

NIST Response to the World Trade Center Disaster

**Standards, Technology, and Practices for:
Cost-Effective Safety and Security of
Buildings and Critical Facilities**

November 12, 2002

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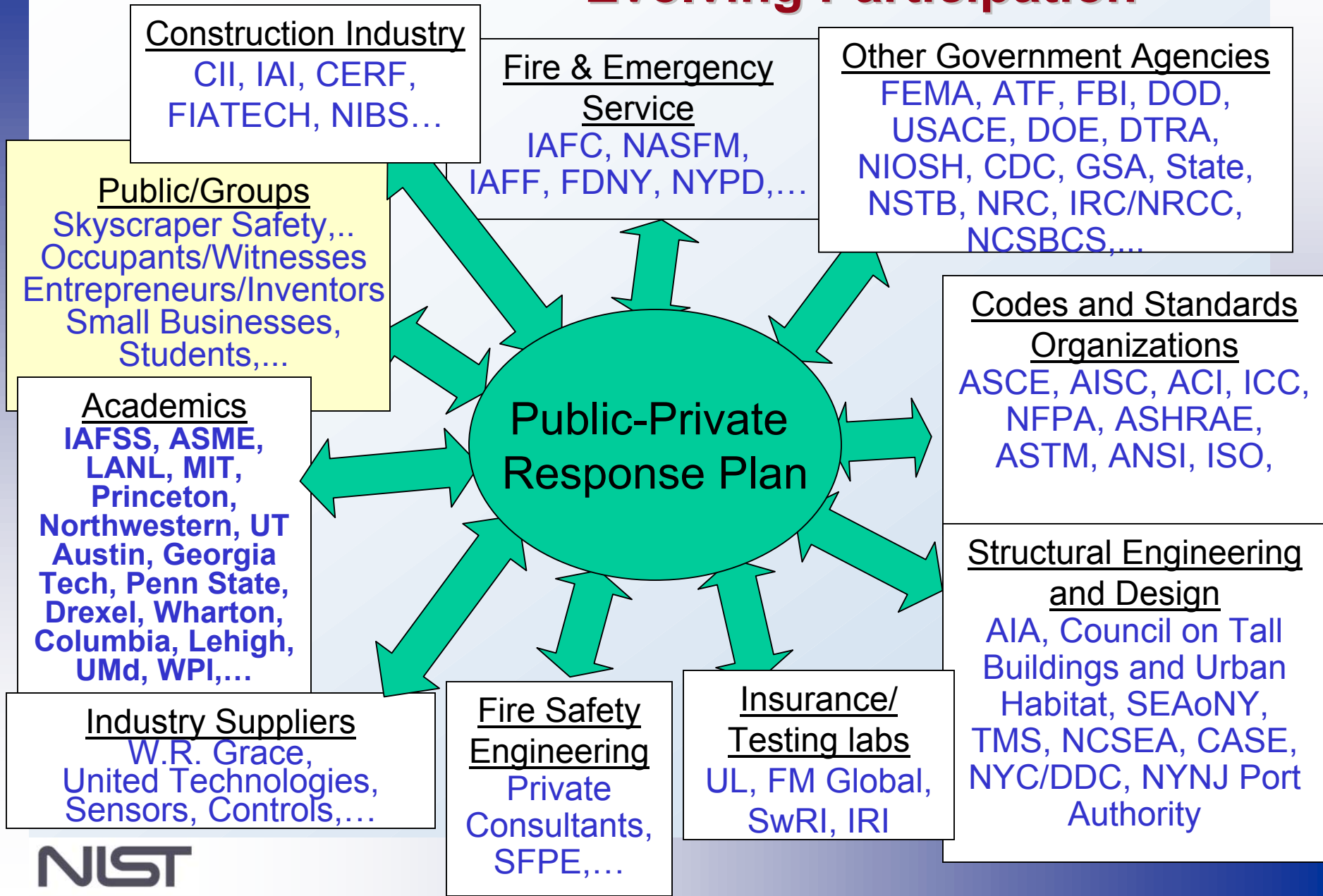
Building and Fire Research Laboratory

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Evolving Participation



National Need

- One of worst-ever building disasters.
- Unprecedented death and destruction in any single U.S. event.
- Never before have over 400 emergency responders lost their lives in a single incident.
- Unprepared for dramatic collapse of buildings occupied and in everyday use.

Critical and urgent national need to:

- Establish the **probable technical causes** of collapses and derive lessons to be learned
 - Disseminate immediate **guidance and tools** to assess and reduce future vulnerabilities
 - Produce the technical basis for **cost-effective changes** to national practices and standards
- Need an integrated effort that draws on capabilities and expertise of a broad coalition of private and public sector organizations.

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)
- Hurricane Mitch and Georges, LAC (1998)

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)

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)

Prior NIST Investigations...

