NIST Response to the World Trade Center Disaster

World Trade Center Investigation Progress

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NIST

Progress Outline

- Status of Data Collection Efforts
- Interim Report on Fireproofing of WTC Floor System
- Fire Model Validation Experiments and Plans for Fire Testing of WTC Floor System
- Approach for Assessing the Most Probable Structural Collapse Sequence
- Status of Steel and its Analysis
- Photographic and Videographic Image Collection and Analysis
- First-Person Data on Occupant Behavior, Evacuation, and Emergency Response
- Selection of External Experts and Contractors

1. Status of Data Collection Efforts

- Solid foundation of technical evidence for review, analysis, modeling, and testing work
  - Building documents, video and photographic records, emergency response records, oral histories, recovered WTC steel
- NIST has received considerable cooperation and large volumes of information from a variety of organizations and agencies
  - Building designers, owners, leaseholders, suppliers, contractors, insurers
  - Local NYC authorities (FDNY, NYPD, DDC, DOB, OEM)
  - OSHA (correspondence on evacuation experience of WTC occupants)
- NIST has a number of requests for materials that are currently pending with, or not yet located and/or provided by, several organizations
- It is vital that this information be made available to NIST

Status of Project Specifications

- Complete set of project specifications not located:
  - Original contract specifications for WTC towers
  - Complete set of tenant alterations, construction logs, maintenance logs for WTC 1, 2, & 7
- Specifications provided to NIST
  - Procurement of materials (steel, concrete) from individual suppliers
- May be possible to reconstruct project specification partially from
  - Individual subcontract and purchase specifications
  - Individual reports for design and fire protection etc.
- NIST is working to locate the complete set of project specifications

Status of As-Built Drawings

- Complete set of as-built drawings not available (WTC 1, 2, 7)
- NIST has original contract drawings for WTC tower *structure,* including revisions made during bid and construction
- NIST has supplementary drawings for majority of WTC tower tenant *structural* modifications:
  - Mostly openings to floor framing systems (WTC 1, 2, 7) to meet tenant needs
  - Strengthening of core columns in upper stories of WTC towers to accommodate additional gravity loads
  - Repairs made to restore structural integrity of inadvertently damaged steel straps that were used to brace floor system to columns

2. Interim Report: WTC Floor Fireproofing

- Documents procedures and practices used in fireproofing of WTC floor system
- Based on review of factual data in the documents reviewed by NIST
  - Few instances of conflicting data or data that need some interpretation
  - Facts presented without interpretation to maximum extent possible
- Nothing in report should be taken to imply floor trusses played a critical role in collapse of WTC towers
  - Issue is a key component of ongoing investigation
- NIST continues to seek, receive, and review additional data on the subject
  - Maintenance and inspection records for WTC towers from different sources
  - Reports of critical UL tests performed for the fireproofing materials supplier
  - NIST welcomes additional factual information from organizations or individuals
- NIST will review all information and update report as needed

Interim Report: WTC Floor Fireproofing (2)

- Issues covered in report:
  - Applicable building codes
  - Building classification and fire rating requirements
  - Fireproofing method and materials
  - Fireproofing thickness requirements and measured data
  - Need for fire endurance testing
  - Fire testing of a similar floor system
  - Additional documents being collected and reviewed
  - Specific information needs to further document procedures and practices

3. Fire Model Validation Experiments and Fire Testing of WTC Floor System

- NIST is using a combination of analytical, experimental, and numerical tools to analyze alternative collapse hypotheses
- NIST is conducting experiments to provide input to its analytical and numerical work, including the validation of those results
- Fire performance of open-web bar joist systems
  - NIST is reviewing previously completed tests on open-web bar joist systems
  - NIST is documenting past performance using available fire incident and insurance investigation reports

Key Factors in Analyzing Collapse Hypotheses

- Speed, direction, orientation, and point of impact of each aircraft
- Dispersion of jet fuel following the impact
- Mass of steel, concrete, heavy machinery, and non-structural building materials and contents – all of which shared in absorbing the energy imparted during impact
- Effects of debris fragments on structure, fireproofing, and other building systems; and gravity load effects on structural stability
- Performance of steel components and connections, at high rates of loading during impact and at elevated temperatures during subsequent fires, and associated failure criteria
- Performance of fireproofing at high temperatures, and extent to which fireproofing may have been missing or knocked off during impact
- Growth and spread of fire and resulting temperature of the structural steel, as a function of time and location
- Coupling fire dynamics and thermal-structural response analyses; factors to be accounted in reconstructing fire growth and path of fire spread:
  - Fire load provided by building contents, jet fuel, and fuel storage tanks
  - Ventilation available for combustion
  - Inter-compartment fire spread through partitions, ceiling/floor systems, air passages in buildings

