NIST Disaster Resilience Programs Overview

ACEHR Meeting
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Is it possible to integrate multiple hazards into a "global" resilience model?

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NIST
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U.S. Department of Commerce

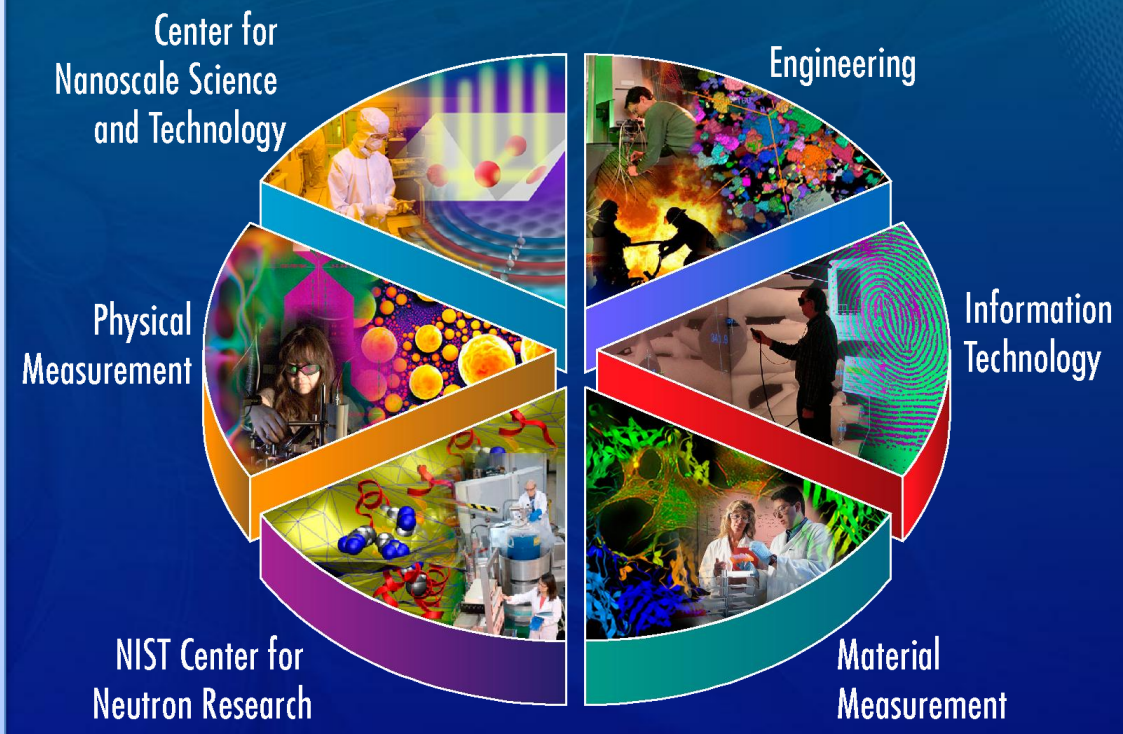
The NIST Laboratories

NIST's work enables

- Advancing manufacturing and services
- Helping ensure fair trade
- Improving public safety and security
- Improving quality of life

NIST works with

- Industry
- Academia
- Other federal agencies
- State and local government agencies
- Measurement laboratories
- Standards organizations



Providing measurement solutions for industry and the Nation

Engineering Laboratory Mission

To promote U.S. *innovation* and *industrial competitiveness* in areas of critical national priority **by anticipating and meeting the:**

- **measurement science and**
- **standards**

needs for technology-intensive manufacturing, construction, and cyber-physical systems in ways that enhance *economic prosperity* and improve the *quality of life.*

Engineering Laboratory Vision

To be *the* source for:

- creating **critical *solution-enabling* measurement science**, and
- critical technical contributions underpinning emerging **standards, codes, and regulations**

that are *used* by the U.S. manufacturing, construction, and infrastructure industries to strengthen leadership in domestic and international markets.

EL is the primary federal laboratory serving the manufacturing and construction industries.

