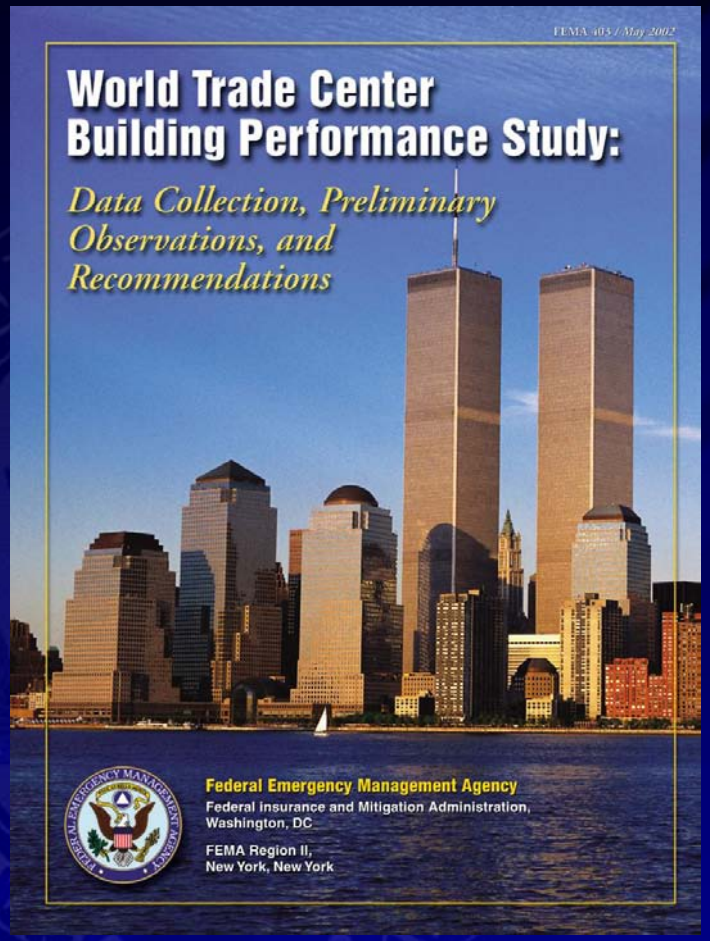
Part 1
World Trade Center Building Performance Study

Data Collection, Preliminary Observations, and Recommendations

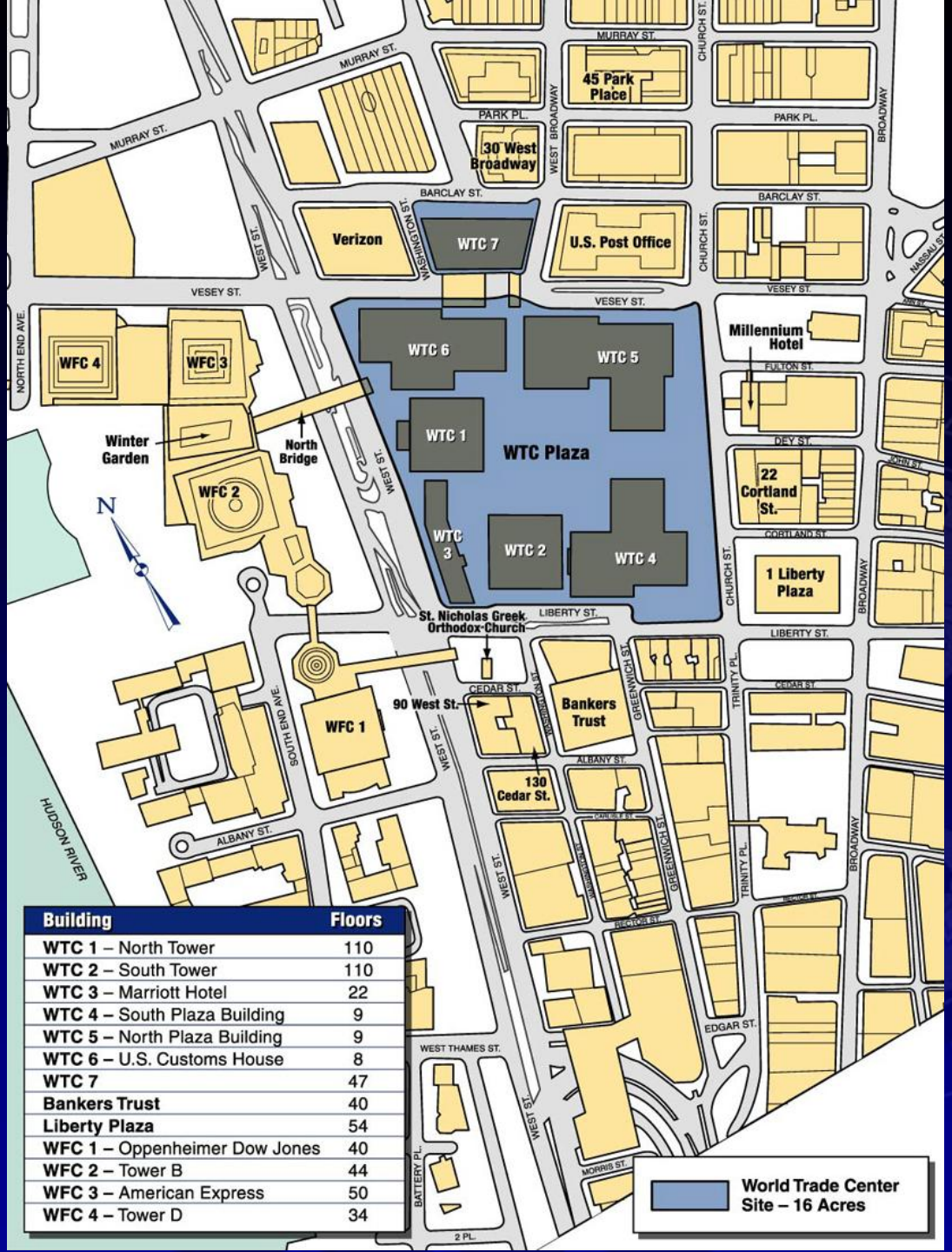


Federal Emergency Management Agency
Federal Insurance and Mitigation Administration
Washington, D.C.

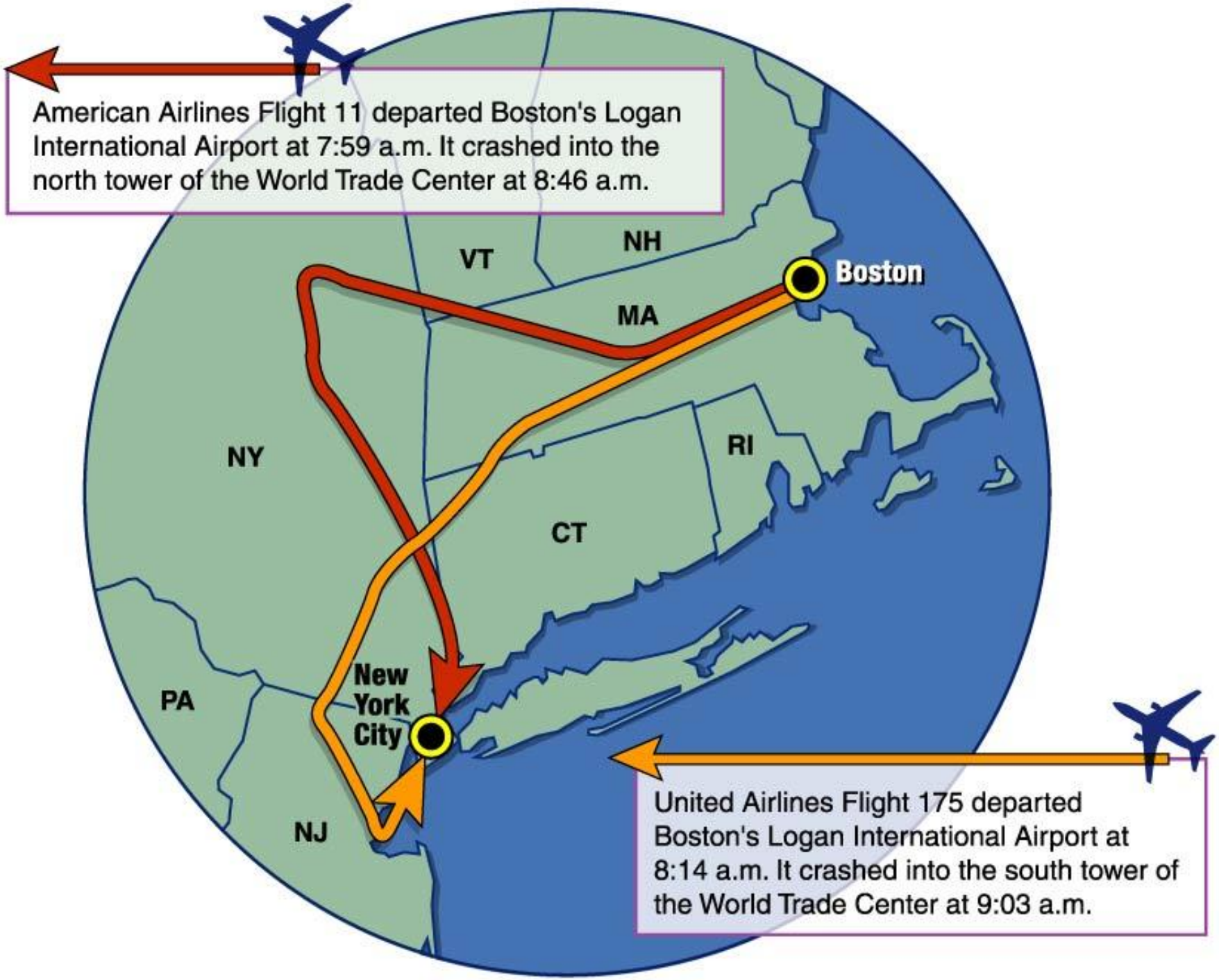
FEMA Region II
New York, New York

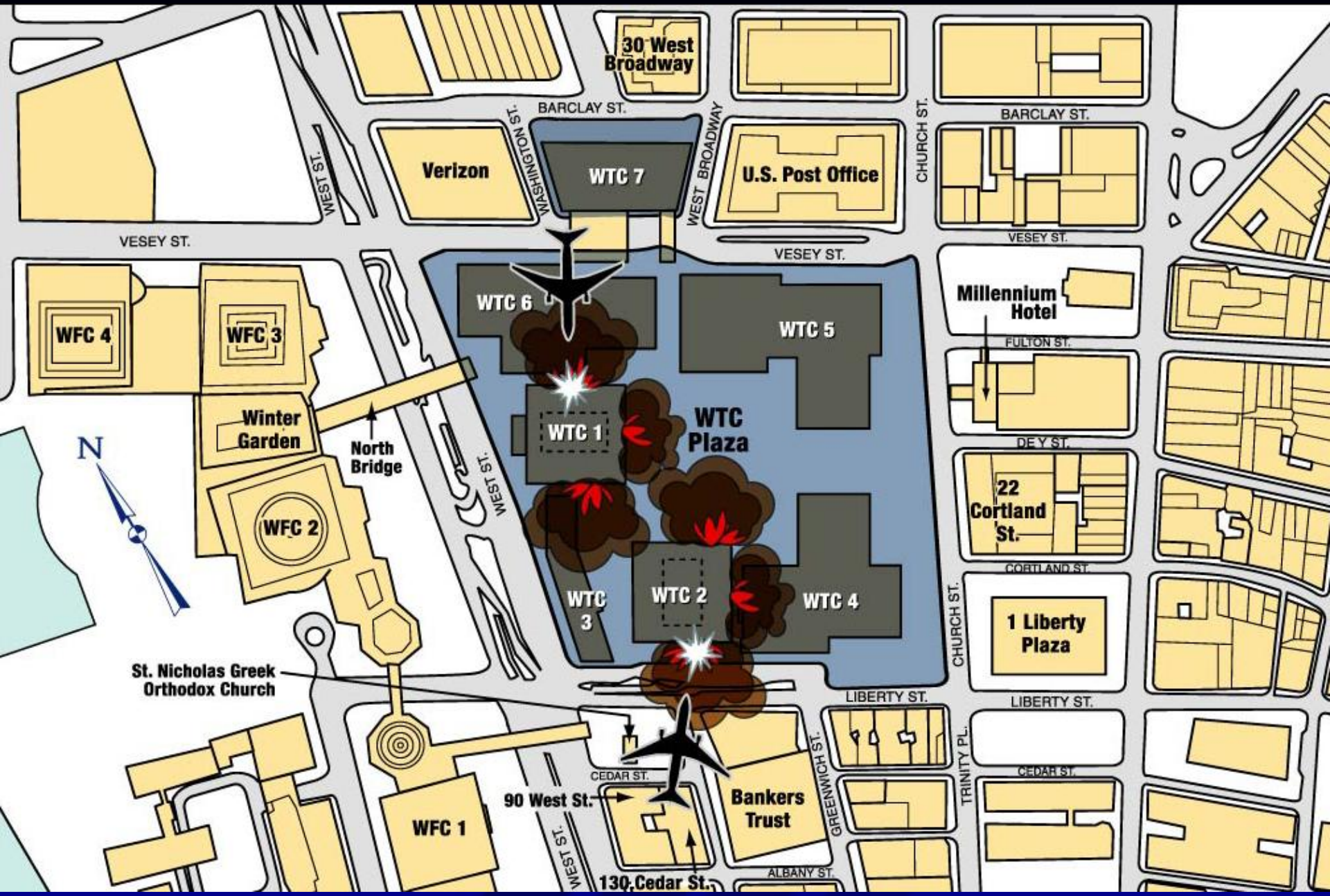
Purpose of the Study

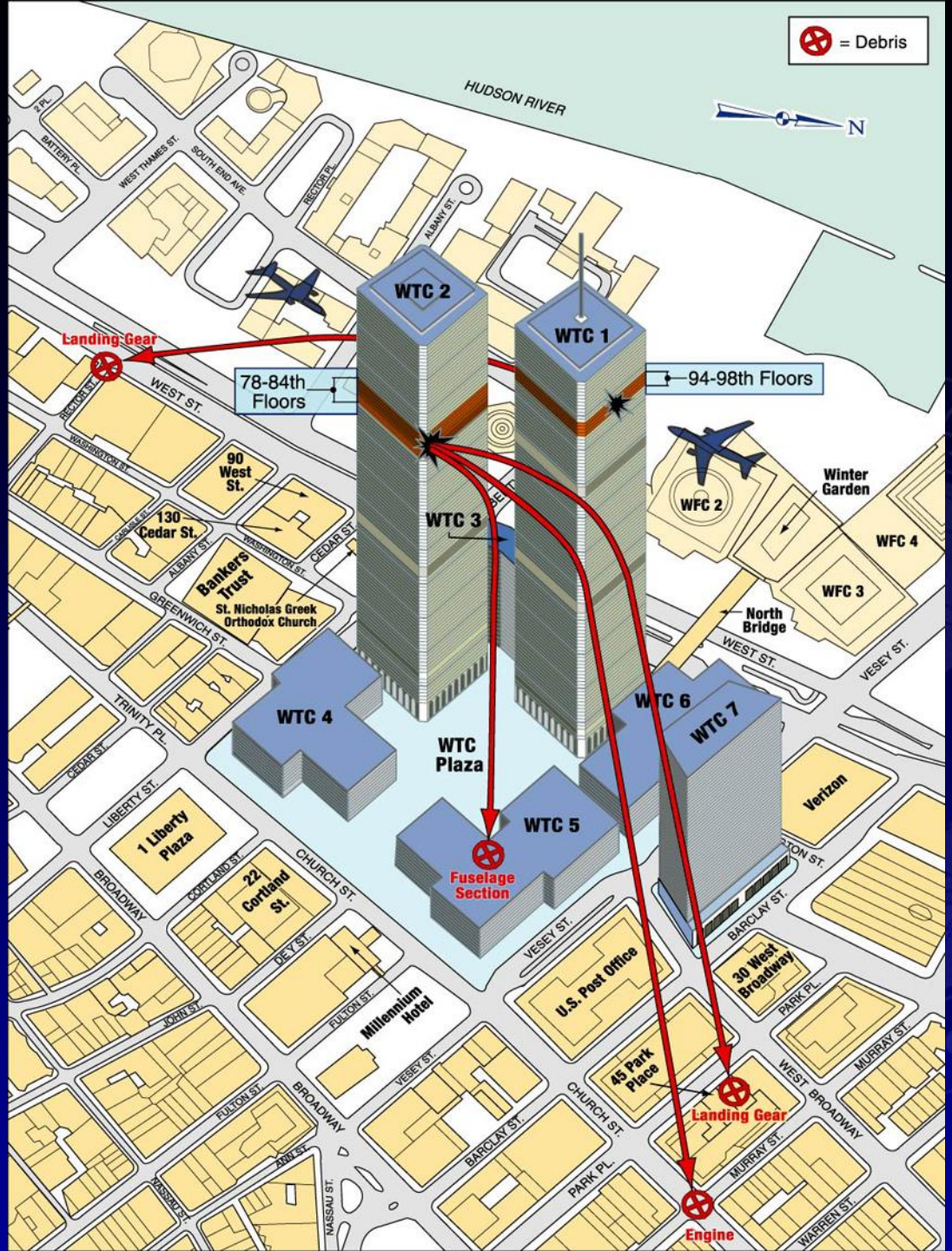
- Examine the damage caused by these events, including the immediate effects of the aircraft impacts on each tower, the spread of fires following the crashes, the fire-induced reduction of structural strength, and the mechanism that led to the collapse of each tower
- Identify additional studies that should be performed
- Collect data
- Develop an understanding of the response of each affected building
- Determine the effects of damage to buildings in the immediate vicinity of the towers from falling debris and fires
- Identify the causes of observed behavior
- Identify additional studies that should be performed

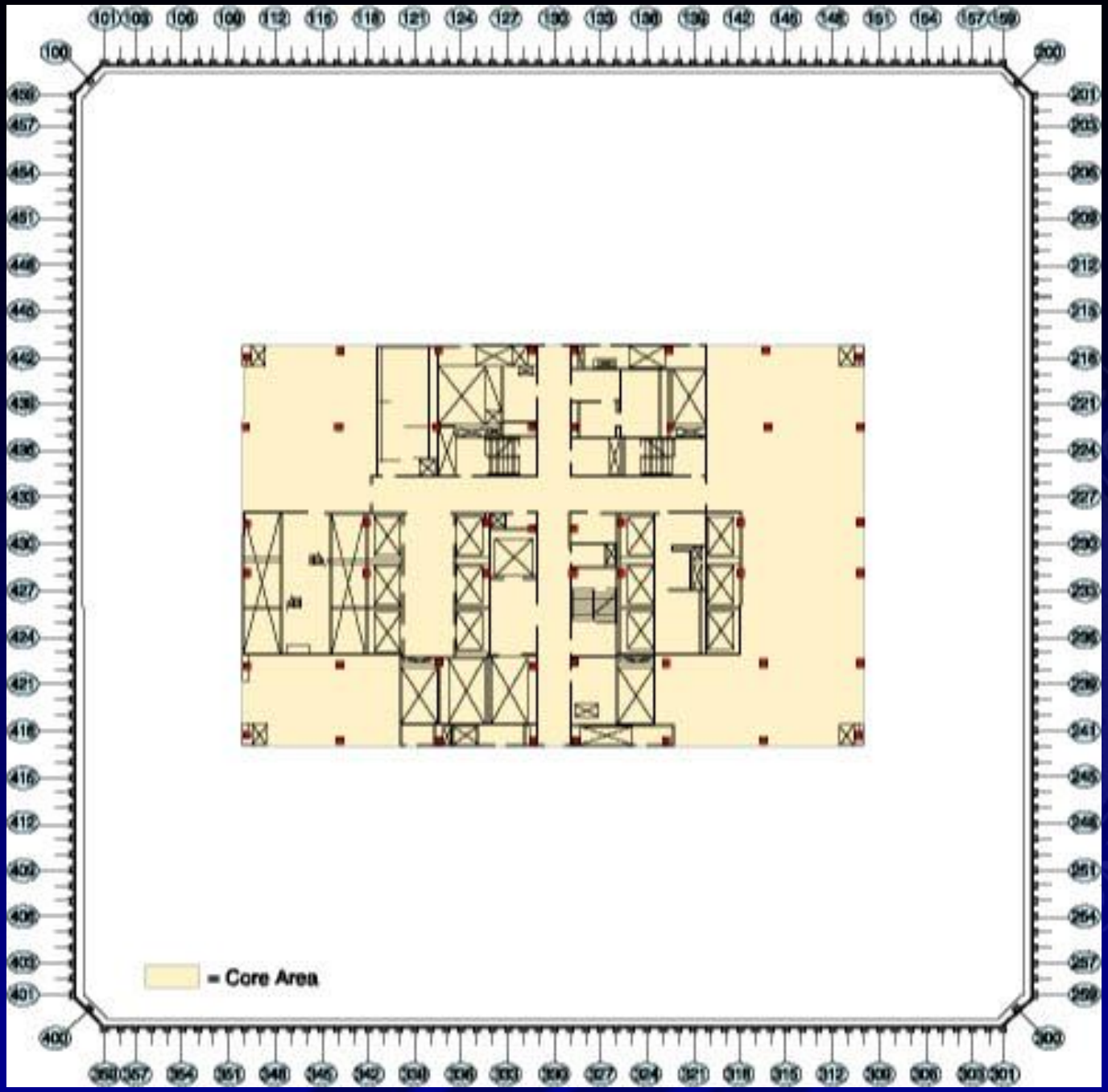


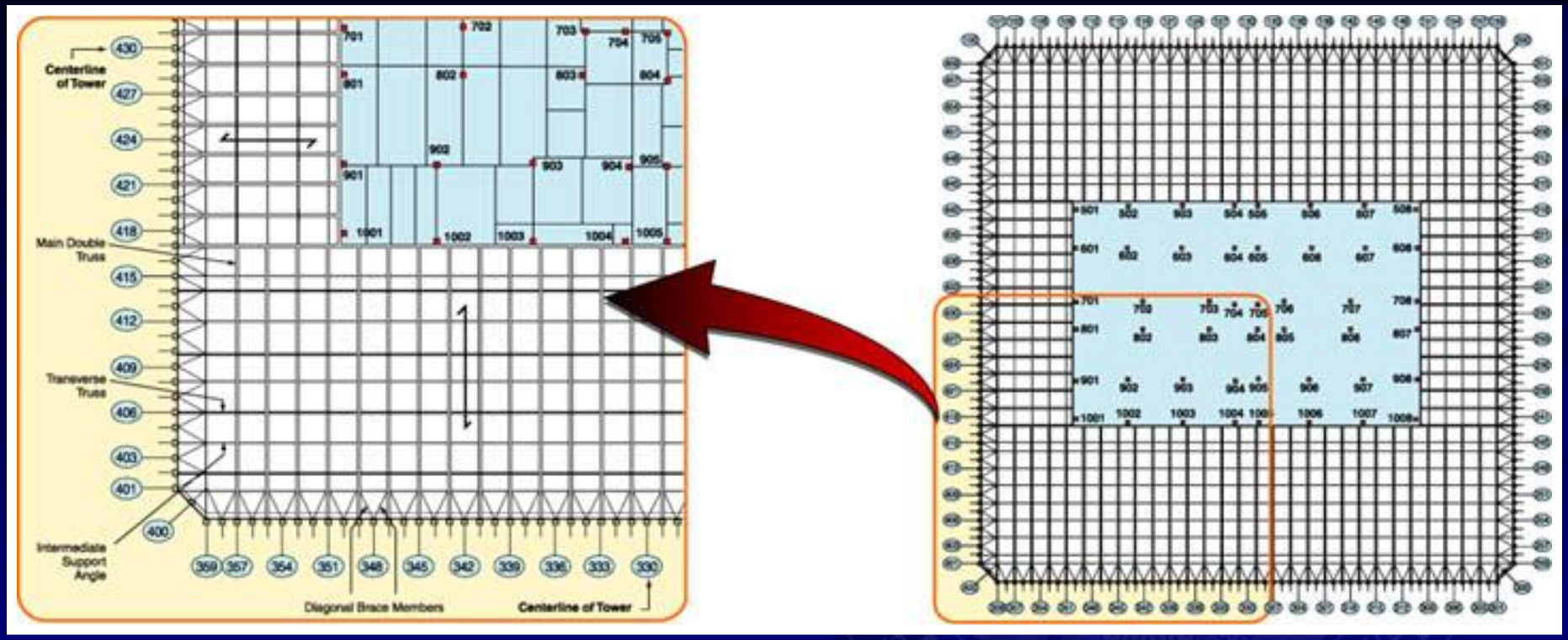
Building	Floors
WTC 1 – North Tower	110
WTC 2 – South Tower	110
WTC 3 – Marriott Hotel	22
WTC 4 – South Plaza Building	9
WTC 5 – North Plaza Building	9
WTC 6 – U.S. Customs House	8
WTC 7	47
Bankers Trust	40
Liberty Plaza	54
WFC 1 – Oppenheimer Dow Jones	40
WFC 2 – Tower B	44
WFC 3 – American Express	50
WFC 4 – Tower D	34