Model Validation Experiments (1)

- Mechanical properties of steel:
  - High strain rates to support aircraft impact damage analysis
  - High temperatures to support analysis of structural response to fires
  - Room temperature, quasi-static loading to:
    - compare actual properties of steel used with specifications
    - analyze baseline structural performance under gravity and wind loads
- Properties of fireproofing materials
  - Thermal-insulation properties as a function of temperature
  - Ability of fireproofing to withstand shock and impact
- Fire tests of floor system connections and interfaces
  - Floor truss-to-column connections
  - Load-transfer between floor truss and concrete deck

Model Validation Experiments (2)

- Fire tests to validate fire dynamics and thermal-structural analyses
  - Large compartment fires
  - Heat release and transfer rate to compartment gases
  - Heat release rate and temperature of steel
    - Truss and column specimens (geometry, cross-section)
    - Fireproofing: two thicknesses, no fireproofing
- Series of office work station fire tests to simulate fire dynamics
  - Based on descriptions of furnishings used in WTC office space
  - Generate database of thermo-physical properties of the materials
- Fire endurance testing of typical floor system and individual steel members
  - Composite floor system (concrete deck, bar joist, bridging truss)
  - Fire conditions prescribed in ASTM E 119
  - Vary fireproofing thickness; use rods and angles

4. Assessing the Most Probable Structural Collapse Sequence

- Several leading hypotheses postulated publicly by experts for the structural collapse sequence between aircraft impact and collapse of WTC 1 and 2
- Little information on initial damage and source of fire ignition in WTC 7
- NIST considers it premature to exclude any of the postulated hypotheses; NIST is analyzing these and other possible collapse sequences
- Objectives of formal approach to analyzing complex failure sequences failure in WTC 1, 2, and 7:
  - What is the most probable collapse sequence?
  - What confidence levels are associated with it?
  - What is the probability of other collapse sequences?
  - What parameters influence on the most probable collapse sequence?

Publicly Postulated Collapse Hypotheses (1)

- **Aircraft impact**
  - Damage to perimeter/interior columns, floor systems in impacted region
  - Full extent of damage unknown and can only be estimated through analysis
  - Loads redistributed among columns (aided by hat truss), with floor systems
- **Hypothesis A**
  - Load carrying columns weakened by fires and failed, initiating overall collapse
  - No need for weakening or failure of floor system
- **Hypothesis B1**
  - Significant portions of one or more floor systems sagged, as they were weakened by fires
  - ***Columns pulled inwards via connections*** due to sagging floor system
  - ***Combined compression and bending failure of columns*** initiated overall collapse

Publicly Postulated Collapse Hypotheses (2)

- **Hypothesis B2**
  - Significant portions of one or more floor systems sagged, as they were weakened by fires
  - ***Shear failure at connections*** to columns
  - ***Buckling failure of columns*** initiated overall collapse
  - Load eccentricities due to partially damaged floor systems could have contributed additionally to column buckling

- **Other factors**
  - Combinations of above hypotheses; other possibilities
  - Role of perimeter versus core columns in collapse initiation
  - Difference in times for collapse of WTC 1 and WTC 2
    - Details of aircraft impact (speed, height, position, orientation with respect to building and core)
    - Condition of fire protection systems (thickness and extent of fireproofing, sprinkler system)
  - Indicators of bias in analysis: rapid loss of stability without need for sustained fire versus delayed loss of stability well beyond observed time-to-collapse

Integrated Approach to Assess Most Probable Structural Collapse Sequence

- Developed with experts in statistical methods and probabilistic analysis
- Provides a rational, consistent approach to assess different collapse sequences by combining three methods:
  - **Mathematical modeling methods:**
    - full understanding of physics based on best available information
    - component, sub-system, full-scale system level analysis
  - **Statistical methods, using experimental design techniques:**
    - account for knowledge and random uncertainties related to collapse events
    - identify and rank influential parameters and their relative effects on analysis results
  - **Probabilistic methods, using event tree and Monte Carlo techniques:**
    - account for knowledge and random uncertainties related to collapse events
    - determine probability of different collapse sequences
    - parameters contributing to uncertainty propagation: component to sub-system to system level