EL Core Mission Functions[1]

- Fire prevention and control
- National earthquake hazards reduction
- National windstorm impact reduction
- National construction safety teams
- Building materials and structures
- Engineering and manufacturing materials, products, processes, equipment, technical data, and standards
- Green manufacturing and construction
- Manufacturing enterprise integration
- Collaborative manufacturing research pilot grants
- Manufacturing fellowships

[1]Authroized by NIST Organic Act or by other statutes

Measurement Science Products

Measurement science research and services include:

- development of performance metrics, measurement and testing methods, predictive modeling and simulation tools, knowledge modeling, protocols, technical data, and reference materials and artifacts
- conduct of inter-comparison studies and calibrations
- evaluation of technologies, systems, and practices, including uncertainty analysis
- development of the technical basis for standards, codes, and practices—in many instances via testbeds, consortia, standards and codes development organizations, and/or other partnerships with industry and academia

Challenges to Measuring Resilience

- Measuring the resilience of communities to natural and man-made hazards as a function of the performance of buildings and infrastructure poses difficult technical challenges due to a lack of adequate:
  - Understanding of the ***natural and/or manmade hazards*** to the built environment and information relative to such hazards for use by design professionals, standards and codes developers, and emergency managers
  - Predictive technologies and mitigation strategies to ***assess the vulnerability*** and ***improve the performance*** of buildings, infrastructure, and communities
  - ***Standard methods to assess the contribution of building and infrastructure performance to community resilience*** for use in making disaster preparedness and mitigation decisions
  - means to ***transfer research results to practice***

NIST Strategic Goal on Disaster-Resilient Buildings, Infrastructure, and Communities

- NIST has had a ***strategic goal on Disaster-Resilient Structures and Communities*** since 2008.
- NIST measurement science research and services provide the ***technical basis for improvements to model codes, standards, and practices*** that enhance the safety and performance of buildings, infrastructure, building occupants, and emergency responders.
- NIST provides the critical knowledge, metrics, and tools to enable the ***transformation to emerging performance-based standards and codes***.
- NIST performs ***technical studies in the aftermath of disaster and failure events*** to derive lessons learned and to recommend needed changes to codes, standards, and practices that will improve the safety and performance of buildings and infrastructure.
- NIST staff ***participate actively in standards and codes development*** (e.g., ASCE, ASTM, ACI, AISC, ICC, NFPA) to implement research results.

EL Goals and Programs

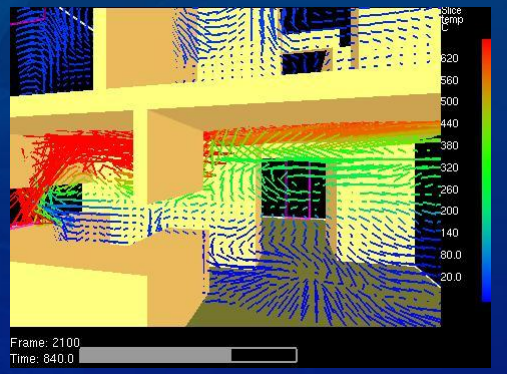
EL Goal/Program	FY 2012 Funding*
Goal: Smart Manufacturing, Construction, and Cyber-Physical Systems	
Smart Manufacturing Processes and Equipment	$3.0M
Next-Generation Robotics and Automation	$3.8M
Smart Manufacturing and Construction Systems	$3.3M
Systems Integration for Manufacturing and Construction Applications	$6.9M
Smart Grid Program	$8.0M
Goal: Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure	
Sustainable Manufacturing	$5.3M
Sustainable, High-Performance Infrastructure Materials	$3.2M
Net-Zero Energy, High-Performance Buildings	$6.4M
Embedded Intelligence in Buildings	$3.2M
Goal: Disaster-Resilient Buildings, Infrastructure, and Communities	
Fire Risk Reduction in Communities	$4.7M
Fire Risk Reduction in Buildings	$5.6M
Earthquake Risk Reduction in Buildings and Infrastructure	$4.1M
Structural Performance Under Multi-Hazards	$3.5M
*** Pending FY 2012 Appropriations** **Total**	**$ 61.0M**

