



NIST Response to the World Trade Center Disaster

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

Part IIC – WTC 7 Collapse

April 5, 2005

**National Institute of Standards and Technology
Technology Administration
U.S. Department of Commerce**

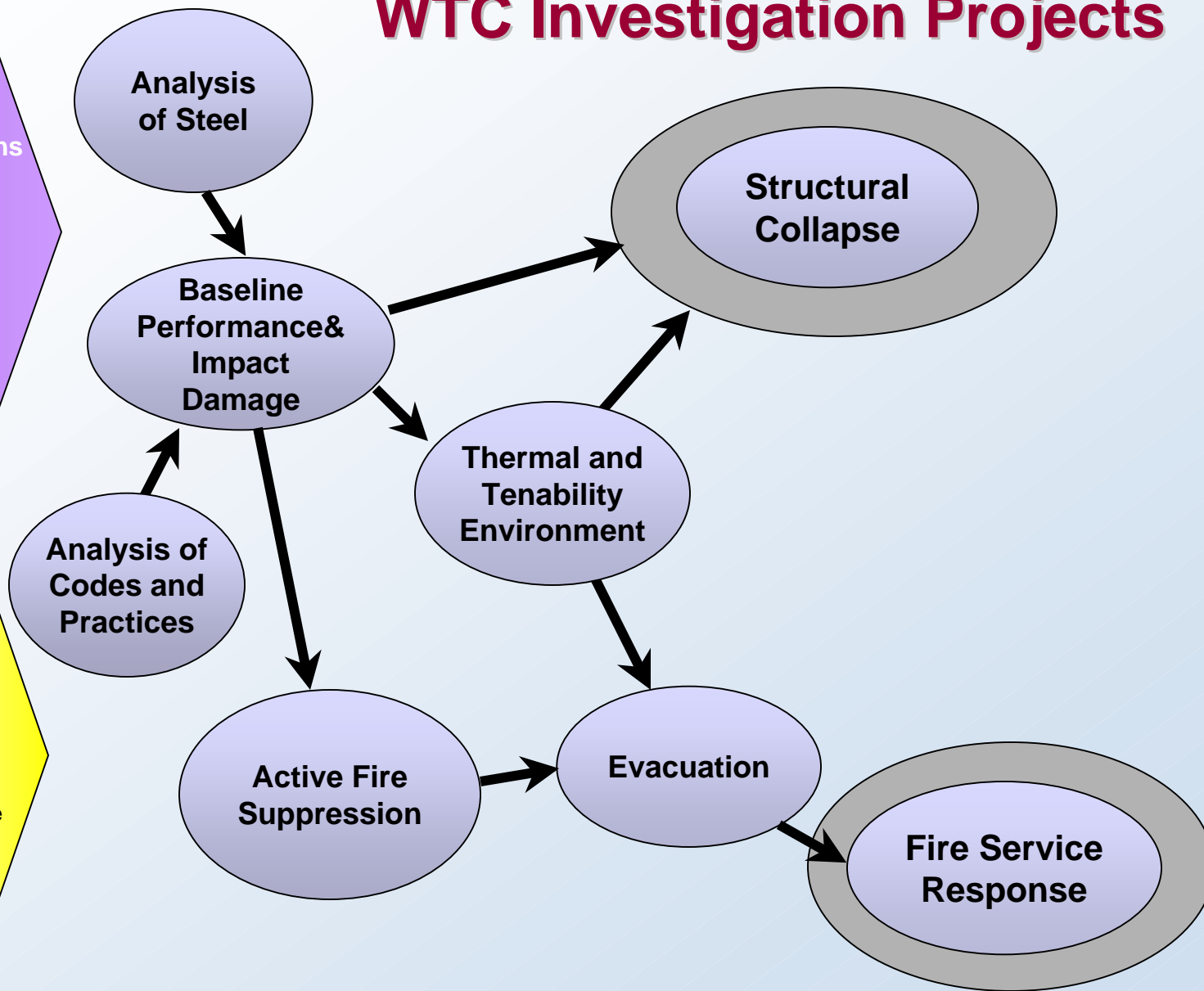
NIST WTC Investigation Objectives

- 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 the procedures and practices that were used in the design, construction, operation, and maintenance of the WTC buildings
- **Identify, as specifically as possible, areas in current national building and fire model codes, standards, and practices that warrant revision**

WTC Investigation Projects

BPAT Recommendations
Government, Industry, Professional, Academic Inputs
Public Inputs

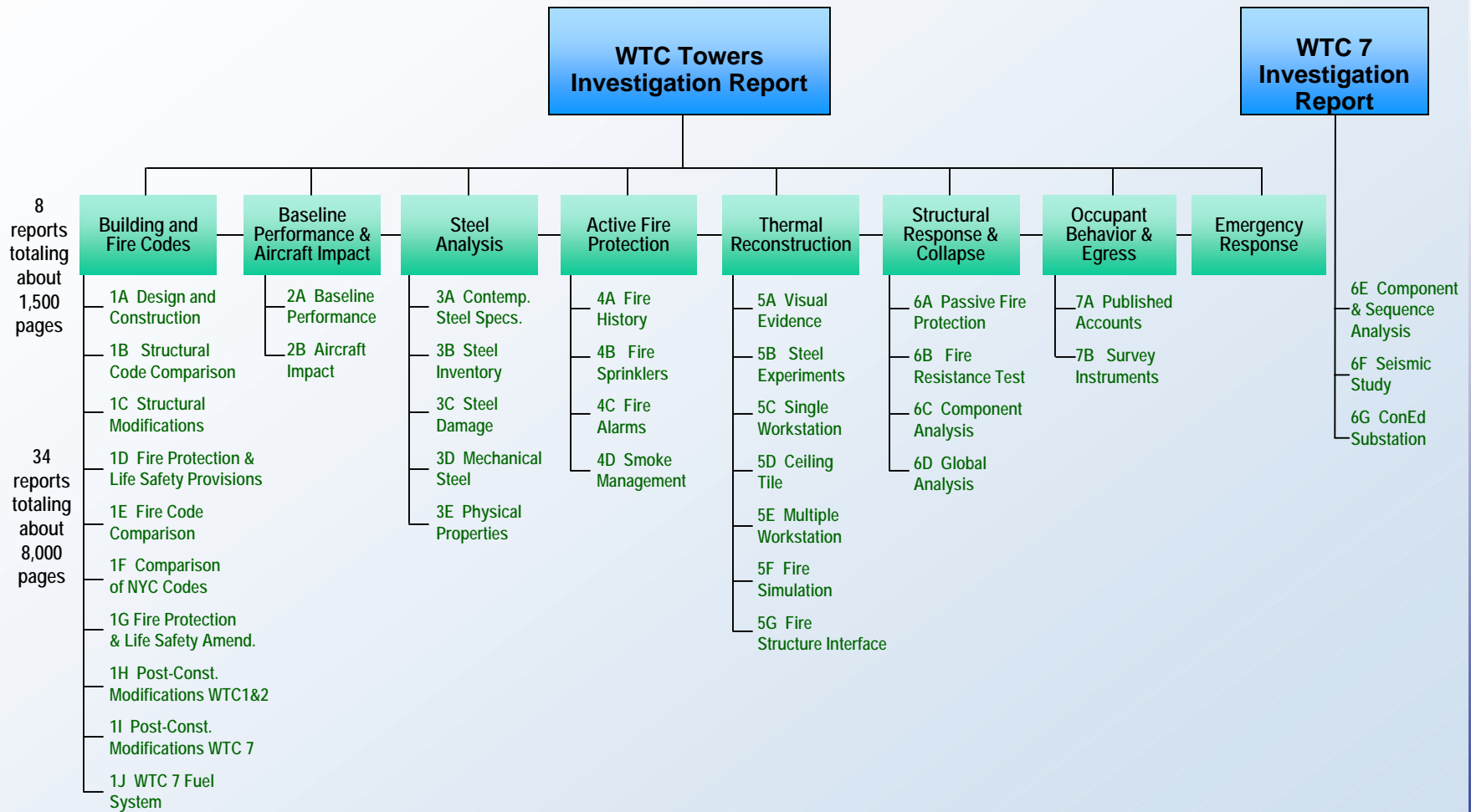
Public Inputs
Documents
Video/ Photographic Records
Oral History Data
Emergency Response Records
Recovered Structural Steel



Schedule for Completion of Investigation

- Major focus is on writing the Investigation reports; technical work is nearly complete.
- The time required to write and review the comprehensive set of draft documents that constitute final WTC investigation findings and recommendations is driving the release date of the report.
- The NIST reports include the overall investigation report for the WTC towers, 8 project separate project reports, and 34 supporting technical reports, totaling some 10,000 pages. This enormous task has taken NIST longer to accomplish than originally anticipated.
- NIST is committed to putting accuracy, quality, and completeness ahead of schedule, taking whatever time is required to do the job right.
- NIST plans to release a draft of the final report for public comment in June 2005; public comment period of about 6 weeks after release of the draft reports; NIST plans to release final Investigation report in September 2005.
- WTC 7 report will be issued as a supplement to the main report: draft planned for October 2005; final for December 2005.
 - Decoupling of WTC 7 report necessary to accommodate overlapping staffing demands for work on WTC towers.
 - This change affects mainly the collapse analysis; other WTC 7 work will be reported with the other Investigation reports.
- WTC Conference: Putting Recommendations into Practice, September 2005.