5. Status of Steel and its Analysis

- NIST has nearly 250 pieces of WTC steel in its possession
  - Vast majority of significant size (exterior column-spandrel panels, box beams, wide flange, truss, channels); several smaller pieces such as bolts
  - Cataloged 235 pieces as of March 28, 2003; includes database with photographic records and member markings
  - Small fraction of WTC steel examined at several salvage yards in cooperation with SEAoNY
- NIST has identified additional steel stored by Port Authority at JFK airport; 12 specimens are in process of being transported to NIST
- Steel in NIST's possession represents roughly 1/4 to 1/2 percent by weight of the approximately 200,000 tons of steel used in WTC towers

Steel from WTC Towers

Clean weld fracture of Interior columns

Failure at connection between floor system and exterior columns

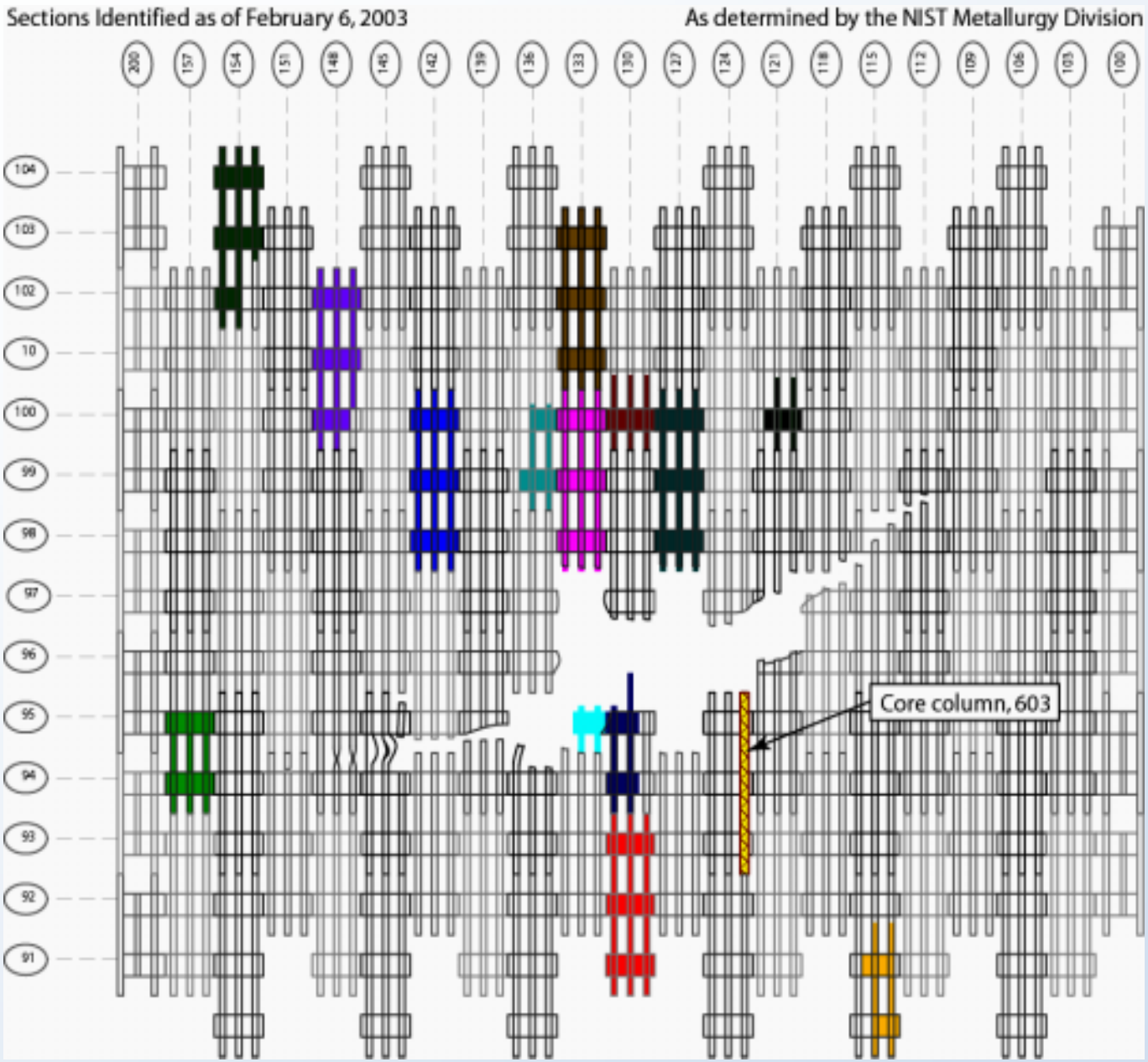
Dr. John Fisher (Lehigh) and Robert Duvall (NFPA)

