Mitigation Methodology

HMM is a comprehensive, science-based community wildfire protection approach

Scan the QR code to learn more

www.nist.gov/el/hmm

Forward-looking Building Codes

Dr. Terri McAllister
Deputy Chief, Materials and Structural Systems Division

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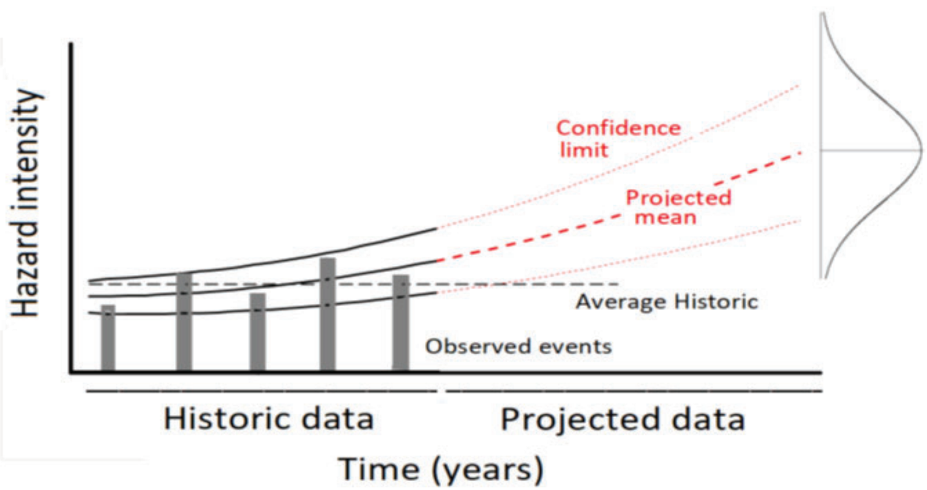
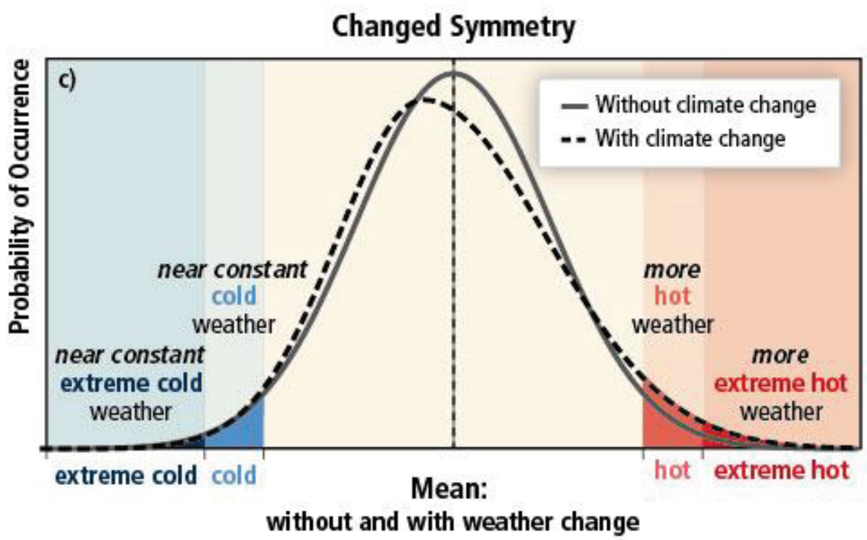
Resilience and Climate

Resilience is the ability to prepare for threats and hazards, adapt to changing conditions, and withstand and recover rapidly from adverse conditions and disruptions.

The definition of hazards is changing from past models to include future climate change.



Source: Ghosn & Ellingwood, 2023



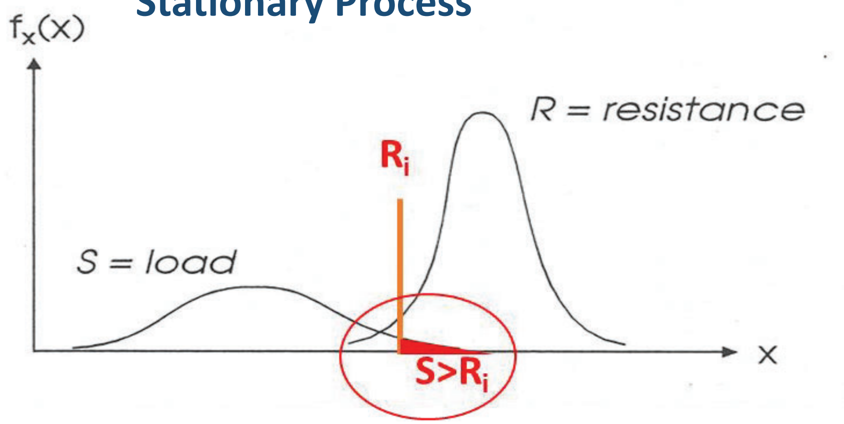
Source: IPCC 2012

Climate to Codes Challenges

Climate Science
- Global climate models based on mean values and confidence intervals
- Regional and Local models downscaled from the global models