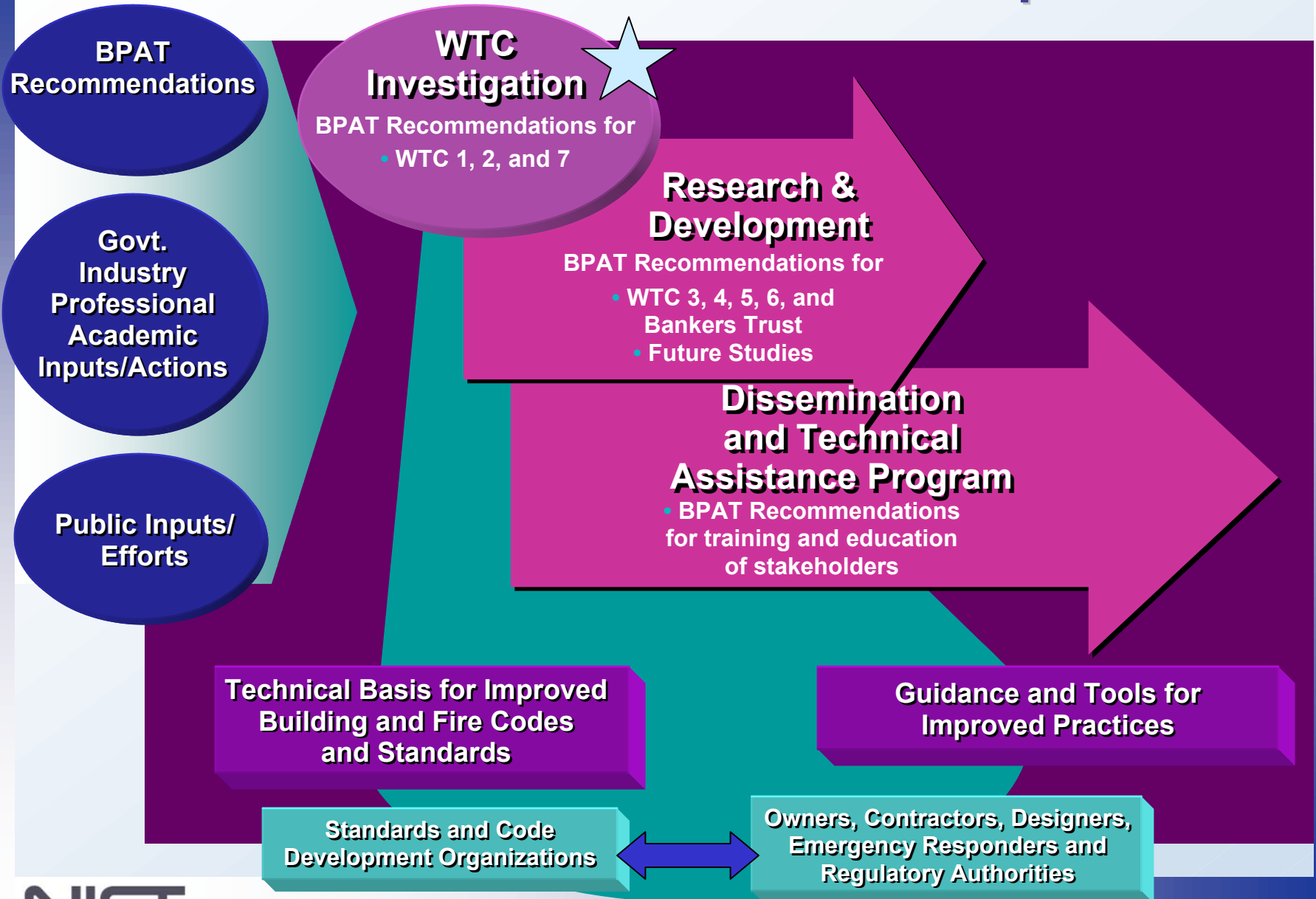
Results:

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

Authorities:

- ***NIST Act (1986)***: structural investigations
- ***NEHRP Reauthorization Act (1990)***: earthquakes
- ***National Post-Storm Data Acquisition Plan***: wind storms and floods
- ***Federal Response Plan***: structural and fire safety; disaster operations and situation assessment; urban and industrial hazard analysis
- ***Fire Prevention and Control Act (1974)***: fire investigations

NIST Public-Private Response Plan



Goals

- **To investigate the building construction, the materials used, and the technical conditions that contributed to the outcome of the World Trade Center disaster**
- To serve as the basis for:
 - Improvements in the way buildings are designed, constructed, maintained, and used
 - Improved tools, guidance for industry and safety officials
 - Revisions to codes, standards, and practices
 - Improved public safety
- **Estimated Time-to-Completion:**
 - Final report in 24 months
 - Interim progress reports and key project reports along the way

Objectives

- Determine technically, why and how the buildings WTC 1, 2, and 7 collapsed following the initial impact of the aircraft
- Determine why the injuries and fatalities were so low or high depending on location, including all technical aspects of fire protection, response, evacuation, and occupant behavior and emergency response
- Determine what procedures and practices that were used in the design, construction, operation, and maintenance of the WTC buildings
- Identify, as specifically as possible, building and fire codes, standards, and practices that are still in use and warrant revision

