

NIST Response to the World Trade Center Disaster

**World Trade Center Investigation Status**

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# Highlights

- Overall Investigation Goals, Status, and Schedule
- Selection of External Experts and Contractors
- Update on Data Collection Efforts
- Original Aircraft Impact Studies
- Assessing the Most Probable Structural Collapse Sequence
- Update on Experimental/Field Work
- Collection and Analysis of Photographic and Video Images
- First-Person Data Collection on Evacuation and Emergency Response
- Analysis of Building and Fire Codes and Practices
- Investigation of Active Fire Protection Systems
- Considerations for Safety Recommendations

# 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 national benefits:
  - Improvements in the way buildings are designed, constructed, maintained, and used
  - Improved tools and guidance for industry and safety officials
  - Revisions to codes, standards, and practices
  - Improved public safety

# Objectives

- Determine:
  - why and how the WTC Towers collapsed following the initial impact of the aircraft, and
  - why and how the 47-story WTC 7 collapsed
- Determine why the numbers of injuries and fatalities were so low or high depending on location, including technical aspects of fire protection, occupant behavior, evacuation, and emergency response
- Determine what procedures and practices were used in the design, construction, operation, and maintenance of the WTC buildings
- Identify, as specifically as possible, areas in national building and fire codes, standards, and practices that warrant revision

# Important Features of NIST Investigations

- NIST investigations are independent, objective, and impartial
- No part of any report resulting from a NIST investigation into a structural failure or from an investigation under the National Construction Safety Team Act may be used in any suit or action for damages arising out of any matter mentioned in such report (15 USC 281a; as amended by P.L. 107-231)
- NIST is not a regulatory agency and does not set building codes or standards
- NIST recommendations are given serious consideration by private sector organizations that develop national standards and model codes – which provide minimum requirements for public welfare. The model codes become regulation when adopted by state and local governments.

