



# Enabling Fire Loss Reduction and Technological Innovation: Building and Fire Research at NIST

**2007 Annual Fire Conference**

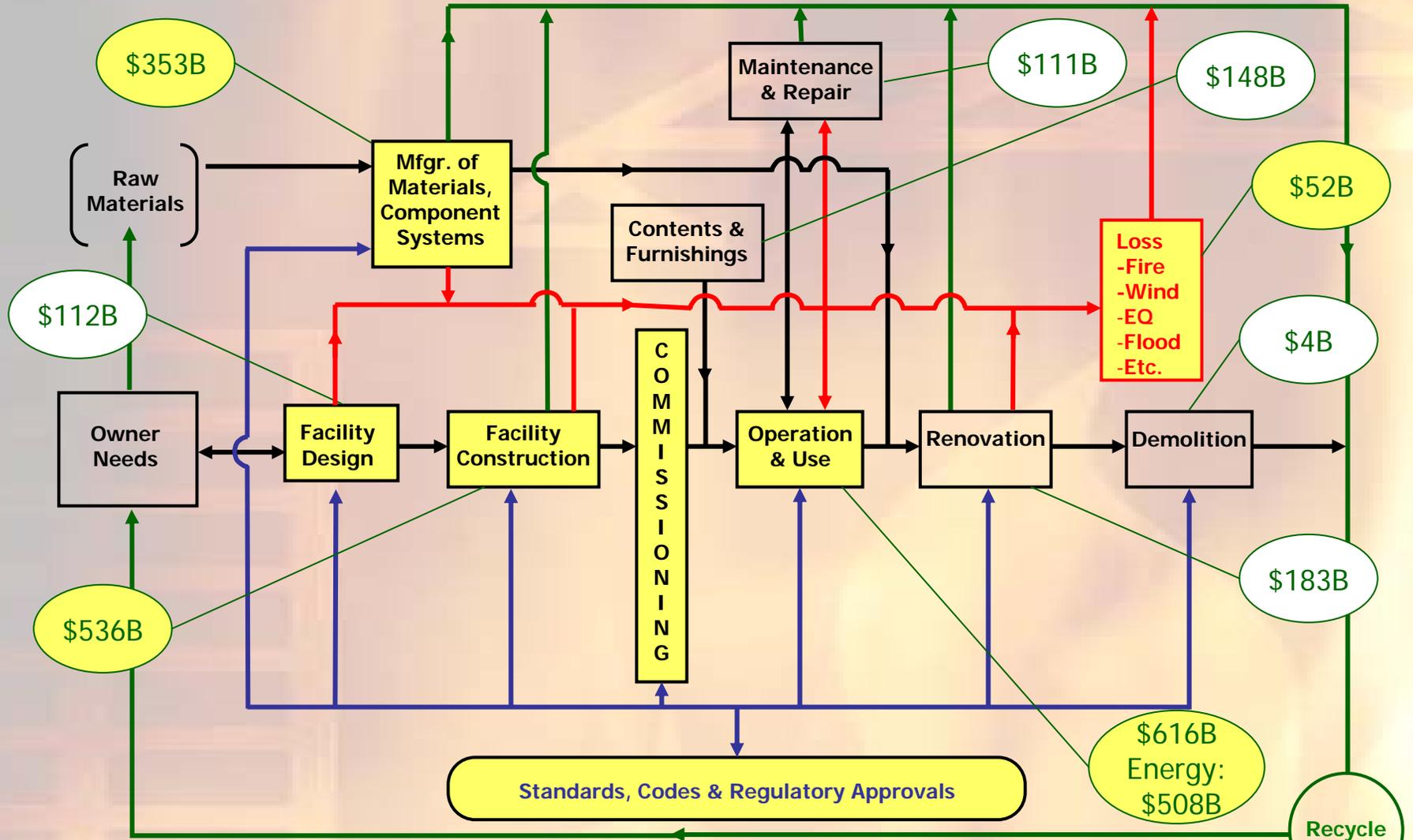
**April 4, 2007**

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Acting Director**

**Building and Fire Research Laboratory  
National Institute of Standards and Technology  
U.S. Department of Commerce**

**BFRL**

# Impacts of Construction Industry Supply Chain in 2005

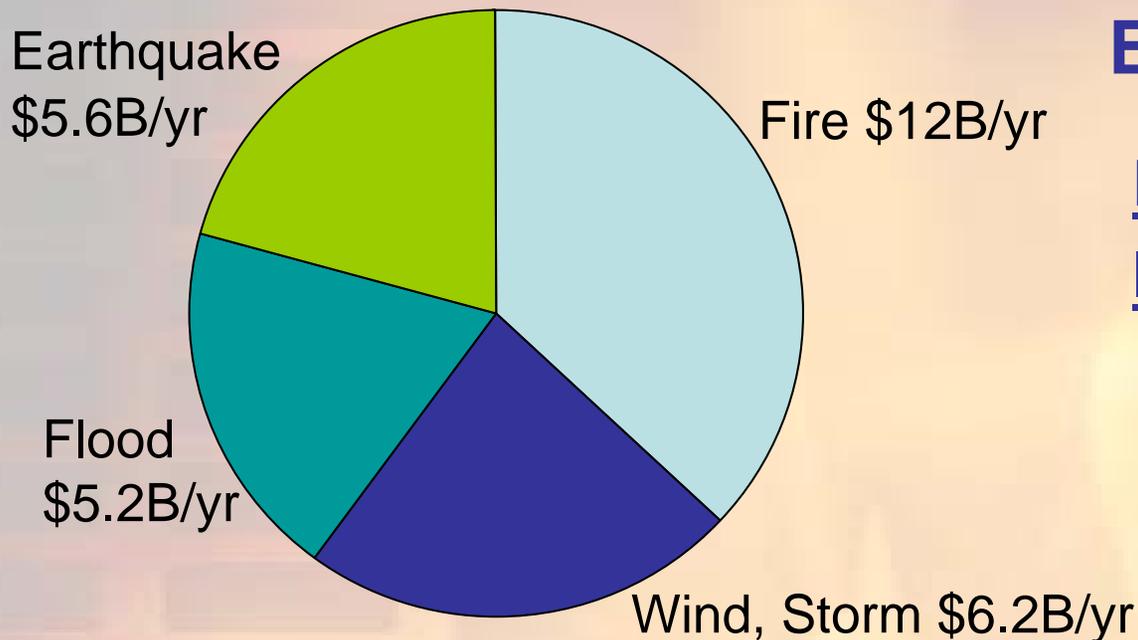


Construction Contribution to GDP	\$611B
Construction Contribution as % of GDP	4.9%
Value of Construction Put in Place	\$1 144B
Volume of Construction Work	\$1 297B
Construction Employment (Establishment Surveys)	7.3M
Construction Employment (Household Surveys)	11.2M

# Fire and Natural Disasters Annual Costs

## Average Property/Insured

### Loss



- Fire costs U.S. Economy \$200B/yr

Fire Deaths 3,675

### Injuries

Civilian 17,925

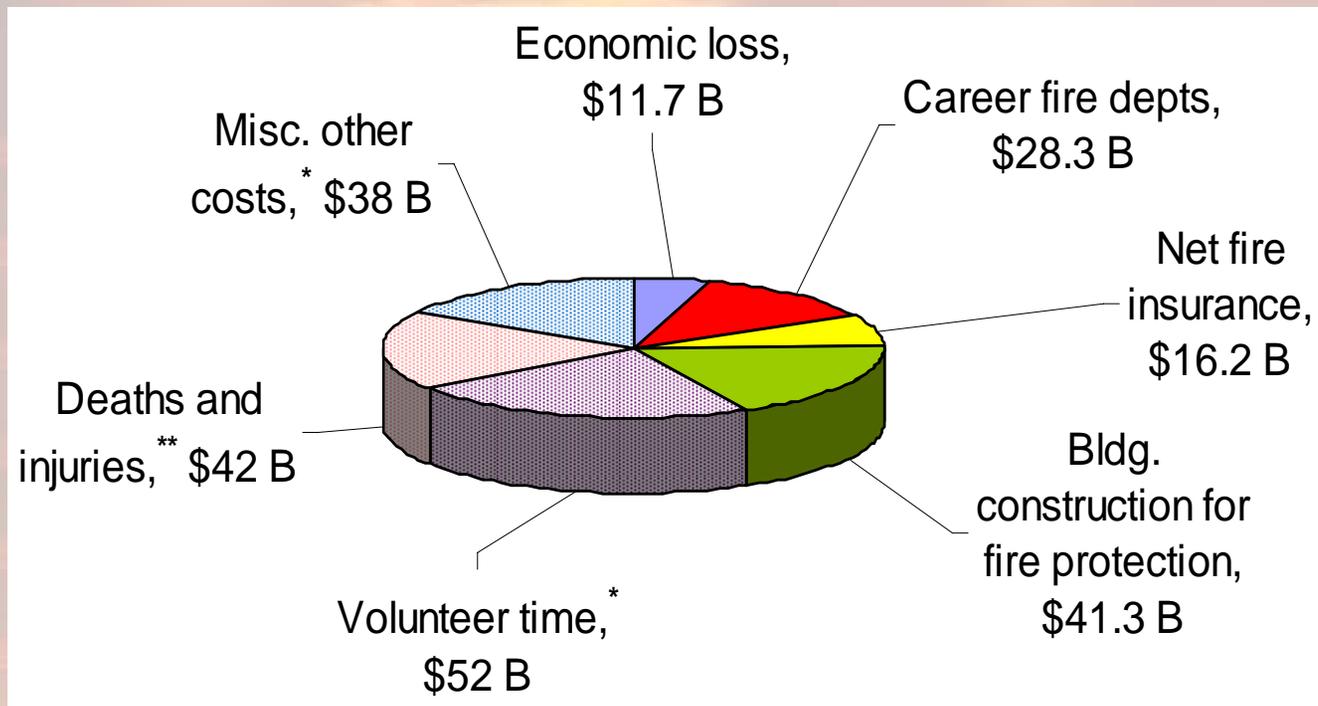
Fire Fighters 78,750

Single event could be as much as \$100-\$200B

Wildland-Urban Interface (WUI) fires \$2 B/year

# Magnitude of U.S. Fire Problem

**Estimated Total Cost# of Fire in the U.S. for 2004: ~\$230 B**



# Hall, J.R., NFPA, December 2006

\* Uncertain; estimates felt to be conservative (low)

\*\* \$6.5 M/death, \$0.22 M/injury, based upon CPSC model

# Magnitude of U.S. Fire Problem

- **Continuing high rates of fire deaths in U.S.** – 50 % more people die in fires each year than perished in the World Trade Center; and per capita fire deaths are 70 % higher than in EU.
- **Costly, sub-optimum building designs due to prescriptive fire codes with unsubstantiated factors of safety** – Impacts of modern furnishings, building materials, and designs on time available for safe egress are unquantified, especially for impaired populations.
- **Mitigation strategies needed in response to manmade fire threats**– Accidental, intentional, and due to new higher risk technologies.
- **Under-investment in fundamental fire research highlighted as critical problem in National Academies study.\***

\**Making the Nation Safe from Fire, a Path Forward in Research*, Nat'l Academies Press, 2003.