Goal: Disaster-Resilient Buildings, Infrastructure, and Communities

- **Fire Risk Reduction in Communities:** To develop and deploy advances in measurement science to improve the resilience of communities and structures to unwanted fires through innovative fire protection and response technologies and tactics
- **Fire Risk Reduction in Buildings:** To develop and deploy advances in measurement science to increase the safety of building occupants and the performance of structures and their contents by enabling innovative, cost-effective fire protection technologies
- **Earthquake Risk Reduction in Buildings and Infrastructure:** To develop and deploy advances in measurement science to resist earthquake effects, improve safety, and enhance resilience of buildings, infrastructure, and communities
- **Structural Performance Under Multi-Hazards:** To develop and deploy advances in measurement science to enhance the resilience of buildings and infrastructure to natural and manmade hazards

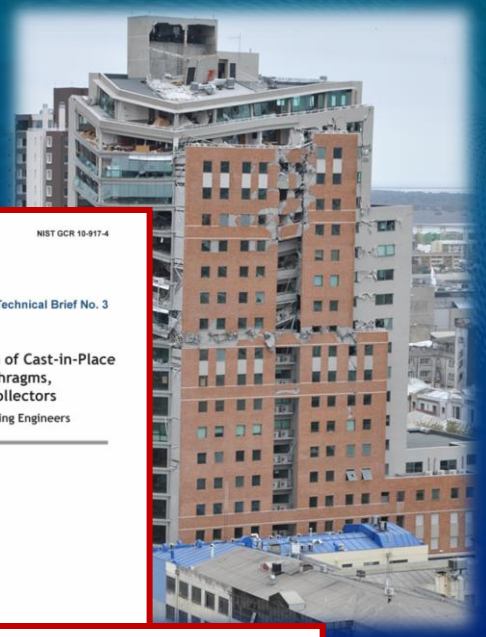
Fire Risk Reduction in Buildings and Communities

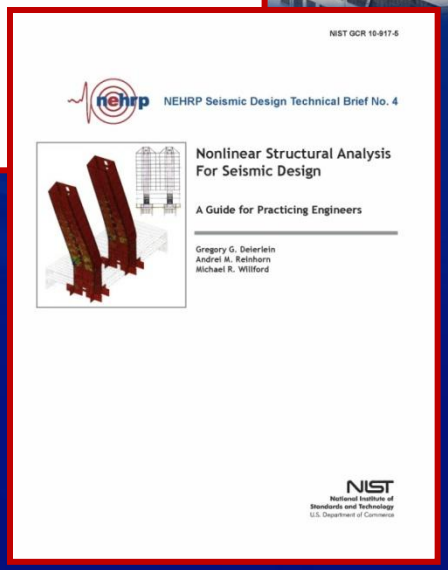
- Enable the development and implementation of advanced technologies and tactics to improve fire service safety and effectiveness
- Enable improved standards, codes, and technologies to increase the fire resistance of Wildland-Urban Interface (WUI) communities
- Enable the manufacture of cost-effective fire-safe materials and products
- Enable effective fire protection technologies
- Derive lessons from analysis of disaster and failure events



Earthquake Risk Reduction in Buildings and Infrastructure

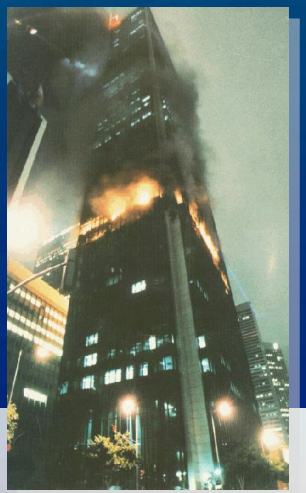
- Technical support for seismic practice and code development.
- Problem-focused, user-directed research to support development of performance-based seismic design concepts and guidelines.
- Problem-focused research and technical resources (e.g., guidelines and manuals) development to improve seismic engineering practice.
- Evaluated technology made available to practicing professionals in the design and construction communities.



