

**Federal Building and Fire Safety Investigation
of the World Trade Center Disaster**

**WTC 7 Technical Approach and Status
Summary**

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Topics for Discussion

- Status of Investigation
- More comprehensive approach for all technical issues
- Progress to date

No findings or conclusions will be presented as the analysis is ongoing

Status Summary

When NIST initiated the WTC investigation, it made a decision not to hire new staff to support the investigation.

After the June 2004 progress report on the WTC investigation was issued, the NIST investigation team stopped working on WTC 7 and was assigned full-time through the fall of 2005 to complete the investigation of the WTC towers.

With the release and dissemination of the report on the WTC towers in October 2005, the investigation of the WTC 7 collapse resumed.

Considerable progress has been made since that time, including:

- ❑ review of nearly 80 boxes of new documents related to WTC 7
- ❑ development of detailed technical approaches for modeling and analyzing various collapse hypotheses
- ❑ selection of a contractor to assist NIST staff in carrying out the analyses.

It is anticipated that a draft report will be released by Spring 2007.

Working Collapse Hypothesis

The current NIST working collapse hypothesis for WTC 7 is described in the *June 2004 Progress Report on the Federal Building and Fire Safety Investigation of the World Trade Center Disaster* (Volume 1, page 17, as well as Appendix L), as follows:

- ❑ An initial local failure occurred at the lower floors (below floor 13) of the building due to fire and/or debris-induced structural damage of a critical column (the initiating event) which supported a large-span floor bay with an area of about 2,000 square feet;
- ❑ Vertical progression of the initial local failure occurred up to the east penthouse, and as the large floor bays became unable to redistribute the loads, it brought down the interior structure below the east penthouse; and
- ❑ Triggered by damage due to the vertical failure, horizontal progression of the failure across the lower floors (in the region of floors 5 and 7 that were much thicker and more heavily reinforced than the rest of the floors) resulted in a disproportionate collapse of the entire structure.

This hypothesis may be supported or modified, or new hypotheses may be developed, through the course of the continuing investigation.

WTC 7 Investigation Approach

Obtain information on

- Building construction
- Building contents and layouts
- Debris damage to structure and fireproofing
- Fires
- Collapse sequence

Identify initiating event scenarios – location and type of local failures that could have led to collapse as observed

- Fire events
- Blast events

Develop and validate fire, thermal, and structural models

Conduct finite element analysis of

- Possible initiation sites and mechanisms
- Fire growth and spread
- Simulate heat transfer to structure
- Sequential events leading to collapse

Determine probable collapse sequence

WTC 7 Investigation Plans on 12/21/05

- Continue data collection – SOM, photos and videos, litigation sources
- Obtain floor layout and contents data for fire analyses
- Determine final status of fuel accountability for WTC 7 following 9-11
- Use SAP to conduct preliminary analysis of global stability with reported debris impact damage (2 bounding cases)
- Develop initiating event hypotheses to guide analyses.
- Conduct parametric studies to determine significant parameters for WTC 7 fires.
- Conduct thermal analysis for fires and fireproofing condition for ANSYS structural model.
- Conduct analysis of structural response of floors 5 to 13 to debris impact damage and fires using ANSYS.
- Have contractor conduct global analysis of WTC 7 structural response to hypothetical initiating events
- Develop collapse hypotheses and probable collapse sequence
- Complete report on ConEd facility
- Complete report on seismic data analysis for WTC 7

Additional Investigative Topics Identified as the WTC 7 Investigation Progressed

- Investigation of hypothetical blast scenarios
- Evaluation of thermite as a possible heat source substance
- Awarded contract for evaluation of hypothetical blast scenarios
- Awarded contract for assistance with conducting analyses of hypothetical initiating fire scenarios using the ANSYS model and damage/fire scenarios developed at NIST (half to be completed by NIST, half by the contractor)
- Approaches for fire and thermal analyses, reflecting the limited available photographic and building condition information
- Inspection of the Banker's Trust building for fireproofing damage from debris impact by exterior panels as WTC 2 collapsed (WTC 7 suffered similar debris impacts by exterior panels as WTC 1 collapsed)
- Preliminary analysis of WTC 7 global response to initiating event locations using a SAP finite element model developed earlier in the investigation
- Evaluation of Manhattan dispatch tapes from 11:30 am to 5:30 pm recorded on 9-11-01