# Trends: Losses#

	<u>1980*</u>	<u>2004</u>
Economic losses	\$18.1 B	\$11.7 B
Career fire dept. expenses	\$13.1 B	\$28.3 B
Net cost of insurance	\$ 9.4 B	\$16.2 B
Bldg. construction for fire protection	<u>\$24.3 B</u>	<u>\$41.3 B</u>
Sub-total	<b>\$64.9 B</b>	<b>\$97.5 B</b>
Civilian deaths	6 505	3 900
Civilian injuries	30 200	17 875

# Hall, J.R., NFPA, December 2006

\* \$ adjusted to 2004

# Trends: Analysis

**Fire deaths and injuries are down 40 % between 1980 and 2004. How has NIST research into fire measurements and standards contributed to this drop?**

- Heat release rate measurements underpin all flammability standards worldwide.
- Children's sleepwear standards can be linked directly to drop in fatalities and burns.
- Residential smoke detector evaluation standards are identified as major factor.
- Cigarette ignition test standards for mattresses and furniture, and reduced-ignition propensity test standard for cigarettes are being adopted by States, Canada.
- Technical data for sprinkler standards better inform local decisions on codes.
- Predictive methods for fire and smoke spread are basis for entire design profession.
- Dissemination of NIST research educates fire service, code officials, designers, and general public.

# Trends: Analysis

Cost of providing fire protection in buildings is up 70 % between 1980 and 2004. Why has that occurred?

- Between 1980 and 2004, GDP increased 83 % (inflation adjusted), and value of construction put in place increased 65 %. These numbers are of the same order as increase in absolute cost of providing fire protection in buildings.
- New regulatory requirements for fire alarms/sprinklers, and more attention being paid to investing in prevention/mitigation strategies to avoid unforeseen losses.
- Buildings designed and constructed according to prescriptive codes and standards
- Significant potential for gaining cost efficiencies through performance-based standards and codes that enable risk-consistent solutions
- Key to early implementation of performance based standards and codes is investment in use-inspired research necessary to underpin codes & standards.

# NIST At A Glance

Gaithersburg, MD



Boulder, CO



- 2,800 employees
- ~2,500 associates and facility users
- NIST Research Laboratories
- Hollings Manufacturing Extension Partnership
- Baldrige National Quality Award
- Advanced Technology Program

BFRL

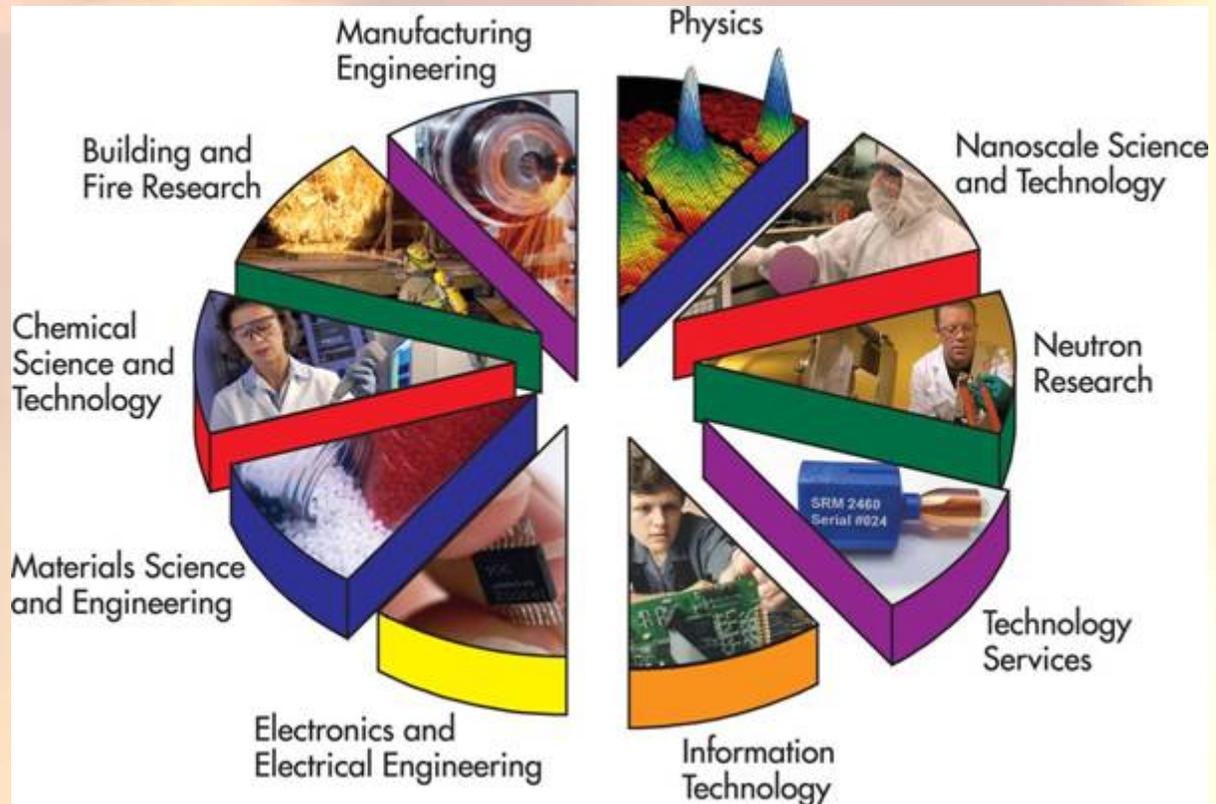
# The NIST Laboratories

## NIST's work enables

- Science
- Technology innovation
- Trade
- Public benefit

## • NIST works with

- Industry
- Academia
- Other agencies
- Government agencies
- Measurement laboratories
- Standards organizations