# NIST WTC Investigation Projects

BPAT  
Recommendations

Government,  
Industry,  
Professional,  
Academic Inputs

Public Inputs

Public Inputs

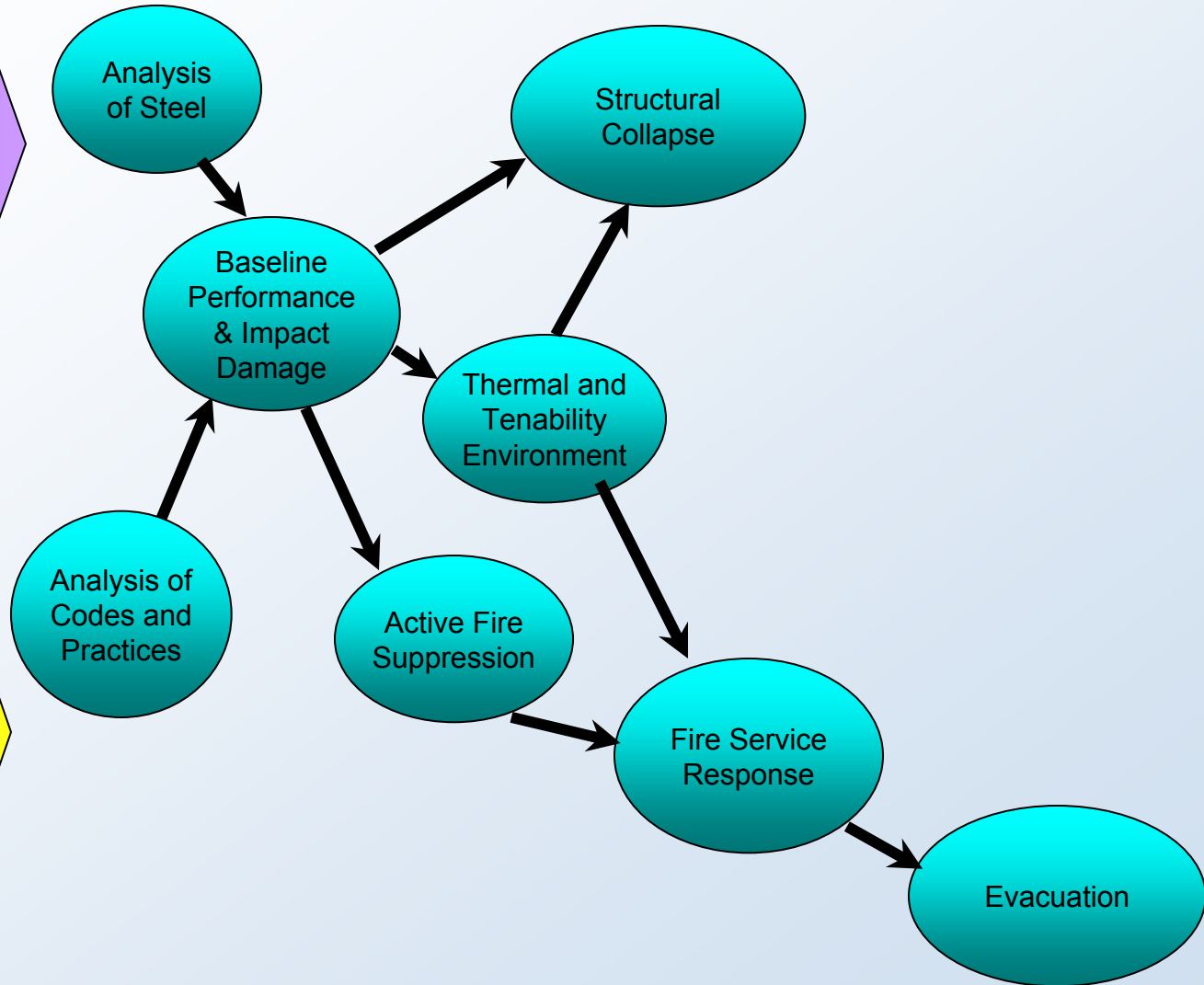
Documents

Video/ Photographic  
Records

Oral History Data

Emergency Response  
Records

Recovered Structural  
Steel



## WTC Investigation Status

- 17 months into investigation; good solid progress on all projects
- \$16 million investigation; \$5.5 million awarded in contracts
- Drawing on complementary talent from NIST, outside experts, and contractors; NIST, not the contractors and experts, is responsible for determining investigation findings, conclusions, and recommendations
- Two public updates issued (December 2002 and December 2003)
- One technical progress report issued (May 2003); expect to release next technical progress report in early Spring 2004
- Draft investigation report planned for completion in early Fall 2004

# Update on Data Collection

- Large amounts of data and information received; summary available at <http://wtc.nist.gov>
- NIST has a few requests for materials that are lost, currently pending, or not yet located; NIST is making efforts to re-create this information from various sources since much of it was lost when the buildings collapsed
- **NIST has received all of the essential information it needs for the WTC investigation;** significant progress achieved since August 2003
- NIST has received considerable cooperation from PA, NYC, designers, leaseholders, contractors, suppliers, survivors, and victims families.



# Safety of WTC Towers in Aircraft Collision

- Buildings are not designed to withstand the impacts of fuel-laden commercial airliners
- Structural safety of the WTC towers in an aircraft collision was a consideration in the original design
  - The impact scenario considered a Boeing 707 aircraft traveling at 600 mph; another document considered an aircraft impact at the 80<sup>th</sup> floor
  - Analysis indicated that such collision would result in only local damage which could not cause collapse or substantial damage to the building
- Fire safety: There are two views on whether the effect of jet fuel and aircraft contents was a consideration in the original building design:
  - One view suggests that an analysis was done indicating the biggest problem would be the fact that all the fuel would dump into the building and there would be a horrendous fire.
  - Another view suggests that the fuel load, and the fire damage that it would cause, may not have been considered.
- Life safety: There are two views on what would be the effect of aircraft impact on occupant life safety:
  - One view, which did not consider the fires, suggests that the aircraft impact would not have endangered the lives and safety of occupants not in the immediate area of impact.
  - Another view, which considered the fires, recognized that a lot of people would be killed even though the building structure would still be there.