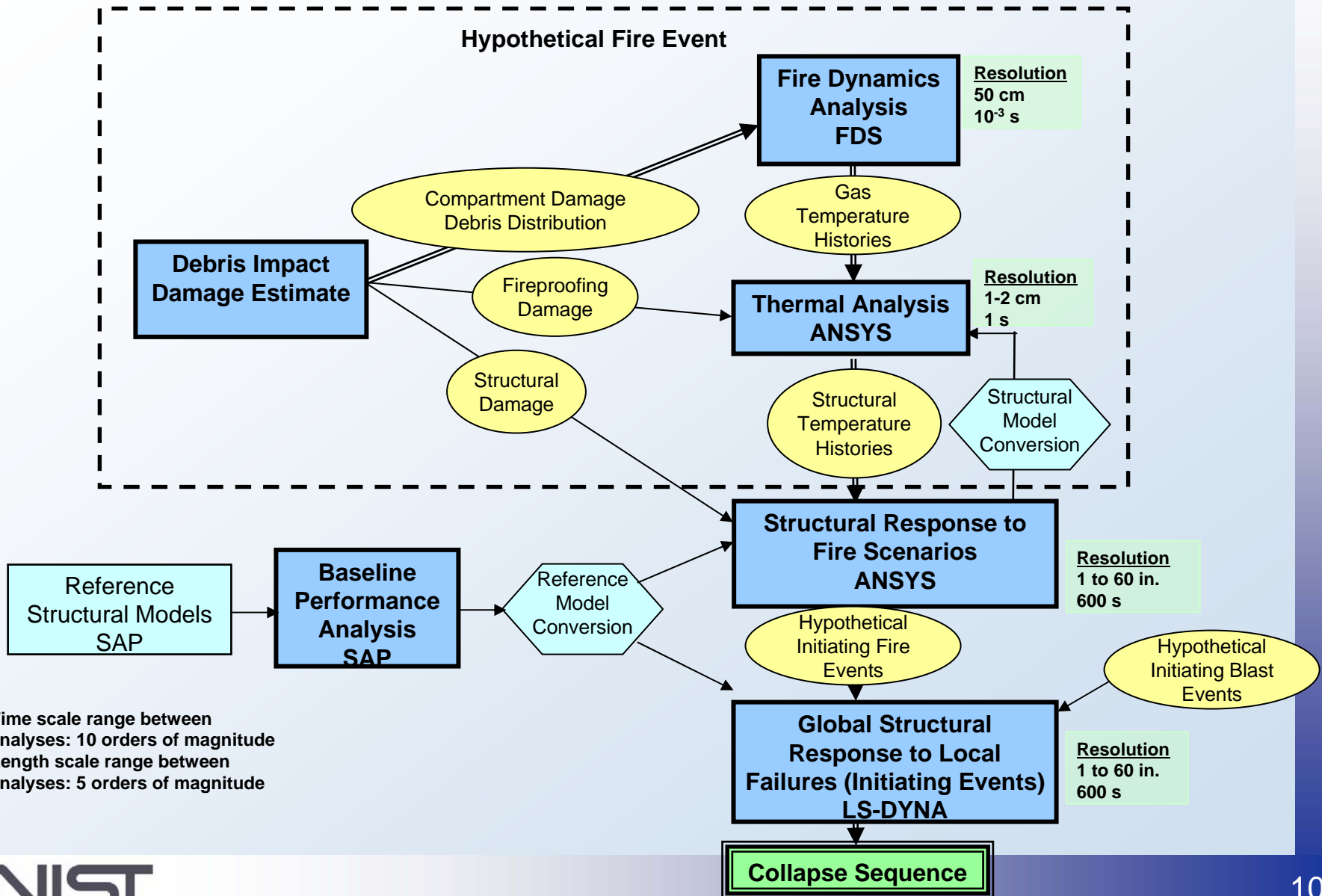
Key Technical Issues for Initial Conditions in WTC 7