WTC Investigation Reports



43 reports for WTC Towers; 4 reports for WTC 7

Working Collapse Hypothesis for WTC 7

If it remains viable upon further analysis, the working collapse hypothesis for WTC 7 suggests that it was a **classic progressive collapse**, including:

An Initiating Event

- ❑ An initial local failure 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 ft²

A Vertical Progression at the East Side of the Building

- ❑ Vertical progression of the initial local failure up to the east penthouse, as large floor bays were unable to redistribute the loads, bringing down the interior structure below the east penthouse

A Subsequent Horizontal Progression from the East to the West Side

- ❑ Horizontal progression of the failure across the lower floors (in the region of Floors 5 and 7, that were much thicker than the rest of the floors), triggered by damage due to the vertical failure

Disproportionate Global Collapse

- ❑ Events resulted in a disproportionate collapse of the entire structure

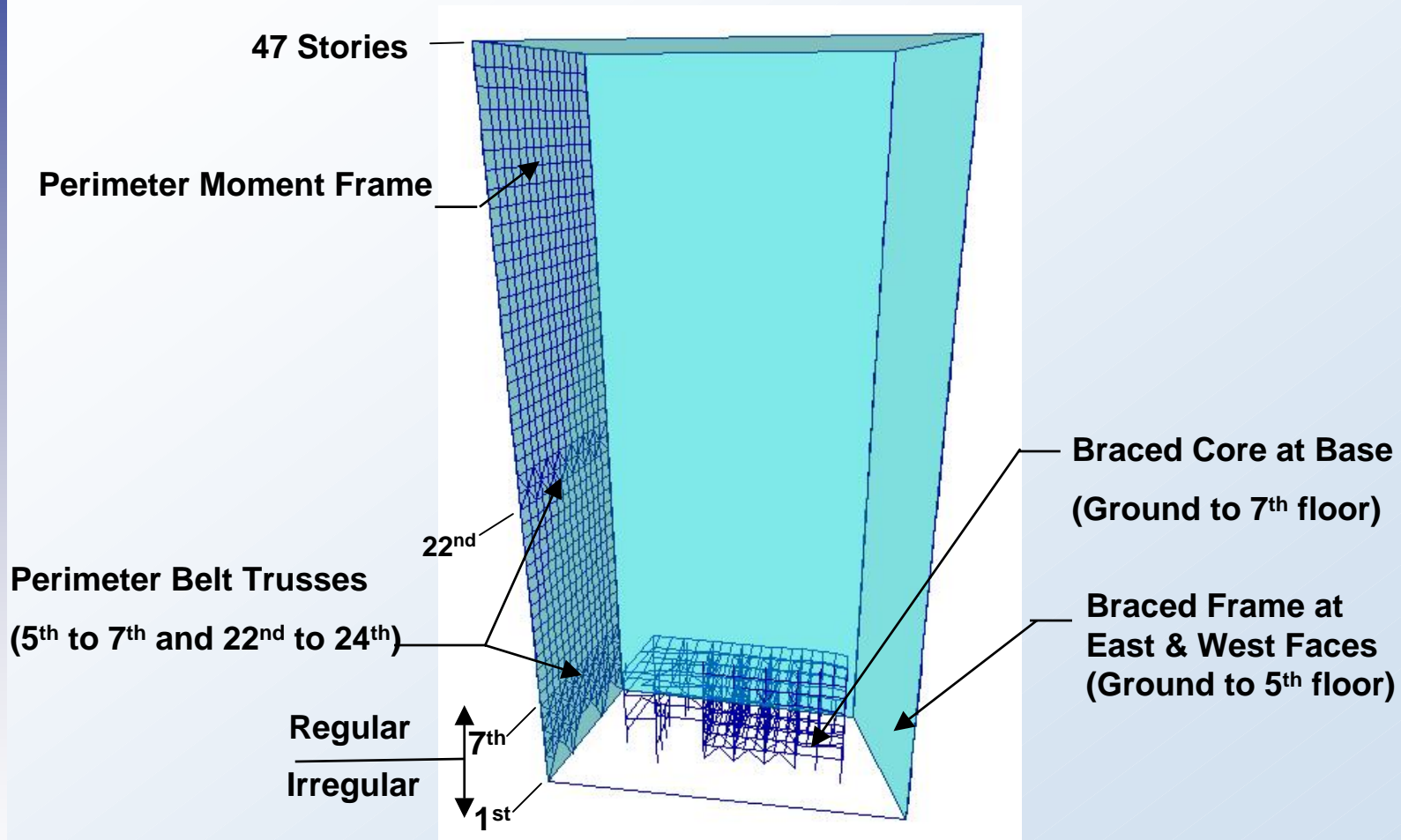
NIST has seen no evidence that the collapse of WTC 7 was caused by bombs, missiles, or controlled demolition.

Building Description

Major Features Relative to the Working Collapse Hypothesis:

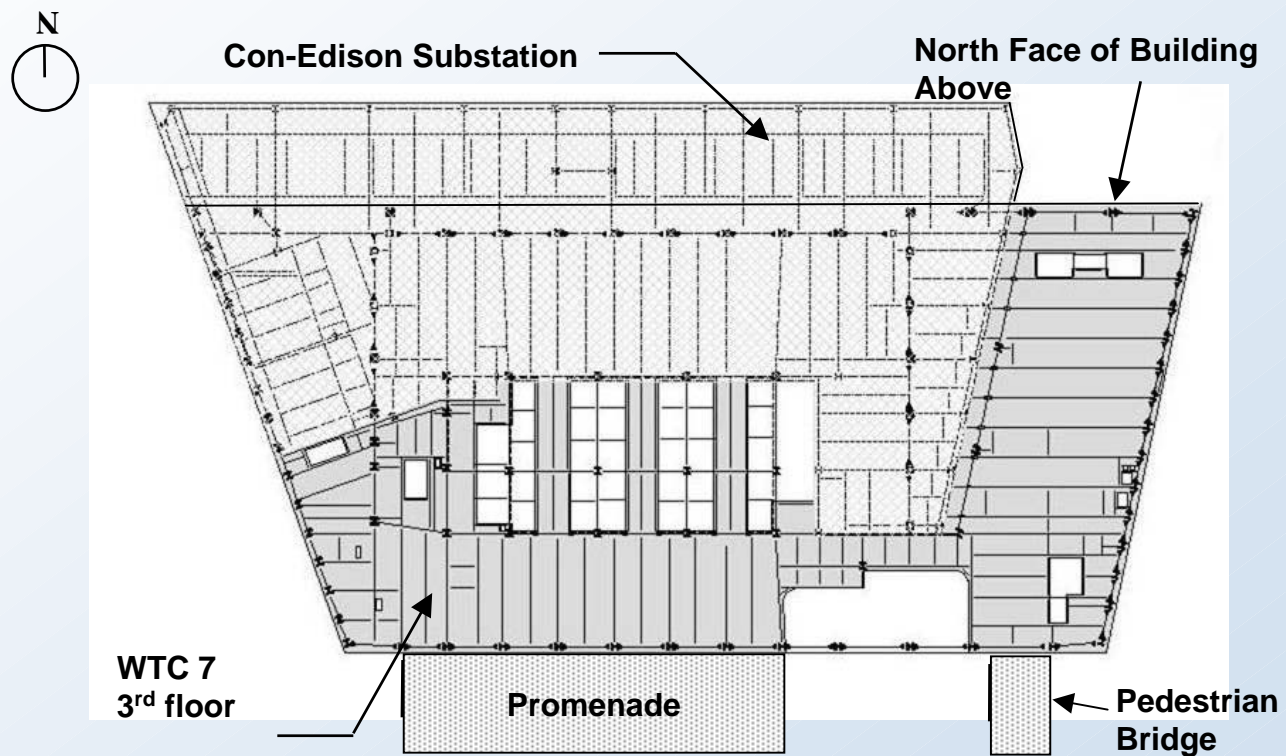
- Framing Differences Above/Below Floor 7
- Framing Relative to Con Ed Substation
- Transfer System Between Floors 5 and 7
- Floor Plan and Built Up Columns
- Roof Layout