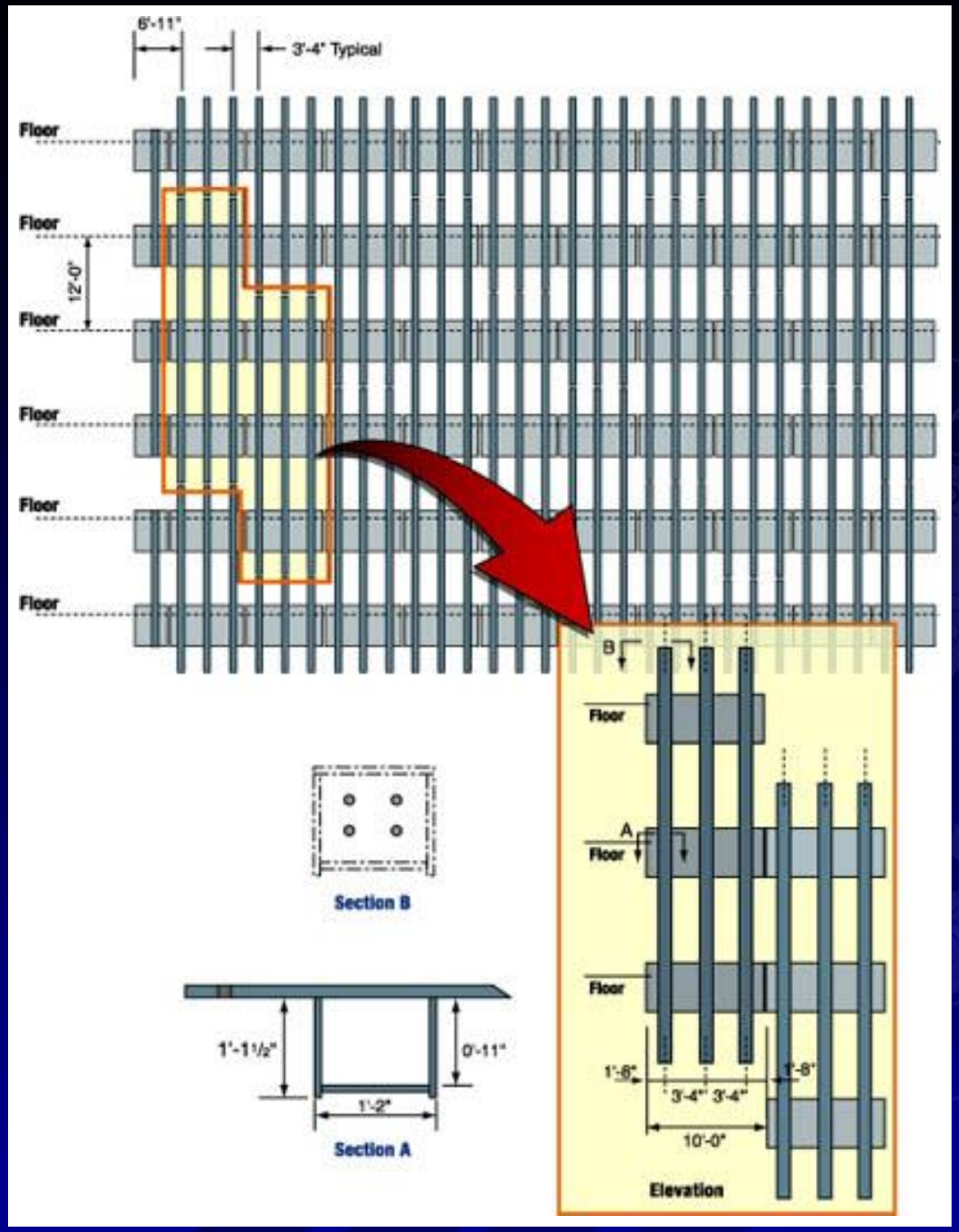

American Airlines Flight 11 departed Boston's Logan International Airport at 7:59 a.m. It crashed into the north tower of the World Trade Center at 8:46 a.m.
VT
NH
Boston
MA
NY
RI
CT
New York City
PA
NJ
United Airlines Flight 175 departed Boston's Logan International Airport at 8:14 a.m. It crashed into the south tower of the World Trade Center at 9:03 a.m.

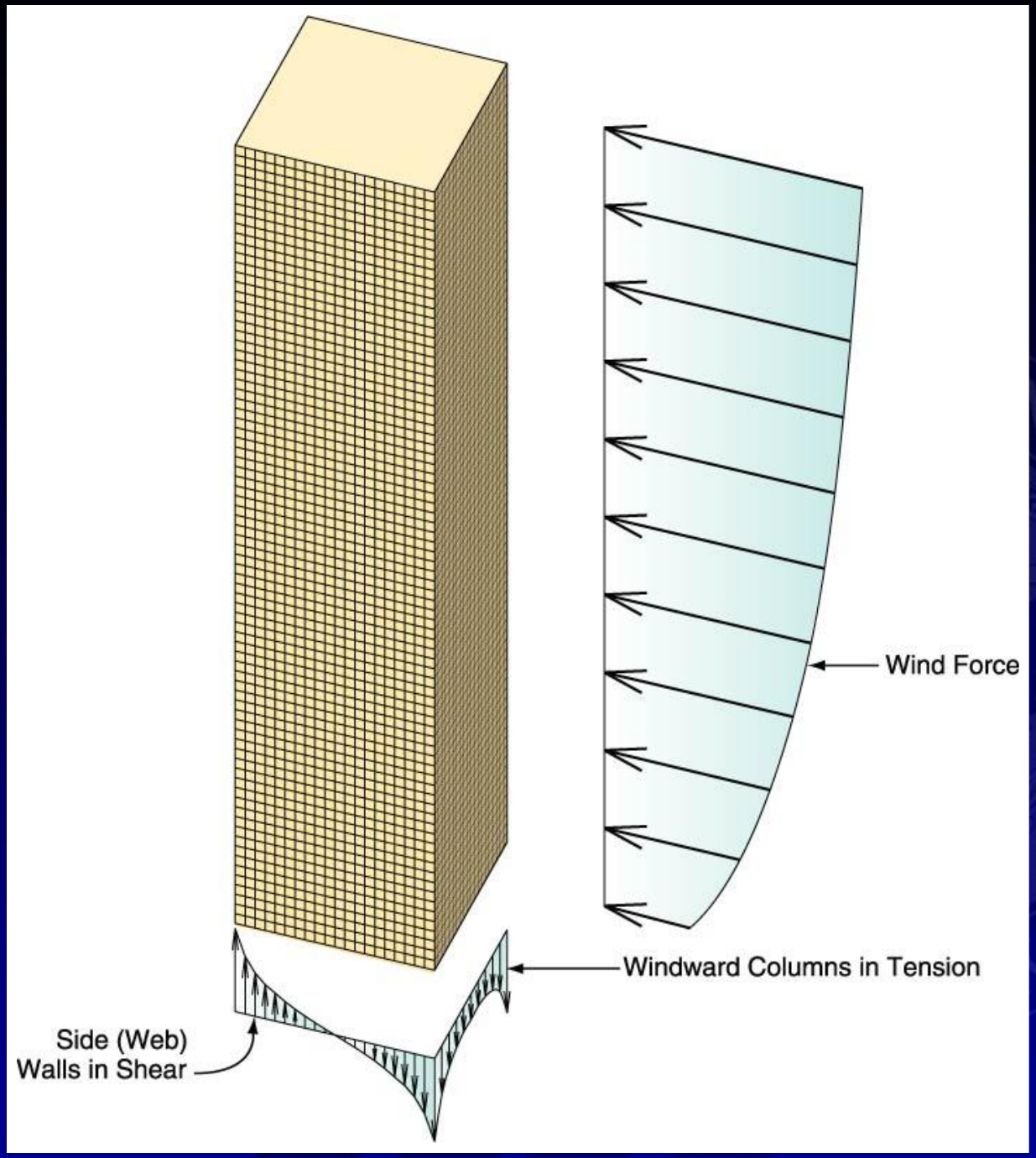

30 West Broadway
BARCLAY ST.
WASHINGTON ST.
WEST BROADWAY
CHURCH ST.
BARCLAY ST.
Verizon
WTC 7
U.S. Post Office
WEST ST.
VESEY ST.
VESEY ST.
VESEY ST.
WTC 6
WTC 5
Millennium Hotel
FULTON ST.
WFC 4
WFC 3
Winter Garden
North Bridge
WTC 1
WTC Plaza
DEY ST.
N
WEST ST.
22 Cortland St.
WFC 2
CORTLAND ST.
WTC 3
WTC 2
WTC 4
CHURCH ST.
1 Liberty Plaza
St. Nicholas Greek Orthodox Church
LIBERTY ST.
LIBERTY ST.
GREENWICH ST.
TRINITY PL.
CEDAR ST.
CEDAR ST.
90 West St.
Bankers Trust
WFC 1
WEST ST.
ALBANY ST.
130 Cedar St.

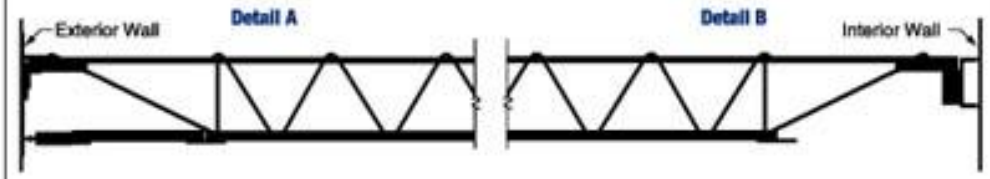

= Debris
HUDSON RIVER
N
WTC 2
WTC 1
Landing Gear
78-84th Floors
94-98th Floors
WEST ST.
90 West St.
130 Cedar St.
Bankers Trust
St. Nicholas Greek Orthodox Church
WTC 3
WFC 2
Winter Garden
WFC 4
WFC 3
North Bridge
WEST ST.
VESEY ST.
WTC 4
WTC 6
WTC 7
WTC Plaza
WTC 5
Verizon
Fuselage Section
1 Liberty Plaza
22 Cortland St.
CHURCH ST.
BROADWAY
U.S. Post Office
30 West Broadway
Millennium Hotel
45 Park Place
Landing Gear
Engine
WEST BROADWAY
MURRAY ST.
PARK PL.
BARCLAY ST.
CHURCH ST.
VESEY ST.
FULTON ST.
BROADWAY
NASSAU ST.
WARREN ST.
BATTERY PL.
WEST THAMES ST.
SOUTH END AVE.
RECTOR PL.
ALBANY ST.
WASHINGTON ST.
CEDAR ST.
GREENWICH ST.
TRINITY PL.
LIBERTY ST.
CORTLAND ST.
DEY ST.
JOHN ST.
ANN ST.


= Core Area

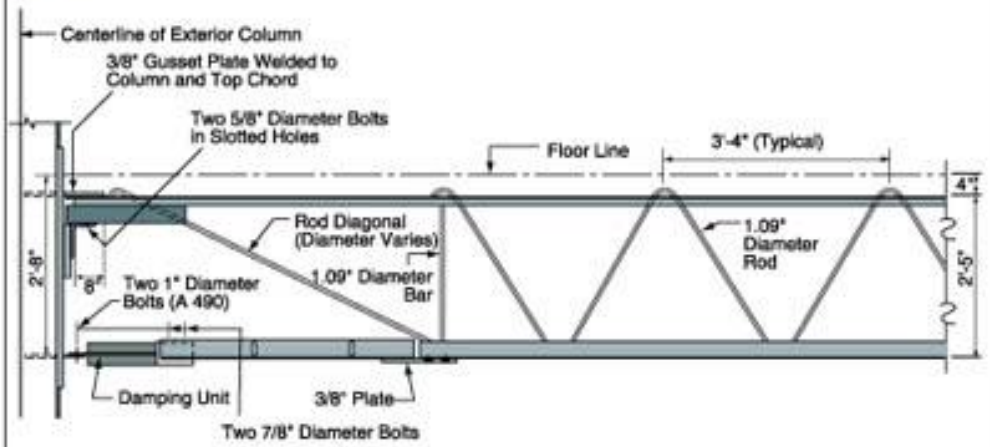

Centerline of Tower
Main Double Truss
Transverse Truss
Intermediate Support Angle
Diagonal Brace Members
Centerline of Tower


6'-11"
3'-4" Typical
Floor
Floor
12'-0"
Floor
Floor
Floor
Floor
B
Floor
A
Floor
Floor
Section B
1'-1½"
0'-11"
1'-2"
Section A
1'-8"
3'-4"
3'-4"
1'-8"
10'-0"
Elevation

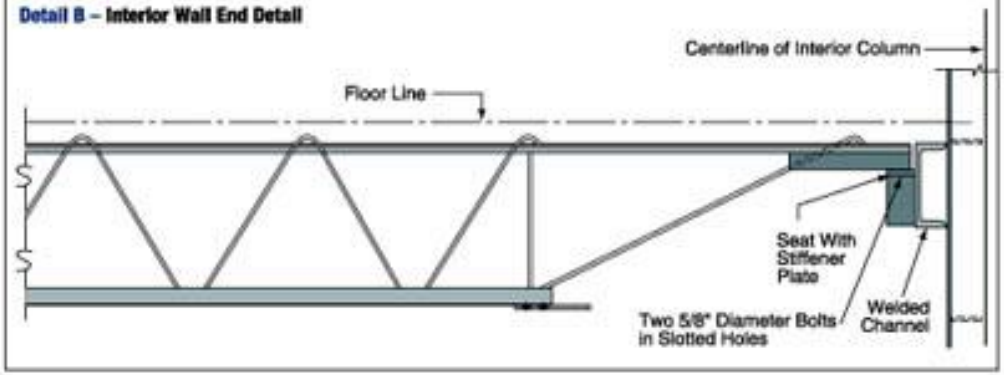

Wind Force
Windward Columns in Tension
Side (Web)
Walls in Shear

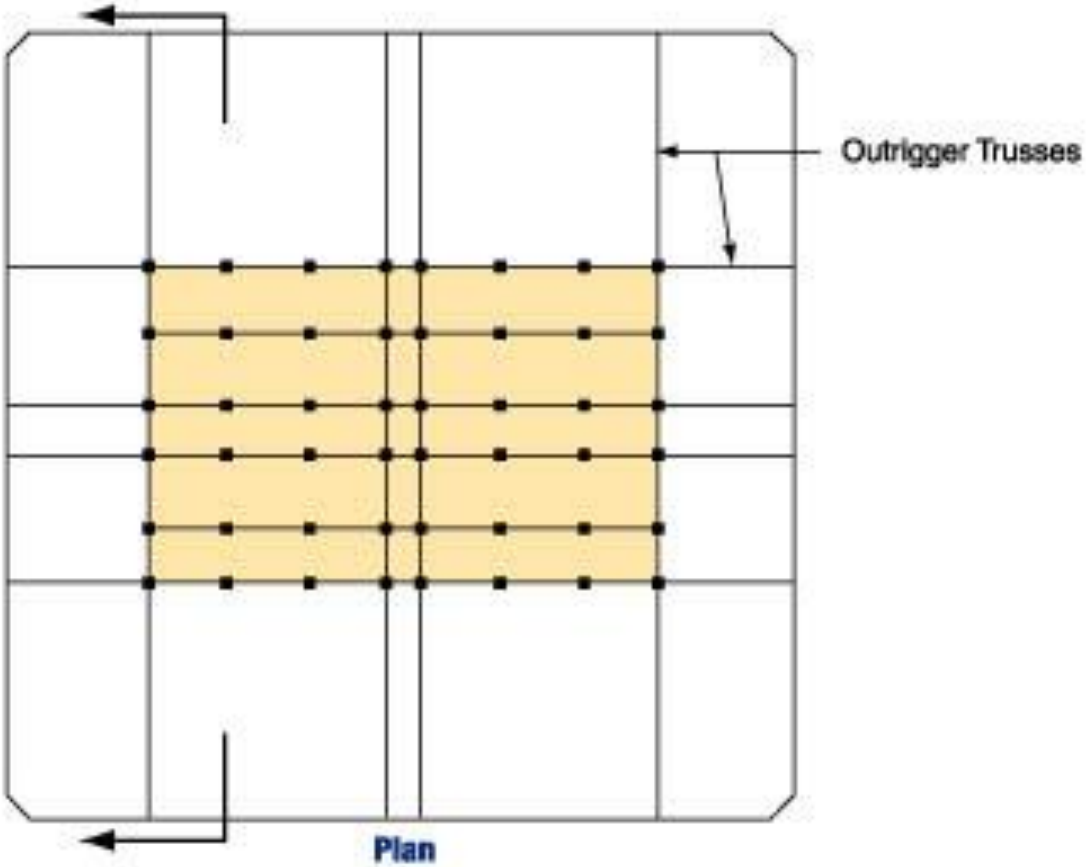


Detail A – Exterior Wall End Detail

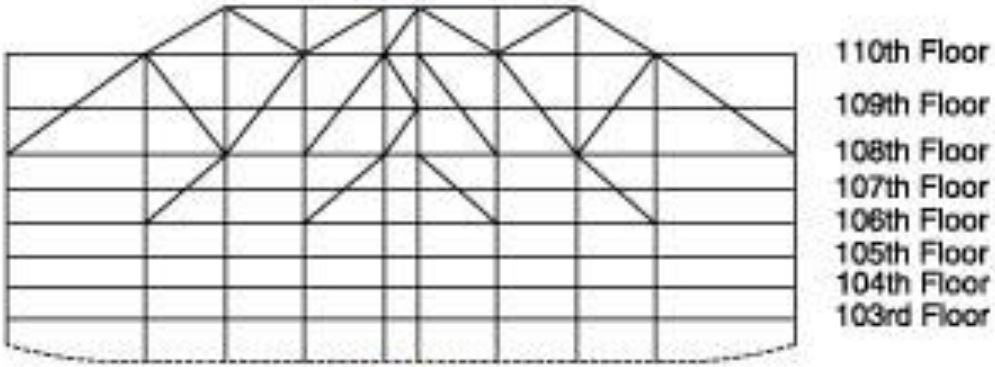


Detail B – Interior Wall End Detail

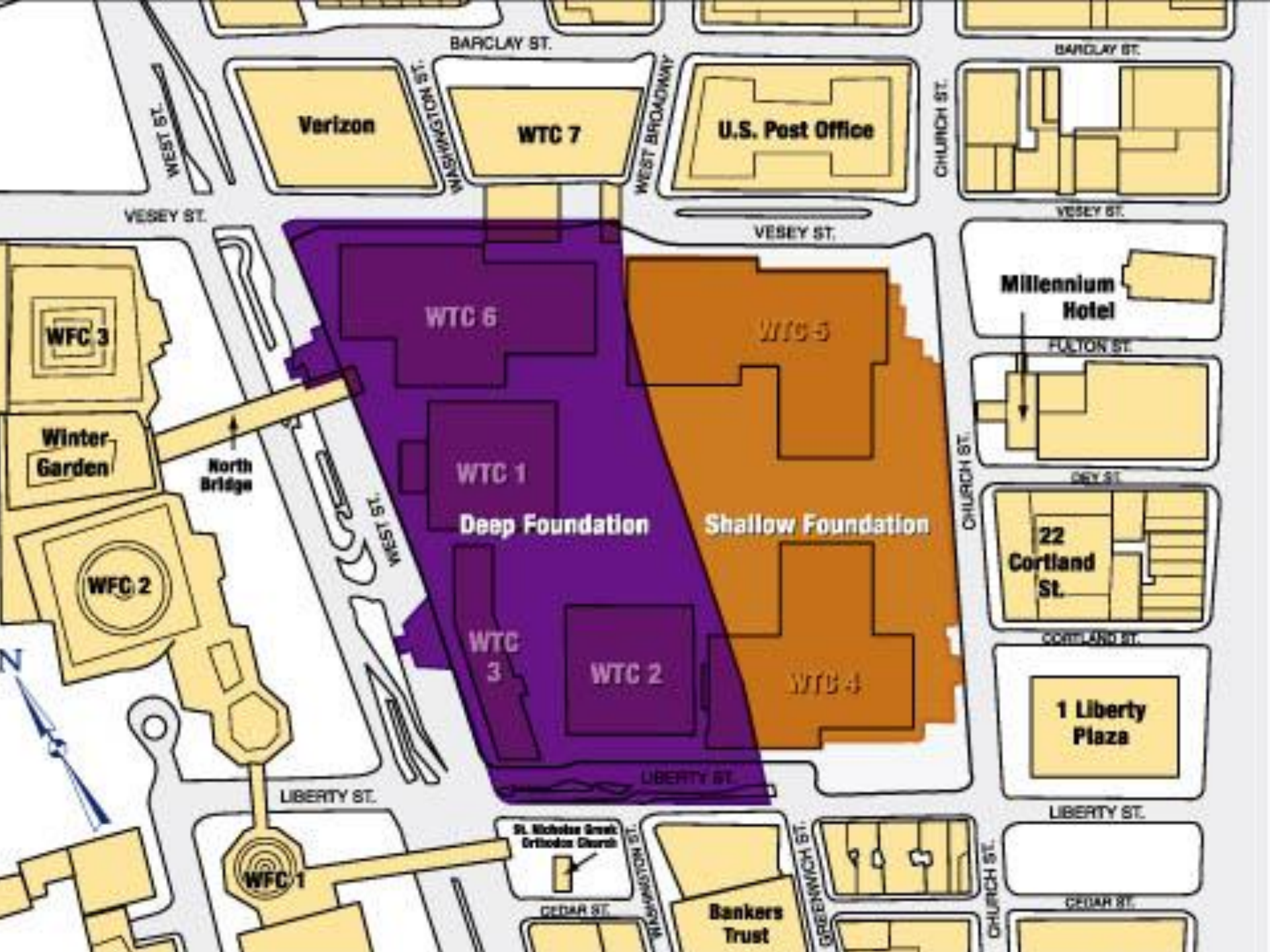


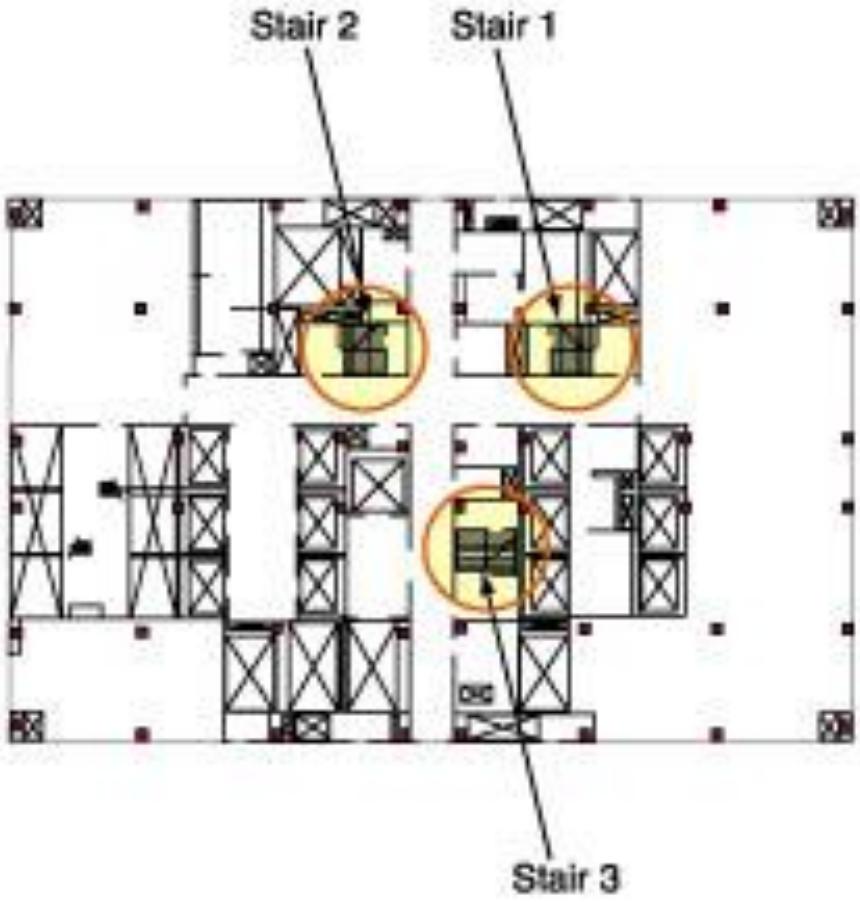


Plan



Section


BARCLAY ST.
BARCLAY ST.
WEST ST.
Verizon
WASHINGTON ST.
WTC 7
WEST BROADWAY
U.S. Post Office
CHURCH ST.
VESEY ST.
VESEY ST.
VESEY ST.
WTC 6
WTC 5
Millennium Hotel
FULTON ST.
WFC 3
Winter Garden
North Bridge
WTC 1
Deep Foundation
Shallow Foundation
WEST ST.
CHURCH ST.
DEY ST.
22 Cortland St.
WFC 2
WTC 3
WTC 2
WTC 4
N
1 Liberty Plaza
LIBERTY ST.
LIBERTY ST.
LIBERTY ST.
St. Nicholas Greek Orthodox Church
WFC 1
WASHINGTON ST.
GREENWICH ST.
CHURCH ST.
CEDAR ST.
CEDAR ST.
Bankers Trust


