NIST’s Fire Protection Goal

Federal Fire Working Group
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Engineering Laboratory (EL)
National Institute of Standards and Technology
The NIST laboratories

- Manufacturing Engineering
- Physics
- Nanoscale Science and Technology
- Neutron Research
- Technology Services
- Building and Fire Research
- Chemical Science and Technology
- Materials Science and Engineering
- Electronics and Electrical Engineering
- Information Technology
Engineering Lab

Building and Fire Research + Manufacturing Labs → Engineering Laboratory
The Engineering Laboratory promotes the development and dissemination of advanced technologies, guidelines, and services to the U.S. manufacturing and construction industries through activities including measurement science research, performance metrics, tools and methodologies for engineering applications, and critical technical contributions to standards and codes development.

Carry out mission related activities in:
• 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;
• manufacturing enterprise integration;
• collaborative manufacturing research pilot grants; and
• manufacturing fellowships.
The National Fire Problem

3,250 fatalities & 16,400 injuries: Civilian
89 fatalities & 83,400 injuries: Fire Fighters

Estimated Total Cost# of Fire in the U.S. for 2006: ~$320B

- Direct Economic loss, $14 B
- Career fire departments, $34B
- Net fire insurance, $20 B
- Bldg. construction for fire protection, $49 B
- Volunteer time,*, $119 B
- Misc. other costs,*, $40 B
- Deaths and injuries,**, $41 B

# Hall, J.R., The Total Cost of Fire in the United States, NFPA, February 2008

** CPSC model: $6.7 M/death, $0.23 M/injury
### Defining the Problem: Declining Life Loss/Increasing Costs

<table>
<thead>
<tr>
<th>Year</th>
<th>Reported Fires</th>
<th>Civilian Deaths</th>
<th>Civilian Injuries</th>
<th>Firefighter Deaths</th>
<th>Firefighter Injuries</th>
<th>Core Cost of Fire ($ B In 2006 dollars)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>3,000,000</td>
<td>6,505</td>
<td>30,200</td>
<td>138</td>
<td>98,070</td>
<td>$69</td>
</tr>
<tr>
<td>1990</td>
<td>2,250,000</td>
<td>5,195</td>
<td>28,600</td>
<td>108</td>
<td>100,300</td>
<td>$80</td>
</tr>
<tr>
<td>2000</td>
<td>1,750,000</td>
<td>4,045</td>
<td>22,350</td>
<td>103</td>
<td>84,550</td>
<td>$95</td>
</tr>
<tr>
<td>2006</td>
<td>1,638,000</td>
<td>3,245</td>
<td>16,400</td>
<td>89</td>
<td>83,400</td>
<td>$114</td>
</tr>
</tbody>
</table>

![Graph showing Civilian Fatalities and Core Cost of Fire](image)

**NFPA, 2009**
- Core Cost of Fire
- Costs of Fire Departments
How does NIST prioritize its research?

- greatest impact (problem size, potential reach)
- cost-effective and implementable solutions
- new construction and retrofit
- engineered buildings and residences
- research to support the technical basis for standards, codes, guidelines, models, software decision-tools, standard reference materials, databases, etc.

PIV measurements of doorway flows for model validation

Fire modeling for performance based design

Reduced flammability materials & products
Fire Protection Strategy and Stakeholder Workshop in June 2009

BFRL/NIST’s Innovative Fire Protection Roadmap

Overview of the U.S. Fire Problem

- The total cost of fire can be estimated by summing the direct costs and the costs of indirect losses, such as the cost of property damage and the cost of medical care.

- Over the past 25 years, property damage due to fire has increased by about 10% per year, while the cost of medical care has increased by about 7% per year.

- The total cost of fire-related injuries and deaths in the U.S. is estimated to be $200 billion per year.