Guiding Principles

- Active, comprehensive, thorough, independent, and objective
- Fully informed of concerns and issues of all parties and within limits of available resources
- Open and inclusive process in planning and conducting investigation and in publishing and disseminating findings and recommendations
- Improve practice, standards, and codes and reduce future risks by focusing on:
 - Fact-finding and analysis of the facts
 - Validating and verifying existing knowledge
 - Creating new technical and/or scientific knowledge
- Non-technical issues outside scope: no findings of fault or negligence of any individual or organization
- Maintain ongoing liaison with professional community, public, and local authorities
- Project teams of NIST and external world-class technical experts

Scope

- Adopt BPAT recommendations that additional studies of Twin Towers and WTC 7 should be conducted.
- Holistic investigation approach considering the interplay between the building, the occupants, and the emergency responders
- Review, analysis, modeling, and re-creation testing work based upon a solid foundation of technical evidence
- Lessons to be learned will be applicable to a broad range of building types, not just the specific buildings that are studied

Lessons to be Learned

- **Lessons for Structural Fire Protection**

- Dynamics of building fires and collapse vulnerability of buildings to fires
- General methodologies for fire safety design and retrofit of structures
- Behavior of fireproofing materials and connections used in steel structures
- Behavior of open-web steel trussed joists in fires
- Collapse mechanisms and role of pivotal components such as transfer girders and floor diaphragms

- **Lessons for Life Safety**

- Firefighting technologies and practices for tall buildings
- Occupant behavior and evacuation technologies and practices for tall buildings
- Control of fire spread in buildings with potentially large open floor plans
- Command, control, and communication systems for fire service response

- **Lessons for Engineering Practice**

- Evaluation process for innovative systems
- Margin of safety and redundancy to accommodate abnormal loads

NIST WTC Investigation Plan

BPAT
Recommendations

Government,
Industry,
Professional,
Academic Inputs

Public Inputs

**Identification
of Technical
Issues and
Major
Hypotheses**

Public Inputs

Documents

Video/ Photographic
Records

Oral History Data

Emergency Response
Records

Recovered Structural
Steel

Objective 1:

**Why and how WTC Buildings
1, 2, and 7 collapsed**

Objective 3:

**Procedures and practices
used in design, construction,
operation, and maintenance
of WTC Buildings**

Objective 2:

**Why injuries and fatalities were
so low or high depending
on location**

Objective 4:
**Building
codes,
standards,
and
practices
that warrant
revision**

**Technical
findings and
recom-
mendations**

**Dissemination
and
deployment
of findings
via R&D and
DTAP**

Steel from WTC Towers



Clean weld fracture of Interior columns

Failure at connection between floor system and exterior columns



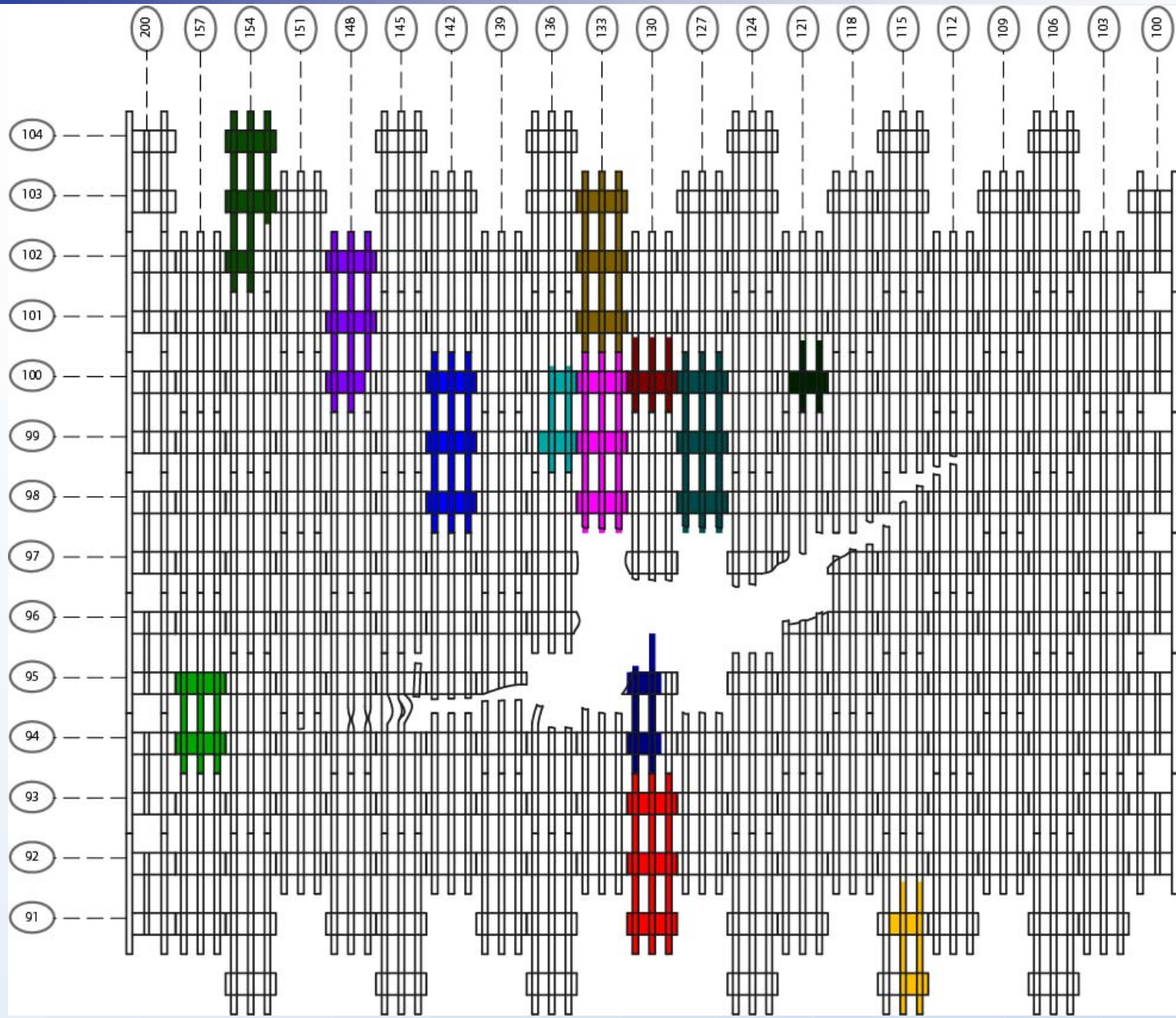
Dr. John Fisher (Lehigh) and Robert Duvall (NFPA)