Stair 2
Stair 1
Stair 3

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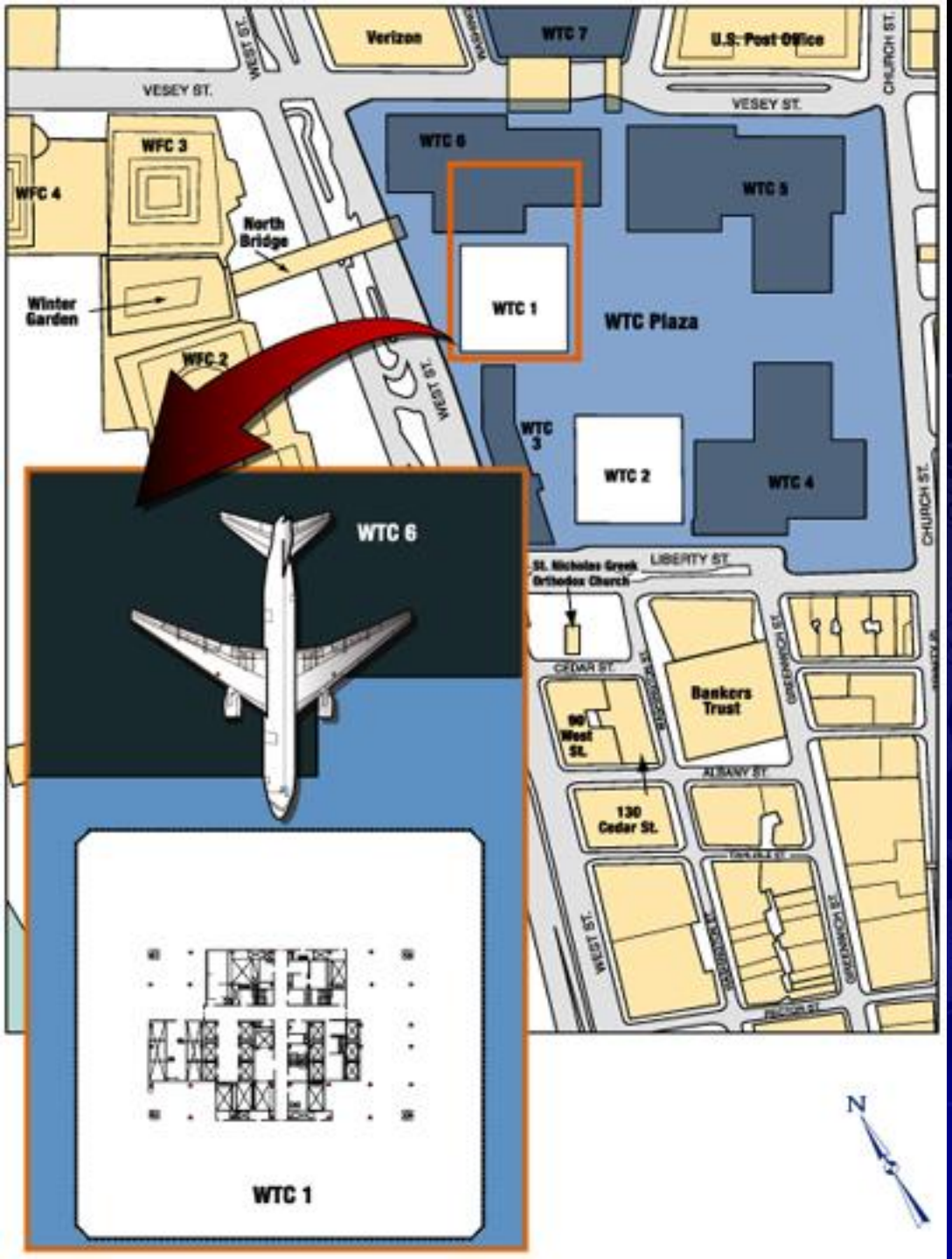
Verizon
WTC 7
U.S. Post Office
VESEY ST.
WEST ST.
CHURCH ST.
WFC 3
WFC 4
WFC 2
North Bridge
Winter Garden
WTC 6
WTC 5
WTC 1
WTC Plaza
WTC 3
WTC 2
WTC 4
WTC 6
WTC 1
St. Nicholas Greek Orthodox Church
LIBERTY ST.
CEDAR ST.
Bankers Trust
90 West St.
130 Cedar St.
ALBANY ST.
GREENWICH ST.
N

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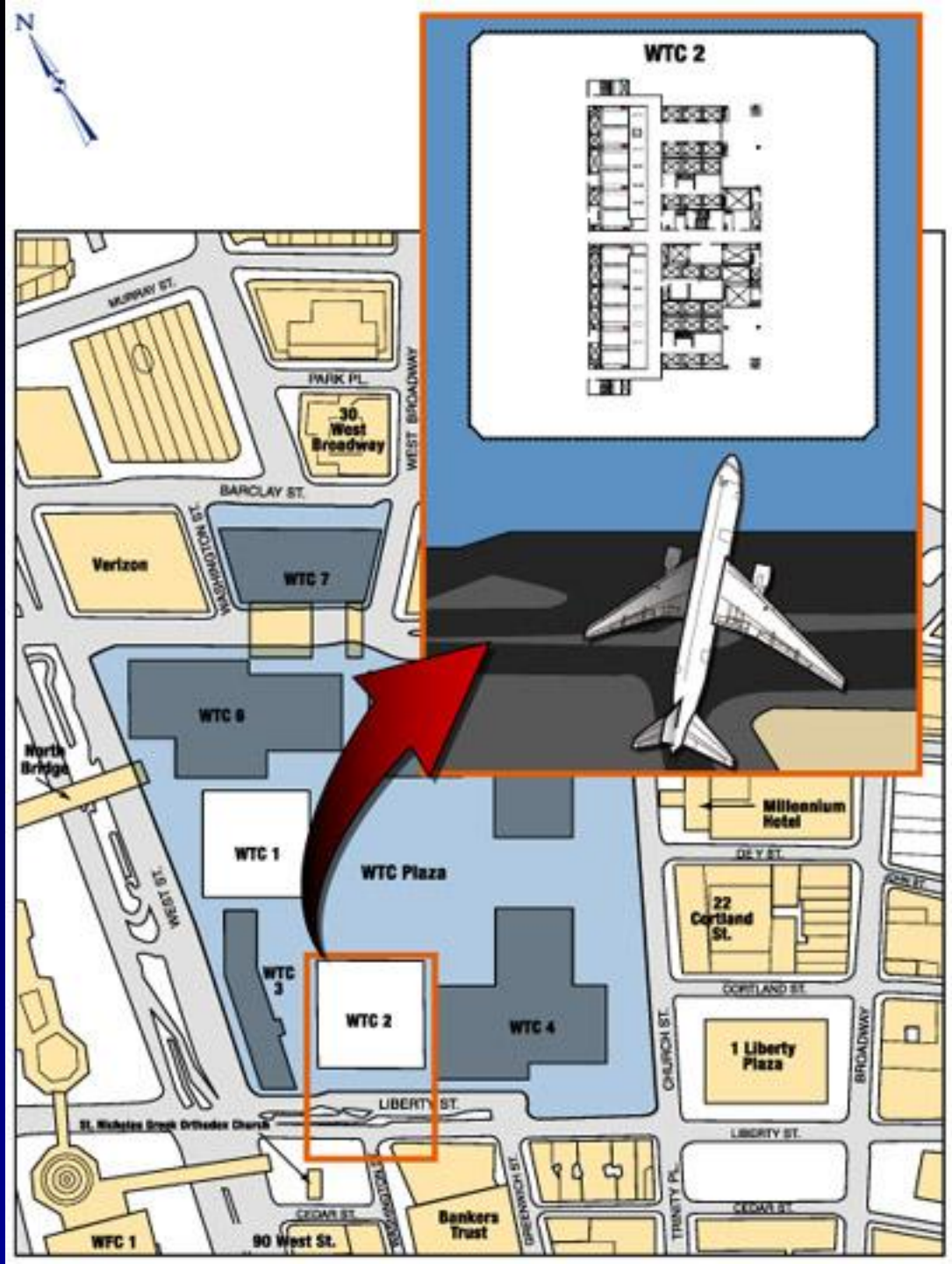
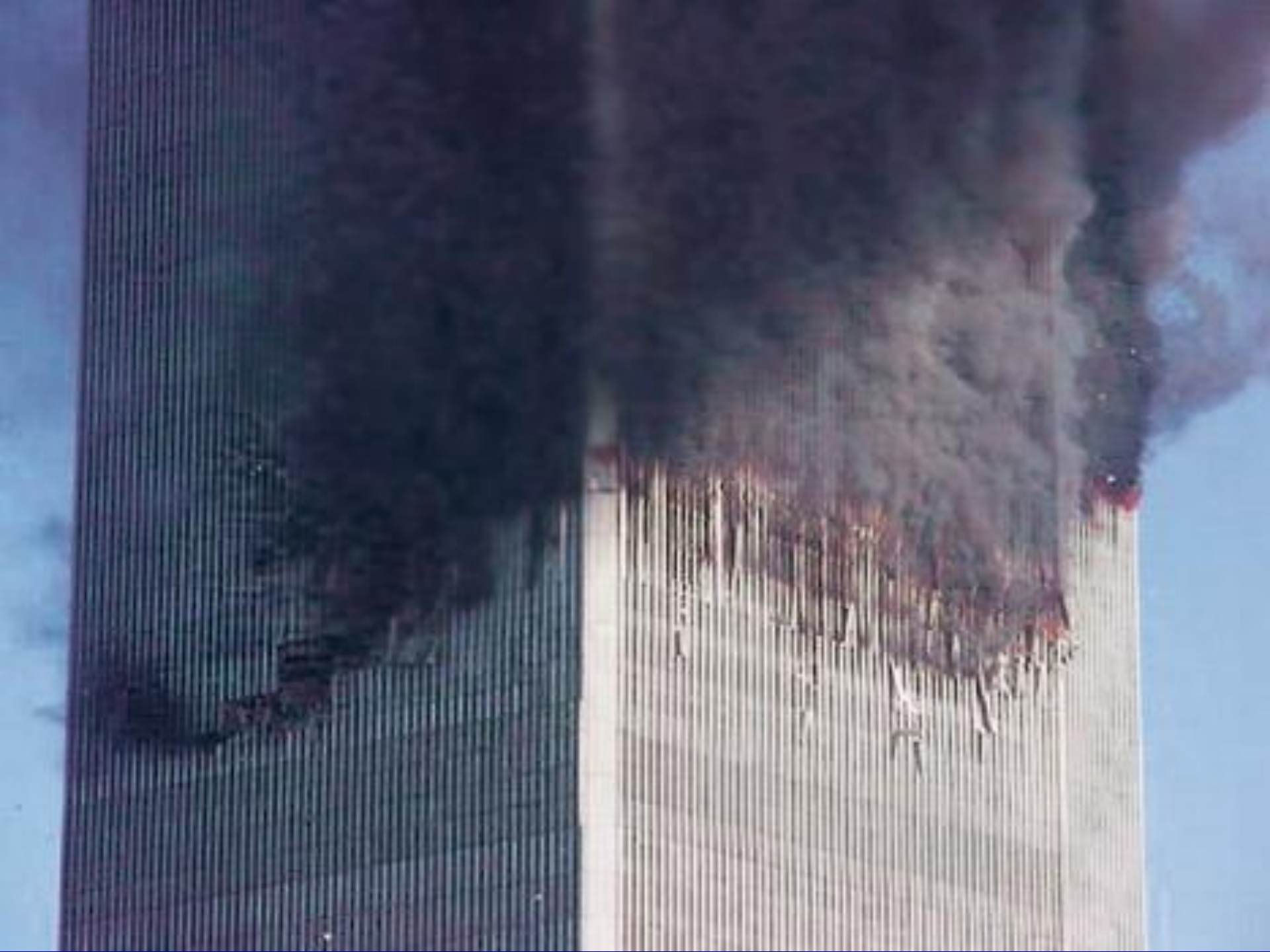
GENERAL NOTES: (1) Column damage captured from photographs and enhanced videos. (2) Damage to column lines 111-115 at level 98 is estimated.


N
WTC 2
MURRAY ST.
PARK PL.
30 West Broadway
WEST BROADWAY
BARCLAY ST.
WASHINGTON ST.
Verizon
WTC 7
WTC 6
North Bridge
WEST ST.
WTC 1
WTC Plaza
WTC 3
WTC 2
WTC 4
Millennium Hotel
DEY ST.
22 Cortland St.
CORTLAND ST.
CHURCH ST.
1 Liberty Plaza
BROADWAY
LIBERTY ST.
St. Nicholas Greek Orthodox Church
LIBERTY ST.
TRINITY PL.
CEDAR ST.
CEDAR ST.
GREENWICH ST.
Bankers Trust
WFC 1
90 West St.



GENERAL NOTES: (1) Column damage captured from photographs and enhanced videos. (2) Damage to column lines 413-418 at levels 81 and 82 is estimated. (3) There is not sufficient information to detail damage to column lines 408-411 at levels 83-84.

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N
45 Park Place
PARK PL.
30 West Broadway
Cladding
Cladding
BARCLAY ST.
BARCLAY ST.
WASHINGTON ST.
WEST BROADWAY
CHURCH ST.
WEST ST.
Exterior Columns
Verizon
WTC 7
U.S. Post Office
VESEY ST.
Exterior Columns
VESEY ST.
VESEY ST.
WTC 6
WTC 5
Millennium Hotel
FULTON ST.
WFC 4
WFC 3
North Bridge
Winter Garden
Exterior Columns
WTC 1
WTC Plaza
DEY ST.
22 Cortland St.
WFC 2
WEST ST.
CORTLAND ST.
WTC 3
WTC 2
WTC 4
CHURCH ST.
1 Liberty Plaza
St. Nicholas Greek Orthodox Church
LIBERTY ST.
LIBERTY ST.
LIBERTY ST.
Exterior Columns
CEDAR ST.
CEDAR ST.
90 West St.
Bankers Trust
GREENWICH ST.
TRINITY PL.
WFC 1
WEST ST.
SOUTH END AVE.
ALBANY ST.
WASHINGTON ST.
ALBANY ST.
130 Cedar St.
CARLISLE ST.
HUDSON RIVER

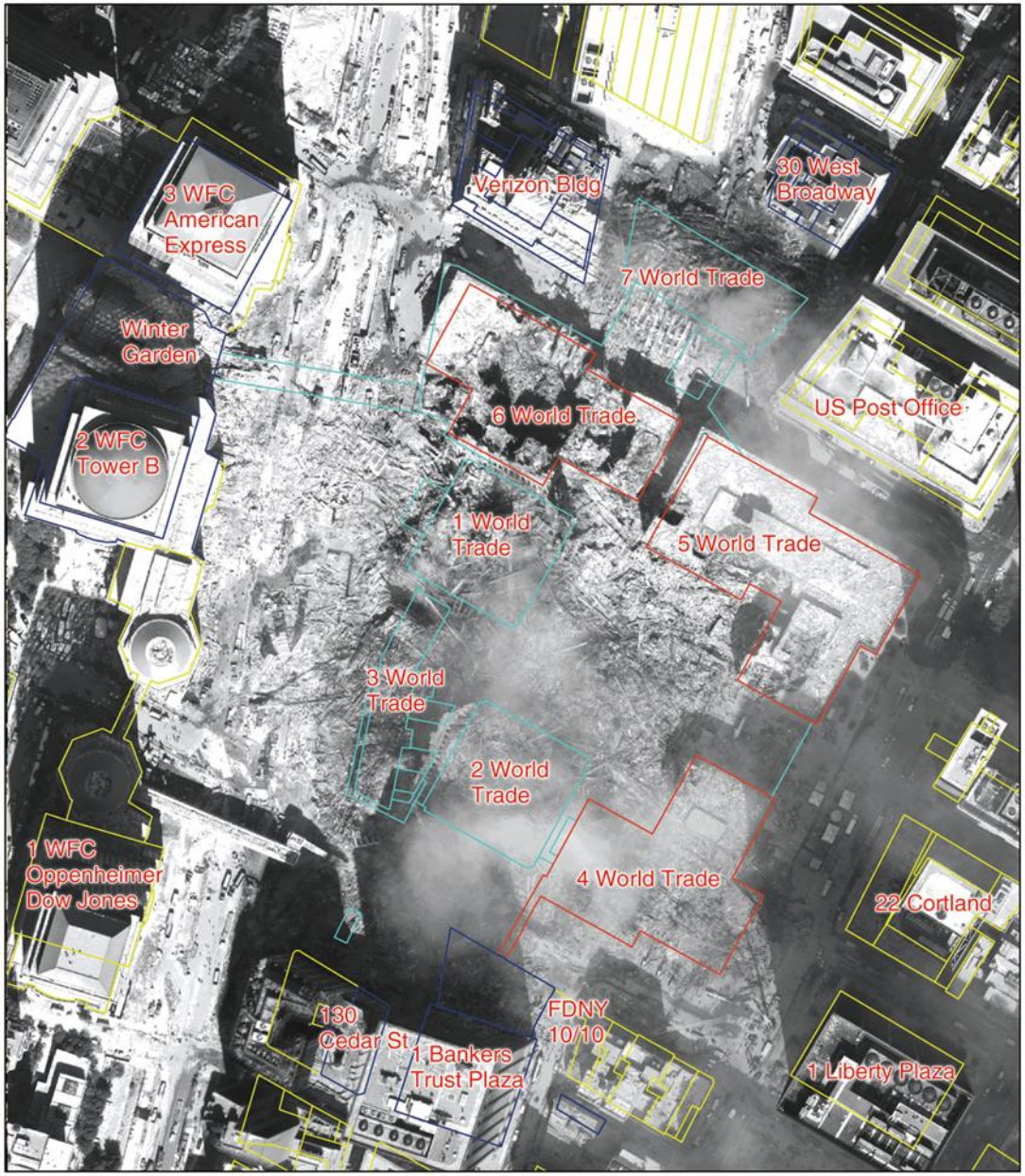


Image Date September 17, 2001

- Damaged But Stable Repairs/Cleaning Required
- Major Structural Damage No Occupancy
- Partially Collapsed
- Destroyed