Global Fire Reduction Breakout Group

Innovative Fire Protection Strategies

- The United States spends over $200 billion annually to contain fire losses at the levels indicated in the table below. Typically, these costs are rising steadily, and are applied to such approaches as:
  - Preventing unwanted ignitions
  - Controlling the intensity and spread of fire
  - Improving the promptness and accuracy of detection
  - Mitigating the potential for harm from the combustion products
  - Providing safe and effective automatic fire control and emergency response
  - Conveying information to occupants and emergency responders
  - Preventing fire-induced structural failure
  - Improving emergency management
  - Assuring adequacy of the egress capacity relative to demand

- Perhaps there are ways to contain fire losses at the current level using fewer resources, perhaps there are new technologies that could increase fire safety at additional cost.

- The role of this Breakout Group is to think broadly and for the long term about the U.S. fire problem as a whole:
  - What is “enough” fire safety and how will we know when we have it?
  - Are there potential changes in how we might approach the reduction of the costs and the remaining fire losses?
  - The world is creating new technologies and advancing existing technologies at a dizzying pace. What use might these be brought to bear on the U.S. fire problem?
  - What metrics should we use in characterizing a potential fire safety technology?
  - Are there institutional barriers to the implementation of innovative fire protection approaches and technologies that we should be starting to re-shape?
  - What fire measurement science can stimulate fire technology development and break down barriers to implementation?

Approximate United States Fire Losses in 2007 (NFPA, 2008)

<table>
<thead>
<tr>
<th></th>
<th>Property Damage</th>
<th>Casualties</th>
<th>Vehicles</th>
<th>Responders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported Fires</td>
<td>9.5 M</td>
<td>0.8 M</td>
<td>0.8 M</td>
<td>1.6 M</td>
</tr>
<tr>
<td>Deaths</td>
<td>5,000</td>
<td>45</td>
<td>400</td>
<td>100</td>
</tr>
<tr>
<td>Injuries</td>
<td>15,000</td>
<td>700</td>
<td>2,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Property Loss</td>
<td>511 B</td>
<td>51 B</td>
<td>51 B</td>
<td>—</td>
</tr>
</tbody>
</table>

Recent data trends:
- Stable or slightly downward
- Increasing moderately
- Increasing sharply
Goal: Reduce the impact of fire on communities, structures, building occupants, emergency responders, and the economy by:

- Deriving lessons from fire investigations
- Reducing the flammability of materials
- Reducing the risk of fire hazard in buildings
- Reducing the risk of fire spread in wildland-urban interface (WUI) communities
- Advancing Fire Service technologies
- Improving structural fire resistance

Structural Fire Resistance Lab

Code changes to protect against fire brands

Standards for thermal imagers
NIST Investigations...

Objectives:

- Probable technical cause
- Lessons learned: successes/failures
- Improve standards, codes, practices
- Establish future research priorities
- Create an information repository on disaster and failure studies

Earthquakes
San Fernando, CA (1971)
Mexico City, Mexico (1985)
Loma Prieta, CA (1989)
Northridge, CA (1994)
Kobe, Japan (1995)
Kocaeli, Turkey (1999)

Hurricanes
Camille, MS/LA (1969)
Alicia, Galveston, TX (1983)
Hugo, SC (1989)
Andrew, FL (1992)
Hurricanes Mitch and Georges, LAC (1998)
Hurricanes Katrina and Rita (2005)

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)

Tornadoes
Jarrell, TX (1997)
Spencer, SD (1998)
Oklahoma City, OK (1999)

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)
Happyland Social Club, Bronx, NY (1990)
Oakland Hills, CA (1991)
Hokkaido, Japan (1993)
Watts St, New York City (1994)
Northridge Earthquake, CA (1994)
Kobe, Japan (1995)
Vandaila 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)

Existing Authorities include:

- **NCST Act (2002)**: building failures, evacuation and emergency response procedures
- **NIST Act (1986)**: structural investigations
- **NEHRP Reauthorization Act (1990)**: earthquakes
- **National Post-Storm Data Acquisition Plan**: wind, storms and floods
- **National Response Plan**: structural and fire safety; disaster operations and situation assessment; urban and industrial hazard analysis; recovery
- **Fire Prevention and Control Act (1974)**: fire investigations
Reduced Materials Flammability

Develop knowledge & tools to enable the materials industry to produce sustainable, cost effective, fire safe products

- Develop small-scale tests that represent the flammability of full-scale materials and products. Outcome: Less costly development of fire resistant materials

- Guidelines for processing nano-additives in polymers and novel fire retardant strategies Outcome: Improve fire performance of plastics, fiber, fabrics and foam used in common products.