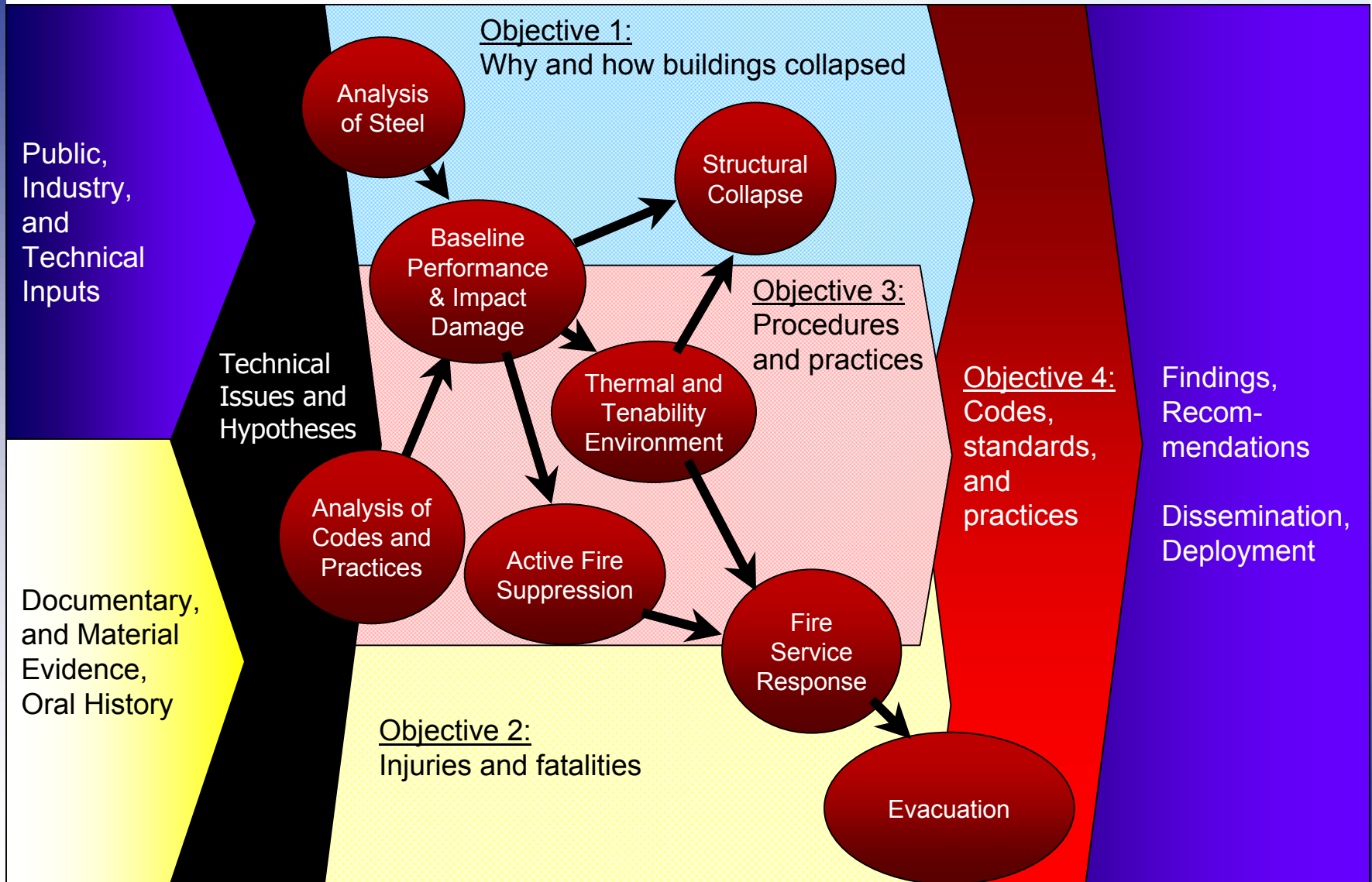
WTC steel columns



Dr. John Gross (NIST)