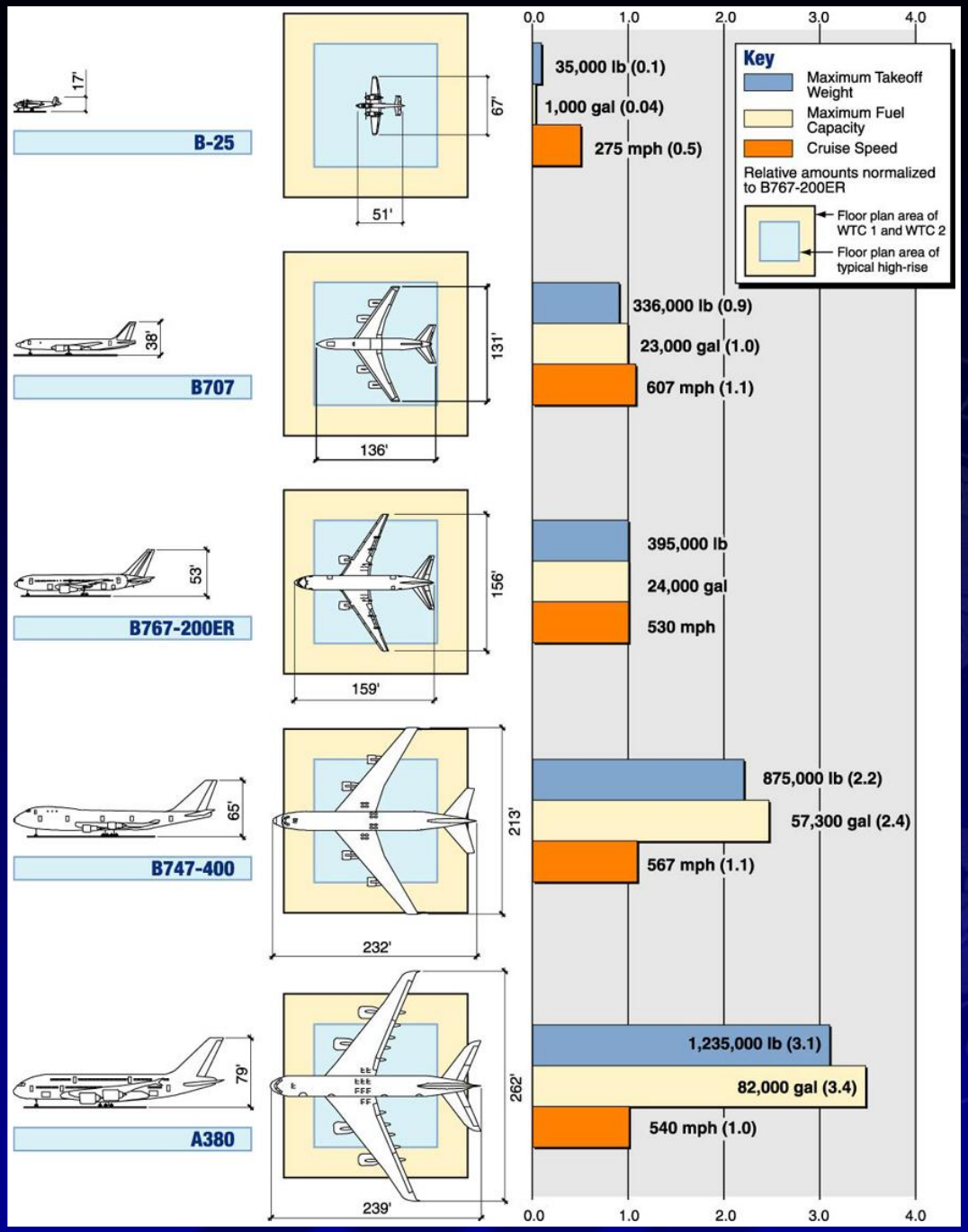
N

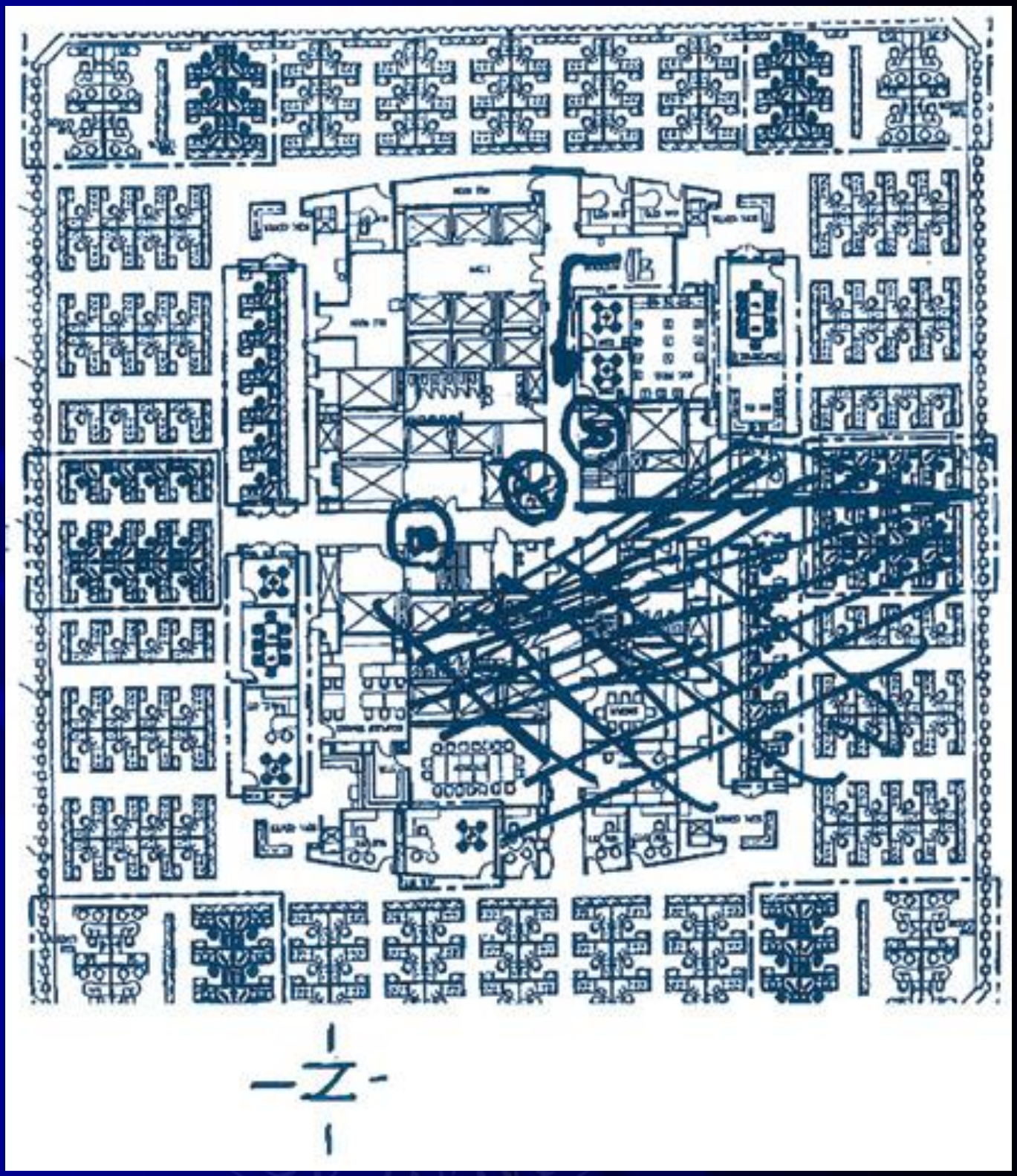
250 0 250 500 750 1000 Feet

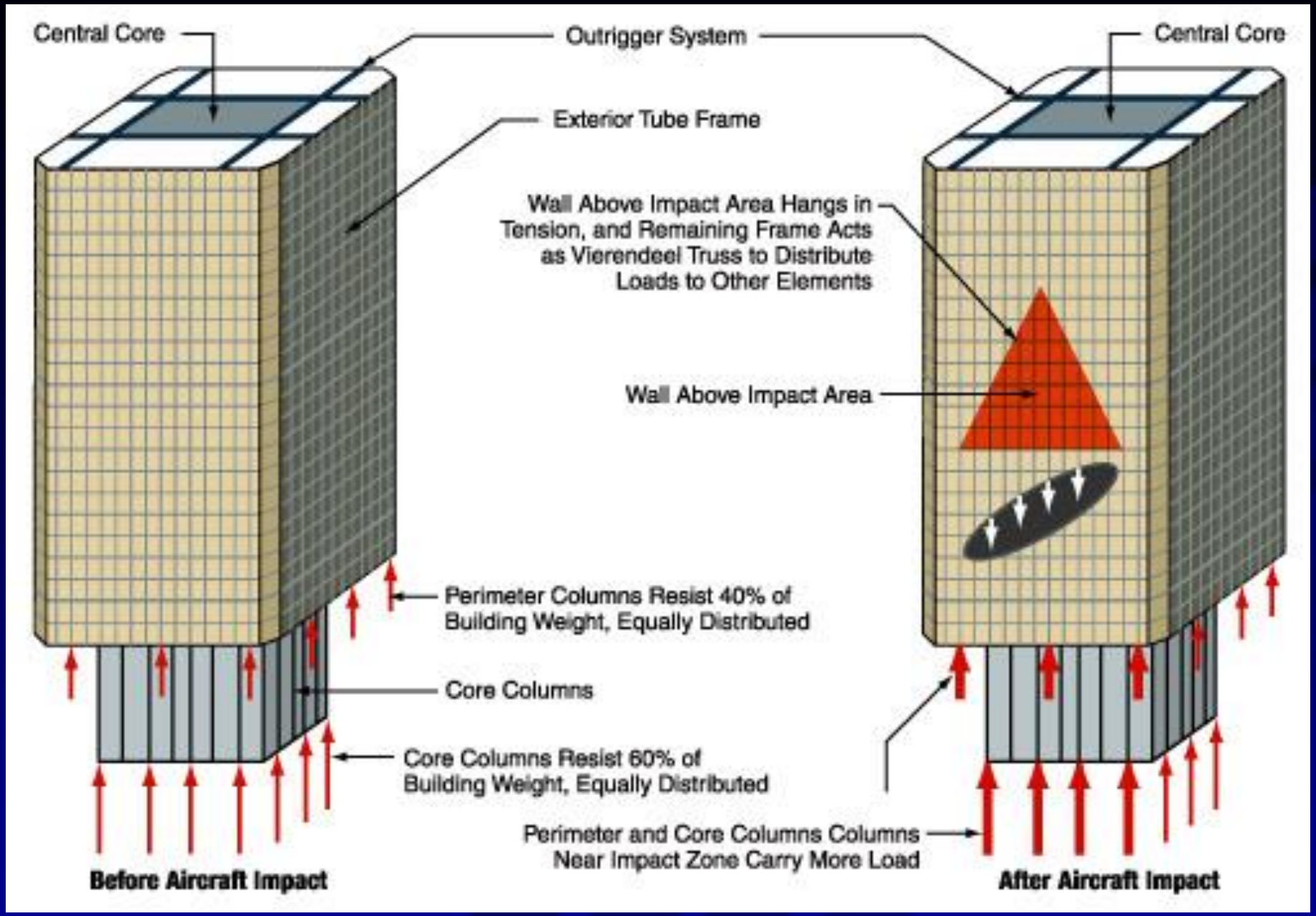
3 WFC
American
Express
Verizon Bldg
30 West
Broadway
7 World Trade
Winter
Garden
6 World Trade
US Post Office
2 WFC
Tower B
1 World
Trade
5 World Trade
3 World
Trade
2 World
Trade
4 World Trade
1 WFC
Oppenheimer
Dow Jones
22 Cortland
130
Cedar
St
FDNY
10/10
1 Bankers
Trust Plaza
1 Liberty Plaza

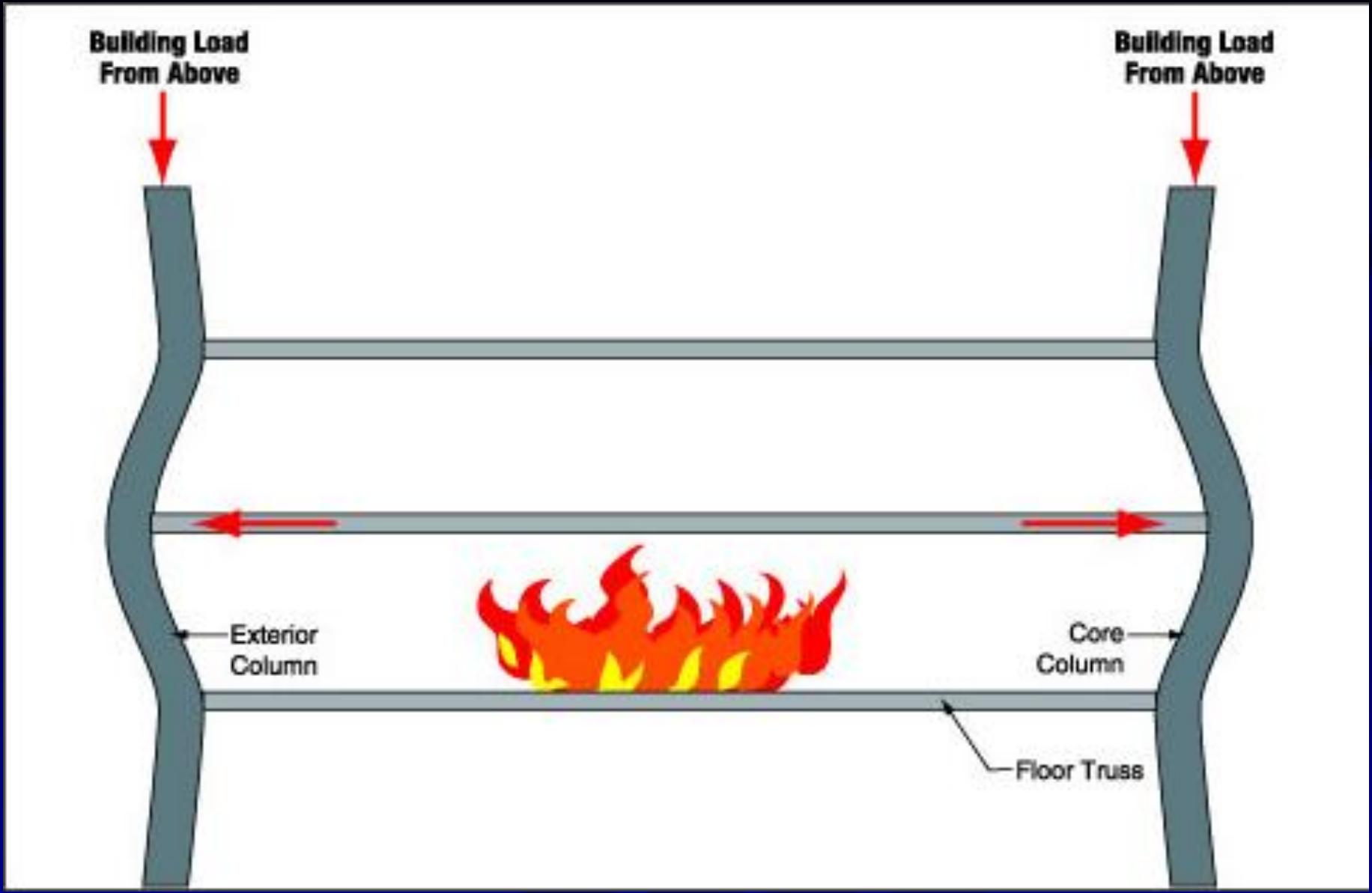
N

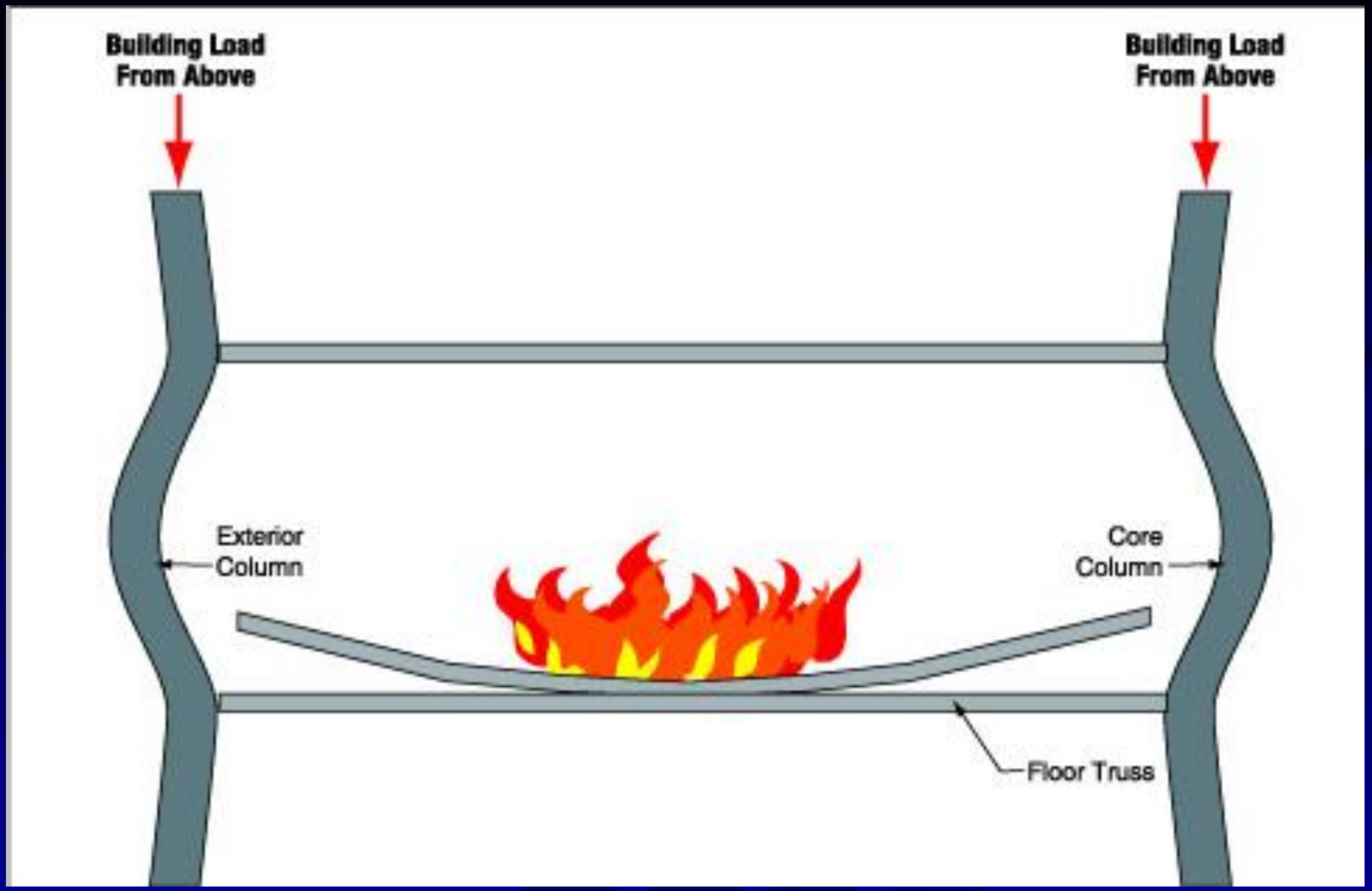
250
0
250
500
750
1000 Feet

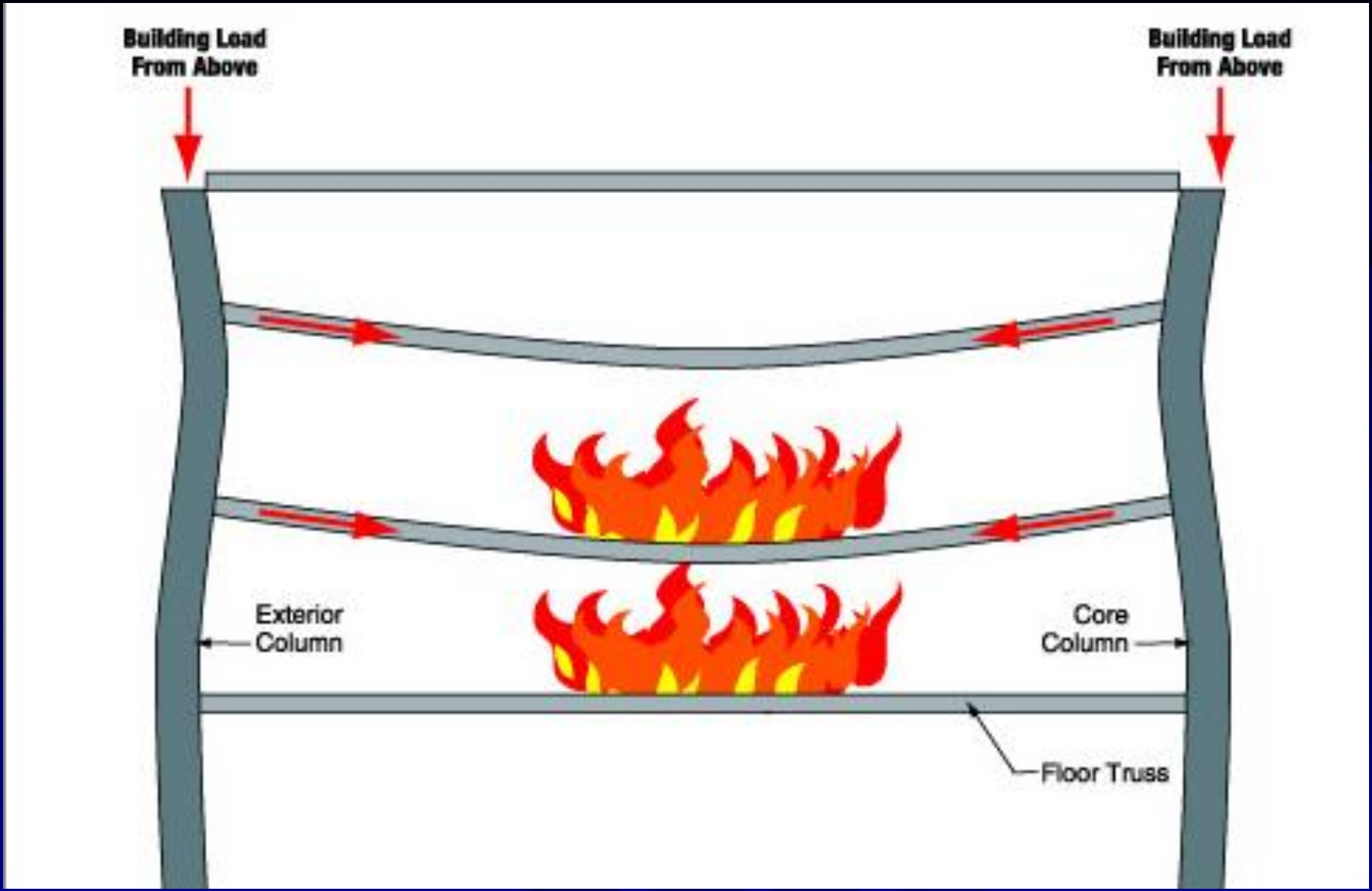

0.0
1.0
2.0
3.0
4.0
Key
Maximum Takeoff Weight
Maximum Fuel Capacity
Cruise Speed
Relative amounts normalized to B767-200ER
Floor plan area of WTC 1 and WTC 2
Floor plan area of typical high-rise
B-25
17'
67'
51'
35,000 lb (0.1)
1,000 gal (0.04)
275 mph (0.5)
B707
38'
131'
136'
336,000 lb (0.9)
23,000 gal (1.0)
607 mph (1.1)
B767-200ER
53'
156'
159'
395,000 lb
24,000 gal
530 mph
B747-400
65'
213'
232'
875,000 lb (2.2)
57,300 gal (2.4)
567 mph (1.1)
A380
79'
262'
239'
1,235,000 lb (3.1)
82,000 gal (3.4)
540 mph (1.0)