WTC 7 Framing

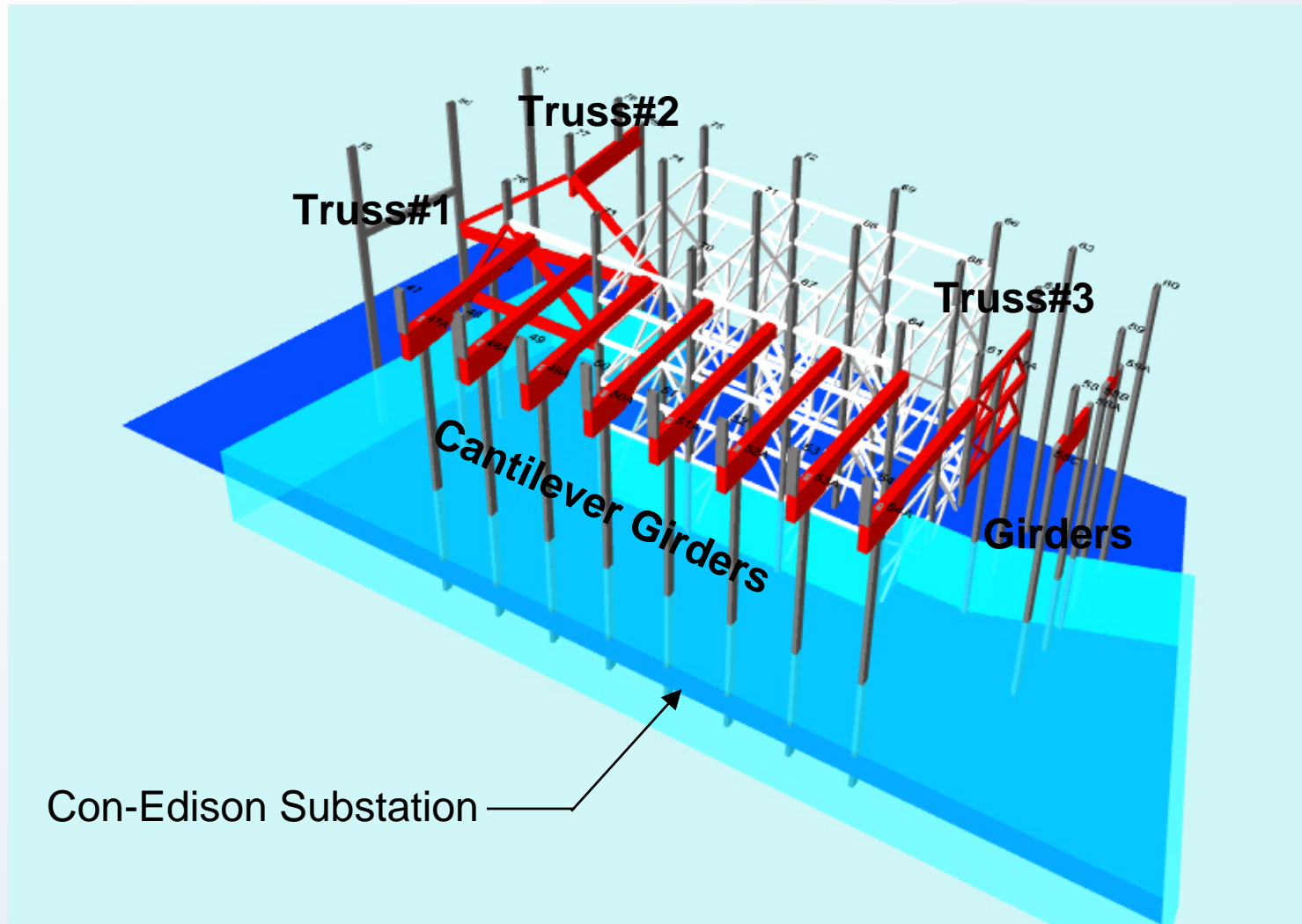


WTC 7 and Con Edison Substation

Below 7th floor, braced frame constructed over Con Ed substation



Transfer System Between Floors 5 and 7



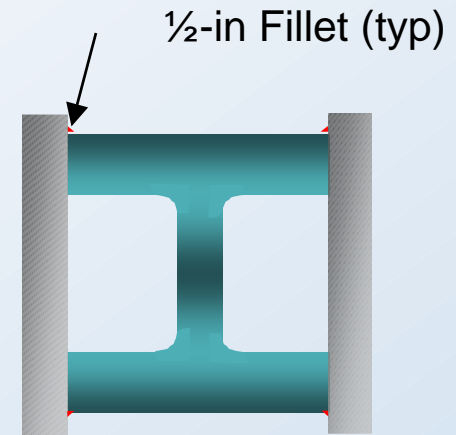
7th Floor Plan – Built-up Columns



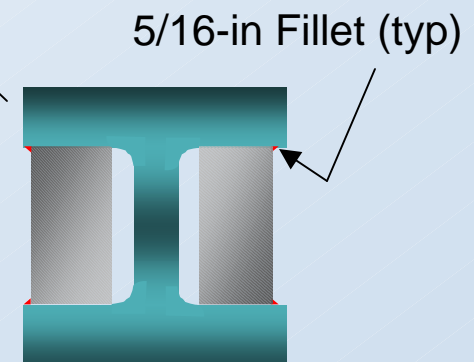
■ Built-up Column

⌚ Non Built-up Column

7th Floor Plan
Built-up Column Locations



Built-up Column with Side Plates

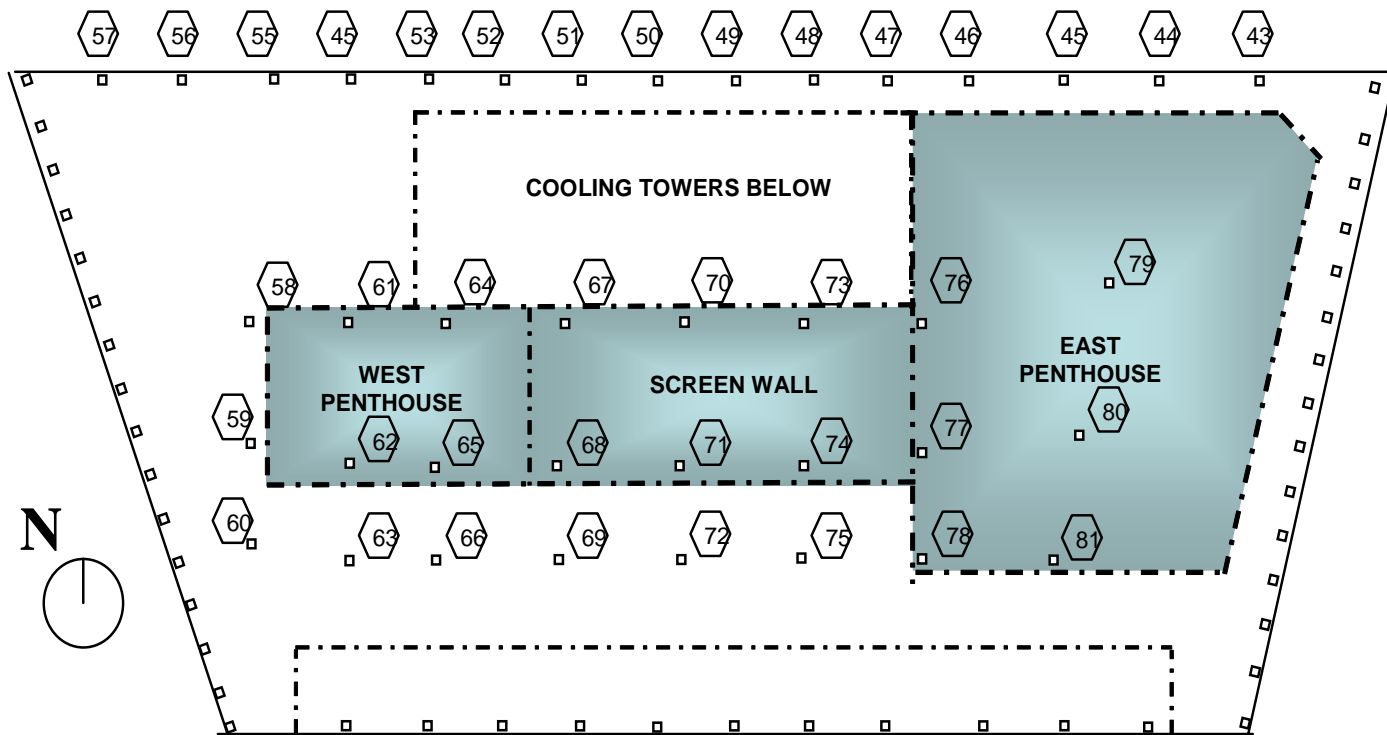


Built-up Column with Web Plates

Roof Layout

WTC 7 was modified:

- Penthouse structures added to the roof
- East half of floors 41 and 43 were removed and replaced
- HVAC and communication systems were added from floor 28 to the roof
- Fuel tanks and backup generators were added



Building Conditions

Data for building conditions has been expanded and enhanced through photographs, video, and interview records:

- Debris Impact from WTC 1 and WTC 2
- Observed and Reported Fire Locations and Times
- External Signs of Collapse

Debris Damage from WTC 2

After WTC 2 collapsed:

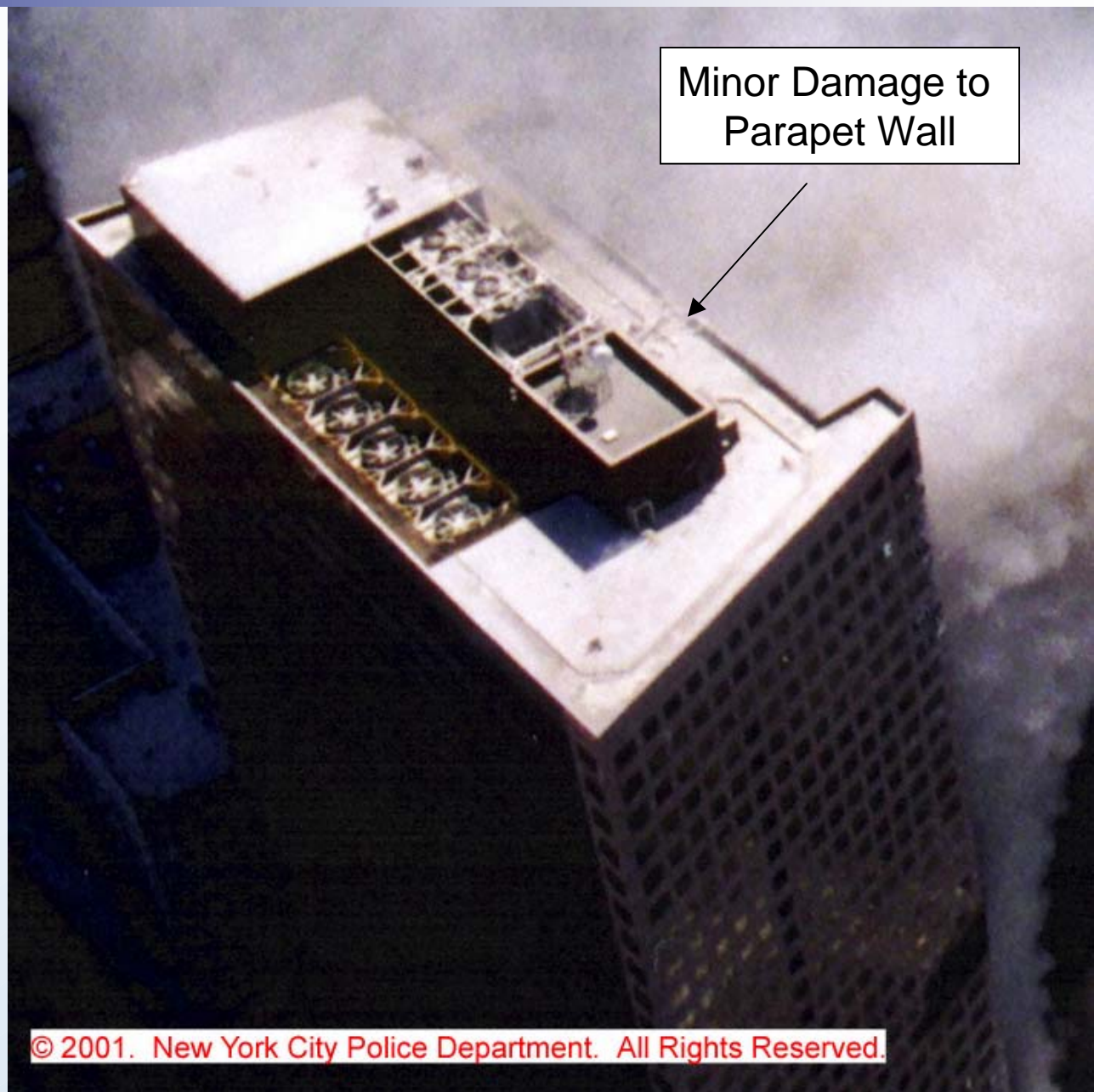
- Some south face glass broken at lower floors
- Dust covered lobby areas at floors 1 and 3
- Power on in building, phones working
- No fires observed