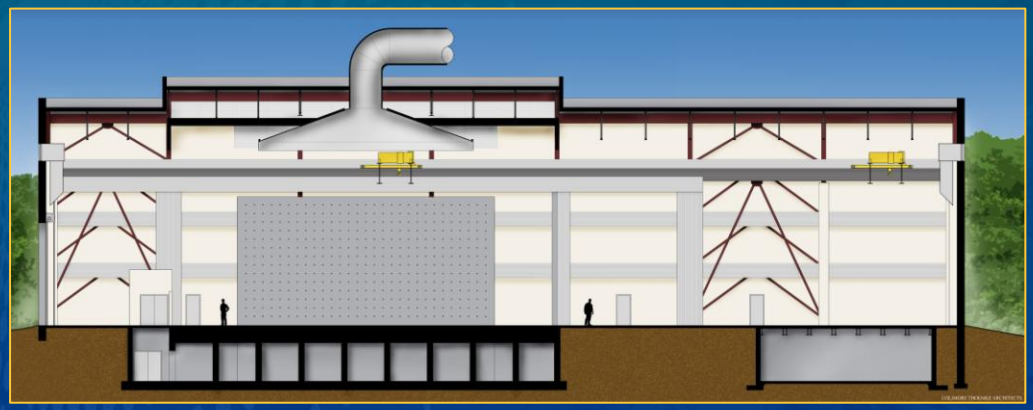


Structural Performance Under Multi-Hazards

- **Prevention of Progressive Structural Collapse**
  - Develop performance-based pre-standards for mitigation of disproportionate collapse incorporating structural robustness metrics, cost-effective strategies to prevent progressive collapse, validated computational tools
- **Fire Safety Design and Retrofit of Structures**
  - Develop a performance-based approach to evaluate fire behavior of structures, incorporating fire loads, material response, and overall structural response to elevated temperatures
  - Deliver verified tools, guidance, and pre-standards for the fire resistance design and rehabilitation of steel and concrete structures
- **Wind Engineering and Multi-hazard Failure Analysis**
  - Develop the measurement science methods and tools that will enable performance-based standards for designing structures to resist wind and storm surge in a multi-hazard context



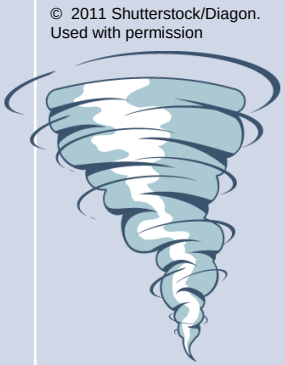
National Fire Research Laboratory



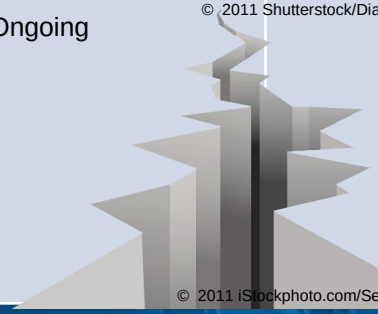
- Develop capability to test performance of real-scale structures under realistic fire and structural loading
- Develop an experimental database on performance of large-scale structural connections, components, subassemblies, and systems under realistic fire and loading
- Develop validated physics-based models to predict fire resistance performance of structures
- Enable performance-based standards for fire resistance design of structures