# Assessing the Most Probable Structural Collapse Sequence

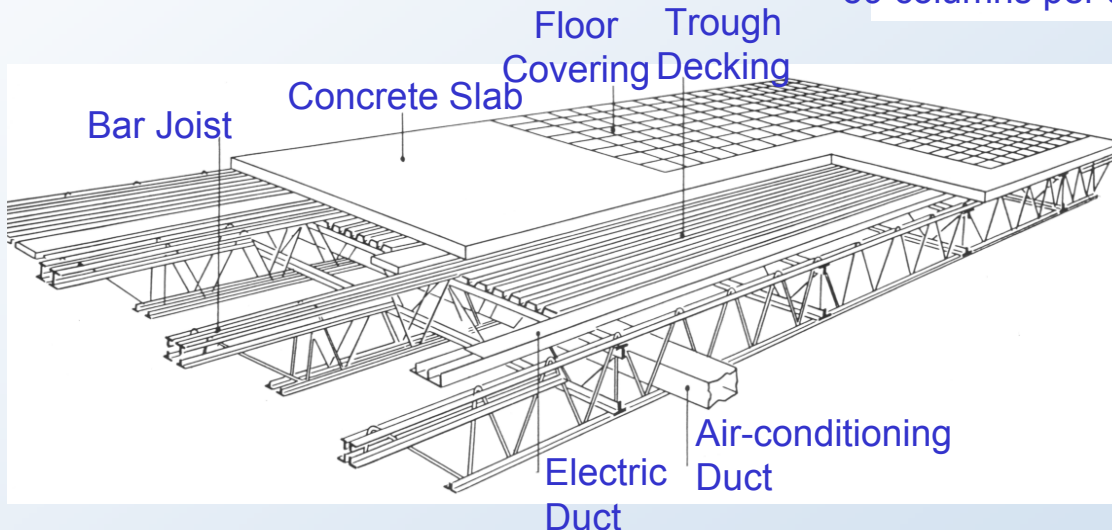
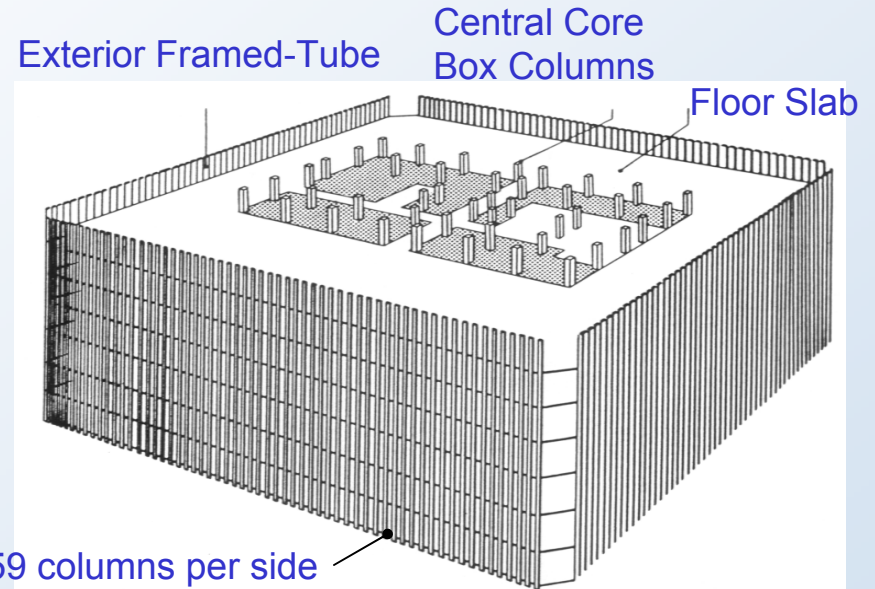
- NIST seeks to determine the most probable collapse sequence for each building



- These are based on photographic evidence, rigorous computer modeling, laboratory simulations, and well-established statistics- and probability-based analysis methods

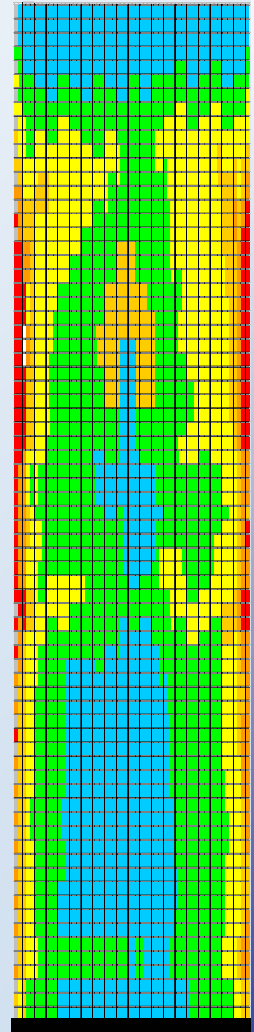
# Examples of WTC Tower Innovations

- WTC tower structural system
- Composite floor truss system using long span open-web bar joists and spray-applied fireproofing
- Design for wind loads and control of wind-induced vibrations
- Elevator system design