Debris Damage from WTC 1

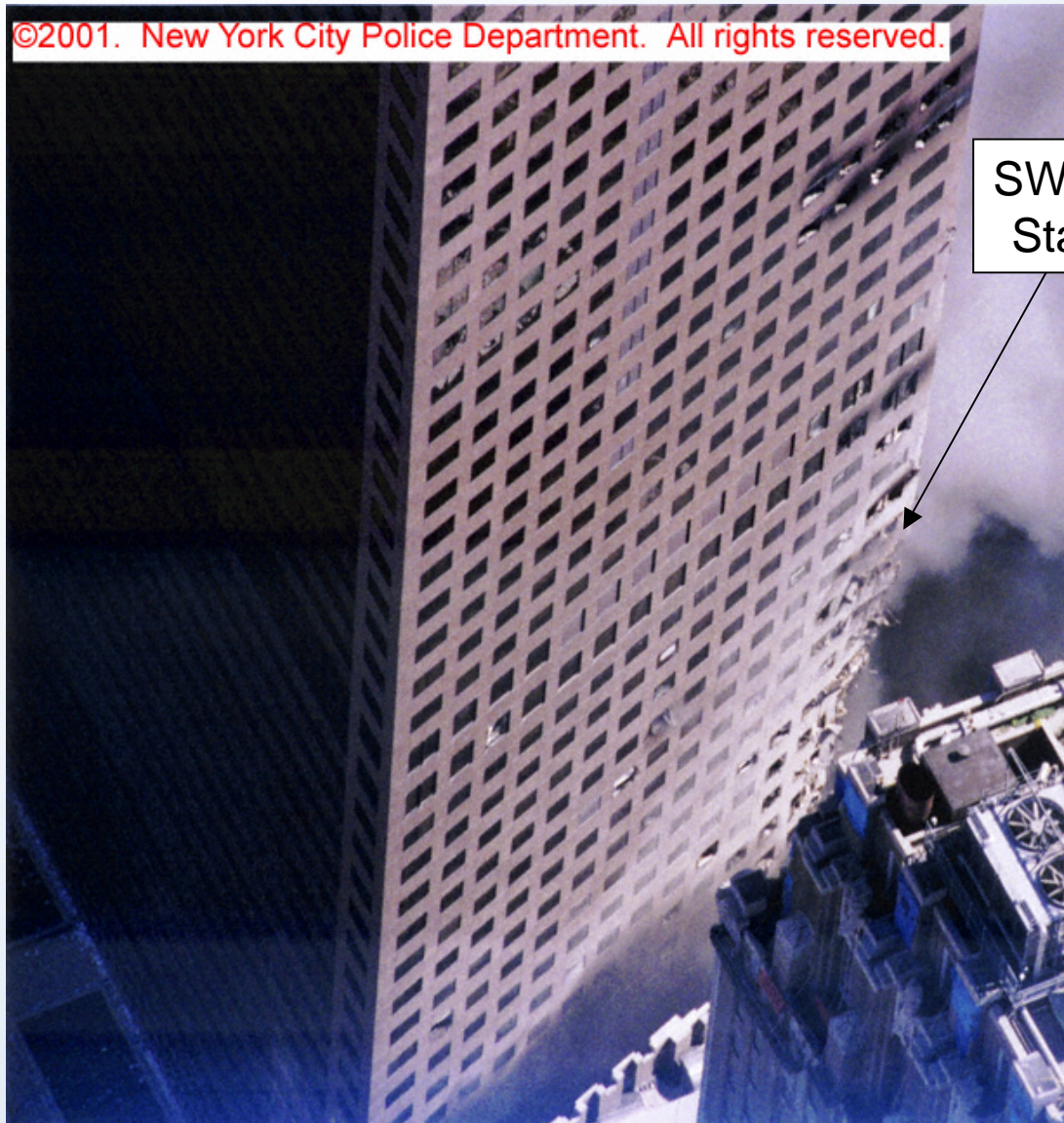
After WTC 1 collapsed:

- ❑ Heavy debris on Vesey Street and WTC 7 Promenade
- ❑ No heavy debris observed in lobby area, white dust coating
- ❑ SW Corner Damage – floors 8 to 18
- ❑ South face damage between two exterior columns - roof level down 5 to 10 floors, extent not known
- ❑ South Face Damage –
 - middle 1/4 -1/3 width south face, 10th floor to ground
 - large debris hole near center around 14th floor
 - 1/4 width south face, above 5th floor, atrium glass intact
 - 8th / 9th floor from inside, visible south wall gone with more damage to west, 2 elevator cars dislodged into elevator lobby

**WTC 7
Roof
After
WTC 1
Collapse**



**WTC 7
SW
Corner
After
WTC 1
Collapse**



SW Corner Damage
Starting at Floor 18

Vesey Street by Pedestrian Bridge After WTC 1 Collapse



Vesey Street by Promenade After WTC 1 Collapse

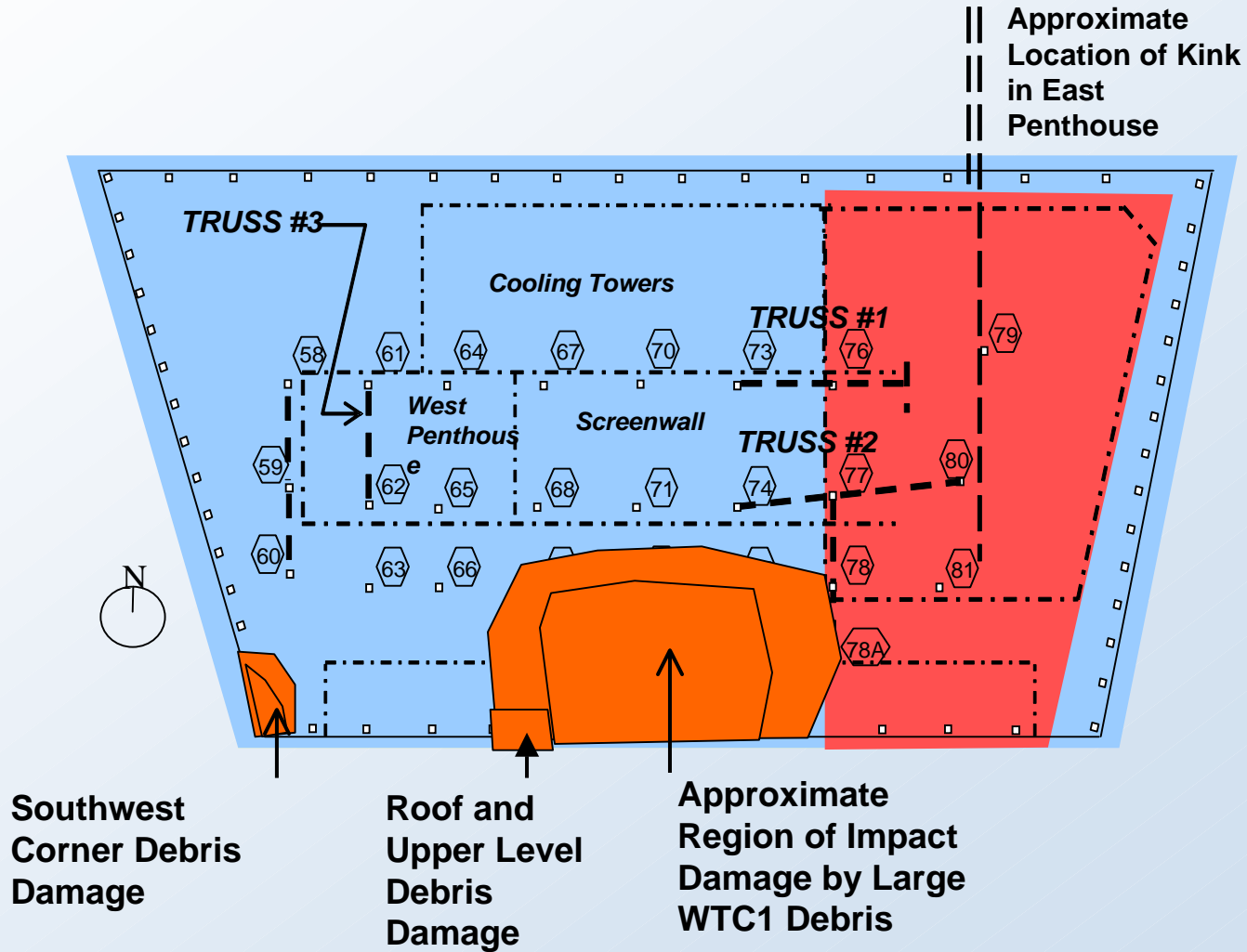
© 2001 Willie Cirone

Pedestrian Bridge →

Third Story Promenade
Standing with Debris
on Top ↓



Estimated Extent of Debris Damage



Observed Fire Locations (11:30-2:30 pm)