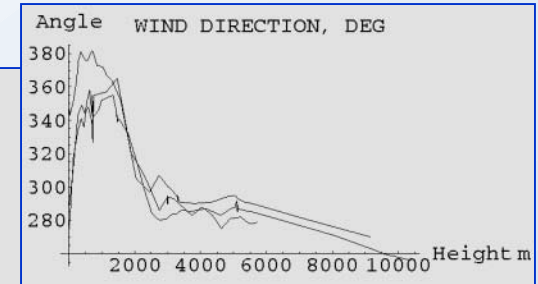
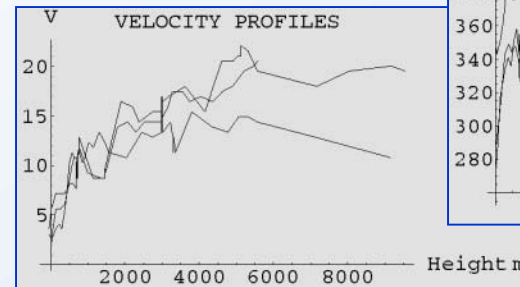


NIST WTC Investigation Plan

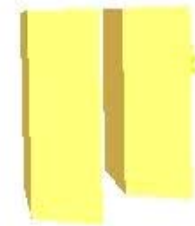


Simulation Tool for Re-creation of Fire and Smoke Movement (Rehm et al.)

Three commercial flights reported data using the Addressing and Reporting System (ACARS)



NIST Smokeview 2.0Beta1_0831 - DO NOT CITE



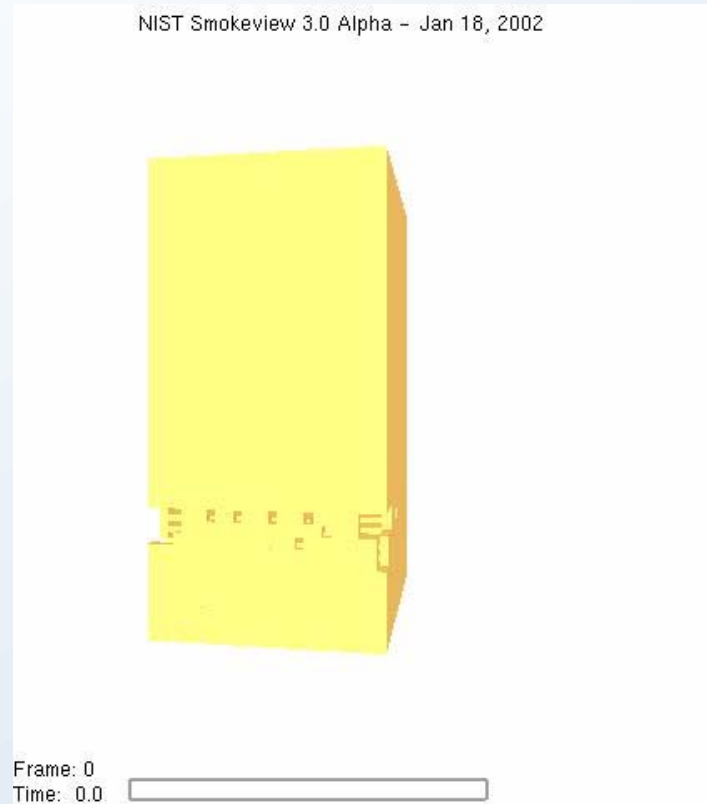
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FDS 1