WTC steel columns

Dr. John Gross (NIST)

NIST

WTC Steel at NIST


Sections Identified as of February 6, 2003
As determined by the NIST Metallurgy Division
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Core column, 603

6. Photographic and Video Image Collection and Analysis

- Photographic and video images of damage and fires to WTC 1, 2, & 7
  - Initial conditions for modeling fires
  - Rates of fire spread through the building
  - Floors on which structural collapse may have initiated
- Many individuals contacted NIST based on news coverage of December 2002 update. Large number of important photos and videos provided to NIST
- NIST continues to seek images; especially interested in:
  - close-up details of fire conditions in all three buildings
  - images of airplane approaching and entering
  - images of WTC 7, particularly on the south face
  - views from south and west faces of WTC towers

Collection of Visual Material

- Assembling collection into a searchable computerized database
- Database now contains:
  - Over 3,100 photographs taken by 66 professional or amateur photographers
  - Over 3,400 video clips from publicly available news coverage, news agencies, and 25 individual videographers
- NIST has received significant visual material from Associated Press, New York 1 News, WNBC New York
- NIST has reviewed similar materials from NYPD and FDNY; arrangements being made to transfer materials of interest to NIST

7. Fire-Person Data on Occupant Behavior, Evacuation, and Emergency Response

- NIST's study of WTC evacuation and emergency response requires a systematic collection of first-person data from:
  - Survivors (occupants, first responders, others with safety responsibilities)
  - Families of victims who were in touch with victims after aircraft impact
  - Individuals with operational and command authority

- NIST believes that:
  - it is possible to learn from the WTC disaster, and to improve public safety through the collection and analysis of first-person accounts, but
  - it will need active participation of WTC employers and survivors in its interviews, surveys, and focus groups

- NIST is cooperating with complementary evacuation studies being conducted by CDC, Columbia University, NYC Department of Health and Mental Hygiene
  - NIST developed list of tenants using information provided by Port Authority and Silverstein Properties, and identified their locations within the buildings
  - April 8, 2003 public meeting in New York City to present study plans to the public and elicit active participation of WTC employers and occupants

Purpose and Methodology for First-Person Accounts

- To determine the behavior and fate of occupants and responders by collecting and analyzing information on:
  - occupant behavior
  - human factors
  - egress
  - emergency communications
  - evacuation system

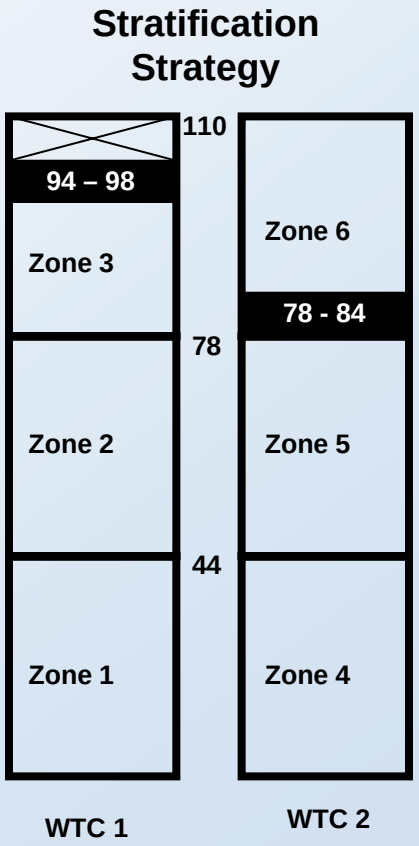
- Methodology for First Person Accounts
  - Face-to-Face Interviews (~750): Designed to maximize accuracy, recall, and detail
  - Telephone Interviews (~800): Designed for statistical representativeness
  - Focus Groups (~15): Designed for in-depth study of specific issues