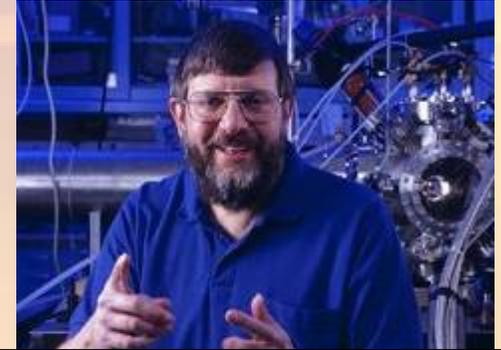
# NIST has... ...world-class staff



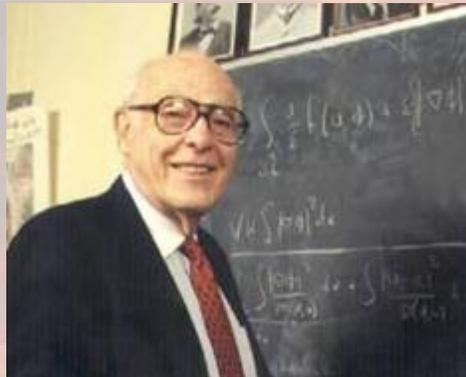
Jan Hall  
2005 Nobel Prize  
in Physics



Eric Cornell  
2001 Nobel Prize  
in Physics



Bill Phillips  
1997 Nobel Prize  
in Physics



John Cahn  
1998 National Medal of  
Science



Anneke Sengers  
2003 L'Oréal-UNESCO  
Women in Science Award



Debbie Jin  
2003 MacArthur  
Fellowship

# BFRL Mission

To promote U.S. *innovation* and *competitiveness* by anticipating and meeting the:

- measurement science,
- standards, and
- technology

needs of the U.S. building and fire safety industries in ways that enhance *economic security* and improve the *quality of life*.

# BFRL Vision

To be *the* source for creating *critical solution-enabling tools*—metrics, models, and knowledge—and promoting *performance-based standards* that are *used* by the U.S. building and fire safety industries to establish global leadership.

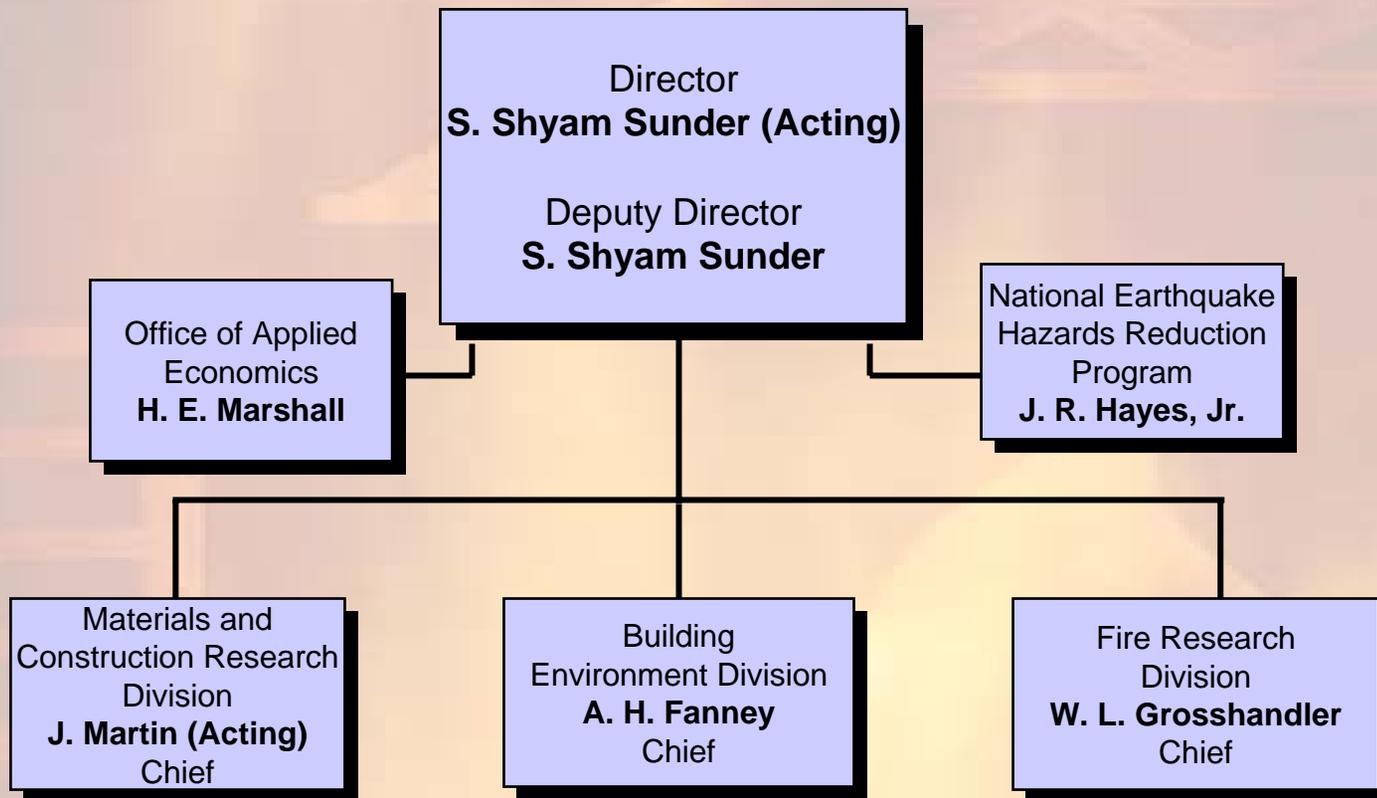
*BFRL is the primary federal laboratory serving the building and fire safety industries*