1. Multiple approaches to evaluate likely fireproofing damage inside WTC 7
 - ❑ Obtain data about initial fireproofing condition from contractors and inspections
 - ❑ Implement analytical approach developed for the WTC towers, adding estimated distributions of accelerations imparted to WTC 7 framing by debris and fireproofing adhesive and cohesive strengths
 - ❑ Inspect Banker's Trust building to draw parallels about fireproofing damage from debris impact where possible from similar events
2. Lack of information about impact damage to the south face of WTC 7
 - ❑ Obtained data from witnesses and mapped reported observations
 - ❑ Mapped south face damage using photo analysis of available images (obtained new images 8/06)
3. Development of initiating event hypotheses
 - ❑ Developed table of hypothetical events based on known fire locations and building construction, identifying fire source, local conditions (combustibles, damage), and technical issues that need to be addressed
4. Fire size and locations
 - ❑ Developed maps of probable fire locations from 11:30 am to 5:30 pm based on very limited photos and videos – less than 1 % of those of the towers and non-continuous, especially lacking on the south face.
 - ❑ From building occupants, obtained data about fire walls, combustible contents (furnishings, fuel tanks, etc.) , floor layouts, and dates of renovations.

Key Technical Issues for Analyses

1. Lack of information on steel frame connections in WTC 7
 - ❑ Developed connection designs based on available data in structural design drawings and standard practice for the mid 1980's
 - ❑ Interviewed building designers
 - ❑ Reviewed available photographs of building during renovations
2. Revised fire analysis approach
 - ❑ Compiled potential ignition and firewall locations, consistent with visual evidence and interviews
 - ❑ Interpolated discontinuous data on fire spread and location timing
3. Revised thermal analysis approach to address reduced amount of data about of fire and initial building conditions in WTC 7 relative to the WTC towers and the analysis approach used there
 - ❑ Developed a simplified approach that included temperature variations over the building floor area but reduced the amount of modeling detail by an order of magnitude. Approach was supported by analyses comparing previous and proposed approaches.
4. Devised approach for data transfer between ANSYS analyses of hypothetical initiating events and LSDYNA analyses of the WTC 7 global response to hypothetical initiating events
 - ❑ Developed an initial approach to transfer temperature, displacement, and stress data from the ANSYS models to the LSDYNA models as initial conditions. This approach will be refined as the ANSYS and LSDYNA models are completed and necessary analyses conducted.

WTC 7 Critical Analysis Inter-dependencies



Hypothetical Blast Analysis

NIST is analyzing scenarios for the event that initiated the collapse of WTC 7. As a part of this work, NIST is considering whether hypothetical blast events could have played a role in initiating the collapse. While NIST has found no evidence of a blast or controlled demolition event, NIST will estimate the magnitude of hypothetical blast scenarios that could have led to the structural failure of one or more critical elements as a result of blast.

- ❑ **Phase I** Identify hypothetical blast scenarios and materials, based on analysis and/or experience, for failing specified columns by direct attachment methods. Preliminary section cutting shall be considered. Compare estimated overpressures for each scenario against window strength.
- ❑ **Phase II** For blast scenarios with overpressures that clearly would not have broken windows, the worst case scenario(s) will be analyzed using SHAMRC software to determine overpressures at windows.
- ❑ **Phase III** If Phase II overpressures did not clearly fail windows, 3 blast scenarios will be selected to determine the sound levels that would be transmitted outside the building through intact windows.