Face-to-Face Interviews

- Three-Step Process
  - Uninterrupted description of the event
  - Structured discussion to elicit sequence of actions
  - Follow-up questions
- Participants: Occupants, First Responders, and Families

Telephone Interviews

- Standardized Set of Questions
- Statistically representative population of occupants from WTC 1 and WTC 2
- Stratification Variables:
  - **Initial Floor Population Density**
  - **Single/Multi-Tenant Floor**
  - **Floor Location**



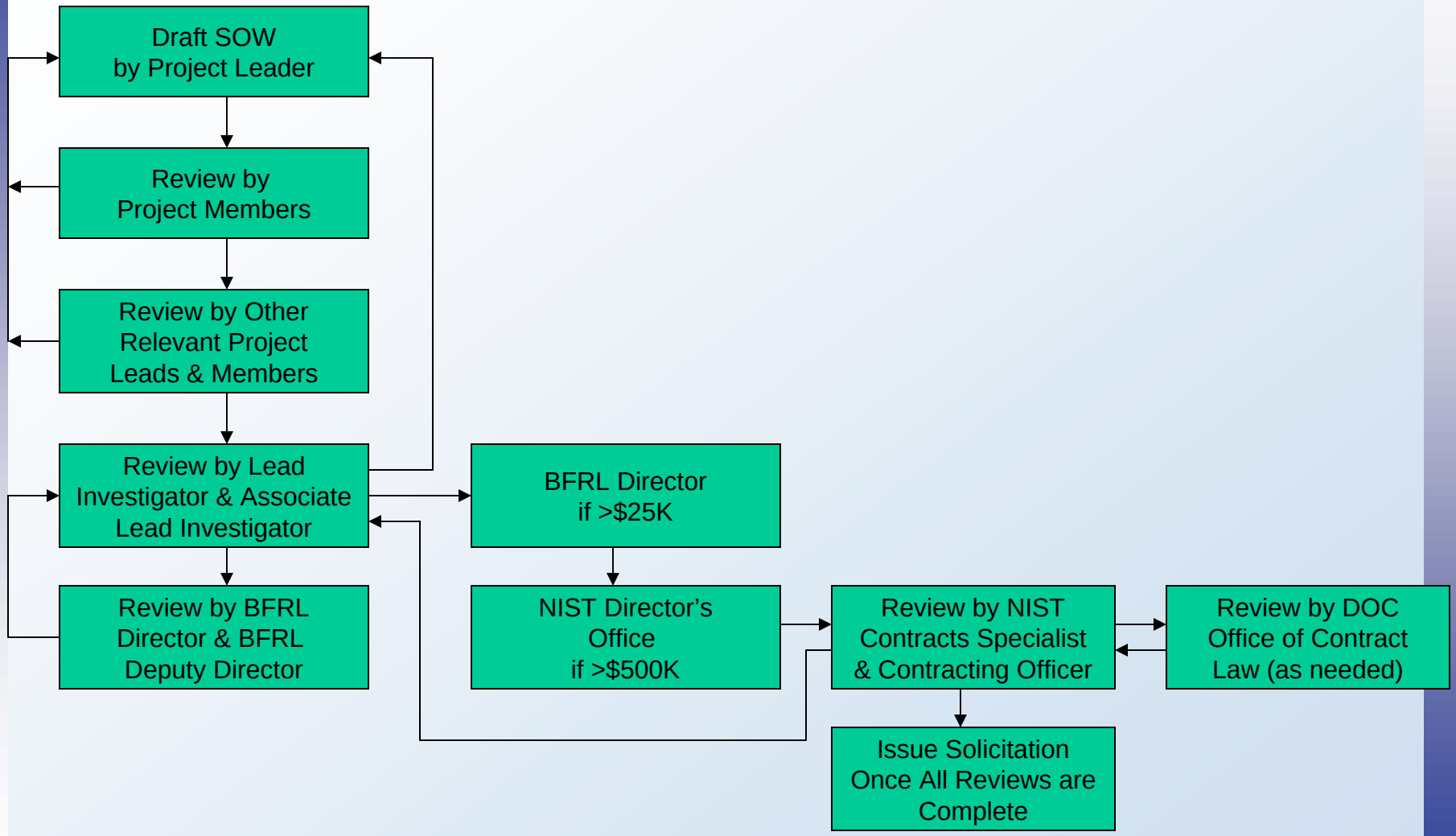
Focus Groups

- Detailed Recall of Specific Group Experiences
  - **5 Groups of ~10 Occupants of WTC 1, 2, or 7**
  - **10 groups of ~5 first responders (a company or other similar group)**