BFRL

# Role of Measurement and Standards

- **Enable innovation and competitiveness – *revolutionary transformation from prescriptive to performance standards***
- **Assure public health and safety**
- **Market access**
- **Affix responsibility, liability**
- **Equity in trade - domestic and international**

# BFRL Organization



- Structures
- Construction Metrology and Automation
- Polymeric Materials
- Inorganic Materials

- HVAC&R Equipment Performance
- Mechanical Systems & Controls
- Heat Transfer & Alternative Energy Systems
- Computer-Integrated Building Processes
- Indoor Air Quality & Ventilation

- Fire Fighting Technology
- Fire Metrology
- Analysis & Prediction
- Integrated Performance Assessment
- Materials & Products

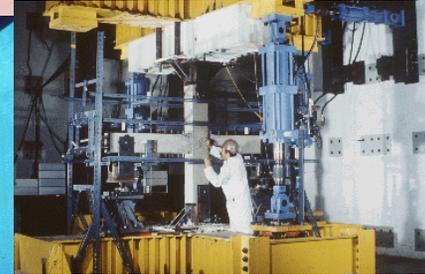
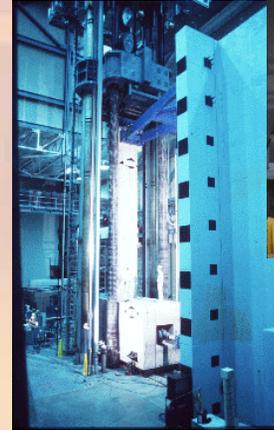
# Measurement Science



*Virtual Cement and Concrete Testing Laboratory*



*Integrating Sphere for Service Life Prediction of Materials*



*Tri-directional Test Facility  
Large-Scale Structures Testing Laboratory*

*High Temperature Guarded Hot Plate for Advanced Thermal Insulation Measurements*

- Building Integrated Photovoltaic Testbed
- Mobile Solar Tracker Facility
- Fire Emulator/Detector Evaluator
- Virtual Cybernetic Building Test Bed
- Well Stirred Reactor / Plug Flow Reactor
- Residential Indoor Air Quality Test Laboratory
- High-Throughput Research



*Residential Fuel Cell Testing Laboratory*



*Large Fire Research Facility*



*Cone Calorimeter*

# NIST Statutory Authorities

- **Fire Prevention and Control act (1974)**
- **National Earthquake Hazards Reduction Program Reauthorization Act (1977, amended 2004)**
  - NIST designated lead federal agency for the U.S. National Earthquake Hazards Reduction Program.
- **National Windstorm Impact Reduction Act (2004)**
- **National Construction Safety Team Act (2002)**

# **NIST Role in Building and Fire Safety Regulations**

- **NIST is a non-regulatory agency of the U.S. Department of Commerce's Technology Administration**
- **NIST does not set building and fire codes and standards**
- **NIST provides technical support to the private sector and to other government agencies in the development of U.S. building and fire practice, standards, and codes by:**
  - **Conducting research which provides the measurements, science, and technical basis for such practice, standards, and codes**
  - **Disseminating research results to practicing professionals**
  - **Having its staff participate on technical and standards committees**
  - **Providing technical assistance to the building and fire safety communities**

# **Technical Priorities for Fire Research**

**Reducing risk of fire spread**

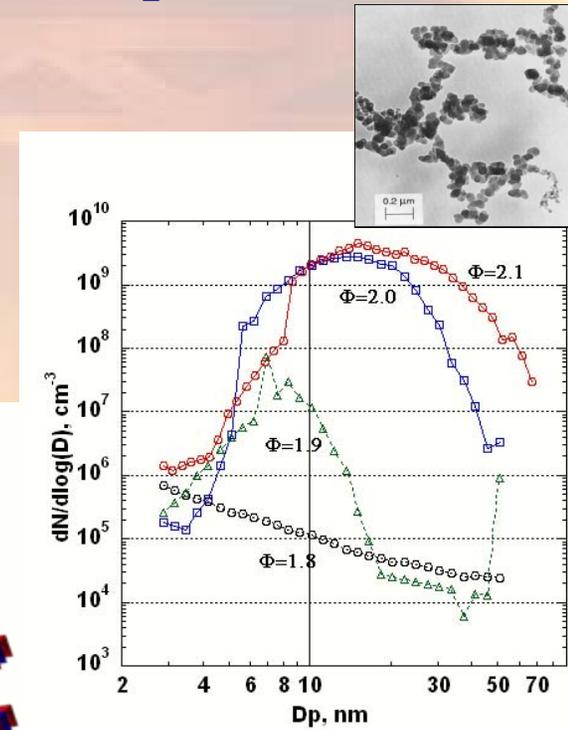
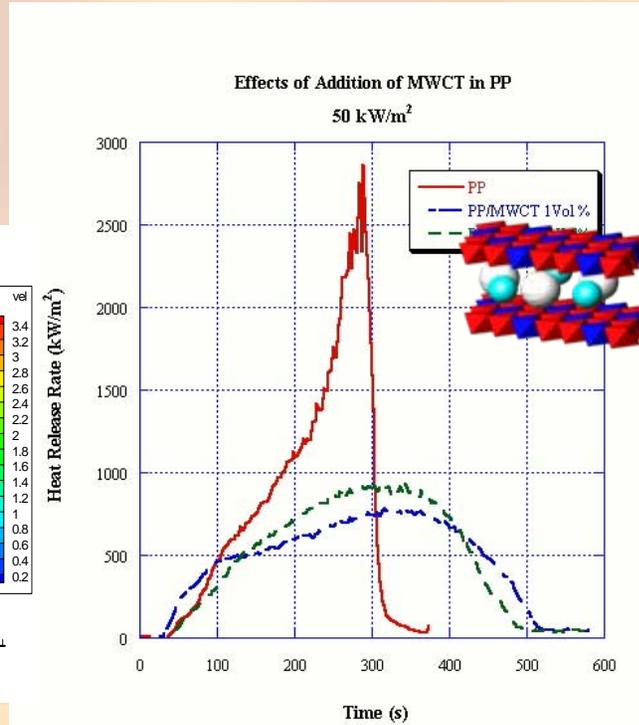
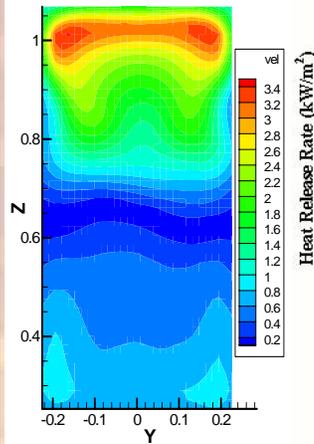
**Reducing risks to building occupants**