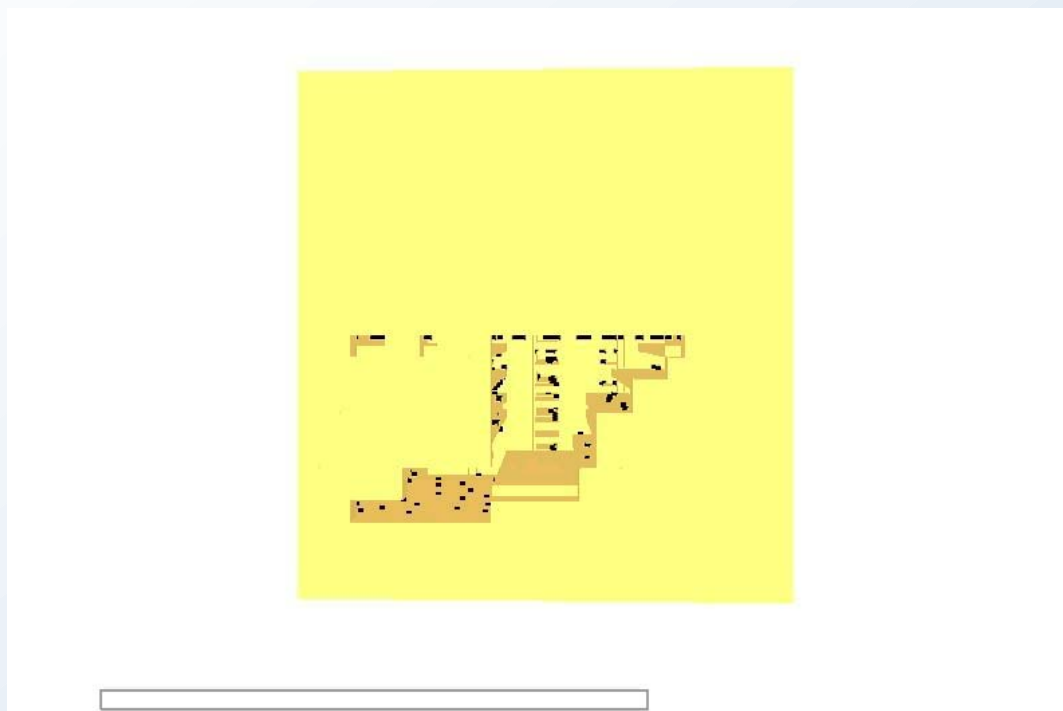
 **Wind 5 m/s
to south**

South Tower Fireball



**Seconds after impact.
About 3000 kg fuel consumed.**

Simulation Tool for Recreation of Fire and Smoke Movement



Legislative Authorities

Structural Failures [P.L. 99-73, Sec. 7; 15 U.S.C. 281a]

The National Institute of Standards and Technology, on its own initiative **but only after consultation with local authorities**, may initiate and conduct investigations to determine the causes of structural failures in structures which are used or occupied by the general public. **No part of any report resulting from such investigation shall be submitted as evidence or used in any suit or action for damages arising out of any matter mentioned in the report.**

Fire Prevention and Control Act [P.L. 93-498, Sec.16, (a), (3)]

NIST conducts and supports research on all aspects of fire with the aim of providing scientific and technical knowledge applicable to the prevention and control of fires. **The Act authorizes NIST to conduct “...operation tests, demonstration projects and fire investigations** in support of the activities set forth in this section.”

National Construction Safety Team Act (PL 107-231):

Purpose of Act:

“...to provide for the establishment of investigative teams to assess building performance and emergency response and evacuation procedures in the wake of any building failure that has resulted in substantial loss of life or that posed the potential for substantial loss of life.”

Purpose of Investigations:

“...to improve the safety and structural integrity of buildings in the United States.”

National Construction Safety Team Act

Issue: No one has the responsibility to derive lessons learned.

Proposal: An “NTSB-like” body...

- Independent, objective, fact, not fault-finding
- Ability to collect, analyze, make public critical information

National Construction Safety Team Act:

- Introduced by Boehlert in House, Clinton in Senate
- Signed into law October 1, 2002

Tasks NIST Director to establish teams, develop reports:

- Launched within 48 hours
- Include at least one NIST employee
- Applies to WTC investigation as well.

Authorities:

- Entry/Inspection
- Subpoena, Briefings, Hearings, Witnesses
- Priority (except for criminal act)

NIST Public-Private Response Plan

**BPAT
Recommendations**

WTC Investigation

BPAT Recommendations for

- WTC 1, 2, and 7

**Govt.
Industry
Professional
Academic
Inputs/Actions**

Research & Development

BPAT Recommendations for

- WTC 3, 4, 5, 6, and Bankers Trust
- Future Studies

**Public Inputs/
Efforts**

Dissemination and Technical Assistance Program

• BPAT Recommendations for training and education of stakeholders

**Technical Basis for Improved
Building and Fire Codes
and Standards**

**Guidance and Tools for
Improved Practices**

**Standards and Code
Development Organizations**

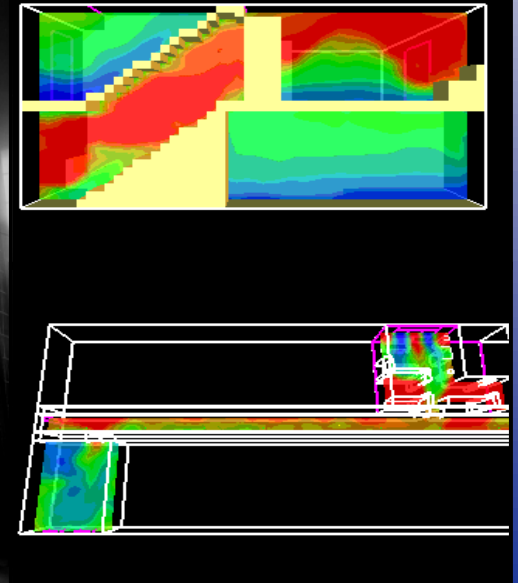
**Owners, Contractors, Designers,
Emergency Responders and
Regulatory Authorities**



R&D Program: Structural Fire Protection

1. Fire safety design & retrofit of structures
2. Method of fire resistance determination
3. Prevention of progressive structural collapse
4. Improved fire resistance coatings

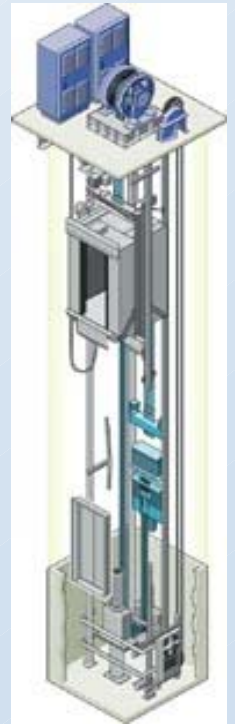
Some Potential R&D Partners: ASCEC (AISC, ACI, SFPE, NFPA, CASE, Council on Tall Buildings, ICC, SEAoNY, TMS, NCSEA), NRC, NRCC, Materials industry, NSF, FM Global, ASTM, ISO, AIA, UL, Universities,...