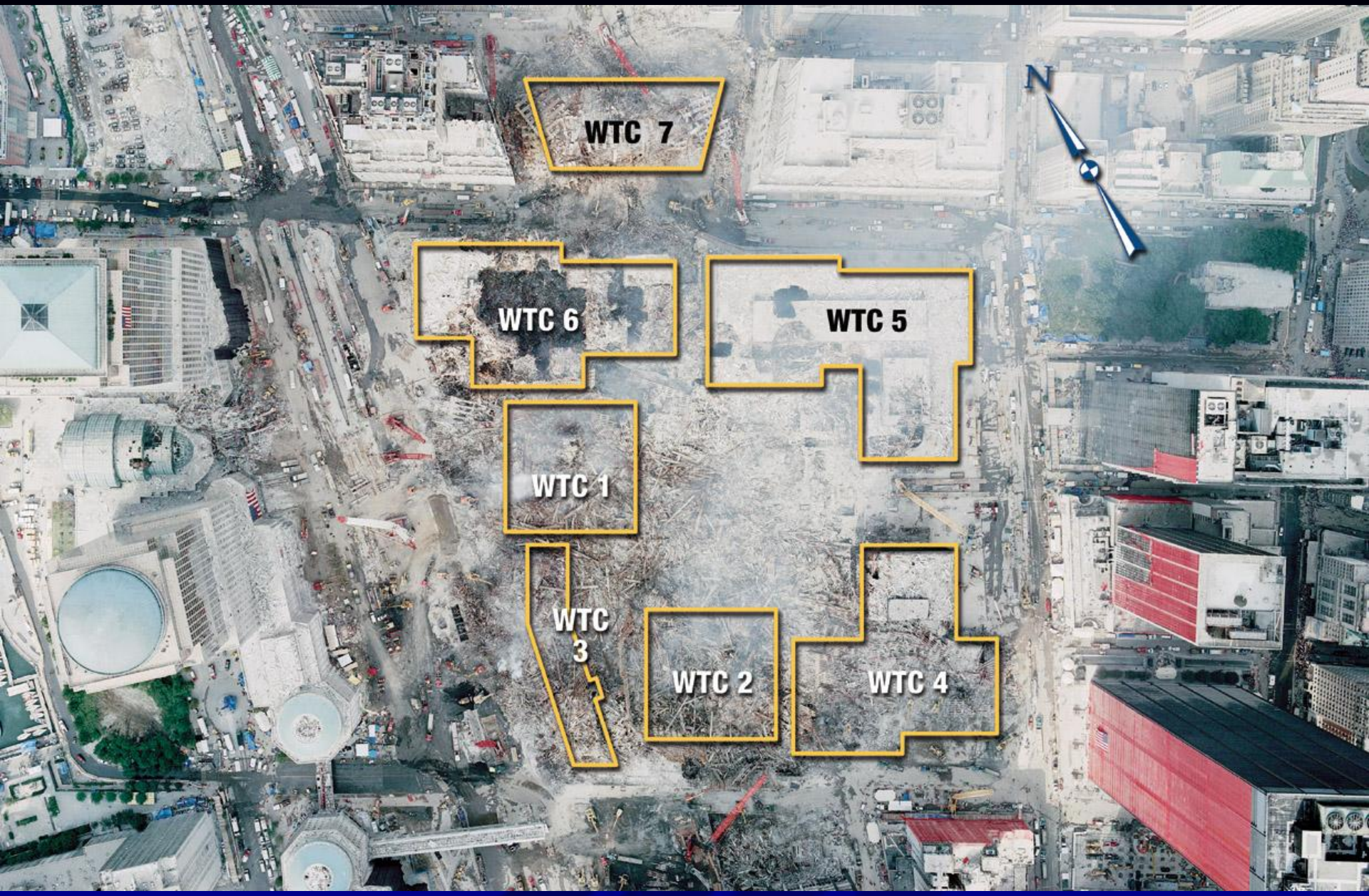



Central Core
Outrigger System
Central Core
Exterior Tube Frame
Wall Above Impact Area Hangs in Tension, and Remaining Frame Acts as Vierendeel Truss to Distribute Loads to Other Elements
Wall Above Impact Area
Perimeter Columns Resist 40% of Building Weight, Equally Distributed
Core Columns
Core Columns Resist 60% of Building Weight, Equally Distributed
Perimeter and Core Columns Columns Near Impact Zone Carry More Load
Before Aircraft Impact
After Aircraft Impact


Building Load
From Above
Building Load
From Above
Exterior
Column
Core
Column
Floor Truss


Building Load
From Above
Building Load
From Above
Exterior
Column
Core
Column
Floor Truss


Building Load
From Above
Building Load
From Above
Exterior
Column
Core
Column
Floor Truss


WTC 7
WTC 6
WTC 5
WTC 1
WTC 3
WTC 2
WTC 4
N

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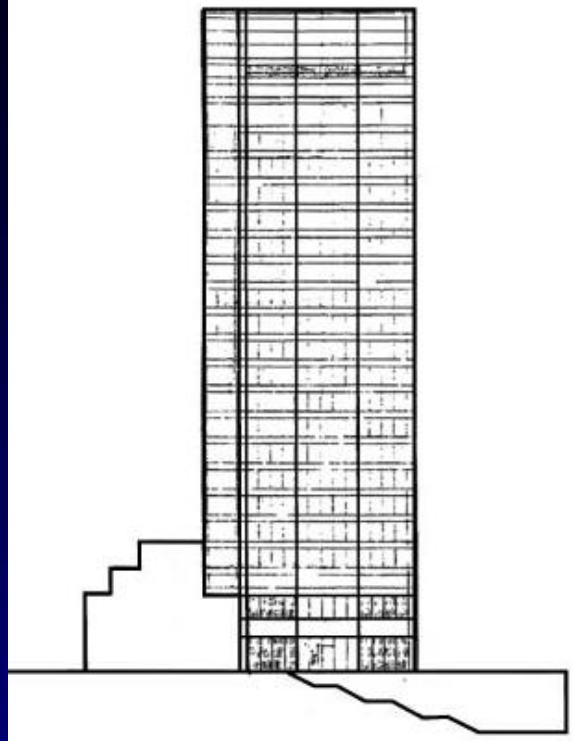
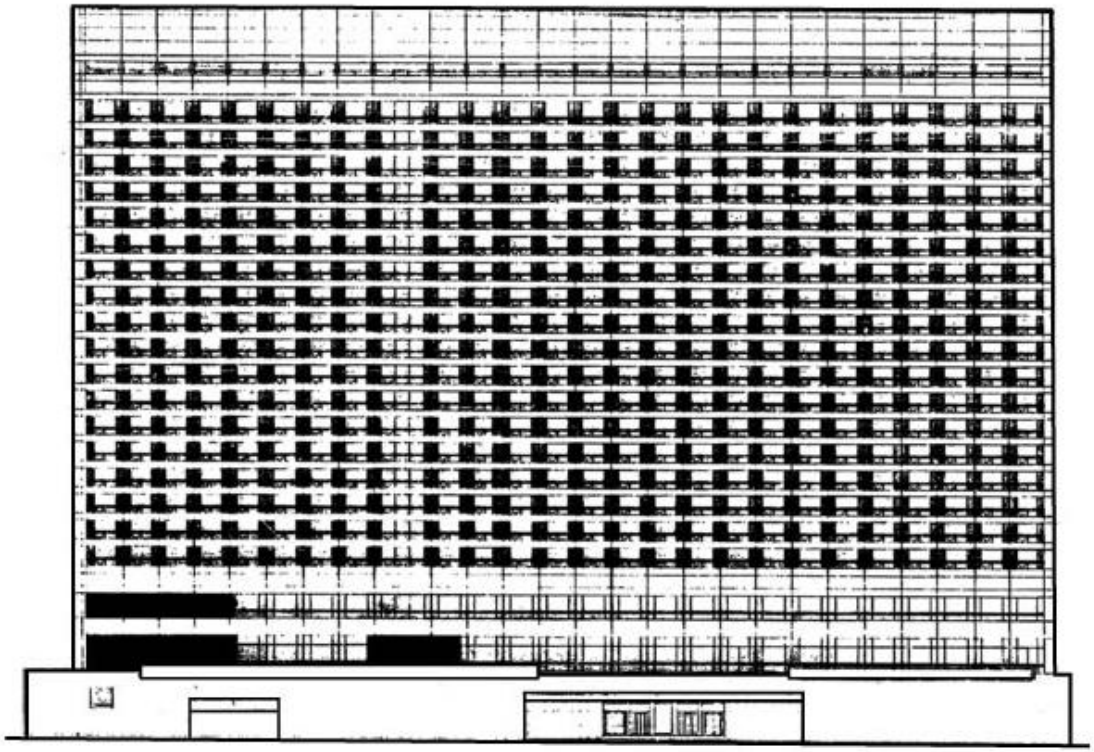
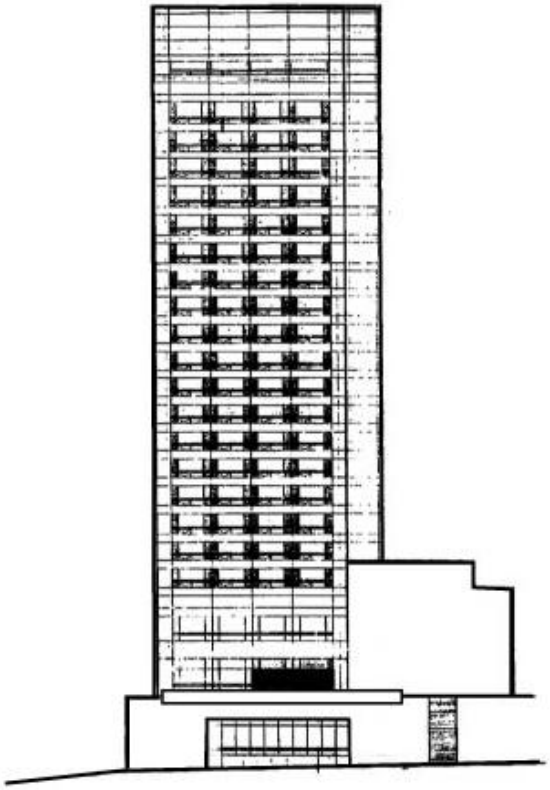


North Elevation (Developed)

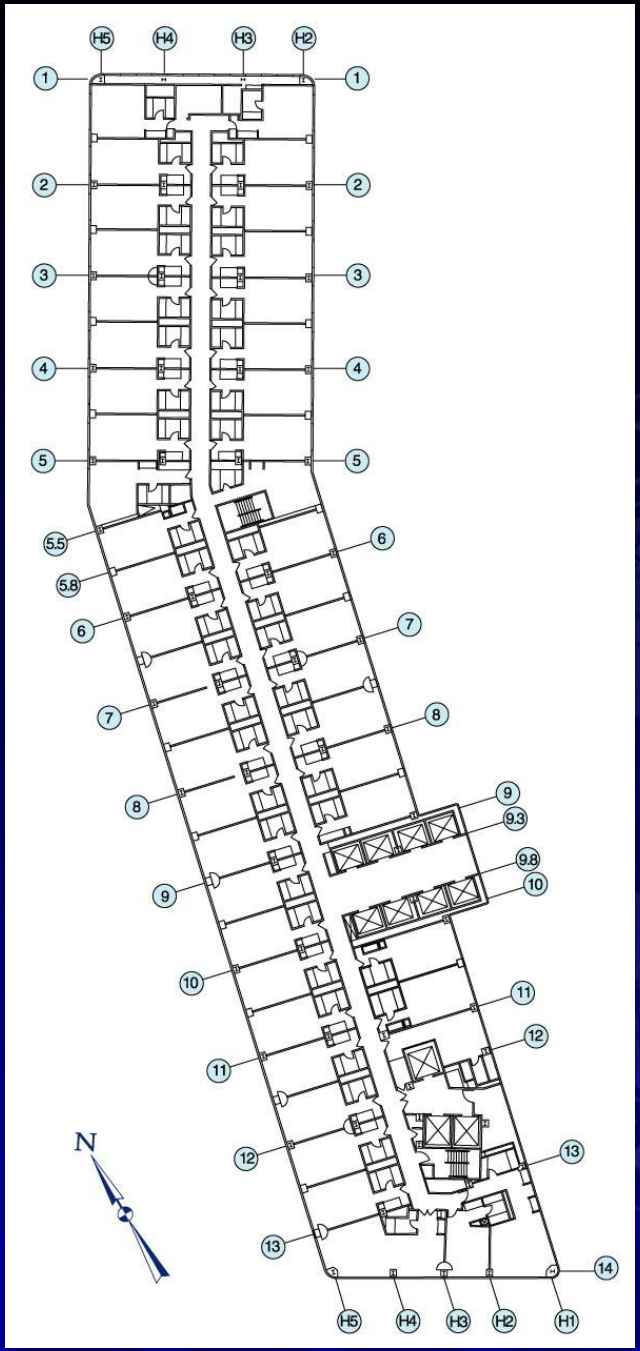


West Elevation (Developed)



South Elevation (Developed)

East Elevation (Developed)


H5
H4
H3
H2
1
2
3
4
5
5.5
5.8
6
7
8
9
9.3
9.8
10
11
12
13
14
H1
N

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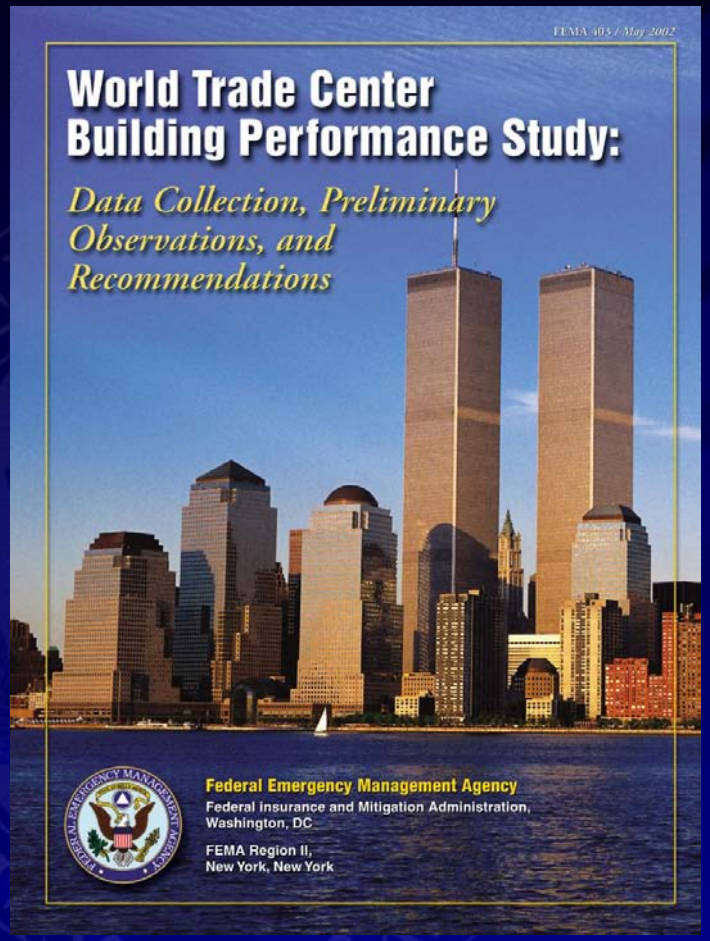
ATF
ATF

Part 2
World Trade Center Building Performance Study

Data Collection, Preliminary Observations, and Recommendations

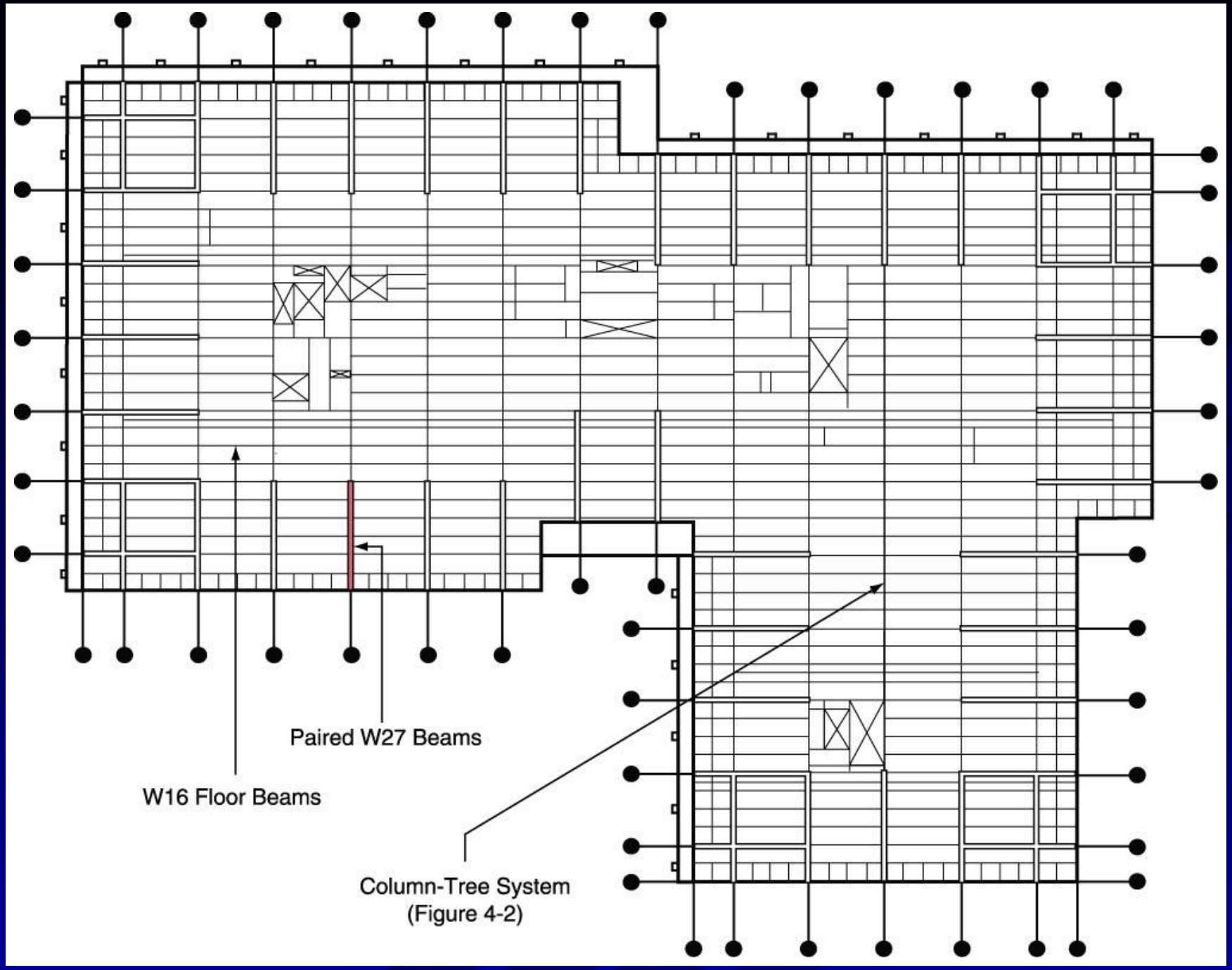


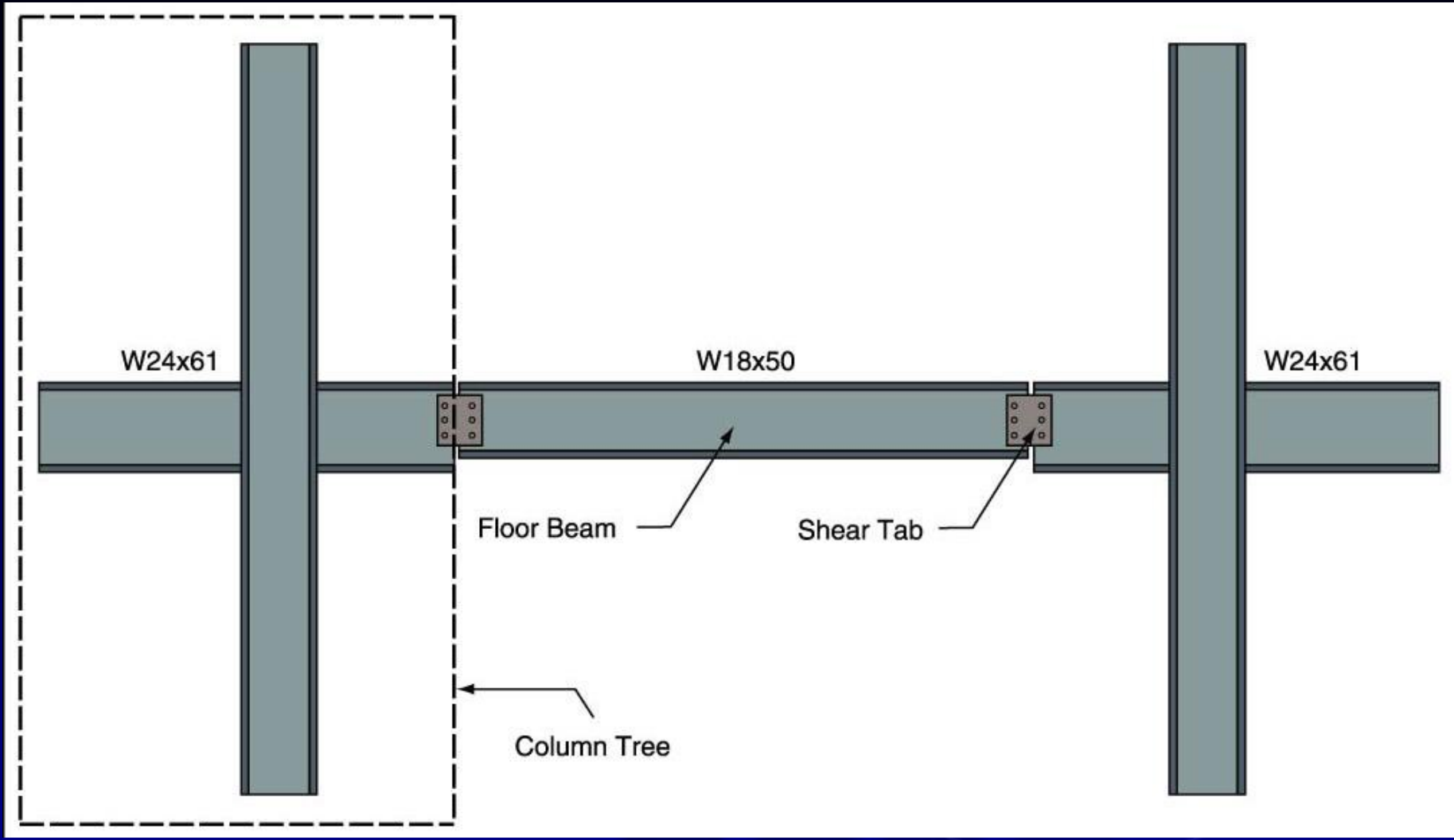
Federal Emergency Management Agency
Federal Insurance and Mitigation Administration
Washington, D.C.