**Increasing effectiveness of first responders**

**Enabling technological innovation**

# Reducing Risk of Fire Spread

- Reduction in heat release rate
- Predicting soot formation and radiant heat flux
- Numerical simulation of flashover
- Test methods and standards



# Fires at the Wildland-Urban Interface

***Problem: Significant increase in structural risk as more communities encroach on wild lands.***



regional



community



residence

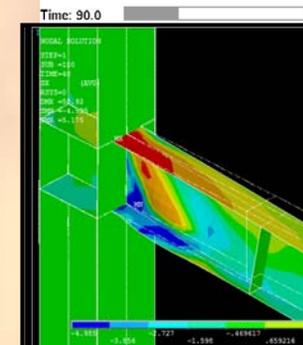
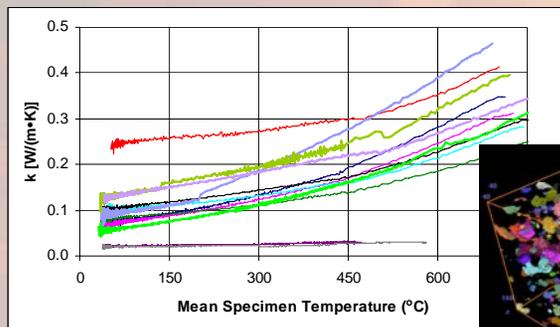
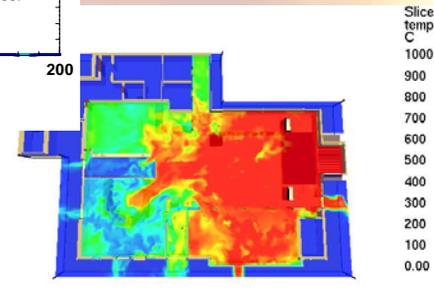
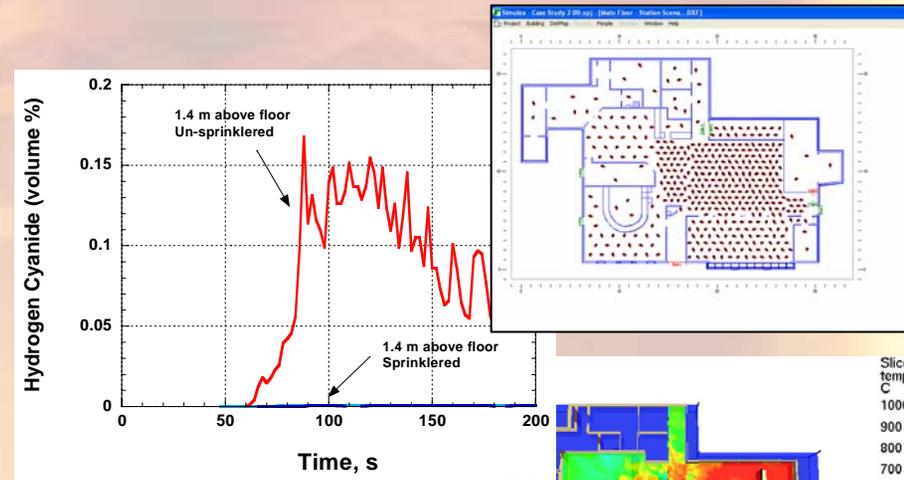


Basic fire spread components

- Coupled fire weather and WFDS models to cover all relevant scales. (NIST & NOAA)
- Database of fuels in communities at the wildland-urban interface. (NIST)
- Physics-based predictive tools to support operational decision-making by incident managers. (NIST & NOAA)

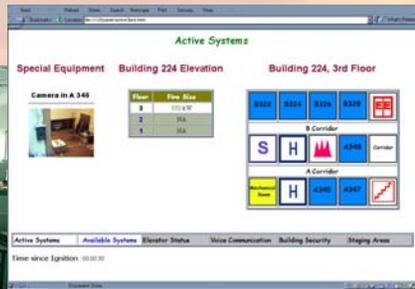
# Reducing Risk to Building Occupants

- Egress model formulation and validation
- Quantification of hindrance to egress due to fire products:
  - loss of visibility
  - CO and CO<sub>2</sub>
  - HCN, HCl, HF, HBr, organics
  - temperature and heat flux
- Structural fire resistance to ensure safe egress:
  - high temperature performance of steel and concrete
  - innovative fire protective coatings
  - structural collapse model formulation and validation