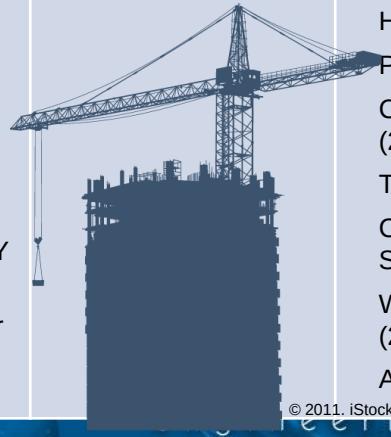
NIST Disaster and Failure Studies

Earthquakes	Hurricanes	Construction/ Building	Tornadoes	Fires
San Fernando, CA (1971)	Camille, MS/LA (1969)	Skyline Plaza Apartments, Bailey's Crossroads, VA (1973)	Jarrell, TX (1997)	DuPont Plaza Hotel, San Juan, PR (1986)
Mexico City, Mexico (1985)	Alicia, Galveston, TX (1983)	Willow Island Cooling Tower, WV (1978)	Spencer, SD (1998)	First Interstate Bank Building, Los Angeles, CA (1988)
Loma Prieta, CA (1989)	Hugo, SC (1989)	Kansas City Hyatt Regency, Kansas City, MO (1981)	Oklahoma City, OK (1999)	Loma Prieta Earthquake, CA (1989)
Northridge, CA (1994)	Andrew, FL (1992)	Riley Road Interchange, East Chicago, IN (1982)	Joplin, MO (2011)*	Hillhaven Nursing Home (1989)
Kobe, Japan (1995)	Hurricanes Mitch and Georges, LAC (1998)	Harbor Cay Condominium, Cocoa Beach, FL (1981)		Pulaski Building, Washington, DC (1990)
Kocaeli, Turkey (1999)	Hurricanes Katrina and Rita (2005)	L'Ambiance Plaza, Hartford, CT (1987)		Happyland Social Club, Bronx, NY (1990)
Maule, Chile (2010)*		Ashland Oil Tank Collapse, Floreffe, PA (1988)		Oakland Hills, CA (1991)
Christchurch, NZ (2011)*		U.S. Embassy, Moscow, USSR (1987)		Hokkaido, Japan (1993)
		Murrah Federal Building, Oklahoma City, OK (1995)		Watts St, New York City (1994)
		World Trade Center Disaster, New York, NY (2001)		Northridge Earthquake, CA (1994)
		Dallas Cowboys Indoor Practice Facility, May 2009		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)



* Ongoing





NIST Disaster and Failure Studies

Results

- Probable technical cause
- Lessons learned: successes and failures
- Improvements to standards, codes, practices, technologies
- Future research priorities

NIST Authorities & Roles:

- ***NCST Act (2002):*** building failures, evacuation and emergency response procedures
- ***NIST Act (1950, as amended):*** structural investigations; fire-resistive building materials; materials, mechanisms, structures, components, and systems)
- ***Fire Prevention and Control Act (1974):*** fire investigations
- ***NEHRP Reauthorization Act (2004):*** earthquakes
- ***National Windstorm Impact Reduction Act (2004):*** wind, storms and floods
- ***National Response Framework:*** structural and fire safety; disaster operations and situation assessment; urban and industrial hazard analysis; recovery

A program focus: Develop and maintain archival disaster and failure database of hazards, performance of buildings and infrastructure, evacuation and emergency response, and related factors (e.g., mitigation, response)

Partners Representing Construction and Building Industry

Construction Industry Institute
- Board of Advisors
- Breakthrough Strategy Committee
- Benchmarking and Metrics Committee
- Cost of Inadequate Interoperability Study
- Workshops and Conferences
- Research Teams

FIATECH Consortium
- Capital Projects Technology Roadmap
- Cost of Inadequate Interoperability Study
- Automating Equipment Information Exchange
- Intelligent and Automated Construction Job Site
- Building Information Modeling
- Workshops and Conferences

Building and Fire Codes and Standards
- Technical Guidelines
- Measurement Techniques
- Performance Prediction Tools
- Committees, Councils, and Boards
- Workshops and Conferences
- Collaborative Research
- Publications
- Working Groups

FIATECH

(Conceived by CII and NIST in 1999)

ICC INTERNATIONAL CODE COUNCIL

NFPA

ASTM INTERNATIONAL

ASCE American Society of Civil Engineers

ASHRAE Advancing HVAC&R to serve humanity and promote a sustainable world

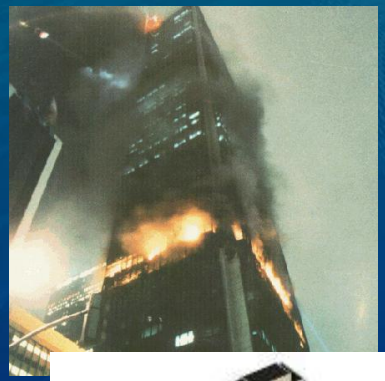
SFPE

Impacts: Fire Protection

- **Smoke Alarm Standards** – enabling a 50 percent reduction in U.S. fire death rate from the mid-1970's via smoke alarm standards
- **Mattress Flammability and Cigarette Ignition** – enabling reduction in smoking related fires and unsafe mattresses through widely adopted standards and regulations for reduced-ignition-propensity cigarettes and mattress flammability
- **Fire Fighter Protective Equipment** – enabling safer and more effective fire fighting through performance metrics and standards for thermal imaging systems, 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 the only installation and design standard for residential sprinkler systems
- **Fire Dynamics Models** – enabling transformation from prescriptive to performance standards through tools to predict the spread of fire, smoke, and toxic products
- **Heat and Visible Smoke Release Measurements** – enabling heat release rate measurements worldwide through better standards