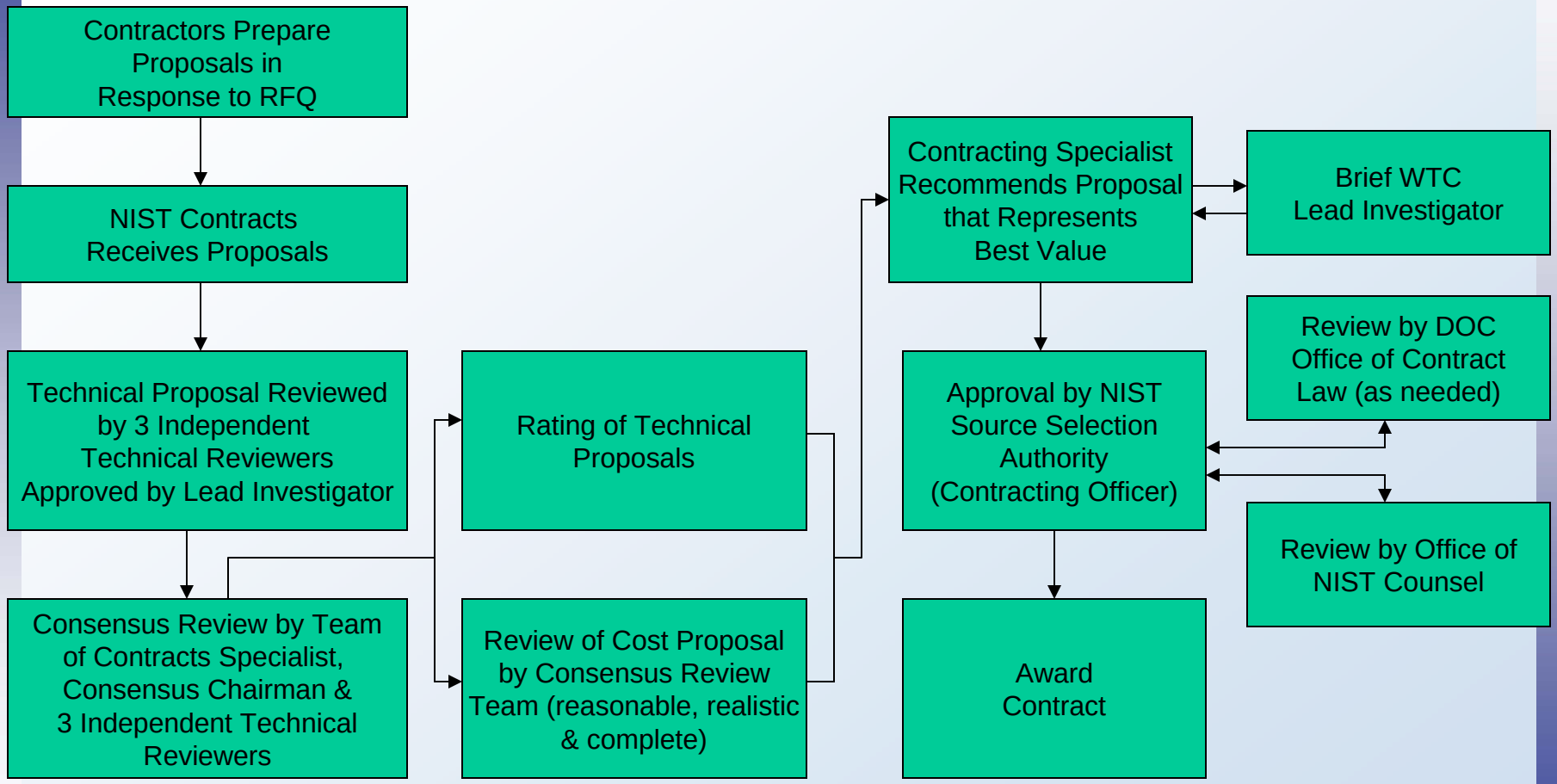
8. Selection of External Experts and Contractors

- NIST has assembled a seasoned group of in-house experts at the agency to carry out the investigation
  - Group has needed technical expertise as well as experience from significant prior investigations
  - Over two dozen NIST experts will be involved over the course of the investigation
- NIST is augmenting its in-house technical staff with experts outside of NIST who can contribute significantly to the goals and objectives of the WTC investigation
  - Contracts to provide specific deliverables on technical tasks within projects
  - Experts to conduct independent third-party reviews or assist with developing methodological approach
- Bulk of the planned contract solicitations have already appeared or will appear shortly. Several of those solicitations are now closed.