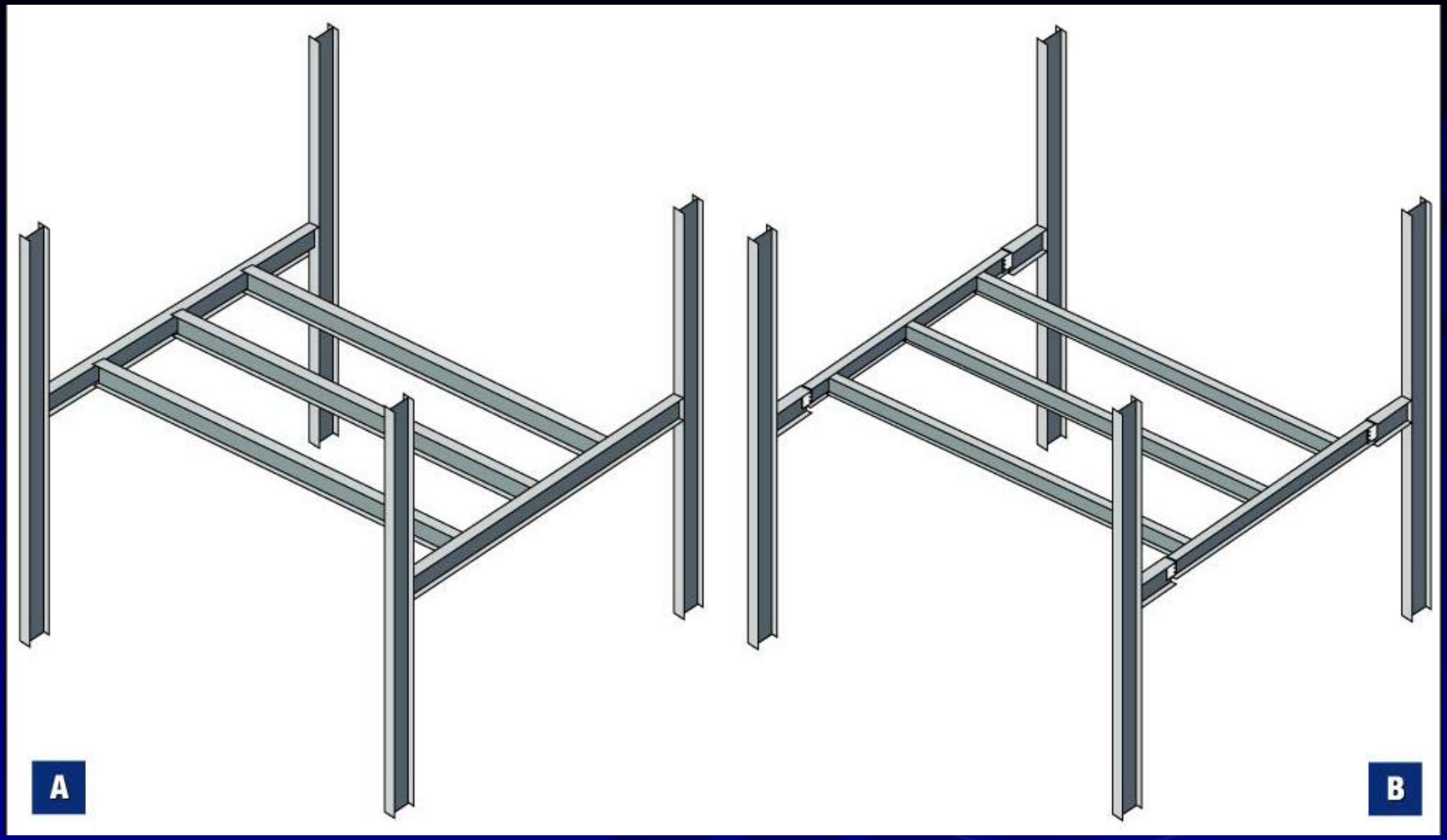
FEMA Region II
New York, New York

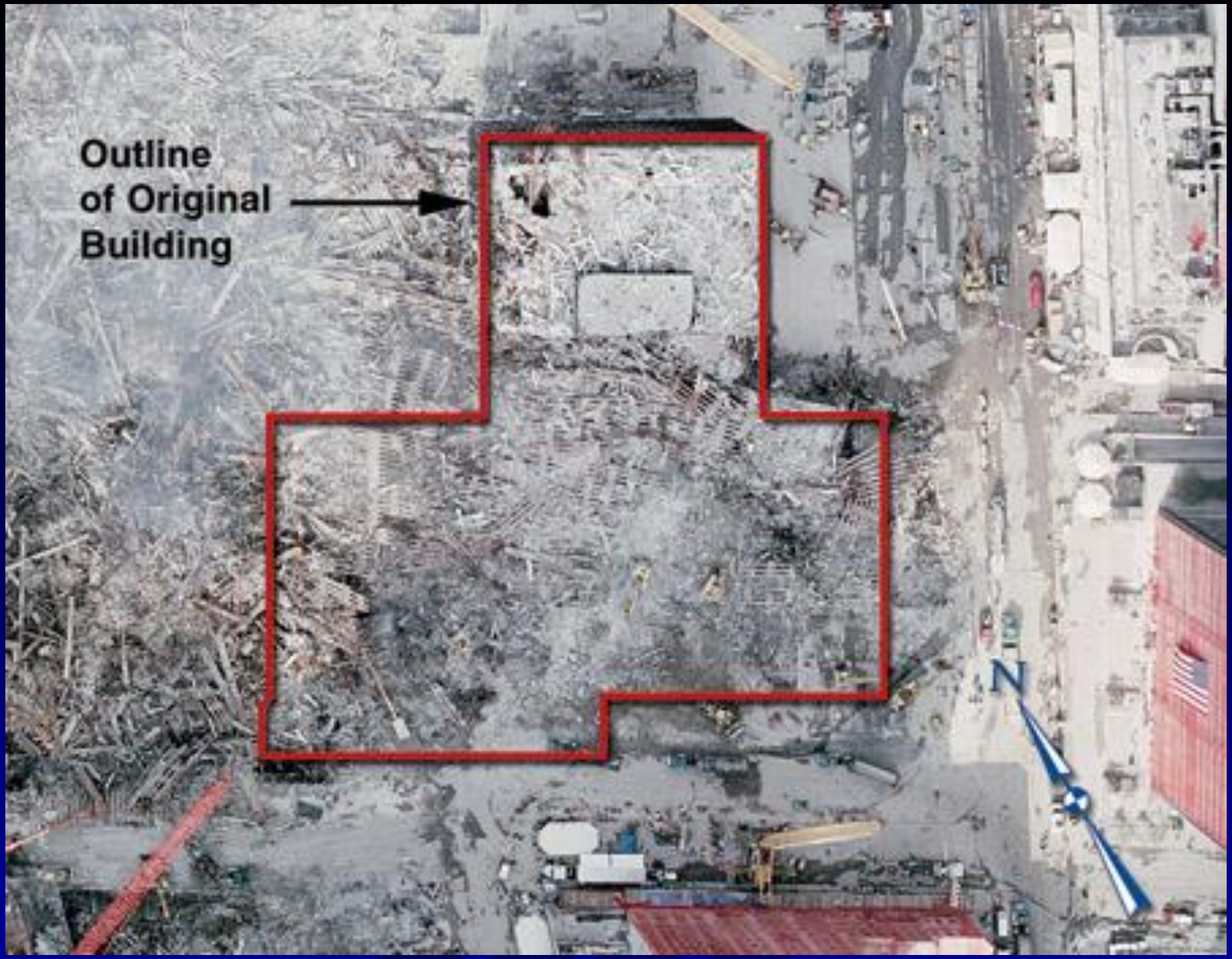
Recommendation

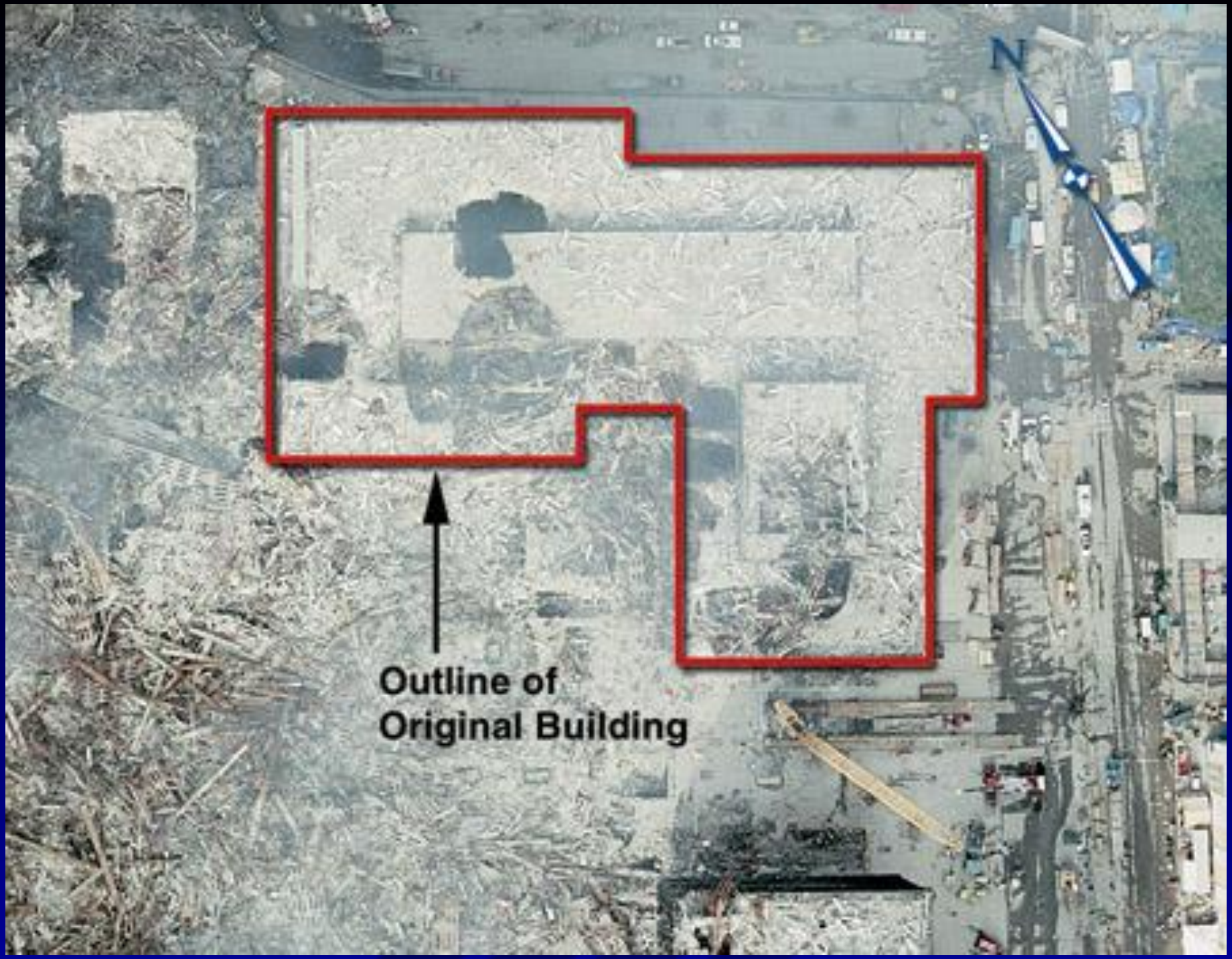
- Conduct further studies to understand how WTC 3 resisted progressive collapse.

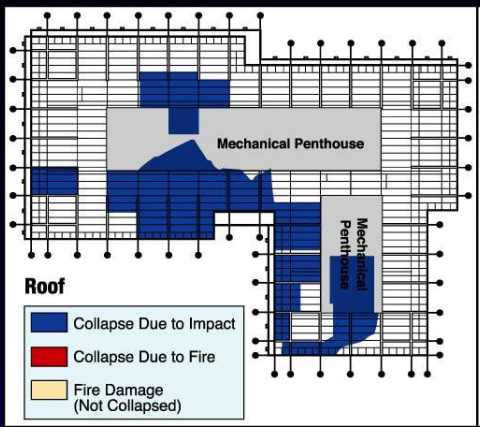

Paired W27 Beams
W16 Floor Beams
Column-Tree System
(Figure 4-2)

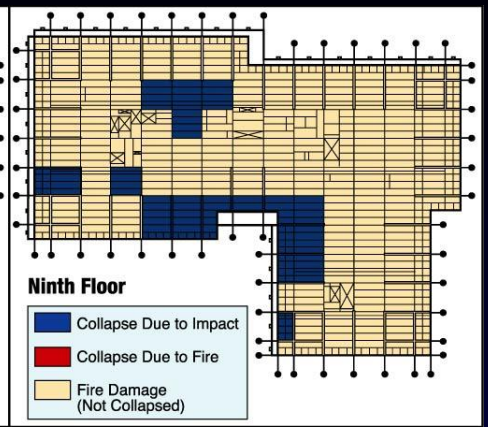

W24x61
W18x50
W24x61
Floor Beam
Shear Tab
Column Tree

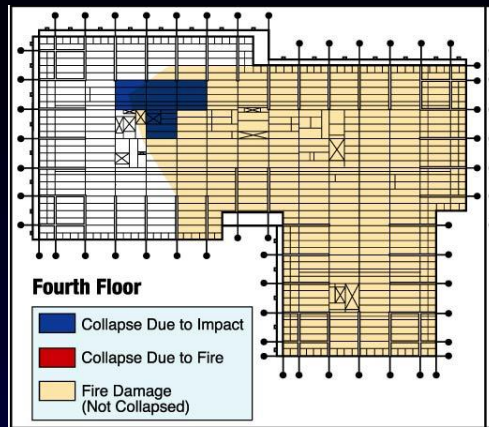

A
B

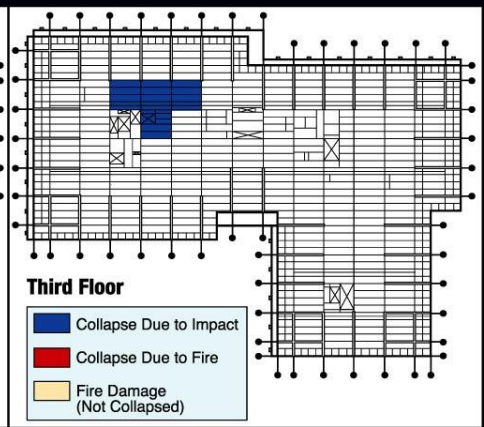

Outline
of Original
Building
N

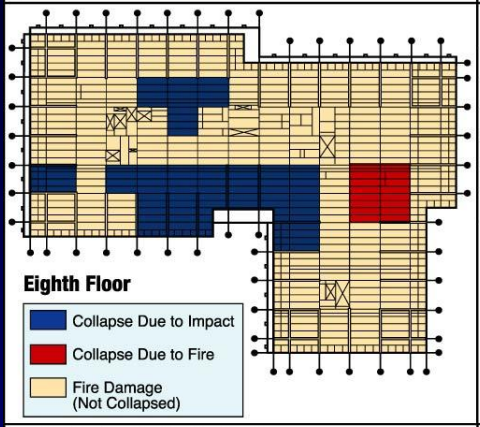

N
Outline of
Original Building

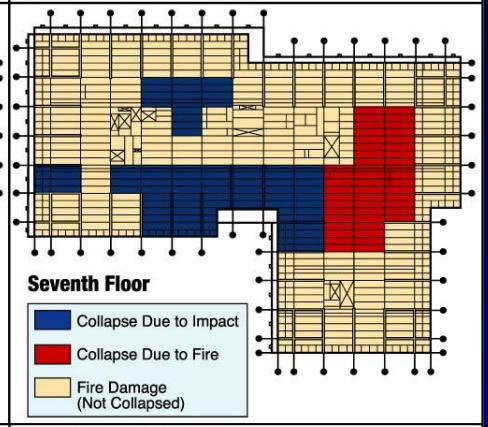

Mechanical Penthouse
Mechanical Penthouse
Roof
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)

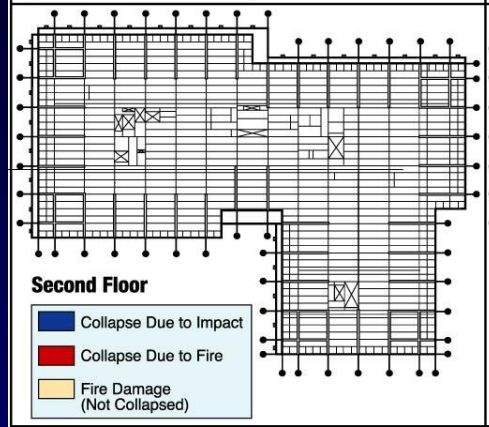

Ninth Floor
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)

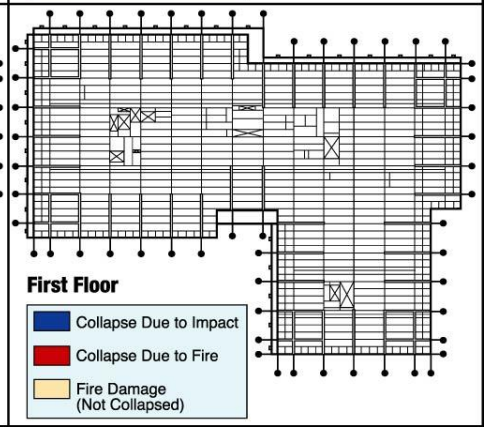

Fourth Floor
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)

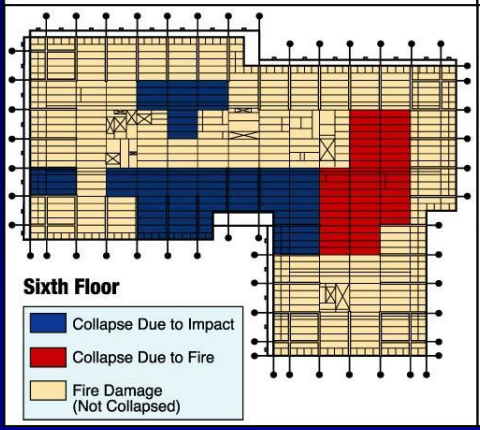

Third Floor
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)

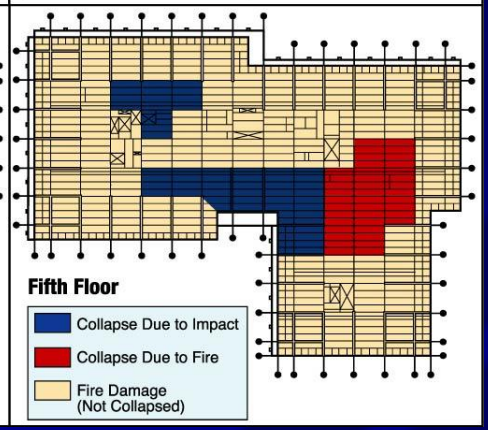

Eighth Floor
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)

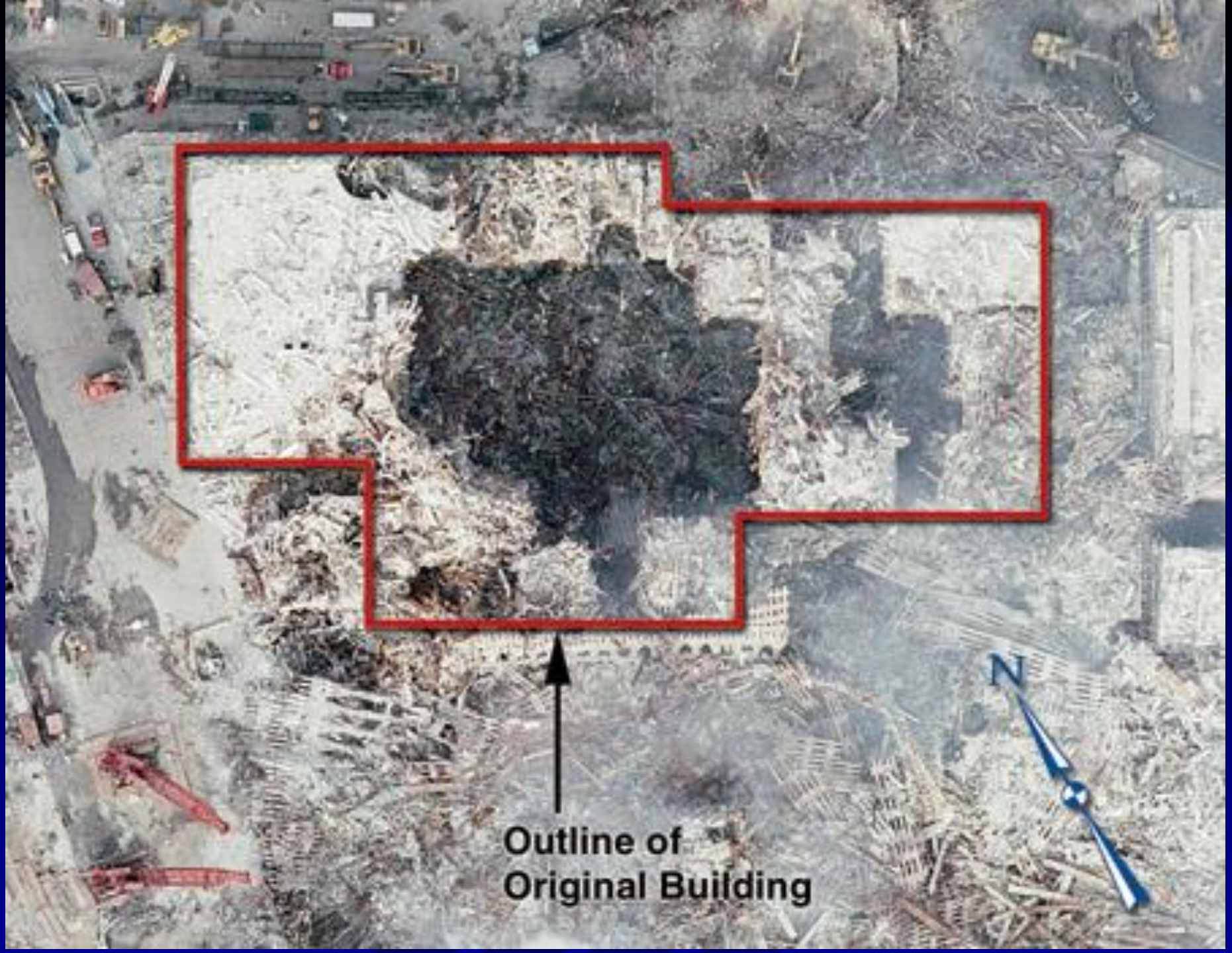

Seventh Floor
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)

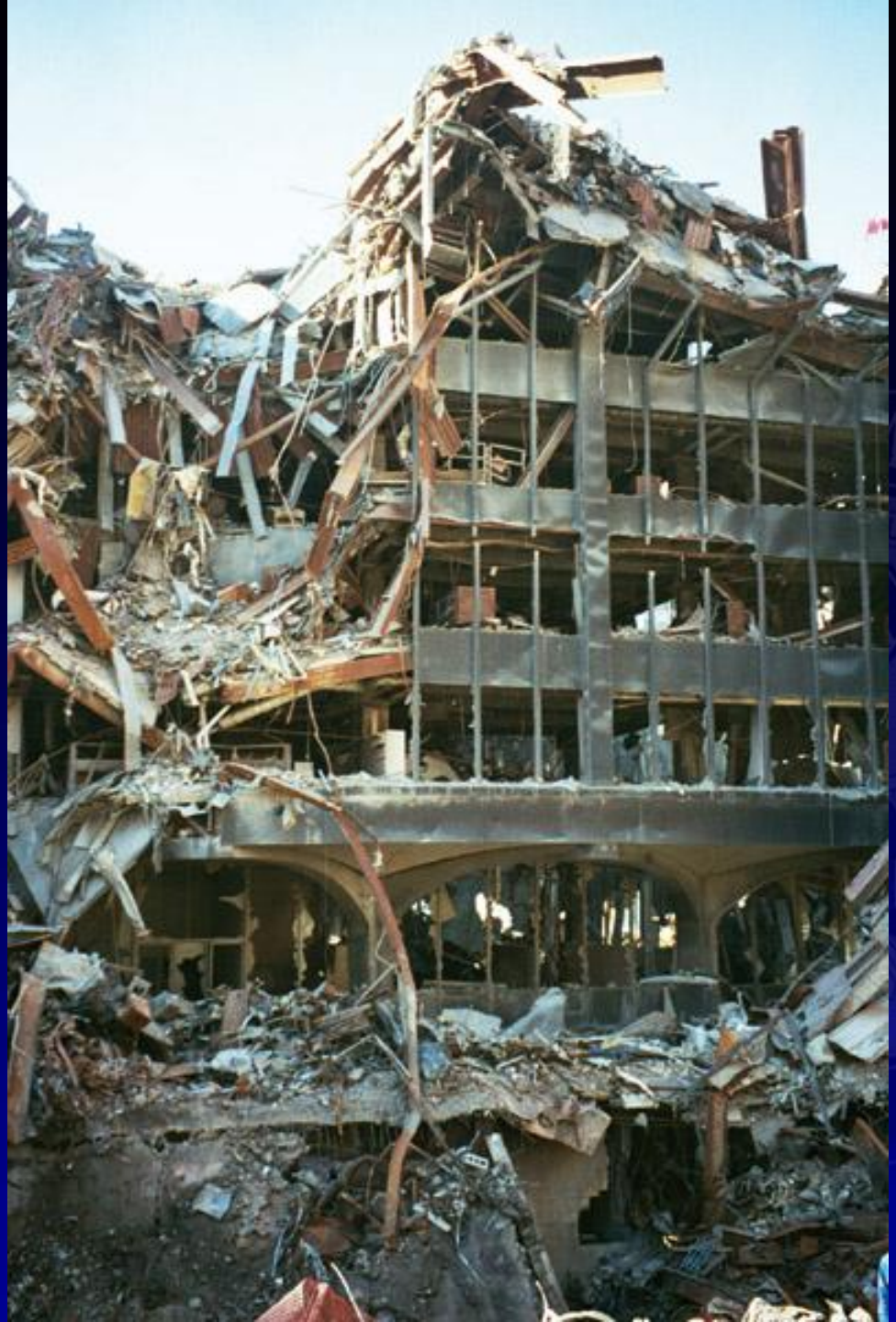

Second Floor
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)