Impacts: Disaster-Resilient Structures

- **U.S. Model Code Changes from World Trade Center Investigation** – enabling enhanced nationwide safety of buildings, occupants, and emergency responders though better fireproofing strength, installation, and inspection; structural integrity and fire-resistance rating; occupant evacuation and fire service access; active fire protection systems; and emergency responder communications
- **Seismic Design of Buildings** – enabling earthquake-resilient buildings through design guidance for special concrete moment frames, special steel moment frames, and reinforced concrete diaphragm systems
- **Fire Resistance of Concrete Construction** – enabling enhanced fire resistance of structures through standards for high-strength concrete in building construction
- **Innovative Connection for Precast Concrete Buildings** – enabling significant cost savings through standards for precast concrete construction in high seismic regions
- **Enhanced Fujita Tornado Intensity Scale** – nationwide adoption of new scale to more realistically relate observed damage to wind speeds
- **Construction Strategies to Avoid Progressive Collapse** – enabling owners, engineers and building officials to prevent structural collapse through risk-informed planning and design

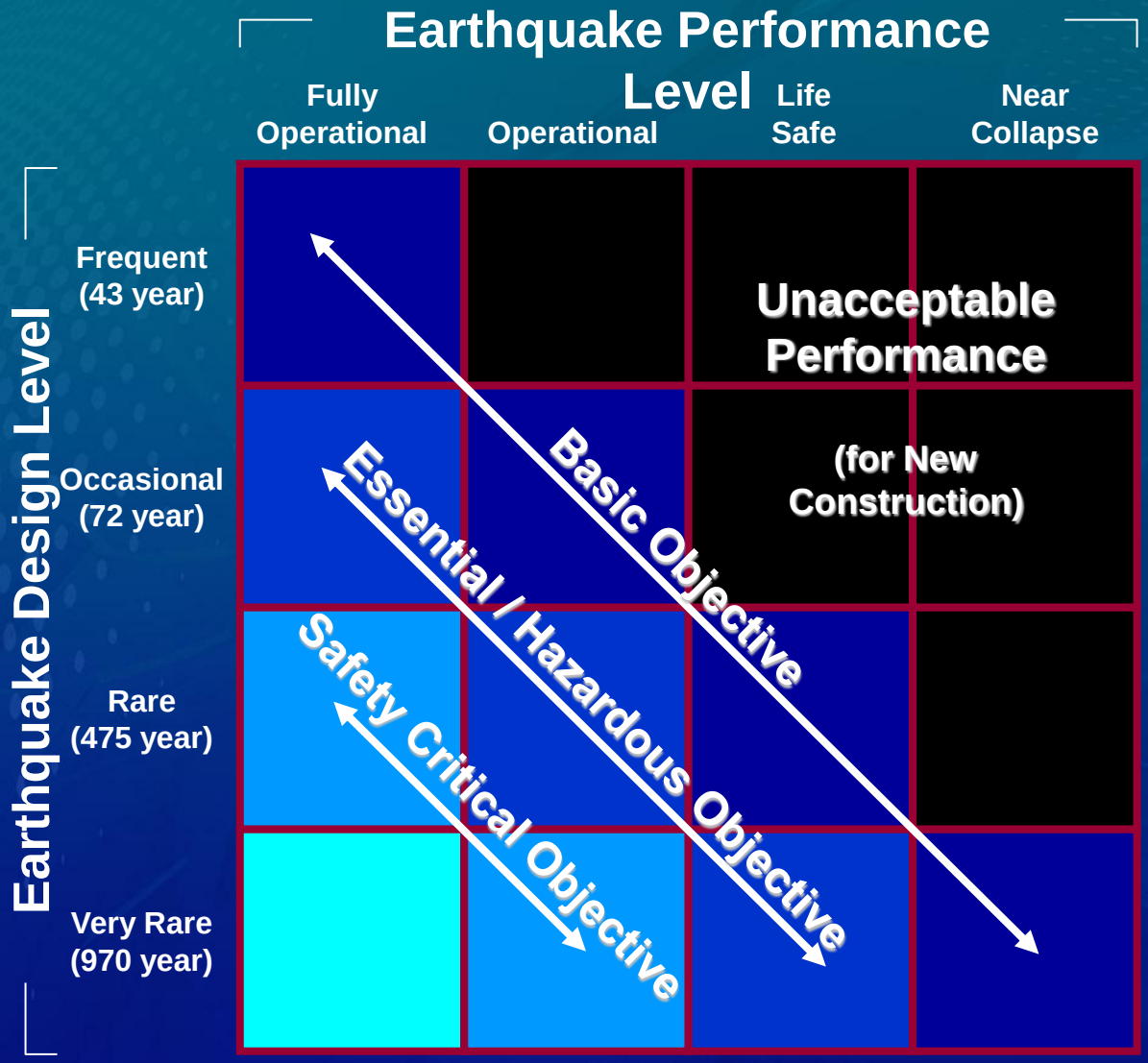


Sample Impacts of Disaster and Failure Studies

- World Trade Center (2001)
  - U.S. model building code changes adopted for fireproofing strength, installation, and inspection; fire-resistance rating; structural integrity
  - U.S. model building code changes adopted for occupant evacuation; fire service access; active fire protection systems; emergency responder communications
- The Station Nightclub Fire (2003)
  - Sprinklers, restricted festival seating, crowd manager, and egress inspection recordkeeping requirements for new and existing facilities adopted in NFPA 101 (Life Safety Code)
- Jarrell, TX, Tornado (1997)
  - Enhanced Fujita (EF) Tornado Intensity Scale adopted by NOAA's National Weather Service
- Northridge Earthquake (1994)
  - Design guidelines for seismic rehabilitation of existing welded steel frame buildings adopted by American Institute of Steel Construction
- Hurricane Andrew (1992)
  - Upgraded wind load provisions adopted in HUD's Manufactured Home Construction and Safety Standards