General

- No diesel smells reported from the exterior, stairwells, or lobby
- No signs of fire or smoke below floor 6 from stairwell and lobby areas
- Fire reported at west wall of floor 7 around 12:15 pm
- In east stairwell, smoke was observed near floors 19-20; signs of a fire observed on floor 23

Looking from southwest corner to the south face

- Fire in SW corner near floors 10 or 11
- Fire on floors 6, 7, 8, 21, 30
- Multiple fires observed on floors numbered 20's and 30's
- Heavy black smoke coming out of south face gash; no fire observed

Looking from southeast corner to the south face

- Fire on floor 12;¹ area above covered with smoke
- Fire on floors 11-12¹ moved to east face and progressed to the north

¹ fires reported on floor 14, but photographs showed east face fires on floor 12

Observed Fires

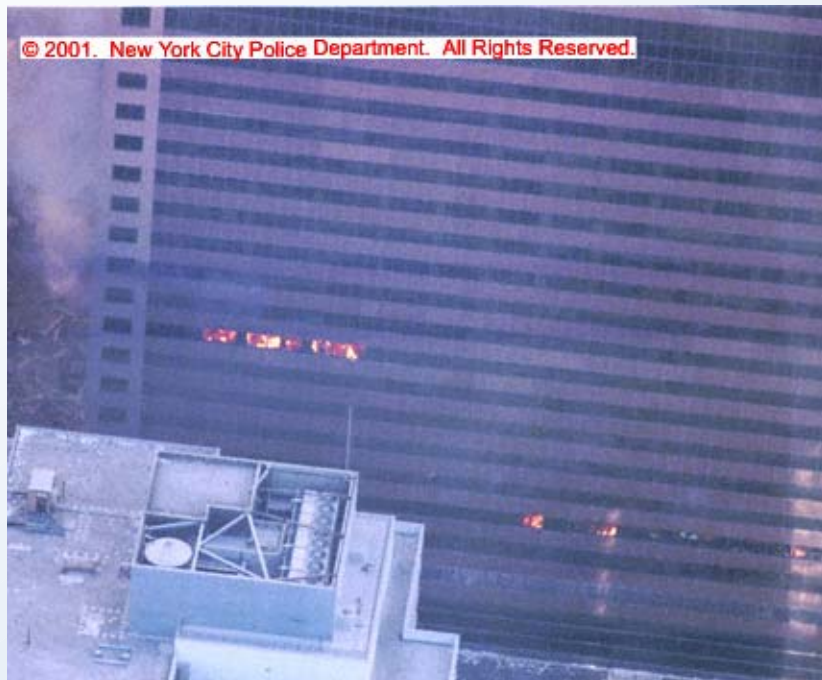
East Face Fires on Floors 11-12 near 2 PM



Fires in WTC 7—which began soon after WTC 1 collapsed—were observed on Floors 7, 8, 9, and 11 near the middle about half an hour before collapse; Floor 12 was burned out by this time. Fires were also seen on Floors 12, 13, 22, 29, and 30 at various times during the day.

Observed Fires

North Face Fires on Floors 7 and 12
near 3 PM



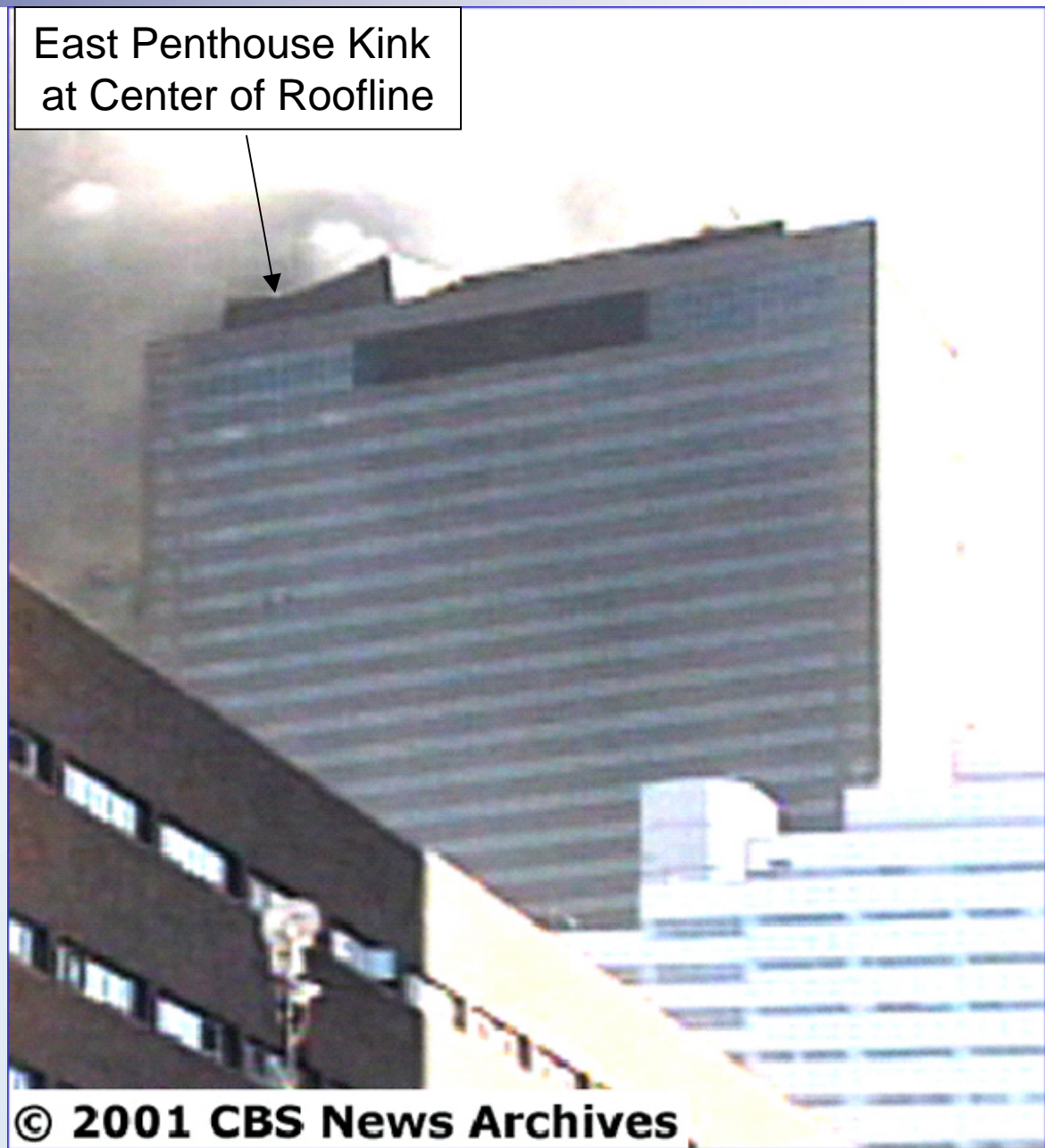
©2001 Nicolas Cianca

5:20:46 p.m.



First Observation of Collapse

East Penthouse Kink
at Center of Roofline



© 2001 CBS News Archives

Observed Sequence of Failures in WTC 7

© 2001 CBS News Archives



Failure Sequence Timeline

Time Interval (sec)	Total Time (sec)	Observation from CNN Net Dub 7 47.avi
0.0	0.0	Movement of east penthouse roofline
0.9	0.9	East penthouse kinks between columns 44 and 45 2 windows at floor 40 fail between columns 44 - 45
0.3	1.2	4 windows fail at floor 40 East penthouse submerged from view (now inside building)
0.4	1.7	3 windows break at floors 41 to 44
0.5	2.2	East penthouse completely submerged
1.8	4.0	Windows break along column 46 at floors 37 and 40
3.0	7.0	North side of west penthouse moves Movement of entire north face of WTC7 (visible above floor 21)
0.2	7.2	West end of roof starts to move
0.5	7.7	East end of roof starts to move Façade kink formed along column 46-47
0.1	7.9	West penthouse submerged Global collapse occurs as windows fail between floors 33-39 around column 55
0.3	8.2	

Initiating Event & Vertical Progression

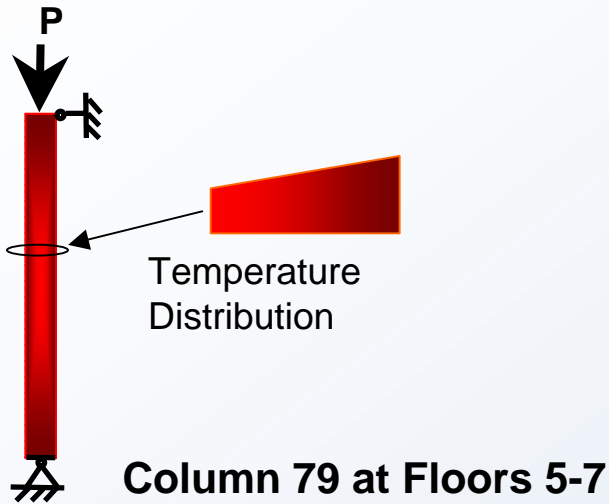
Initiating Event

- ❑ First exterior sign of failure was at the east penthouse roofline, aligned with interior columns 79, 80, and 81. Postulated initiating events include the failure of these columns.