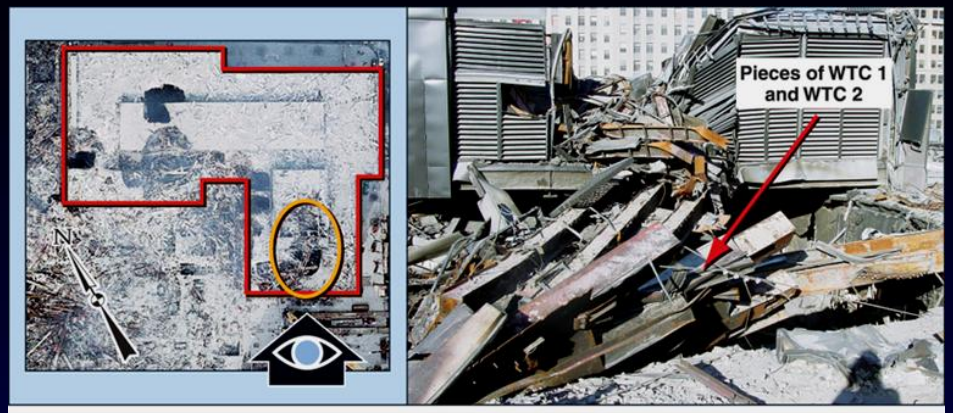

First Floor
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)


Sixth Floor
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)

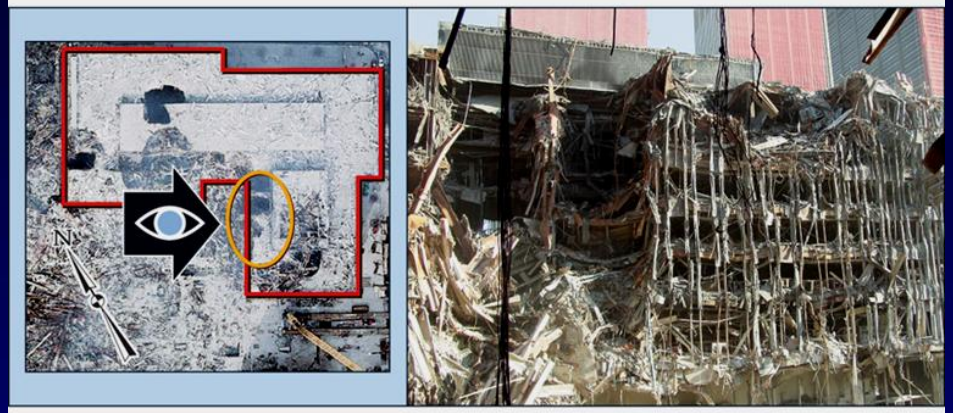

Fifth Floor
Collapse Due to Impact
Collapse Due to Fire
Fire Damage
(Not Collapsed)

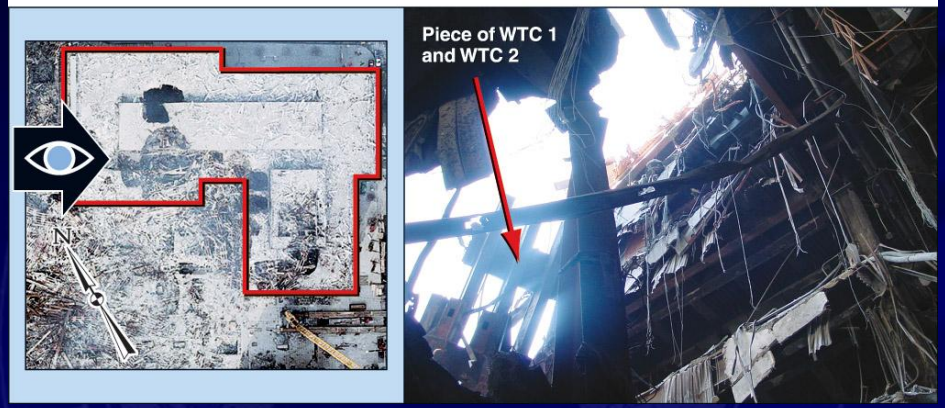

Outline of
Original Building
N




N
Pieces of WTC 1
and WTC 2

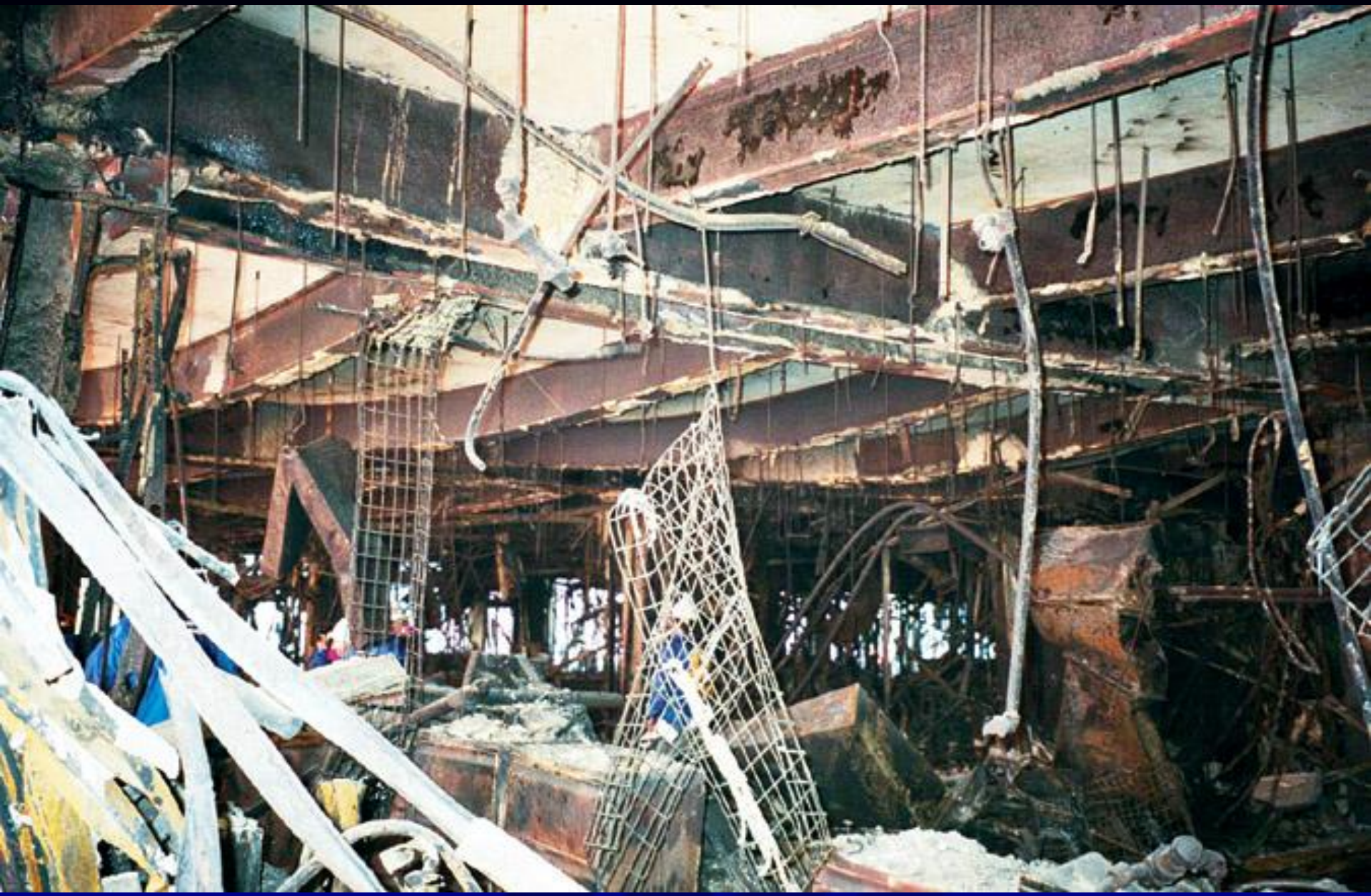
N


N

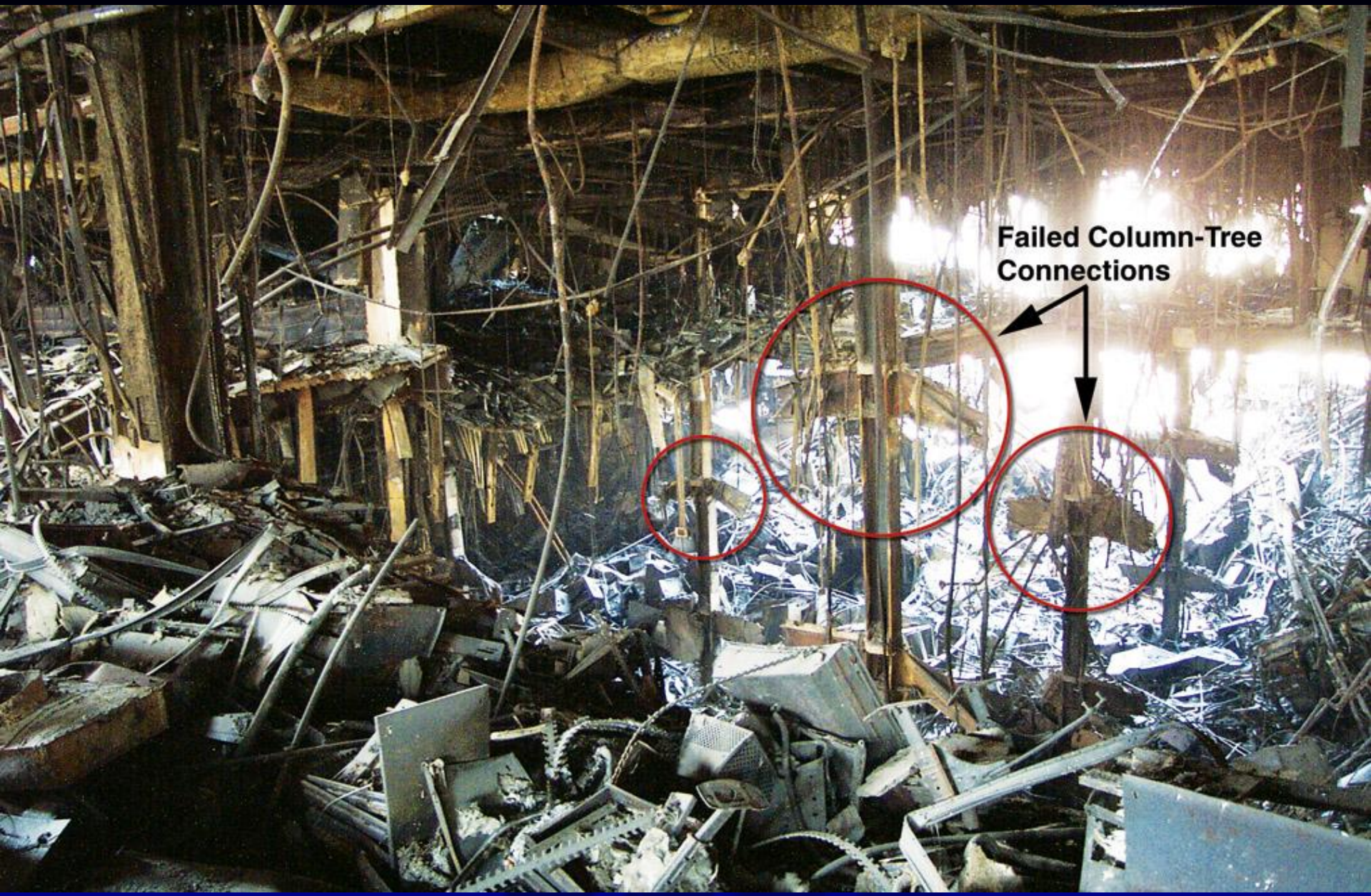

N
Piece of WTC 1
and WTC 2

N

Roof
9th Floor
8th Floor
7th Floor
6th Floor
5th Floor
4th Floor
3rd Floor

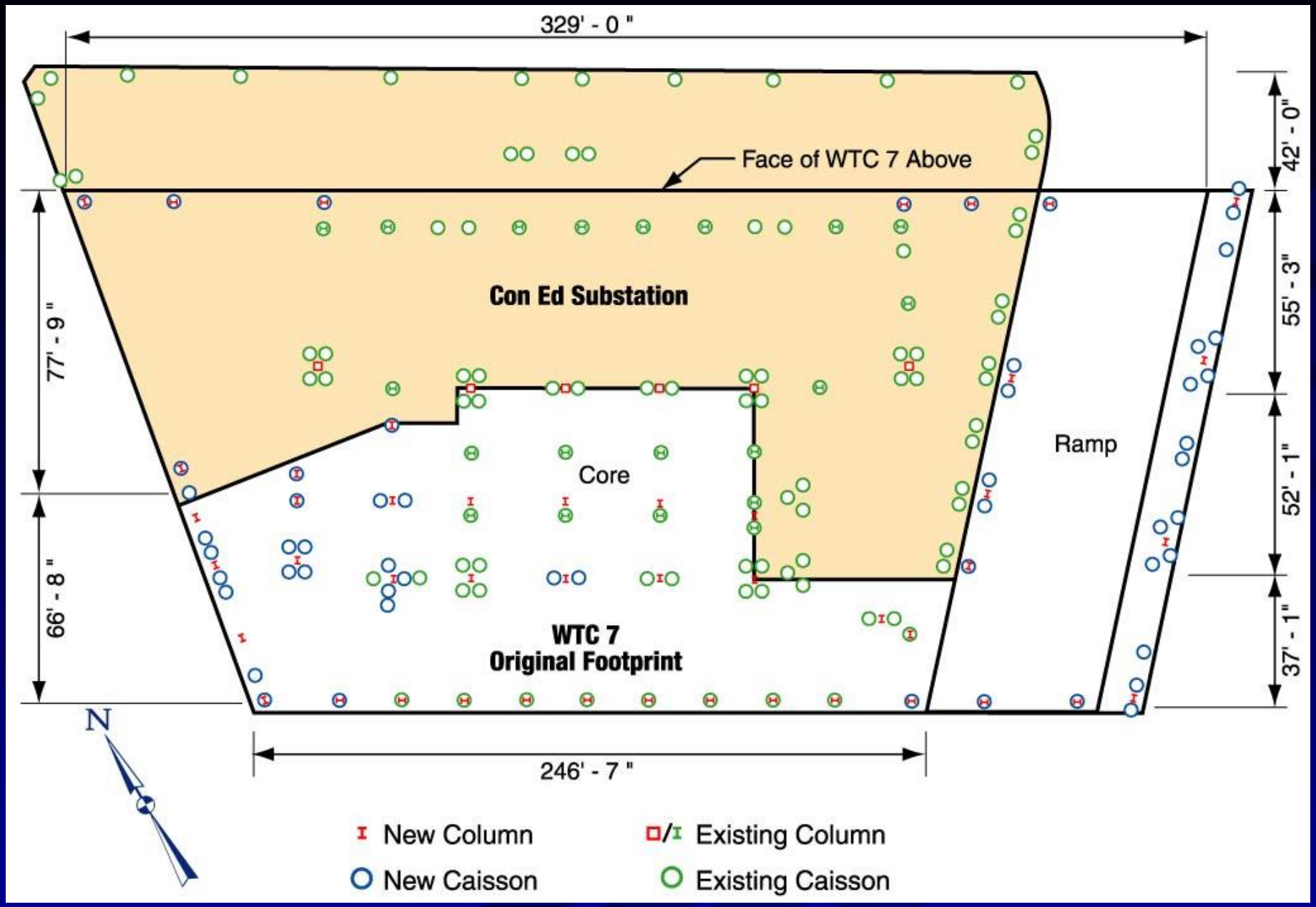


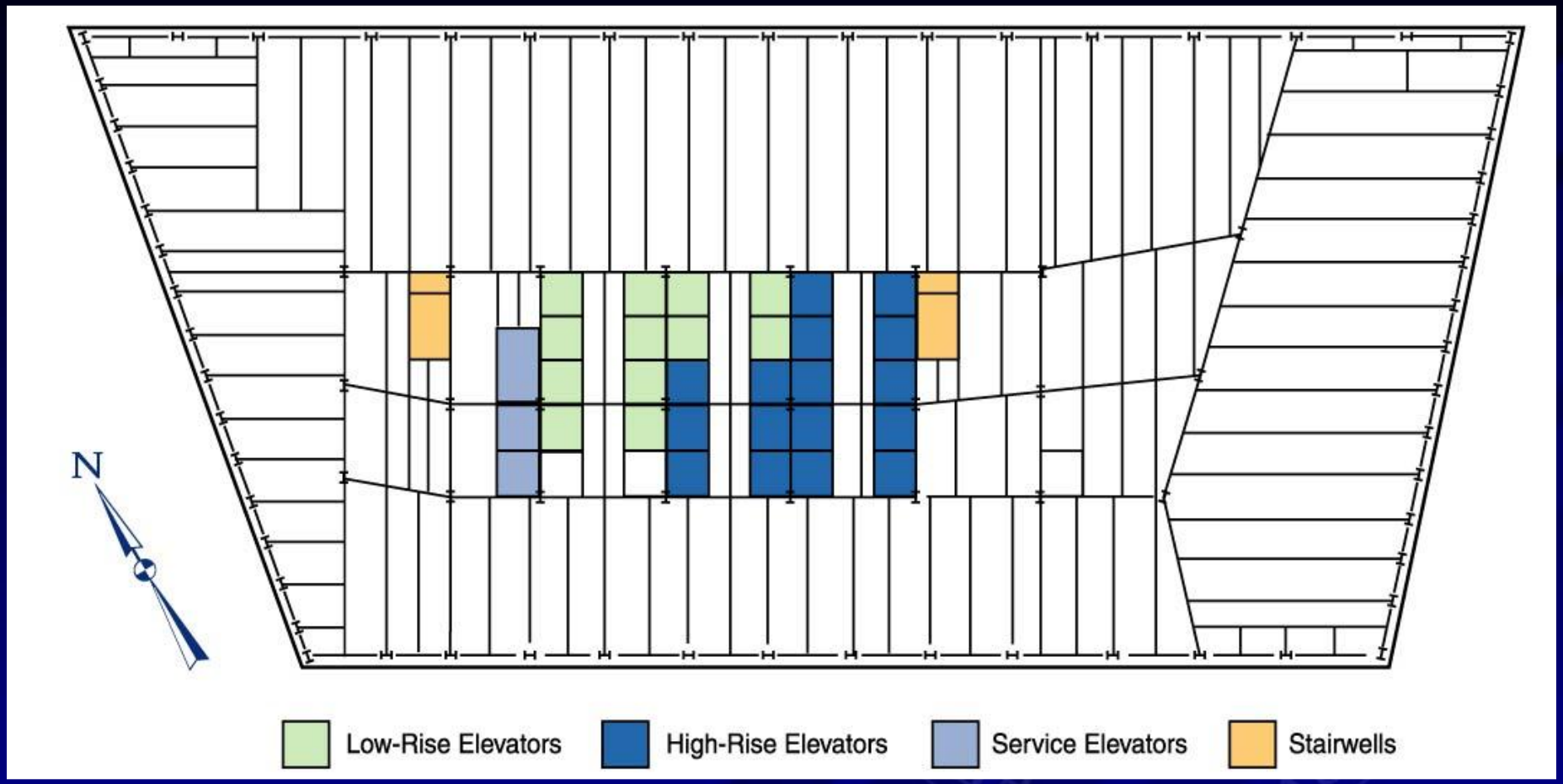
3rd Floor
2nd Floor

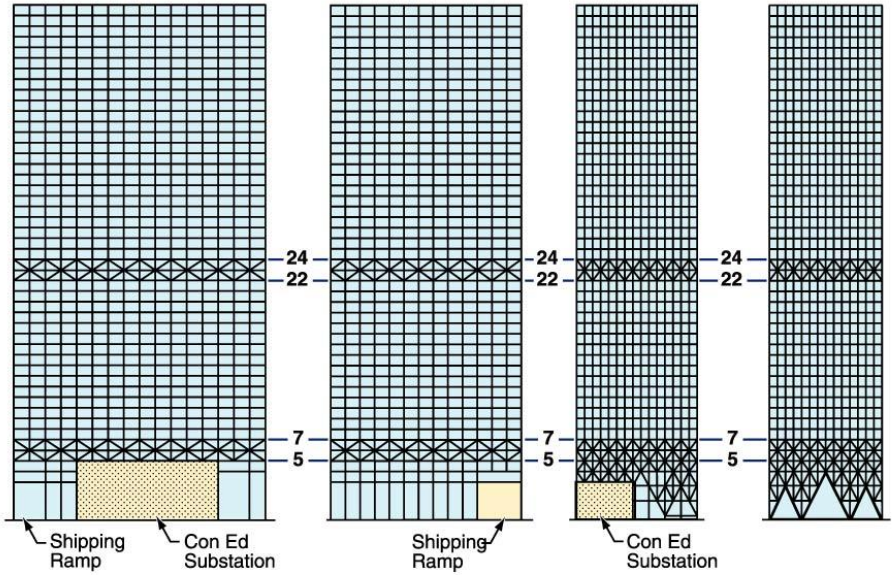

Failed Column-Tree
Connections

Recommendations

- Conduct further studies to determine the performance of connections and their adequacy under real fire exposures.
- Determine the combined structural and fire properties of the critical structural connections so that predictions of their behavior under overload conditions can be made. This can be accomplished with a combination of thermal transfer modeling, structural finite element modeling (FEM), and full-scale physical testing.