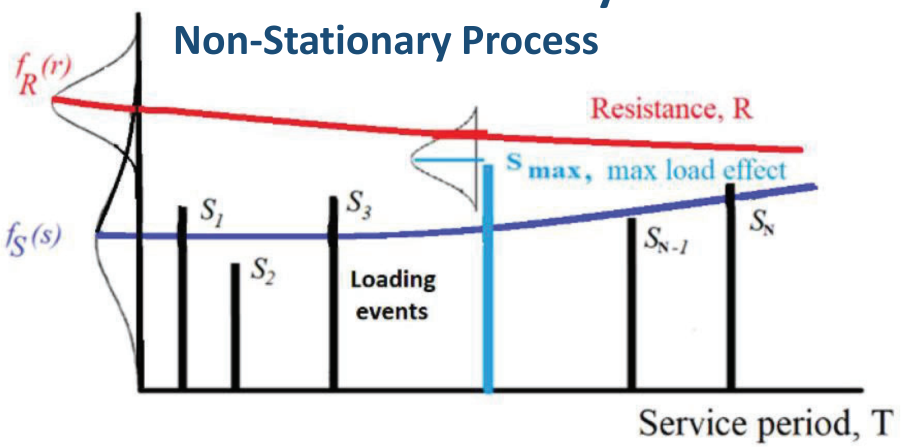
Codes
- Current engineering standards are based on the tails of stationary distributions
- Future hazards require new reliability models to account for non-stationary processes

Structural Reliability
Stationary Process



Source: Ghosn, 2024

Structural Reliability
Non-Stationary Process

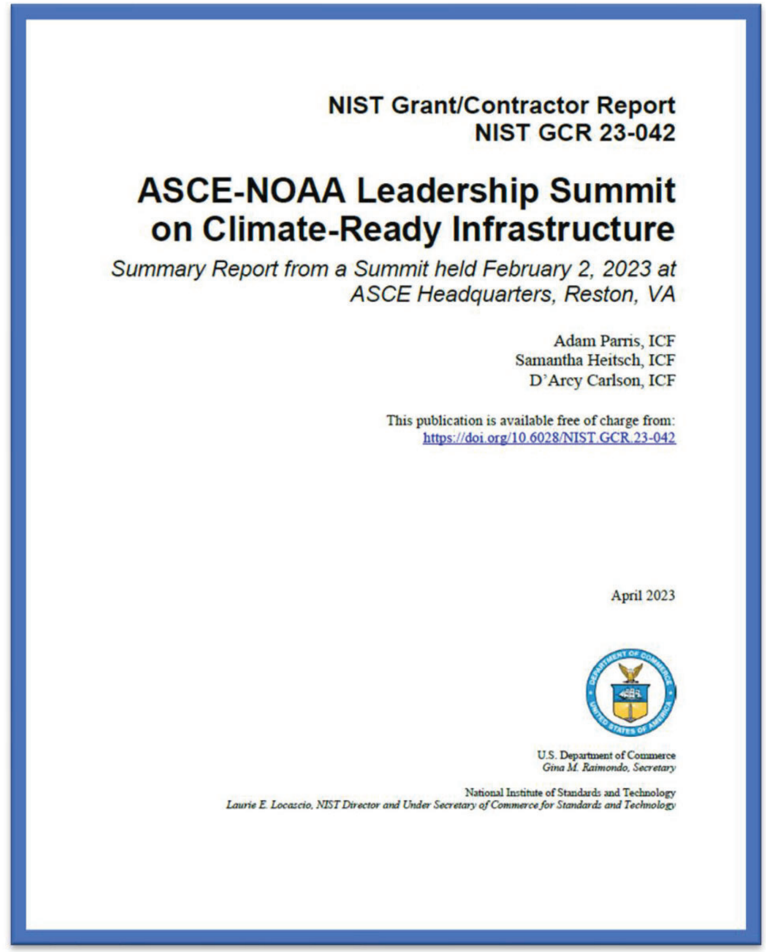


Source: Ghosn & Ellingwood, 2023

Collaboration with NOAA & ASCE

NIST

- ASCE-NOAA Partnership began in late 2021, with support from the University of Maryland. Key scope:
  - The needs of the civil engineering community, especially regarding weather and climate information in support of codes and standards
- Federal participants include NIST, FEMA
- Key publications to-date:
  - Feb 2023 Leadership Summit Summary Report
  - ASCE-NOAA 2023 Workshops Report