Vertical Progression

- ❑ Columns 79, 80, and 81 supported large tributary areas for floor spans of approximately 50 ft. Failure of column 79, 80, or 81 would likely result in failure at the floor-column connections and would progress vertically up to the east penthouse.

Initiating Event: Thermal-Structural Response of Critical Components



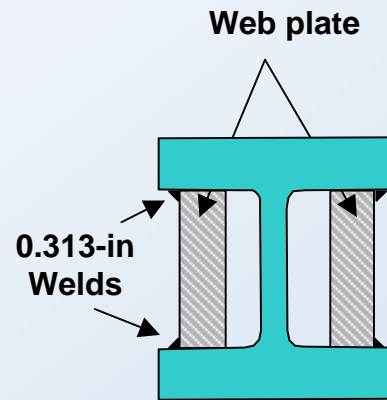
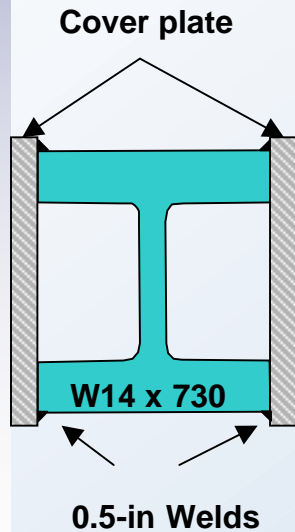
Possible Modes of Column Failure:

- Squashing (Yielding) of Column
- Cover Plate Weld Failure
- Failure of Column Splice

Thermal Structural Analysis

- Uniform and Gradient Temperatures
- Damaged and Intact Fireproofing
- Temperature Dependent Material Properties

- Thermal Softening
- Axial Thermal Expansion
- Bowing from Thermal Gradients



Columns 79 and 81 at Floors 5-7

Status of Initiating Event Analysis

NIST continues to evaluate the factors that could have caused column 79, 80, or 81 to fail

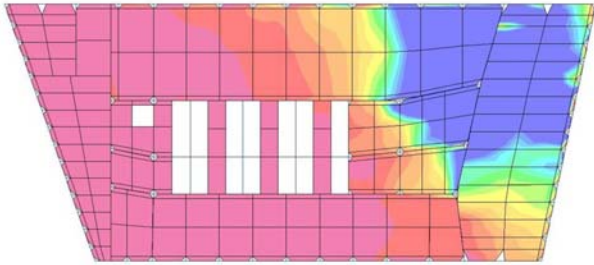
Possible contributing factors include:

- Damage to components adjacent to truss #2 from debris impact
- Damage to fireproofing from normal activities prior to event or debris damage
- Unusual fuel loads (fuel lines, high density of building contents)

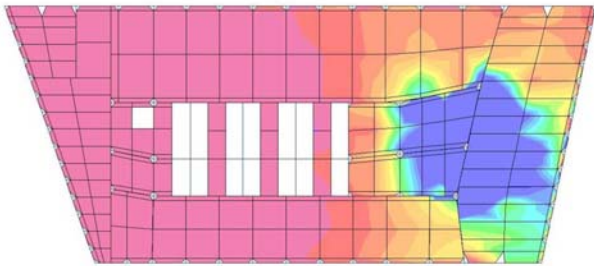
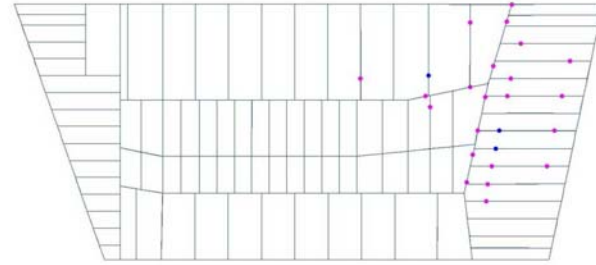
Analysis to date indicates:

- Massive size of columns 79, 80, and 81 appears to require severe fires and/or damaged fireproofing to initiate thermally-related failures

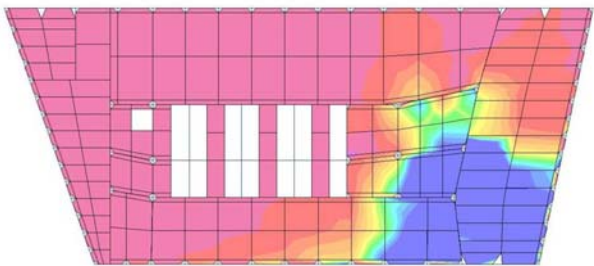
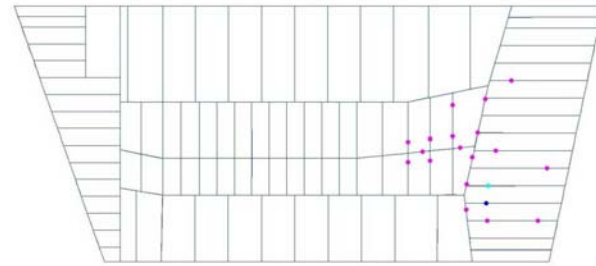
Vertical Progression: Floor Response to Loss of Column Support



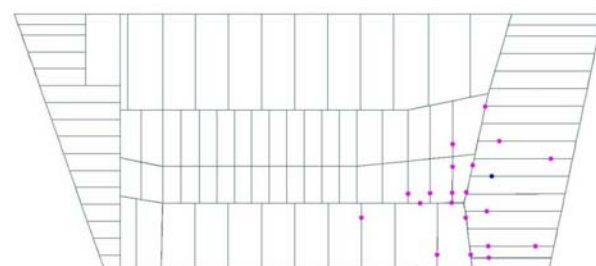
Col 79
Beam Hinges →
← Slab Force



Col 80
Beam Hinges →
← Slab Force



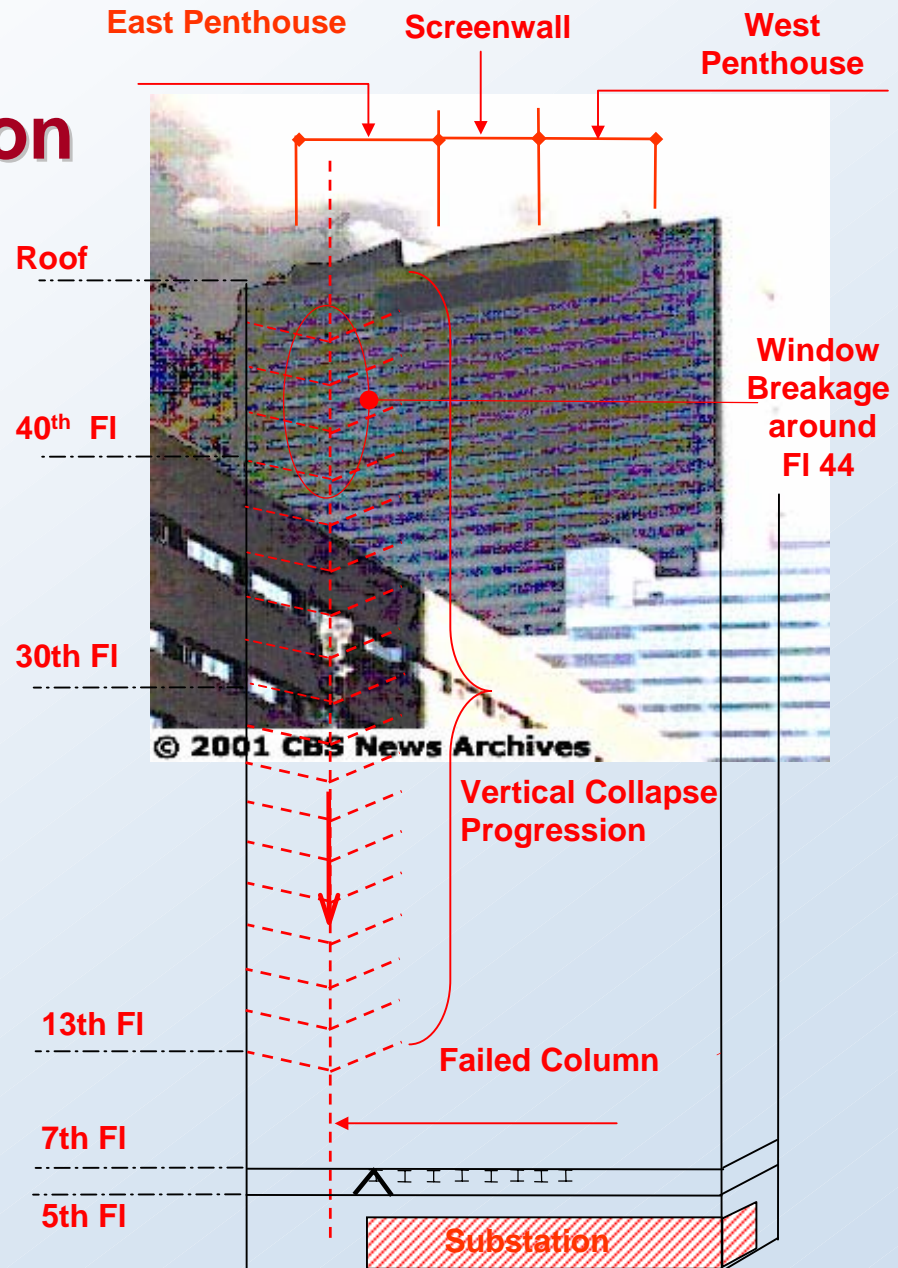
Col 81
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Initiating Event & Vertical Progression