# Analysis of Structural Steel

- **NIST believes the collection of steel from the WTC towers is adequate for purposes of its investigation**
- NIST is documenting failure mechanisms and damage via an extensive visual analysis of the WTC steel and enhanced image analysis of photographs of the damaged buildings
- **Preliminary results show that the measured room temperature steel strength met relevant ASTM specifications; in many instances exceeding the specifications by 5,000 to 15,000 psi**
- Work is ongoing to evaluate the design of the steel building components and system and their performance under impact and fire conditions up until the time of collapse initiation



*Simulated distribution of column yield strengths*

# Fireproofing and Fire Rating of Floor System

- **There appears to have been no technical basis for:**
  - **selection of fireproofing material for the WTC floor system, and**
  - **specified fireproofing thickness to achieve the expected 2-hour rating**
- Project specific fire endurance testing was not and is not normal practice but may be conducted when circumstances warrant it, e.g., in a new or innovative application
- In 1966, the Architect of Record and, in 1975, the Structural Engineer of Record stated that the fire rating of the floor system could not be determined without testing
- NIST has not found any evidence indicating that a test based on ASTM E 119 had been conducted to determine the fire rating of the WTC floor system; Port Authority informed NIST that “there are no test records in our files”
- NIST has awarded a contract to Underwriters Laboratories to determine the fire rating of typical WTC floor systems under both as-built and specified conditions; these tests are expected to be conducted in Spring 2004
- Origins of current fire endurance rating test method nearly a century old; hourly ratings are relative and apply to subassemblies tested in a standard fire; may not be adequate for major fires and the building as a complete system; **NIST is considering need for improved methods to determine the fire endurance of building systems in major fires**

# WTC Fire Model Validation Experiments



**Prediction of steel temperatures through fireproofing**



**Assess the effect of impact on damage to ceiling tile systems**

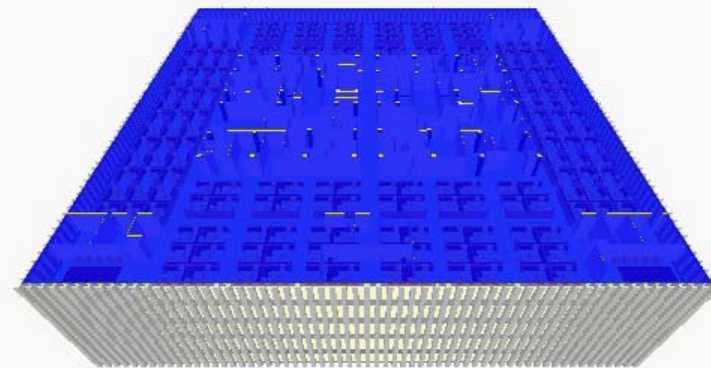
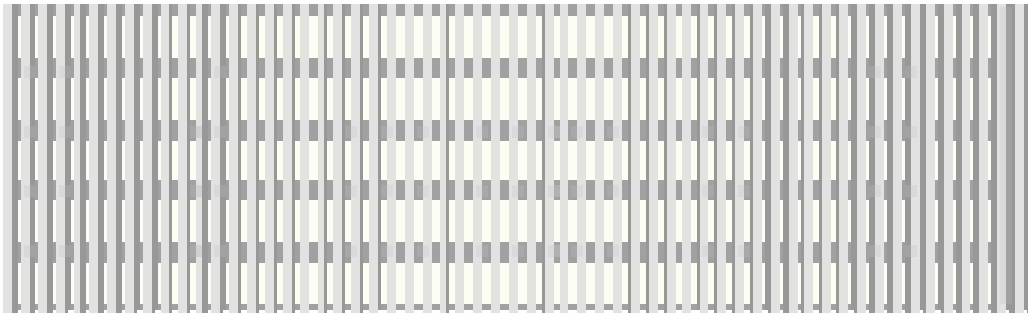