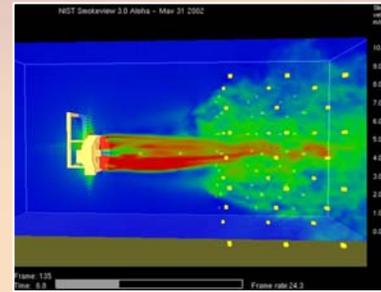


# Increasing Effectiveness of First Responders

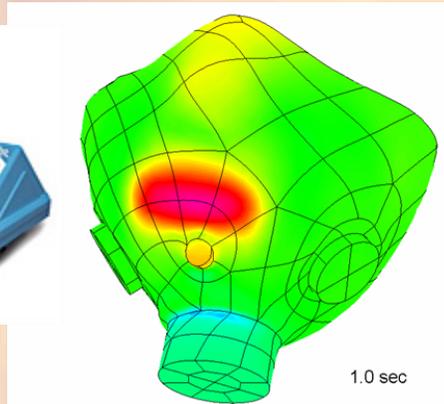
- Information-rich environment for decision makers



- Dynamic fire fighting simulation tools



- Increasing effectiveness of fire fighting technologies



# Enabling Technological Innovation

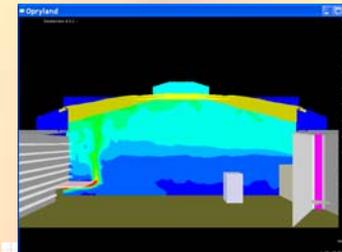
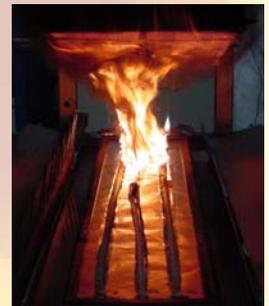
Thermal imaging camera standards

Emergency responder and occupant locator technology measurement standards

Methodologies for predicting reduced flammability of nano-composites

Performance predictions for advanced sensing and information management for fire detection and monitoring.

Predictive tools for innovative fire protection building design



Schirmer Engineering Corp.

# Role of Fire Grants Program

## Objective:

- To support basic and applied fire research as authorized by 15 USC 278f, and Federal Fire Prevention and Control Act of 1974 (PL 93-493).
- Established in 1978 from NSF funds to expand cadre of those working in fire safety science, and to help fill pipeline of fire protection engineers (FPEs) needed to serve society.
- To create critical mass with NIST researchers and assemble expertise necessary to hurdle complex physical, sociological, and economic barriers.

## Summary of proposal and award data, FY2003-FY2006:

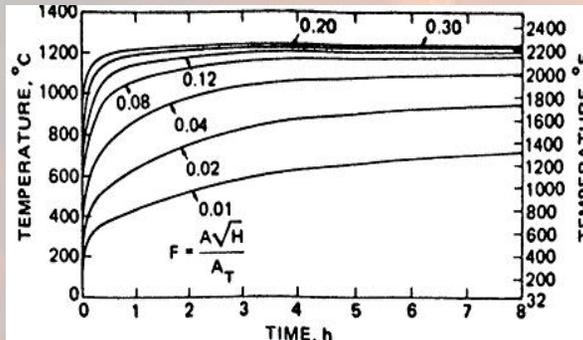
- 20 to 30 grants at any given time (80 % to 90 % at universities)
- 5 to 8 new grants per year
- 1 in 3 success rate on actual submissions

# Impact of Fire Grants Program



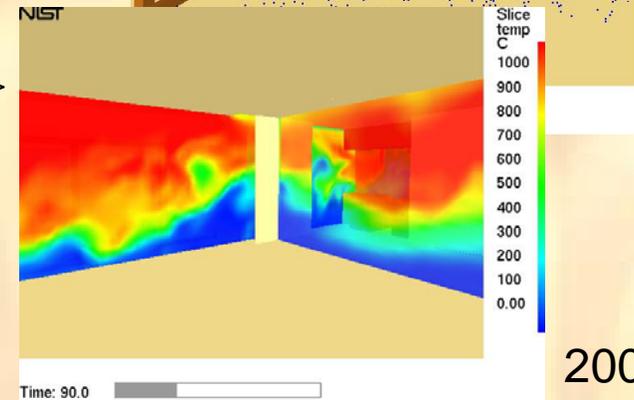
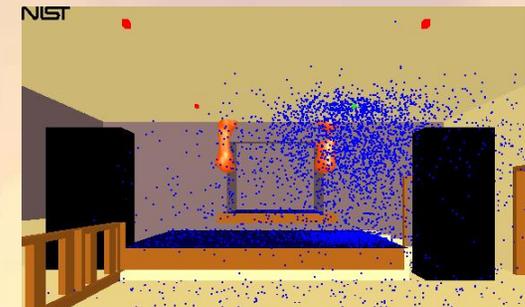
Between 1978 and 1984 Howard Emmons (Harvard University, member NAE and NAS), with \$1.7 M grant, established framework for building fire models upon which the NIST zone model (CFAST) and the NIST CFD model (FDS) are built, and upon which the entire Fire Protection Engineering profession now depends.

Father of Fire Science



1978

from correlation  
to  
simulation/visualization



2007

Academic centers at Princeton, University of Utah, Cal Tech, UC Berkeley enabled ground breaking advances in fire dynamics, fire chemistry, toxicity, soot and heat transfer, and the impact of elevated temperatures on structures.