R&D Program: Human Behavior, Emergency Response & Mobility

1. Fire simulation re-creation tool
2. Occupant behavior & response
3. Technology for emergency mobility
4. Guidelines, equipment standards for fire & emergency responders

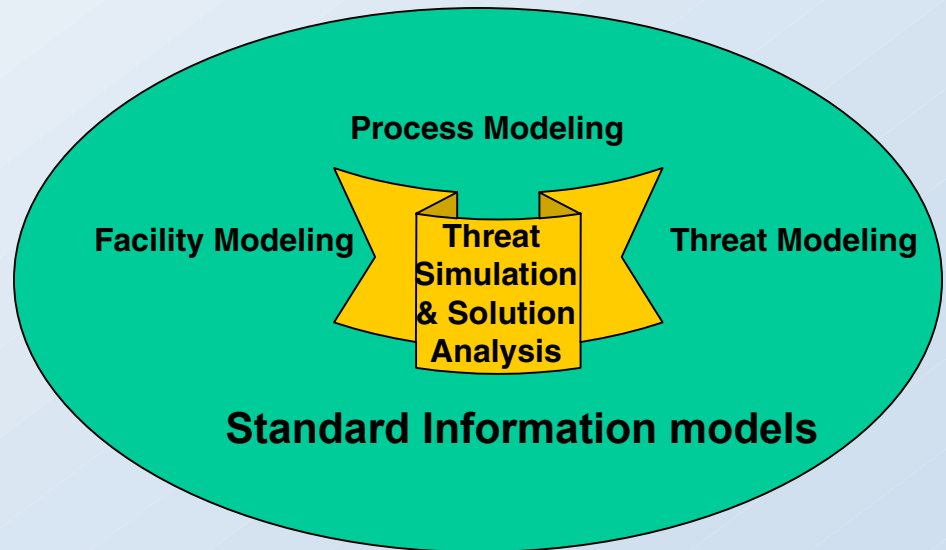
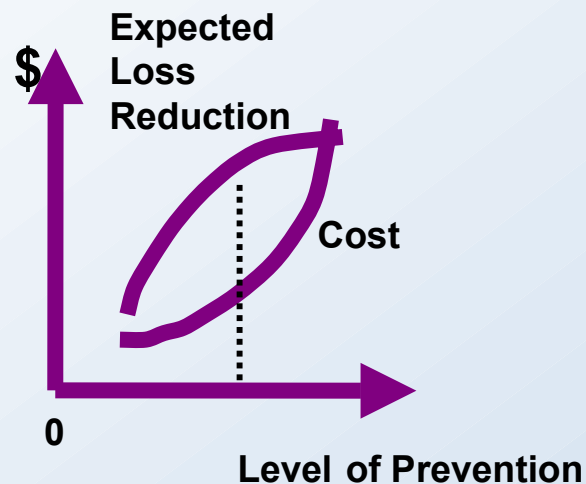
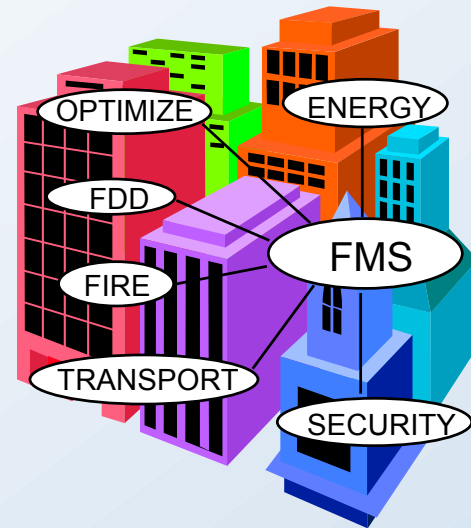
Some Potential R&D Partners: NFPA, FDNY, NYPD, WTC Occupants, FEMA, USFA, NSF Universities, SFPE, IAFC, Elevator Industry,...