**Single workstation burn tests for input to fire dynamics simulator**



**Multiple workstation burn tests for validation of fire model predictions**

# Reconstruction of the WTC Fires



Slice  
temp  
F

1800
1627
1454
1280
1107
934
761
588
414
241
68.0

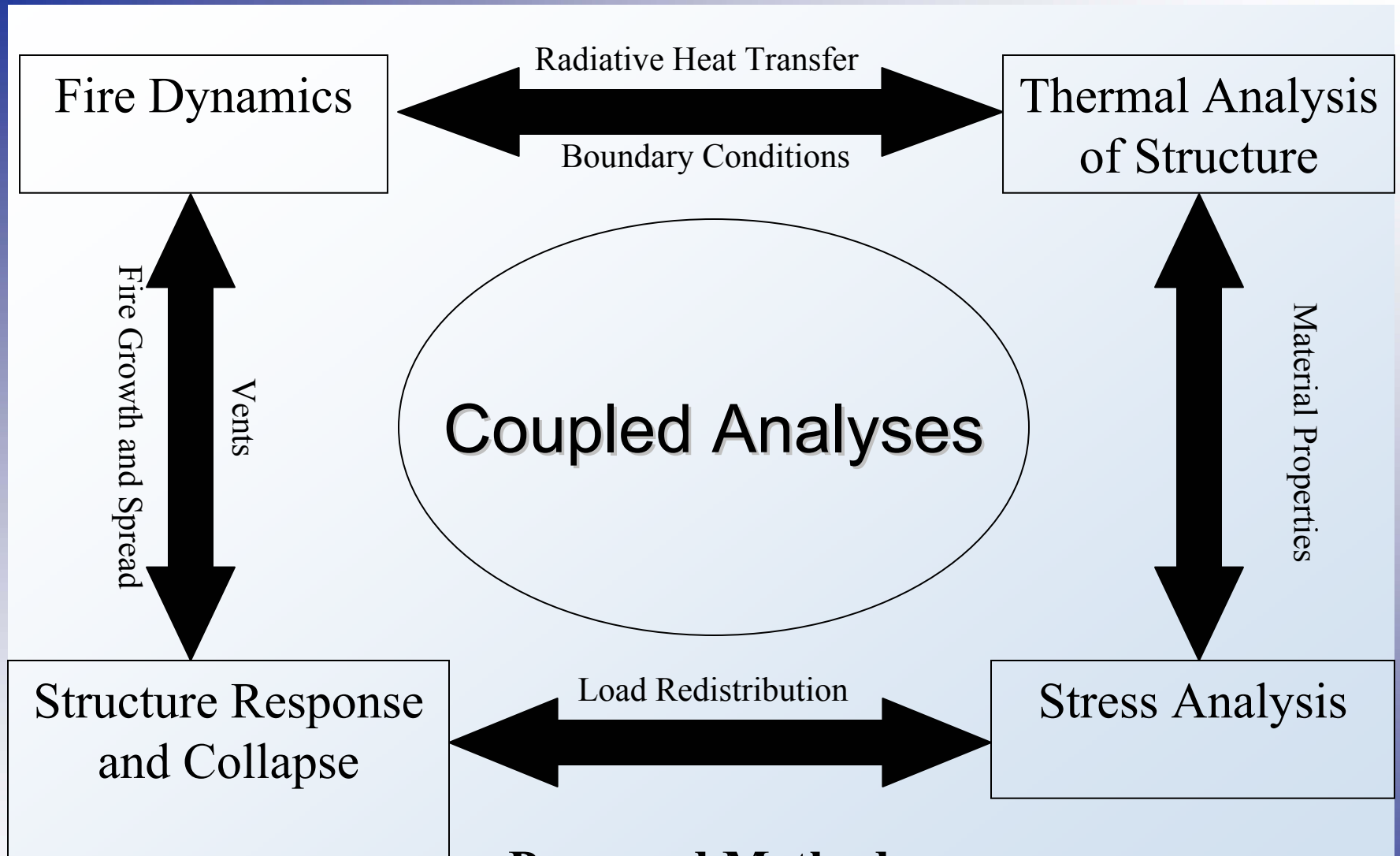
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# Collection and Analysis of Photographic and Video Images