- Standards for evaluating the sustainability of flame retardant additives for fire safe products Outcome: this will allow industry to better specify materials that meet sustainability goals while maintaining fire safety.
Reduced Risk of Fire Hazard in Buildings (1/2)

Enable effective fire prevention and fire protection technologies

- Develop guidelines on the dispersion, ignition, burning, and detonation behavior of hydrogen released in a compartment.
  Outcome: Provide technical basis for standards/codes development to enable safe use of hydrogen.

- Develop data and models for people movement in buildings during emergency situations.
  Outcome: Guidance and technologies for efficient and safe design of egress elements in buildings (stairwells, stair widths, lighting, elevator use, …)

- Identify technologies that reduce the flammability of upholstered furniture.
  Outcome: Provide guidance to furniture manufactures on how to significantly reduce furniture fire hazards (using barrier materials, cover fabrics, …)
Enable effective fire prevention and fire protection technologies

• **Characterize the burning behavior of cigarettes.**
  Outcome: Enable adoption of standards for highly reduced ignition propensity cigarettes.

• **Develop validated computational models to predict fire hazards.**
  Outcome: Enable performance-based design, fire reconstruction, and technology development.

• **Develop quantitative performance metrics for fire detection system standards.**
  Outcome: Detection systems that exhibit high sensitivity to a wide range of fires and that are immune to common nuisance sources.
Reduced Risk of Fire Spread in WUI Communities

Develop risk assessment and mitigation tools to reduce structure ignitions in WUI fires

- Characterize ignition of structures during a WUI fire. Outcome: Guidelines & test methods for standards/codes.

- Develop computational tools to predict fire spread. Outcome: Tools to support decision-making by incident managers, community planners, building codes and standards organizations.

- Develop model of the costs of WUI mitigation at the community-scale. Outcome: Economic model for community planning.

NOAA Fire Weather  NIST Fire Behavior (WFDS)

900 km (domain)  ~8 km (grid cell)  1 km (domain)  ~1 m (grid cell)

regional  community  residence  components
Advanced Fire Service Technologies

Enable the development & implementation of critical technology to improve Fire Service safety & effectiveness

- Develop performance metrics and practices for critical fire fighting equipment (thermal imagers, firefighter locator, hose stream, ventilation,...)
  Outcome: More effective fire ground operations.

- Develop performance metrics for advanced personal protective equipment technologies (PASS, respirators, lens, face mask, turnout gear,...)
  Outcome: Improved fire fighter safety.

- Develop measurement and predictive methods to support computer-based fire fighting simulators.
  Outcome: More effective fire fighting practices and improved fire fighter safety.
NIST Large-Scale Fire Research Laboratory

- Advance real-scale fire metrology
- Develop metrics for performance-based standards and codes
- Enable model validation
- Support post-fire analysis and investigation
Example Experiments at the NIST Large-Scale Fire Research Laboratory

- Bus Fires
- Wind Effects on Fire
- World Trade Center Study

- Mattress Fires
- Compartment Fires
- Fire Brands
NIST Structural Fire Resistance Laboratory

- 20,000 ft\(^2\) (2,000 m\(^2\)) addition
- Large exhaust hood (20 MW sustained fire)
- Structural loading capabilities under realistic fire conditions
- Planned Completion: Nov. 2011
NIST Structural Fire Resistance Laboratory
Technical Approach

• Expand existing Large Fire Laboratory to include capabilities for experiments on structural connections, assemblies, and systems at elevated temperatures (precisely loaded in 3-D) in actual fires to answer key issues:

  – How do structures with different overall system designs or with innovative materials perform in a fire?