- DuPont Plaza Hotel Fire, San Juan PR (1986)
  - Passage of the Hotel-Motel Sprinkler Act
- L' Ambiance Plaza, Hartford CT (1982)
  - Improvements in OSHA's safety and inspection requirements for lift-slab construction

Development of Resilience Metrics

- Community resilience relies on the ability to maintain or restore building and infrastructure functionality in a prescribed timeframe following a hazard event
- NIST is working to develop resilience metrics for buildings to include:
  - the structural system
  - non-structural systems
  - utility infrastructure
  - duration of recovery and associated economic losses
- NIST will use data from past events, engineering judgment, and engineering analyses to evaluate the resilience performance of the structural system and its impact on the other related systems, including post-disaster recovery time
- NIST will provide a technical basis for cost/benefit analysis of design and rehabilitation approaches to enhance the resilience of structures
- NIST intends to build on the performance-based engineering approach to include design for resilience as an option
- In the future, NIST will consider development of resilience metrics for infrastructure lifelines (utilities, transportation, and communication systems) and communities



A vocabulary for performance expectations

Is it possible to extend this performance-based design approach to multiple hazards?

Summary

- The U.S. Department of Commerce through NIST is dedicated to providing the technical basis for standards and codes used by U.S. industry in areas of critical national need.
- The NIST Engineering Laboratory provides critical measurement science tools that underpin improvements to codes, standards, and practices used by the design and construction industry.
- NIST conducts disaster and failure studies to learn from these events, recommend needed changes to codes, standards, and practices, and identify areas where additional research and development is needed to improve the safety and performance of buildings, infrastructure, building occupants, and emergency responders.
- NIST works in close partnership with industry—and with standards and codes development organizations—to implement the results of its research critical to enhancing the resilience of buildings, infrastructure, and communities.

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