NIST Grant/Contractor Report
NIST GCR 23-042

ASCE-NOAA Leadership Summit on Climate-Ready Infrastructure

Summary Report from a Summit held February 2, 2023 at ASCE Headquarters, Reston, VA

Adam Parris, ICF
Samantha Heitsch, ICF
D'Arcy Carlson, ICF

This publication is available free of charge from:
https://doi.org/10.6028/NIST.GCR.23-042

April 2023

U.S. Department of Commerce
Gina M. Raimondo, Secretary

National Institute of Standards and Technology
Laurie E. Locascio, NIST Director and Under Secretary of Commerce for Standards and Technology

Community Resilience Collaboration

NIST

2023-2024: NIST, NOAA, and ASCE hosted 3 workshops to support the use of climate projections for community resilience planning

Sea Level Rise & Storm Surge
- New York City, NY
- South Florida
- San Francisco Bay, CA

Rain & Inland Urban Floods
- Philadelphia, PA
- Michigan
- Boulder, CO

Wildfire & Urban Planning
- Austin, TX
- Ashland, OR
- CALFIRE, CA

Credit: Jerry Coli, Pixabay

Credit:12019, Pixabay

Credit: sippakorn yamkasikorn, Pixabay

Workshop outcomes:

- Climate use cases
- Range of practices adopted by communities
- Informs basis for guidance, including appropriate use of climate science and decision making considerations

Standard Development Organizations

NIST

ASCE 7-28: Standard for Minimum Design Loads for Buildings and Other Structures

- Published every 6 years
- The 2028 version will have a new section on Future Conditions

Other SDOs

- ASTM, American Concrete Institute

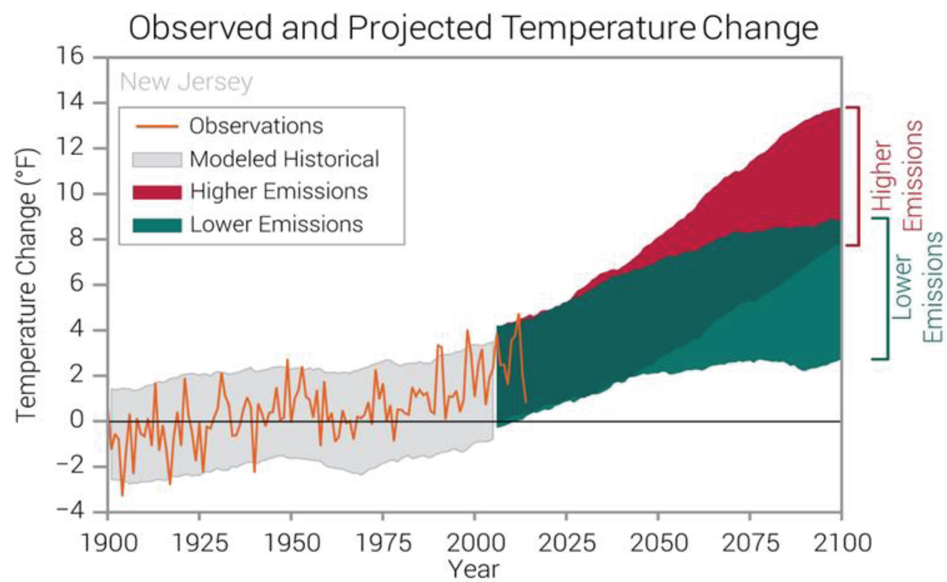
NIST Grants to support ASCE 7-28 (Begins Oct 2024)

- Nonstationary reliability methods
- Wind maps
- Atmospheric icing criteria
- Consequences of climate change in structural loads
- Corrosion in reinforced concrete
- Ground failure and impacts on structures
- Adaptive design and assessment of reinforced concrete structures

NIST Workshops for Future Codes

NIST will host 4 workshops in 2025 for advancing building and infrastructure codes. These cross-cutting topics will include climate-affected hazards (e.g., sea level rise, temperature, rain, snow, ice, wind, flood) and social impacts/consequences:

- **Climate projections for design** - confidence/uncertainty in climate projections, downscaling of climate models, converting climate hazard projections to engineering design criteria
- **Climate effects on the built environment** - changes in hazard demand relative to historical basis, changes in structural capacity due to changes in material properties and geotechnical conditions
- **Engineering design guidance and criteria** - non-stationary reliability, service life, design scenarios
- **Adaptation and resilience** - buildings and infrastructure systems, material durability, carbon mitigation of building materials



Source : NCA4, Vol II, 2018

Thank you!