# Stakeholders & Contributors to Fire Loss Reduction and Fire Protection Innovation



# NIST Fire Research Program

**NIST  
University  
Grants**

**NIST  
Laboratory  
Research**

**Industry**

**State/Local  
Governments**

**Innovations in Fire  
Measurement Science  
and Standards**

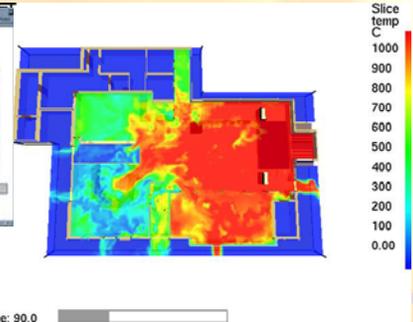
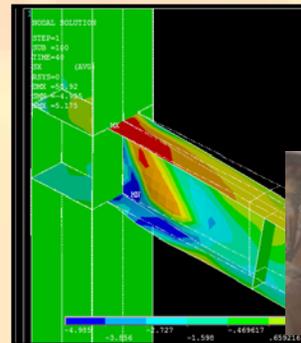
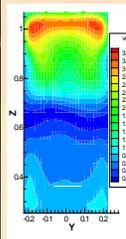
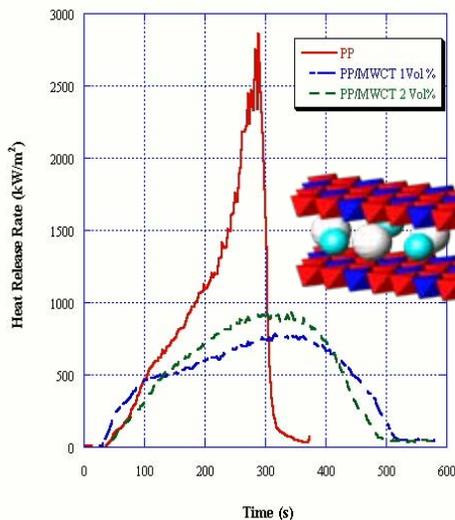
**Outcomes**

- Reduce heat release rate
- Simulate flashover
- Validate egress models
- Smoke, toxic products
- Structural fire resistance
- Information-rich environment
- Fire fighting simulation tools
- New fire fighting technologies

- Performance-Based Safety Standards/Codes
- Materials, Products, and Design Innovations

- Decreased Fire Spread
- Reduced Occupant Risk
- Increased First Responder Effectiveness

Effects of Addition of MWCT in PP  
50 kW/m<sup>2</sup>



# NIST Investigations...

- **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)
  - Pulaski Building, Washington, D.C. (1990)
  - 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)

## Results:

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

## 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

# Safety of Threatened Buildings

## Increased Structural Integrity    Enhanced Fire Resistance



**Fire Protective Coatings for Structural Steel** - Predictive criteria for selection of fire protective coatings to accelerate development of materials with reduced vulnerability to extreme events.

### **Prevention of Progressive Collapse**

To develop and implement performance criteria for codes and standards, tools, and practical guidance for prevention of progressive structural collapse.



**Fire Resistance of Uncoated Structural Steel** - Develop efficient test method for evaluating fire resistance of steel; Benefits of FR steel not adequately tested under ASTM E119

### **Fire Safe Building Structures**

To develop and implement verified and improved standards, tools, methodology and guidance for fire resistance design and retrofit of concrete and steel structures.

### **Fire Resistance of Building Partitions**

Technical basis for accurate measurement & prediction methodologies for inclusion of fire resistance properties of walls, floors & ceilings in performance-based fire safety design

# Safety of Threatened Buildings

## Improved Emergency Egress & Access

**Occupant Behavior and Egress**  
Reliable predictions of time to egress

**Emergency Use of Elevators**  
Technical and procedural means to allow use of elevators during emergencies for evacuation of occupants with disabilities from, and for first responder access to, high rise buildings



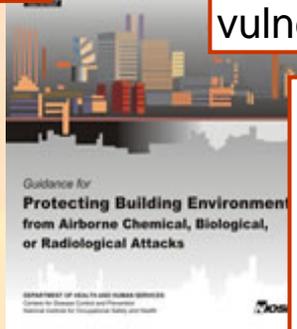
## Building & Emergency Equipment Stds & Guidelines

**Equipment Standards for First Responders** - Technologies that enhance building information transfer to support informed fire fighting decisions

**Standard Information Models**  
Standard building information models that facilitate simulation of building system behavior during adverse events

**Technologies for Building Operations in CBR Attacks** - Analysis tools and guidance for assessment and subsequent reductions in vulnerability of buildings to CBR attacks

**Cost-effective Risk Management Tools**  
User-friendly tool for building owners/managers to aid in selection of cost-effective strategies for management of terrorist and environmental risks



# Fire Safety Standards

- **Consumer Products**
  - Cigarette flammability
  - Mattress flammability
  - Electronic equipment flammability
  - Toxicity of commodity materials
- **Fire Fighter Safety: Emergency Equipment Standards and Guidelines**
  - Personal Alert Safety System (PASS ) device
  - Thermal imaging cameras
  - Fire fighter clothing
  - Elevator use and safety
  - Incident command and information delivery standards
- **Public Safety**
  - Fire alarms and detectors
  - Local suppression systems for residential kitchen fire protection
  - Fire model validation
  - Fire resistant partitions in structures
  - Life Safety Code development
  - Sprinkler system installation and performance
  - Fire and explosion investigations

# Impact on Standards and Codes

- **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** – protecting consumers nationwide from unsafe mattresses via standard mattress flammability test method
- **Risk of Cigarette Fires** – enabling reductions in smoking related fires through standard test method for reduced-ignition-propensity cigarettes adopted in several States and Canada
- **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 fundamental heat release rate measurements worldwide via improved standard test method