- Visual database now contains:
  - 6,194 photographs taken by more than 85 photographers
  - 150 hours of videotape (5,726 video clips) representing more than 20 sources
- From the analysis of the visual images to date, NIST has identified significant events for WTC 1 and 2 related to aircraft impact, fire development, and building damage
- **NIST has developed detailed mappings for the fire, smoke, and the condition of windows at several specific times for each WTC tower; work is underway for WTC 7**







**Proposed Method:**

Probabilistic, Nonlinear, Coupled Analysis  
of Collapse Induced by Fire-Structure Interaction

# First-Person Data on Occupant Behavior, Evacuation, and Emergency Response

- Buildings are designed for fire protection and evacuation under normal fire conditions, not conditions found in major emergencies
- Critical lack of information on which to base evacuation and emergency response practice, standards, and codes in such conditions
- **First-person interviews of occupants, current and retired first responders, and family members in contact with victims are providing valuable information regarding major emergencies in tall buildings.**
  - Firefighting (access time, physiological factors, fight fires versus evacuation, use of elevators)
  - Evacuation in tall buildings (defend-in-place, phased versus full, counter flow, egress capacity)
  - Emergency command, control, and communications in major events (information flow, interagency coordination, repeaters, overload, technology, interoperability)
  - Building design features to support such operations (stairs, elevators, integrity of egress paths)
- **NIST has made good progress in its first-person data collection efforts**
  - Telephone interviews: completed all 800 planned
  - Face-to-face interviews: completed about one-third of approximately 450
  - Focus groups: in process
- The personal privacy and confidentiality of individual respondents will be protected to the maximum extent permitted by law

# Multiple Data Sources

- Existing published first-person accounts of WTC evacuation; over 725 accounts collected and analyzed
- Communication tapes from Port Authority of NY & NJ and NYPD; 1000 plus hours of taped recordings
- Filings with the Occupational Safety and Health Administration by survivors and families of victims; about 60 written statements
- Documents from Port Authority, FDNY, NYPD, and others on design of egress and emergency communication systems; WTC evacuation history; WTC evacuation planning and drills; emergency response preparedness and operational data
- Photographic and video data on occupant behavior, evacuation, and emergency response
- First-person data collection from survivors, current and retired first responders, and families of victims
- Access to NYC 9-1-1 tapes and logs, and transcripts of about 500 interviews with FDNY employees involved in WTC emergency response activities

# Occupant Behavior, Evacuation, and Emergency Response Study

- NIST is developing a detailed chronology of events related to the emergency response and evacuation
- NIST is analyzing the contents of emergency communications data already received to:
  - better define the events of September 11, 2001
  - document the performance of the emergency communication systems
- NIST is using computer egress modeling to better understand the evacuation experience on September 11, 2001:
  - Obtained three existing computer models
  - Supporting information from evacuation history of WTC towers
  - Supporting information from first-person accounts

# First-Person Interviews: Preliminary Findings

- **Evacuation**

- Most people had participated in evacuation training and knew where the closest stairwell was located; most respondents indicated that they had not ever used the stairwell system; many people found stairwell transfer floors confusing on 9/11
- Ingress/egress was a tremendous physical challenge for both first responders and many occupants; inadequate footwear presented a mobility challenge, particularly for many women, as discarded shoes often littered the stairwells, leaving many people shoeless

- **Emergency Response**

- All radio communications evaluated so far (PANY&NJ, NYPD, and FDNY Channel 30) experienced surge load conditions after the attack; as a result roughly a third to a half of the communications were not complete; traffic volume made it difficult to handle flow and delivery of information; multiple concurrent transmissions on the same frequency – or doubling – made it more difficult
- First responders – including key incident commanders -- did not have adequate information (voice, video, and data) on and an overall perspective of the conditions in the buildings and what was happening elsewhere at the WTC site; interagency information sharing was inadequate

- **Building Damage**

- Multiple first responders – including those with command authority – report that there was a large gouge on the south face of WTC 7; the gouge appeared to extend from the sub-cellar to the 10<sup>th</sup> floor and covered roughly a third of the length of the south face and roughly 15-20 % of the building depth; possible implications for structural weakening and fire ignition/spread