Exterior Observations:

- ❑ East Penthouse Kink
- ❑ Window Breakage



Horizontal Progression & Global Collapse

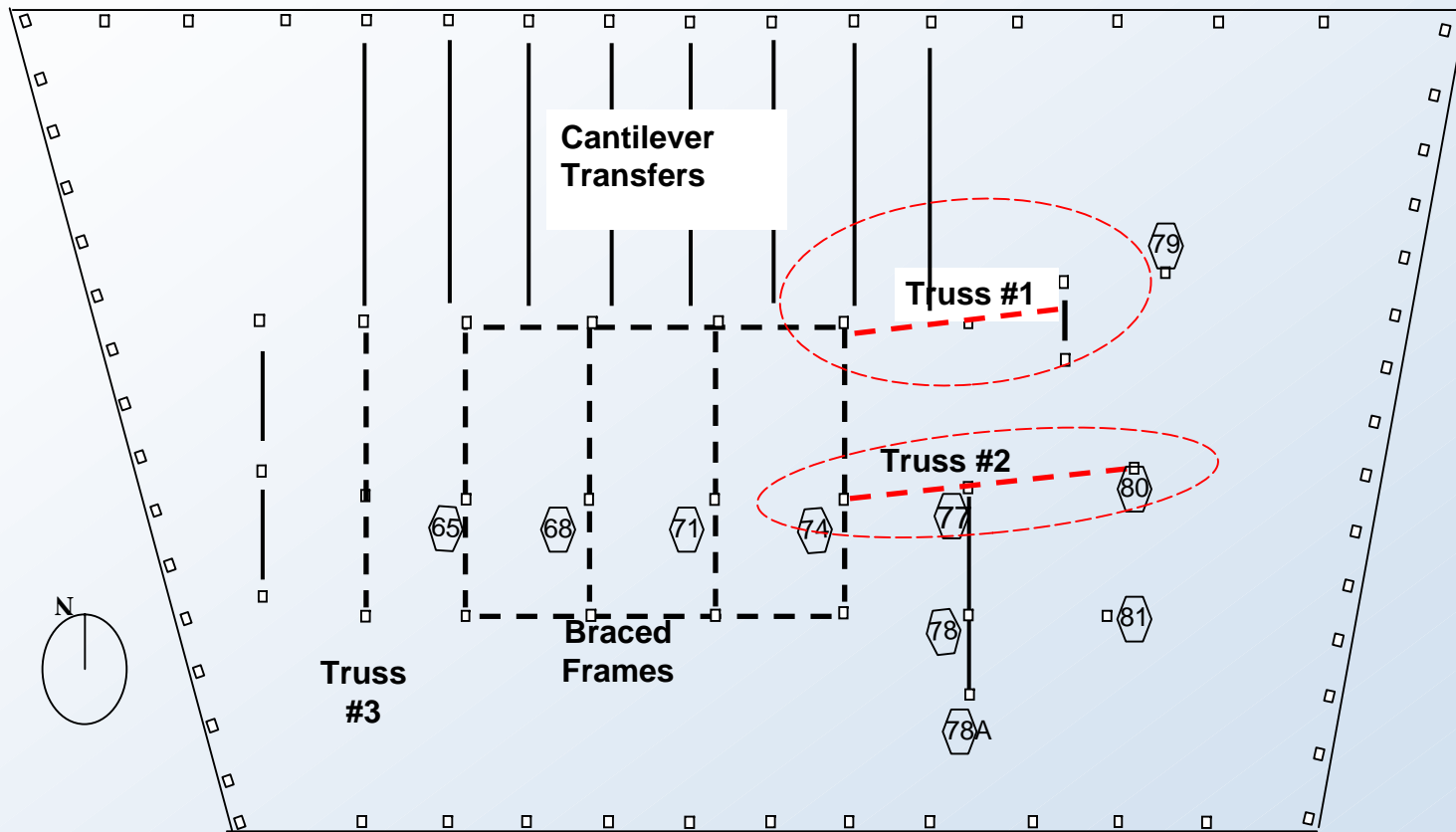
Horizontal Progression

- ❑ A vertical failure would pile debris on the east side of the building, damaging or severing transfer girders and trusses between floors 5 and 7.
- ❑ This secondary damage has been postulated to cause a horizontal progression of failure in the core columns at or near floors 5 and 7.

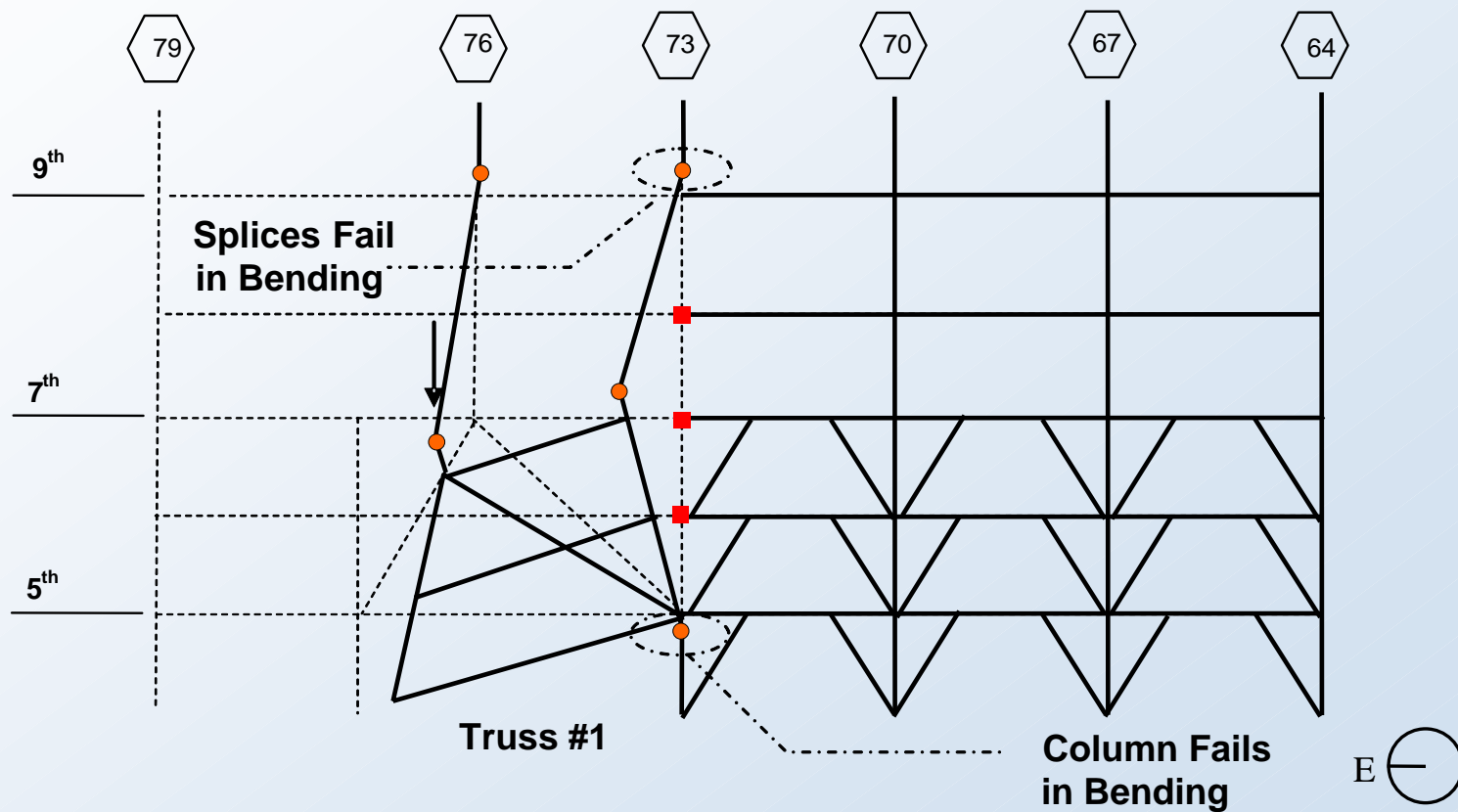
Global Collapse

- ❑ The global collapse occurred with few external signs and is postulated to have occurred with the failure of core columns