  – How do large-scale structural components and connections perform in a fire, relative to small-scale components and connections?

  – What design trade-offs between active fire protection systems (e.g., sprinklers) and passive fire protection (e.g., increased structural fire resistance rating) are scientifically and economically justified
Examples of Research Partnerships

- **CPSC, SPSC**
  Performance test methods

- **USFA, NFPA FPRF**
  Fire fighting tactics

- **Forest Service, NOAA**
  Predictive tools

- **NRC & DOE**
  Validated fire models

- **NFPA**
  Fire fighter technology

- **USFA, DHS, NIOSH**
  Personal protective equip
Committee Participation

- Standards Council (2000-2006, Bukowski)
- Technical Correlating Committee, Protective Clothing and Equipment (Amon)
- NFPA Research Section (Madrzykowski)
- NFPA-2 Hydrogen Technologies (Yang)
- NFPA-13D Residential Sprinklers (Madrzykowski)
- NFPA-72 Fire Alarm Systems (Cleary, Bukowski)
- NFPA-76 Telecommunications (Cleary)
- NFPA-130 Fixed Guideway Transit and Passenger Rail Systems (Peacock)
- NFPA 211 Chimney, Fireplace, Vent and Solid Fuel Burning Appliances (Peacock)
- NFPA-262 Fire Tests (Gann)
- NFPA-295 Forest and Rural Fire Protection (Maranghides)
- NFPA 555 Hazards and Risk of Contents and Furnishings (Bukowski)
- NFPA-921 Guide for Fire and Explosion Investigation (Madrzykowski & Kerber)
- NFPA-1800 Electronic Safety Equipment (Bryner & Amon)
- NFPA 2001 Clean Agent Extinguishing Systems (Yang)
- NFPA-5000 Building and Construction Code (Peacock)
- Technical Toxicity Advisory Committee, Chair (Gann)
- Upholstered Furniture Flammability Working Group (Pitts)
- Tech. Advisory Committee modeling incipient fires with FDS (McGrattan)
- Tech. Advisory Committee modeling smoke detectors sloped ceilings (McGrattan)
Technology Transfer

- Release and maintenance of software
- Annual Fire Conference, publications, reports
- FIRE.GOV newsletter
- Participation in fire service conferences (IAFC, IAFF, FDIC, IAAI, NASFM)
- Participation in model code development to incorporate recommendations from WTC investigation
- Collaborations through NAFTL and the International Forum of Fire Research Directors
- Active standards committee work (NFPA, ASTM, ISO, UL, ASME, ICC)
NIST Fire Research Success Stories

• Smoke Alarm Standards – supported the development of smoke alarm standards, enabling a significant reduction in U.S. fire death rate from the mid-1970’s

• Reduced Mattress Flammability and Cigarette Ignition – enabling reductions in smoking related fires and unsafe mattresses through standard test methods for reduced-ignition-propensity cigarettes and mattress flammability

• Fire Fighter Protective Equip. – enabling safer and more effective fire fighting through performance metrics and standards for thermal imagers and personal alert safety systems

• Fire Fighting Tactics – supported development of guidelines for wind driven fires and positive pressure ventilation firefighting tactics

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

• Heat Release Measurements – enabling fundamental heat release rate measurements worldwide via improved standard test method

• Material Flammability – enabling a new generation of sustainable materials with experiments detailing the mechanisms and effectiveness of nanoparticle fire retardants.
Technology focused research agenda:

- Prioritizing research based on potential impact
- Focused on cost-effective and implementable technological solutions
- Providing the technical basis for standards, codes, guidelines, models, software decision-tools, standard reference materials, databases, etc.
- New construction and retrofit applications
- Engineered buildings and residences
- Enhanced facilities for structural fire resistance
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