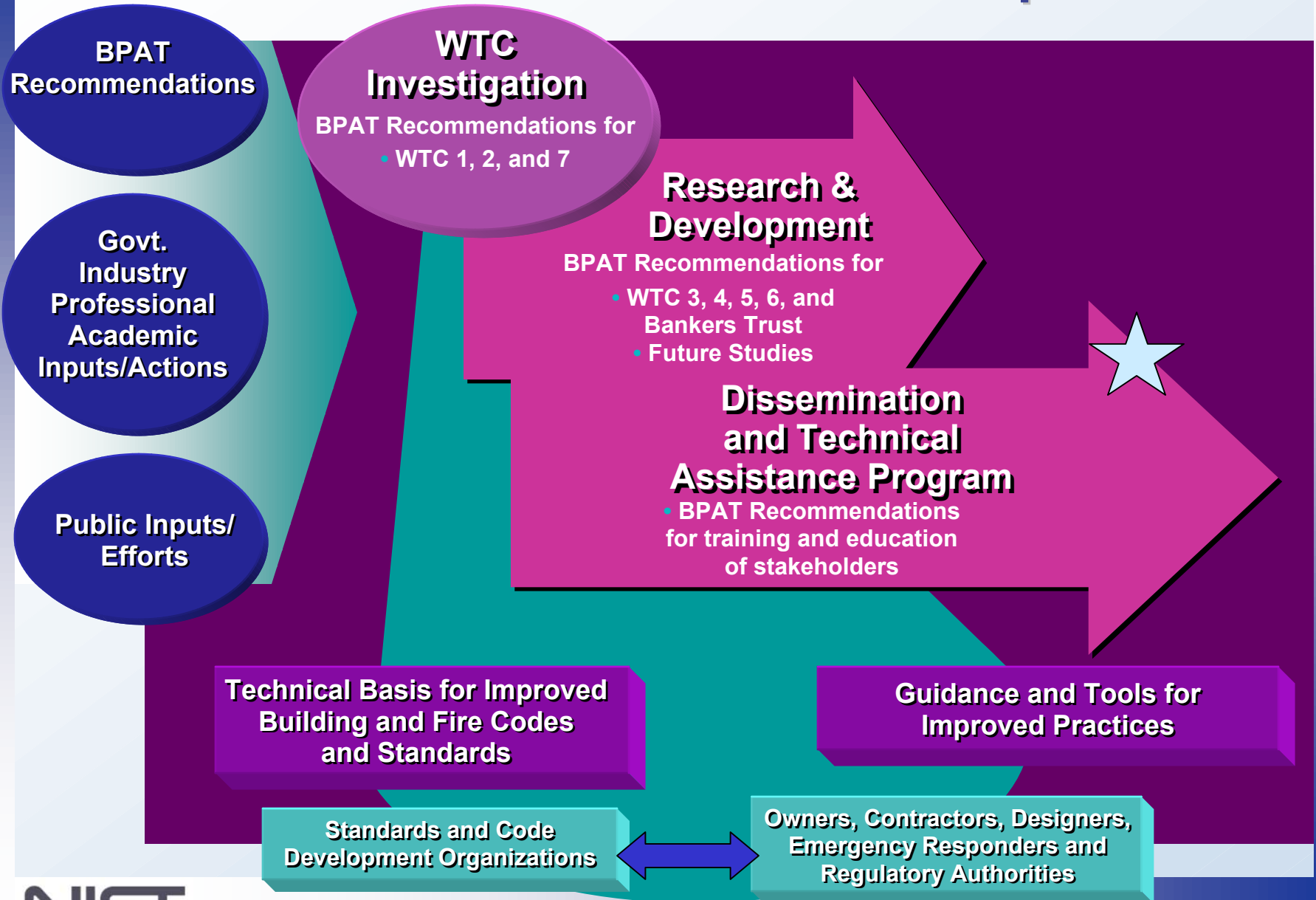
R&D Program: Building Vulnerability Reduction

1. Standard information models
2. Guidelines, advanced technology for Chemical, Biological, Radiological attacks
3. Cost-effective risk management tools

Some Potential R&D Partners: IAI, FIATECH, ASHRAE, GSA, DOD, State Department, GSA, Wharton, NSF, CII, NCSBCS,...



NIST Public-Private Response Plan



Dissemination and Technical Assistance Program

Concept:

- Forum through which facility owners and contractors deliver and disseminate results of research into ongoing projects and practice.
- Draw on top management, chief scientists/technology officers to motivate needed change.
- Complement and support parallel efforts of engineering societies to improve technology, codes, and standards.

Functions:

- Best practices, vulnerability assessment, standards and codes actions
- Demonstrations, evaluations, benchmarking, clearinghouse

Some Potential Partners:

- The Infrastructure Security Partnership (TISP/ASCE)
- Construction Industry Institute (CII), and (FIATECH)
- Civil Engineering Research Foundation (CERF)
- National Institute of Building Sciences (NIBS)

Desired Outcomes

Make buildings safer

Enhance safety of fire and emergency responders

Better protect occupants and property in future

Better emergency response capabilities and procedures in future disasters

Thank You

All BPAT Recommendations to be Addressed

NIST Response Plan

Investigation → R&D → Dissemination & Technical Assistance

Building Chapters

WTC 1 & 2. Impact, fire, floor systems, structural, materials, arrest collapse...

WTC 7. Initial damage, fuels, fire-structure interactions, collapse mechanisms, axial capacity, level of fire resistance for key members

WTC 3. Progressive collapse.

WTC 4,5,6. Performance of connections in fire, structural performance in overload.

Bankers Trust. How collapse was halted.

Peripheral buildings. Software verification.

Future Study Chapter

Building Evacuation
Emergency Personnel
Archival Information

Fire Structural Interactions
Fire and Structural Professions in Design
Fire Protection Engineering Discipline

Education of Stakeholders
Study Process
Response to Disasters
SEAoNY Response Plan