Truss #1 and Truss #2 Locations



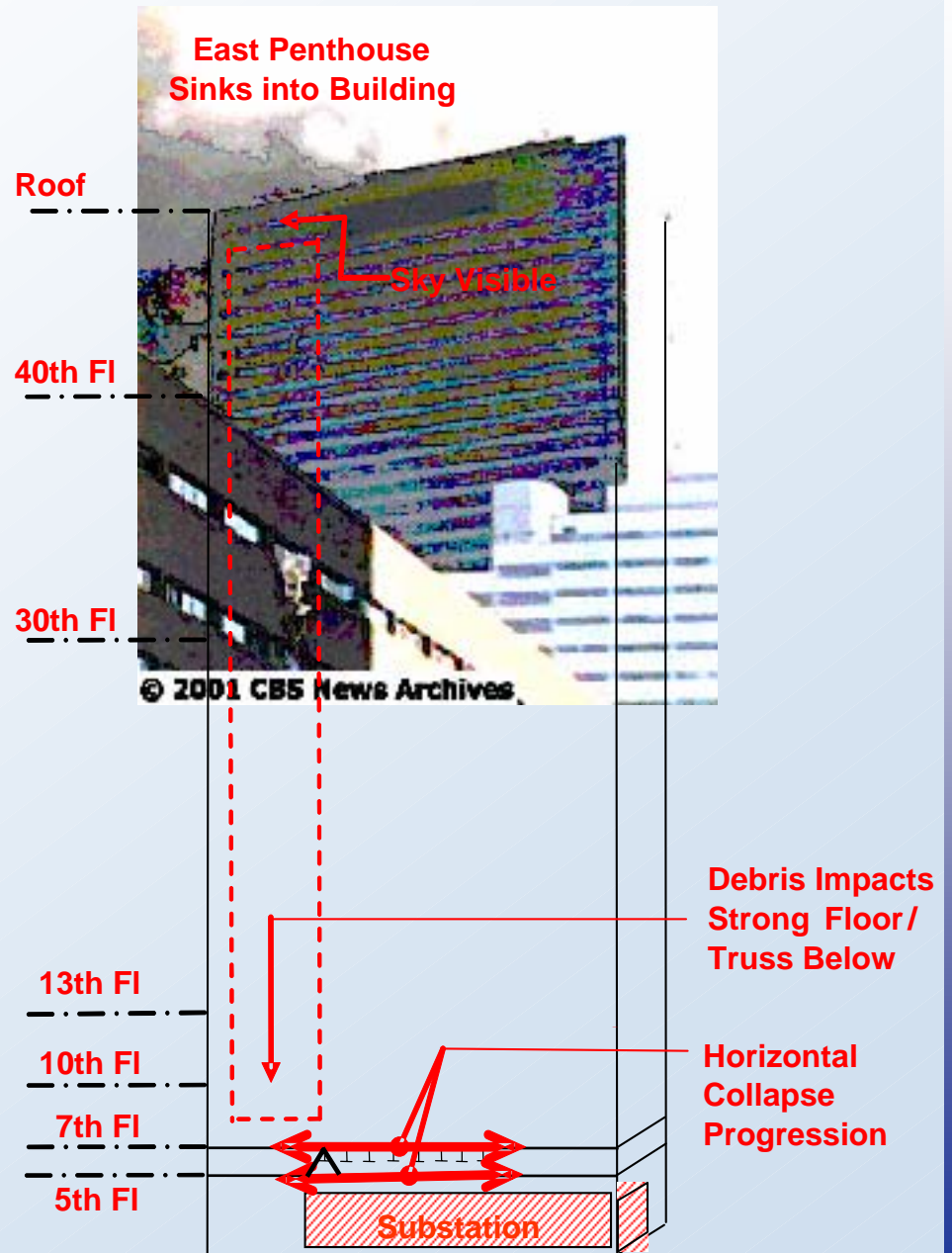
Horizontal Progression – Truss #1



Horizontal Collapse Progression

Exterior Observations:

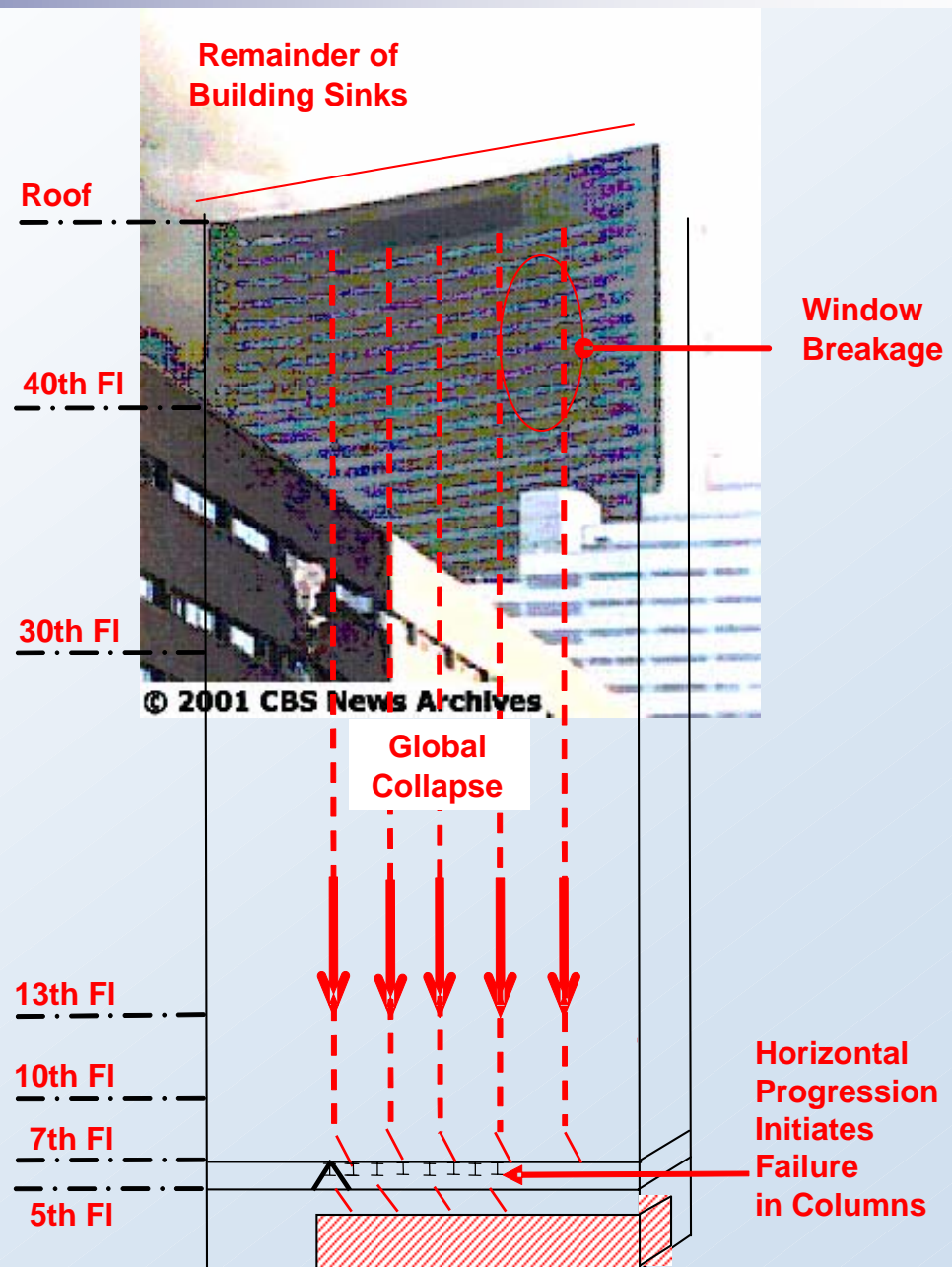
- East Penthouse Sinks
- Further Window Breakage
- No Movement for 5 sec



Global Collapse

Exterior Observations:

- ❑ Center and West Penthouses Sink
- ❑ North Façade Kink at Column 76
- ❑ Window Breakage in Front of Truss #3



Fuel System for Emergency Power in WTC 7

- NIST has reviewed and documented the fuel system for emergency power in WTC 7
- **Floor 5—which did not have any exterior windows and contained the only pressurized fuel distribution system on the south, west and north floor areas—is considered a possible fire initiation location**, subject to further data and/or analysis that improve knowledge of fire conditions in this area.
- The two 6,000 gallon tanks supplying the 5th floor generators through a pressurized piping system were always kept full for emergencies and were full that day.
- Both tanks were found to be damaged by debris and empty several months after the collapse. Some fuel contamination was found in the gravel below the tanks and sand below the slab on which the tanks were mounted, but no contamination was found in the organic marine silt/clay layer underneath.
- This finding allows for the possibility, though not conclusively, that the fuel may have contributed to a fire on Floor 5.

Observations on Fifth Floor

- Critical columns (79, 80, 81) carrying large loads from about 2,000 ft² of floor area were present on the 5th floor.
- The 5th floor was the only floor with a pressurized fuel line supplying the emergency power generators.
- Two 6,000 gallon fuel tanks supplying a pressurized line possibly contributed to fires; tanks were found to be damaged by debris and empty several months after collapse.
- In a 1997 facility condition survey, fireproofing was observed to be prominently missing on 5th floor framing above main lobby; possible repair not confirmed.
- A majority of the 5th floor was not protected by sprinkler systems, with the exception of mechanical space to east and office area to north side of building; no evidence of sprinklers in enclosures on 5th floor (also on floors 7, 8, and 9) which housed OEM generators and day tanks. Seventh floor generator room may have been sprinklered, conflicting data.
- Two of the three sprinkler risers which were located next to stairs (#1 and #2) on the west side of the building transferred towards center on the 5th floor along with stairs.
- Sprinkler systems on floors 1 through 20 were supplied directly from the city distribution system through an automatic pump located on the 1st floor; water supply could be interrupted by loss of power to fire pump or significant damage to underground city main in vicinity of building.

Web site <http://wtc.nist.gov>

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Regular mail:

**WTC Technical Information Repository, Stop 8610,
100 Bureau Drive, Gaithersburg, MD 20899-8610.**

Background Slides

Visual Observations for WTC 7

- ❑ *The first exterior sign of structural failure in WTC 7 was the sinking of the east penthouse roof structure into the building.*
- ❑ *Witnesses reported structural damage to WTC 7 on its south face and southwest corner from WTC 1 debris.*