ANSYS Analysis of Initiating Events

The response of WTC 7 to debris impact damage and fire events is being analyzed to identify initiating events of component and subsystem failures leading to global collapse.

The analysis will use an ANSYS model of the lower 16 floors, as significant fires were observed between floors 7 and 13.

The ANSYS model includes steel framing, concrete slabs with smeared properties for steel decks and reinforcement, material properties for elastic, plastic, and creep behavior at elevated temperatures, break elements for connection capacity and service gravity loads.

Analyses of up to 12 damage and fire scenarios will be based on:

- ❑ two structural damage states based on available evidence
- ❑ assumed fireproofing conditions
- ❑ temperature histories that may be up to 7 h long

Analysis Cases for ANSYS Modeling of WTC 7 to Evaluate Hypotheses for Initiating Fire Events

	Damage State 1		Damage State 2	
	7-13	5-6 and 7-13	7-13	5-6 and 7-13
Fire Floors	7-13	5-6 and 7-13	7-13	5-6 and 7-13
Fireproofing Condition				
Intact (Full adhesive bond, debris induced accelerations < 50 G)	1	4	7	10
Bare (Poor adhesive bond, debris induced accelerations > 1 G) OR 90% damage (Partial adhesive bond, debris induced accelerations > 7 G)	2	5	8	11
50% damage (Partial adhesive bond, debris induced accelerations > 4 G)	3	6	9	12

The fireproofing condition was not directly observed, and its condition is based on analysis that considers the FP bond strength, accelerations imparted by the debris impact, and observations from the Banker's Trust building.

LS-DYNA Analysis of Global Response to Initiating Events

The LS-DYNA global analyses will determine if global collapse will result from initiating events (due to fire or blast) which will be input as initial conditions.

Task 1. Floor Component and Subsystem Analyses

- ❑ Determine floor response and failure modes for up to 20 initiating event scenarios
- ❑ Develop an equivalent floor model mesh appropriate for global analyses

Task 2. Global Analyses

- ❑ Determine global structural stability for two damage states
- ❑ Conduct a sensitivity study where up to 20 initiating events are analyzed, through member removal or other appropriate approach, to determine structural stability following the loss of support and the sequence of member failures that result from a given scenario
- ❑ Conduct final analyses that simulate the initiating event, whether due to fire or other effects, and the subsequent failure sequence up to global collapse (including the vertical and horizontal progression of failures up to the point of global instability)

Progress to Date

- 12/05 Completed table of initiating events for WTC 7.
- 1/06 Completed review of 80 boxes of data and drawings held by SOM.
- 4/06 Awarded contract to ARA for global analyses.
- 5/06 Completed ANSYS analysis of WTC 7 floor sections with inclusion of temperature-dependent material properties, composite floor behavior, and creep.
- 6/06 Completed preliminary simulations of fire progress and thermal heating of structural elements.
- 6/06 Completed evaluation of thermite as a possible heat source substance for review.
- 7/06 Completed information gathering on building layout and contents.
- 8/06 Inspected Banker's Trust building for fireproofing damage from debris impact by exterior panels as WTC 2 collapsed. Discussions to perform the inspections started in 3/06 and were not approved until 7/06.

Progress to Date

- 8/06 Completed preliminary analysis of WTC 7 global response to initiating events using a SAP model developed earlier in the investigation, including design of connection details and development of failure criteria.
- 8/06 Awarded contract to ARA (with CDI and SGH as subcontractors) for analysis of hypothetical blast events and assistance with structural analysis of initiating events.
- 8/06 Completed analysis of visual evidence: fire progress and building damage.
- 8/06 Completed analysis of seismic data.
- 10/06 Completed FDS fire models and analyses for floors.
- 10/06 Updated south face damage.
- 11/06 Completed video analysis of building vibration.
- 12/06 Developed ANSYS model for thermal analyses, initiated analyses.
- 12/06 Completed LSDYNA floor and global models; initiated floor analyses.
- 12/06 Developed hypothetical blast scenarios for analysis of overpressures.