Statement of Work Development Process



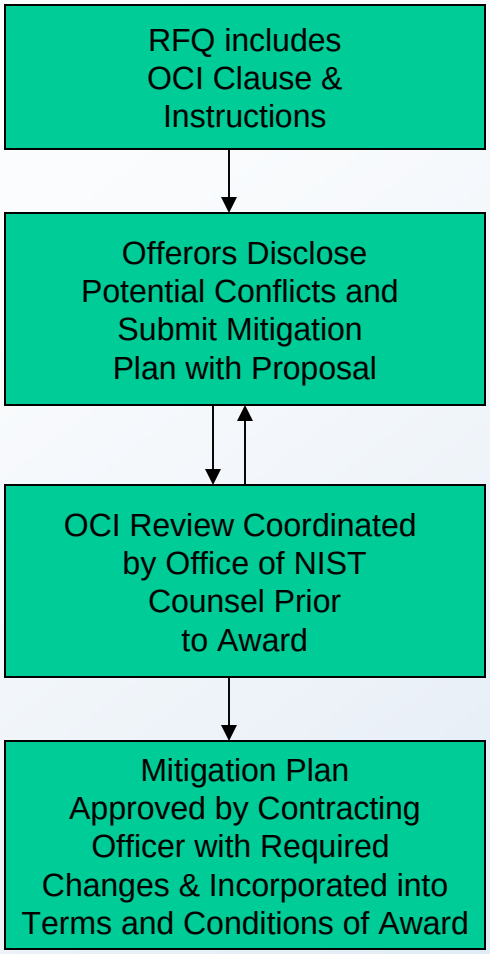
Contract Review & Selection Process



Sole Source Award Considerations

- May choose to issue a contract on a sole source basis consistent with federal laws and acquisition regulations
- Considered when there is only one uniquely qualified source or when the need is urgent and compelling
- Intent to make a sole source award is posted for 15 days on FedBizOpps and the NIST WTC web site
- Organizations that feel they are qualified may submit a capability statement to NIST for review/consideration
- To date, NIST has awarded 2 sole source contracts in support of the WTC investigation

Mitigation of Potential Conflicts of Interest



Organizational Conflicts of Interest Requirement: Offerors must identify all business relationships in which they will provide data, research services or advice concerning the WTC disaster, including any involvement in related litigation. If any such relationship would constitute a real or apparent conflict of interest, they must provide a plan for mitigation of the conflict. Third party reviews of such plans may be required to assure that contract deliverables will be completely objective. These reviews may include, but are not limited to, other government agencies, non-profits, academia, or an independent contractor.

No contractor deliverables shall include findings, conclusions or recommendations.

World Trade Center Investigation Contract Solicitations

WTC No.	Project No.	Title	Status
1	7	Outside Experts for Occupant Behavior and Evacuation	Awarded 9/30/02 and 10/16/02
2	5, 6, 7	Fire Safety Engineering Expertise	Awarded 12/23/02
3	5	Media, Visual and Database Expert with Experience in Obtaining Visual Materials for the World Trade Center	Cancelled 12/27/02
4	3	Document and Evaluate the Steel Recovered from the WTC Towers	Award Anticipated on 4/23/03
5	7	WTC Investigation Survey Administration and Report Delivery: Questionnaires, Interviews and Focus Group Synopsis	Award Anticipated by 5/30/03
6	2	Development of Structural Databases and Baseline Models for the WTC Towers	Awarded 2/23/03
7	1	Analysis of Building and Fire Codes and Practices	Closed 4/16/03
8	7	World Trade Center Investigation First Person Accounts of Egress	Awarded 4/15/03
9	6	Fire Endurance Testing of the WTC Floor System	Closed 4/23/03
10	2, 5, 6	Outside Experts for Baseline Structural Performance, Impact Analysis, Structural Response to Fire, Collapse Initiation and Probabilistic Assessment of the WTC Investigation	Closed 4/25/03
11	2	Analysis of Aircraft Impacts into the WTC Towers	Open; closes 5/12/03

Thank You