# Analysis of Building and Fire Codes and Practices

- Procedures and practices of interest:
  - Design and construction of WTC towers and WTC 7
  - New and innovative design features, technologies and materials
  - Passive and active fire safety systems
  - Emergency access and egress systems
  - Structural modifications, inspection, and maintenance
- **NIST has completed a preliminary comparison of then current building regulatory and code requirements**
  - Provides context to study specifications and criteria used in the design, construction, operation, and maintenance of the WTC buildings
- **NIST has completed preliminary documentation of the fuel system for emergency power in WTC 7**
  - Fuel tanks, fuel distribution system, control system, fire protection

# Code Comparison: Preliminary Findings

- PONYA adopted 1968 NYC Building Code for final design of WTC 1 and WTC 2, and WTC 7
- Designers were allowed to use “acceptable engineering practices” with approval of PONYA where code provisions were obsolete (1963 directive)
- All five codes reviewed have similar wind pressure distributions; for tall buildings (e.g., over 1000 ft), the largest base shear is obtained from BOCA (1965)
- NYC introduced progressive collapse resistance requirement by Rule in August 1973
- 1968 NYC Code reduced fire resistance ratings from 1938 edition; 2001 edition reduced further from 1968 edition

<b>Fire Resistance (hours)</b>	1938	1968	2001
Columns	4	3	2
Floors	3	2	1-1/2

# Investigation of Active Fire Protection Systems

- NIST is investigating the design, capabilities, and performance of the active fire-protection systems in the WTC towers and WTC 7:
  - Sprinkler system, including fire standpipes, pre-connected hoses, water supply
  - Fire alarm systems, including provisions for redundancy and modifications made after the 1993 bombing
  - Smoke management systems, including reviews conducted after the 1993 bombing
- **NIST has completed a review of the history of post-occupancy fire incidents and has identified events that were large enough to activate more than one sprinkler or, if sprinklers were not present, events judged to be equivalent**



# Fire History of WTC Buildings 1, 2, and 7

- NIST gathered information on significant fires in the buildings after occupancy and prior to 9-11-01
- The extensive records of fire incidents kept in the WTC 1 offices of the PANYNJ were lost in the collapse
- Information was collected from FDNY [434 Bureau of Operations Fire Reports (1970-2001) and 87 Bureau of Fire Investigation Records (1977-2001)]
- There were 12 significant fires defined by NIST as those activating multiple sprinklers or equivalent in addition to the well known 1975 fire starting on floor 11 of WTC 1 and 1993 parking garage bombing

# Considerations for Safety Recommendations

- Recommendations based on the findings of the investigation will seek to enable:
  - making buildings safer
  - improving safety of occupants and first responders, and
  - improving evacuation systems and emergency response capabilities
- Distinguish unique circumstances related to the terrorist attacks from more common building and fire safety issues
- Emphasis on needed performance-based, not prescriptive, solutions

# Purpose of Public Meeting

To solicit comments from the public on:

- (1) specific technical aspects of the individual projects as reported in our December 2003 progress update and presentations to the National Construction Safety Team Advisory Committee (available on the NIST WTC Investigation Web site <http://wtc.nist.gov>);
- (2) information that NIST might consider in the time remaining that is within the scope of the eight projects described in the investigation plan (the plan is available at the same Web site); and
- (3) areas that NIST should consider, within the scope of its investigation, in order to make recommendations for specific improvements to building and fire practice, standards, and codes, and their timely adoption.

***All comments received will be given serious consideration by the appropriate investigator.***

# Contact Information

- **Anonymous tip line:**       **888-804-7581**       **(toll free)**
- **WTC web site:**               **<http://wtc.nist.gov>**
- **Mail address:**               NIST World Trade Center Investigation Team  
100 Bureau Drive, Stop 8610  
Gaithersburg, MD 20899-8610
- **E-mail:**                       **[wtc@nist.gov](mailto:wtc@nist.gov)**
- **Facsimile:**                   301-975-6122
- Survivors, families, and retired first responders may volunteer to participate in the face-to-face interviews by contacting:  
  
**877-221-7828**               **(toll free)**
- Alternately, families of victims may volunteer to participate in the face-to-face interviews via the following web site:  
  
**<https://wtc.nist.gov/family>**

**Thank You**