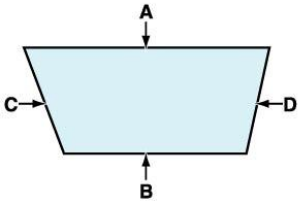

329' - 0 "
Face of WTC 7 Above
42' - 0"
55' - 3"
52' - 1"
37' - 1"
77' - 9 "
66' - 8 "
Con Ed Substation
Core
Ramp
WTC 7
Original Footprint
246' - 7 "
N
New Column
Existing Column
New Caisson
Existing Caisson

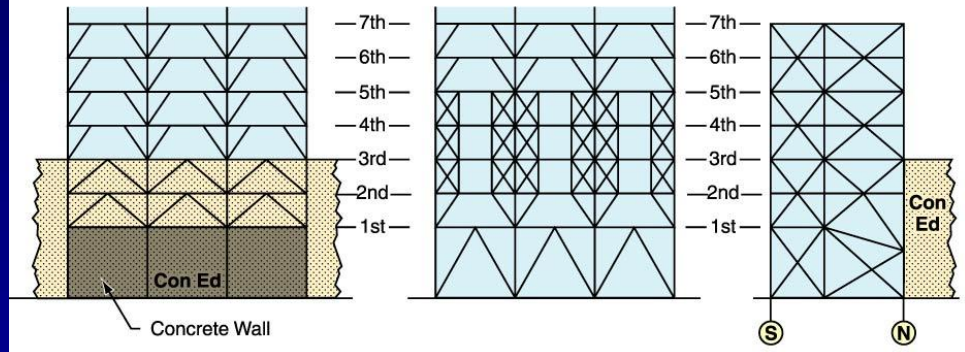

N
Low-Rise Elevators
High-Rise Elevators
Service Elevators
Stairwells



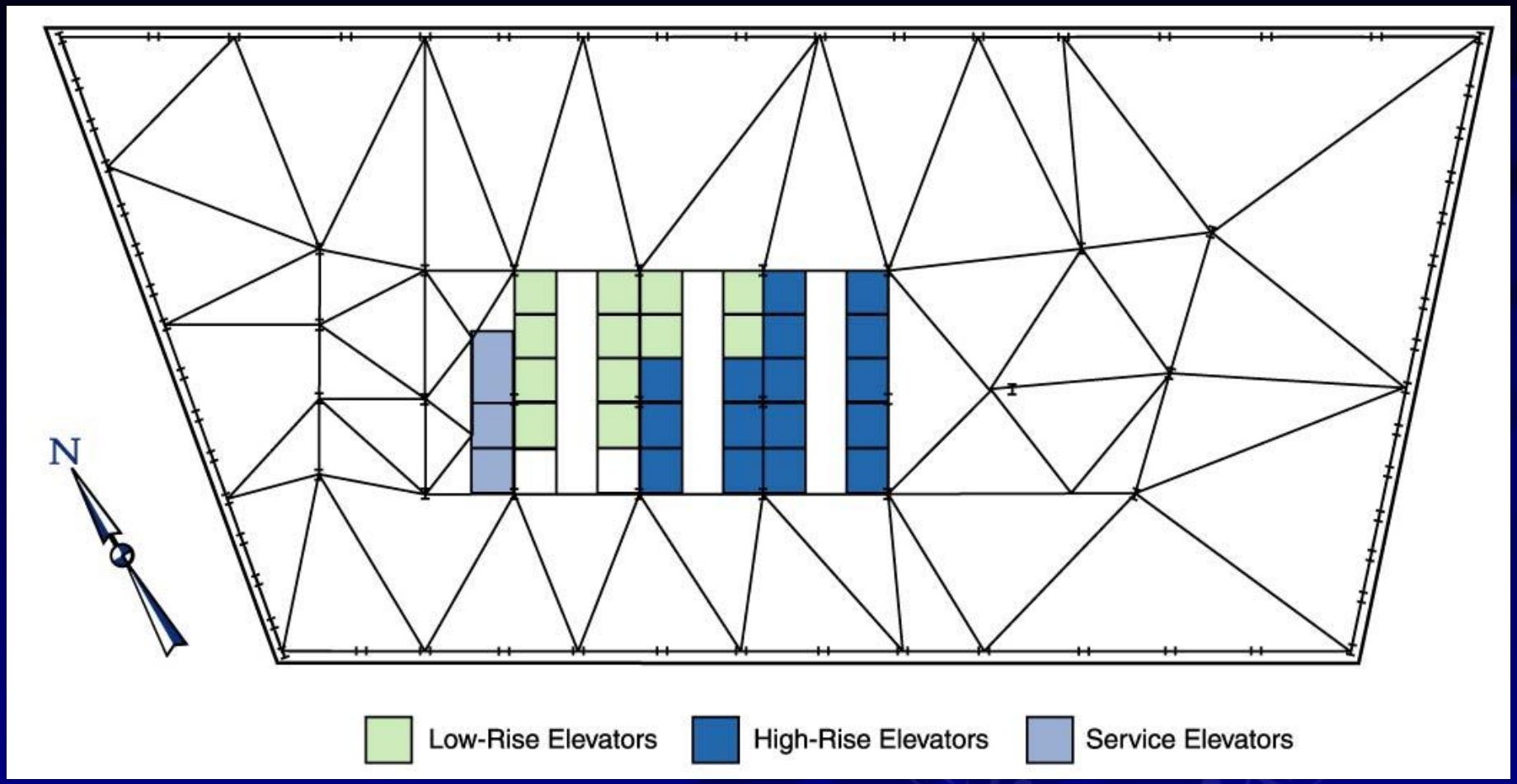
A - North Elevation B - South Elevation C - West Elevation D - East Elevation

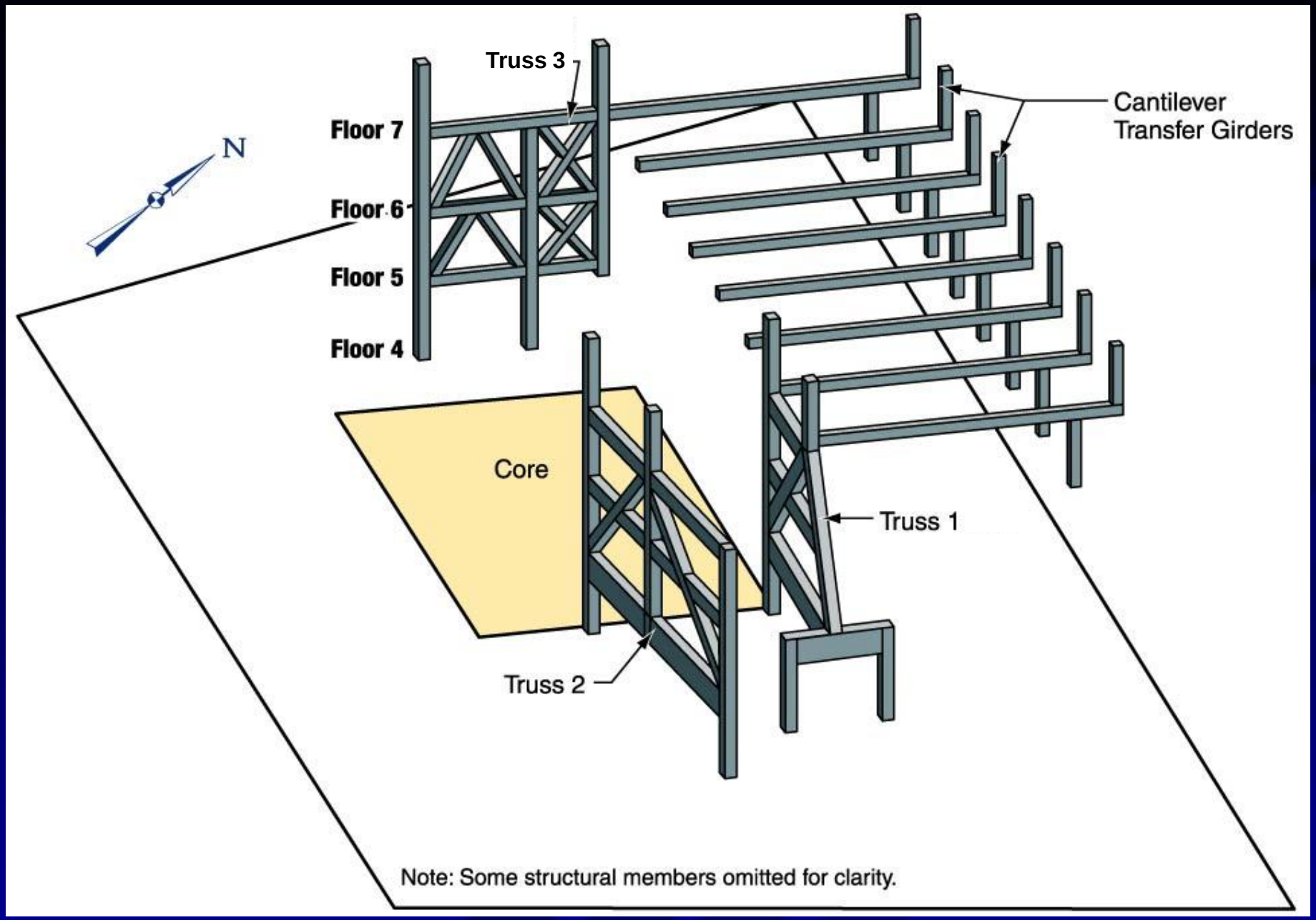
NOTE: Belt trusses located at floors 5-7 and 22-24.

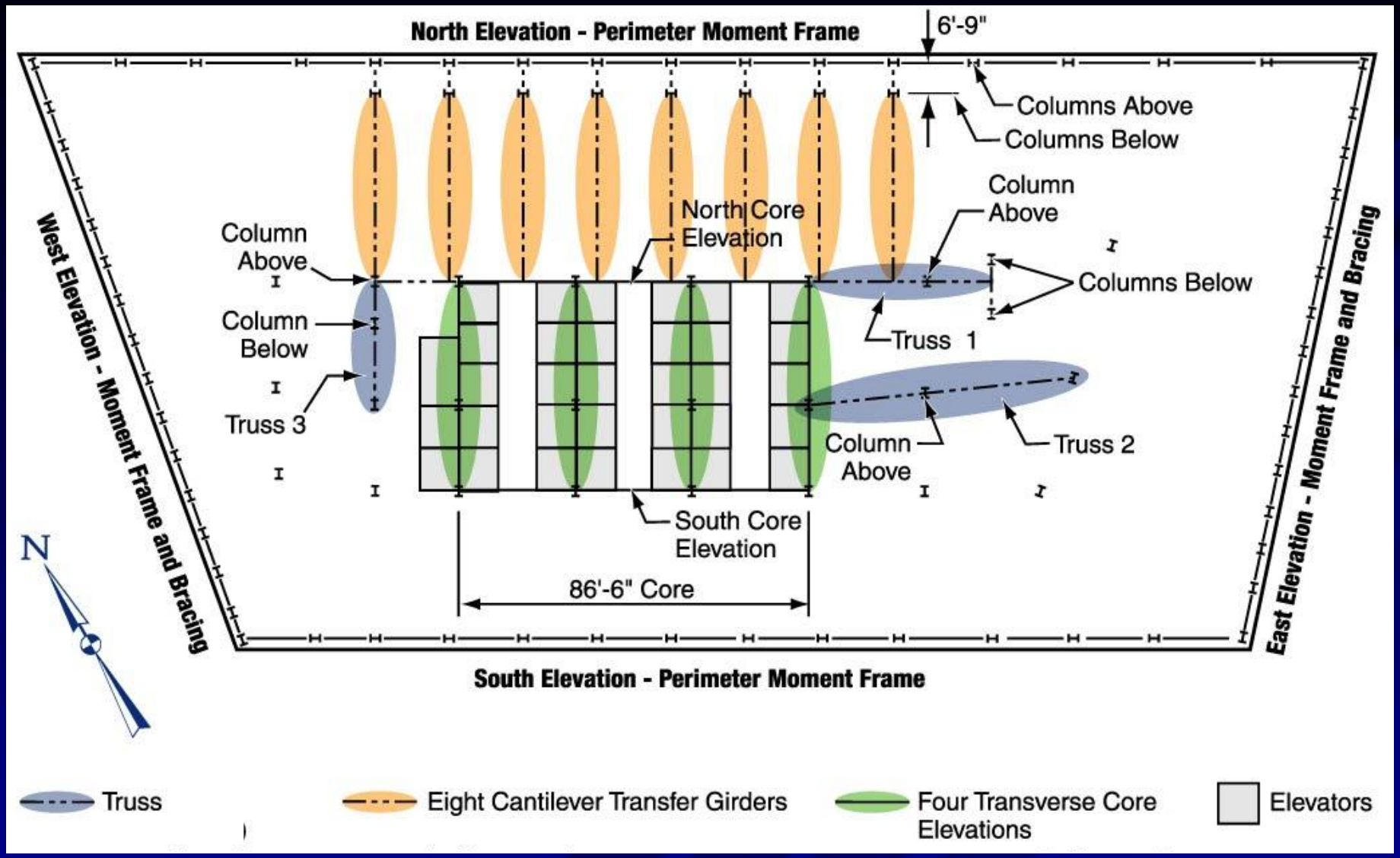


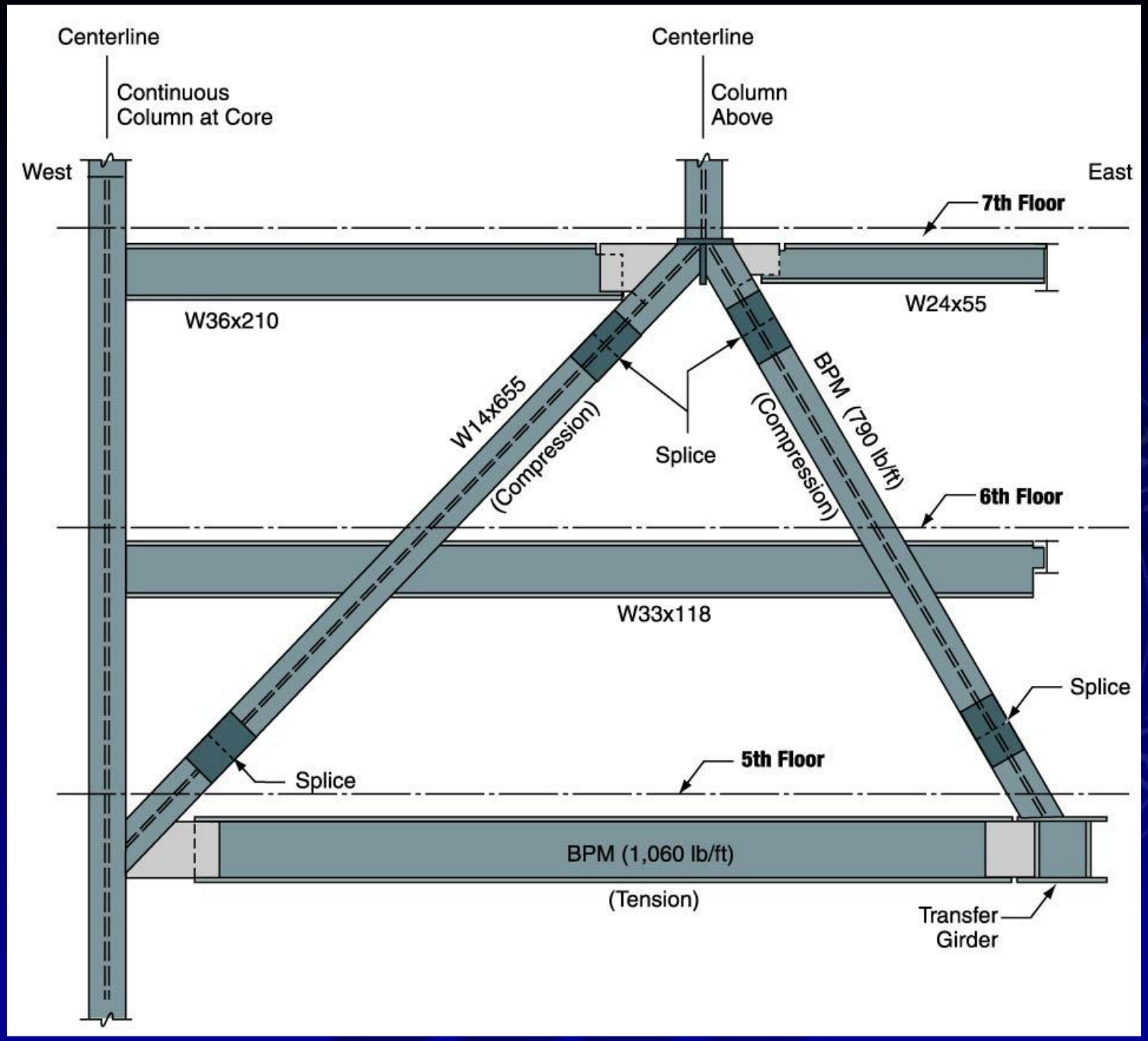


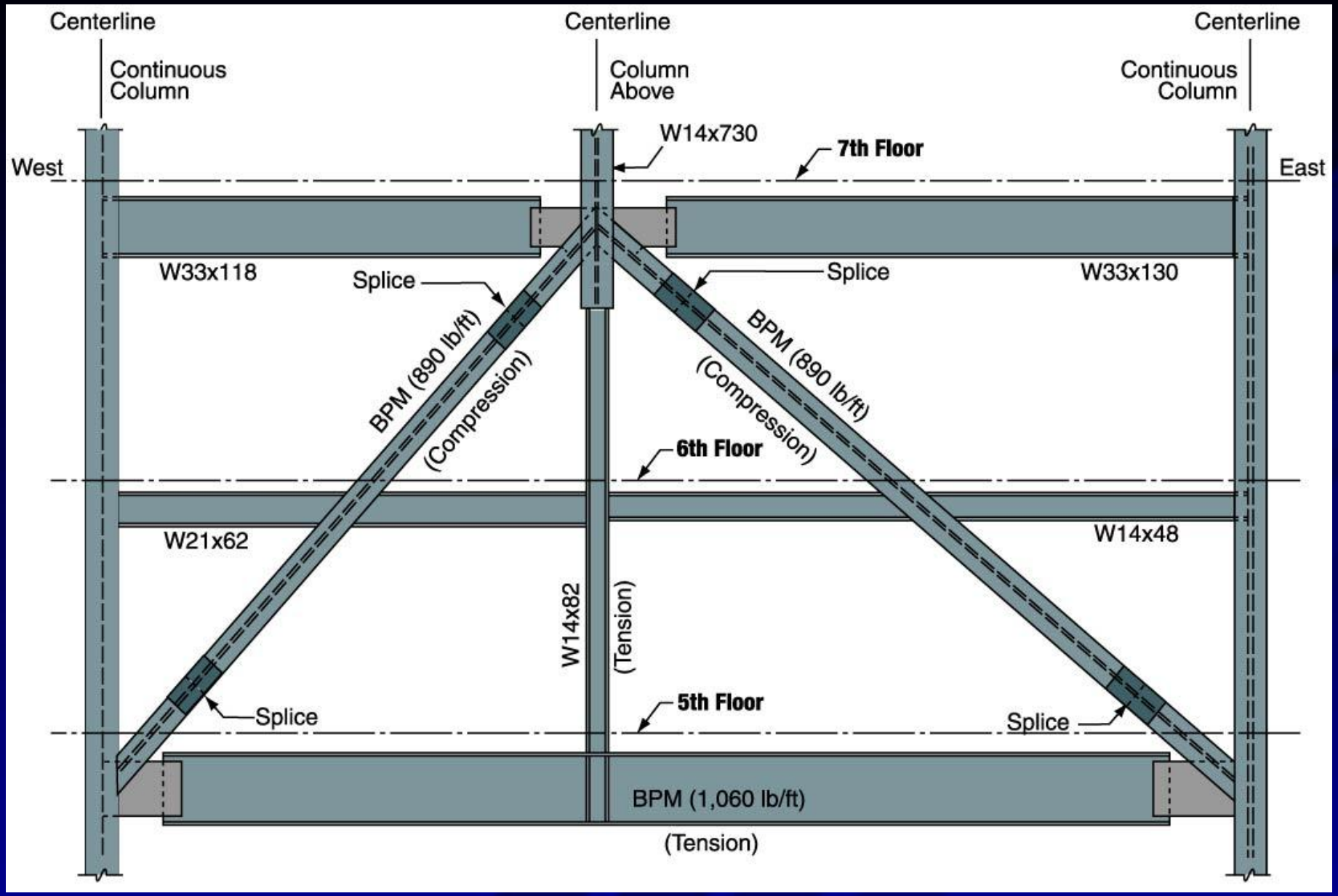
E - North Core Elevation F - South Core Elevation G - Transverse Core Elevations

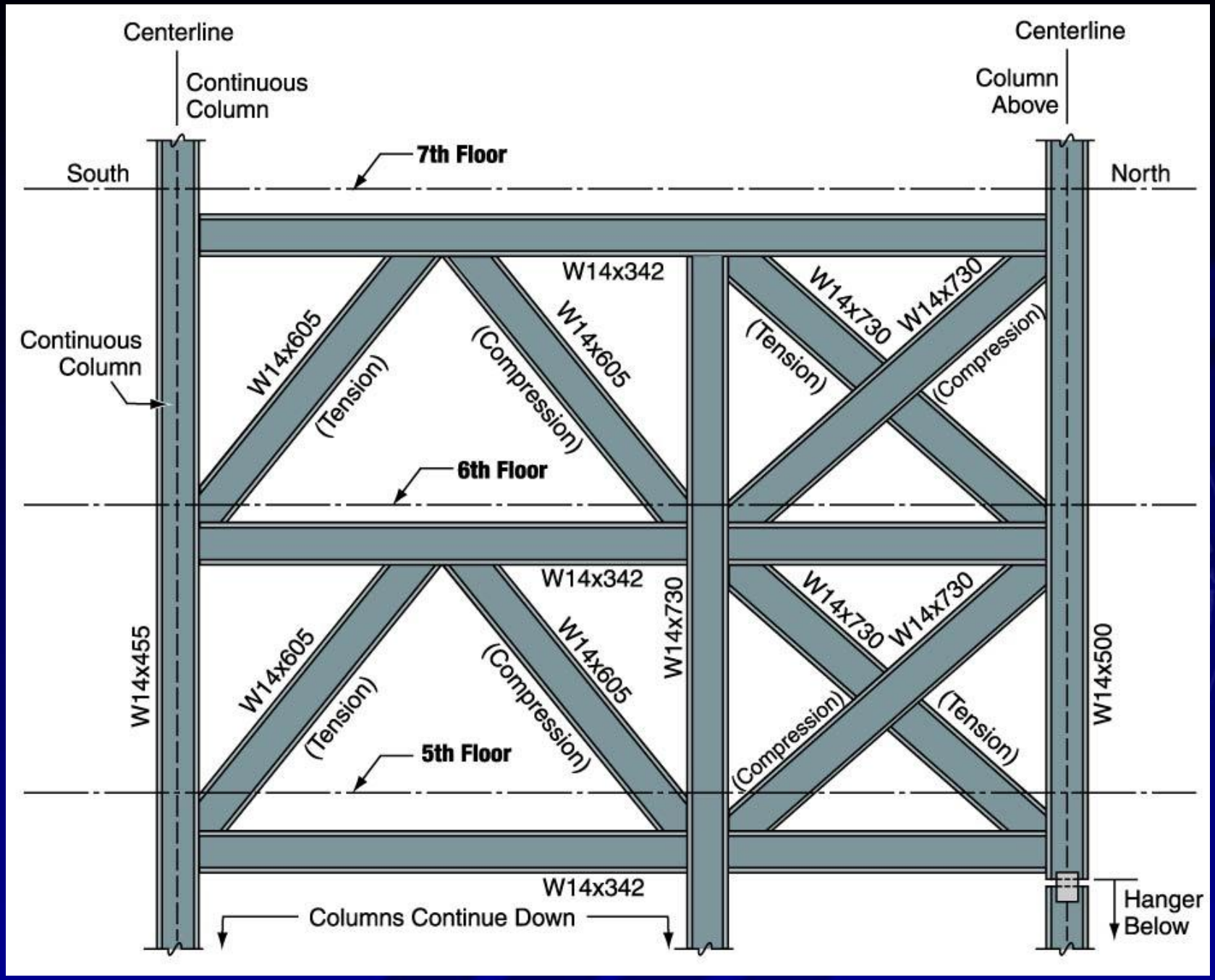

N
Low-Rise Elevators
High-Rise Elevators
Service Elevators

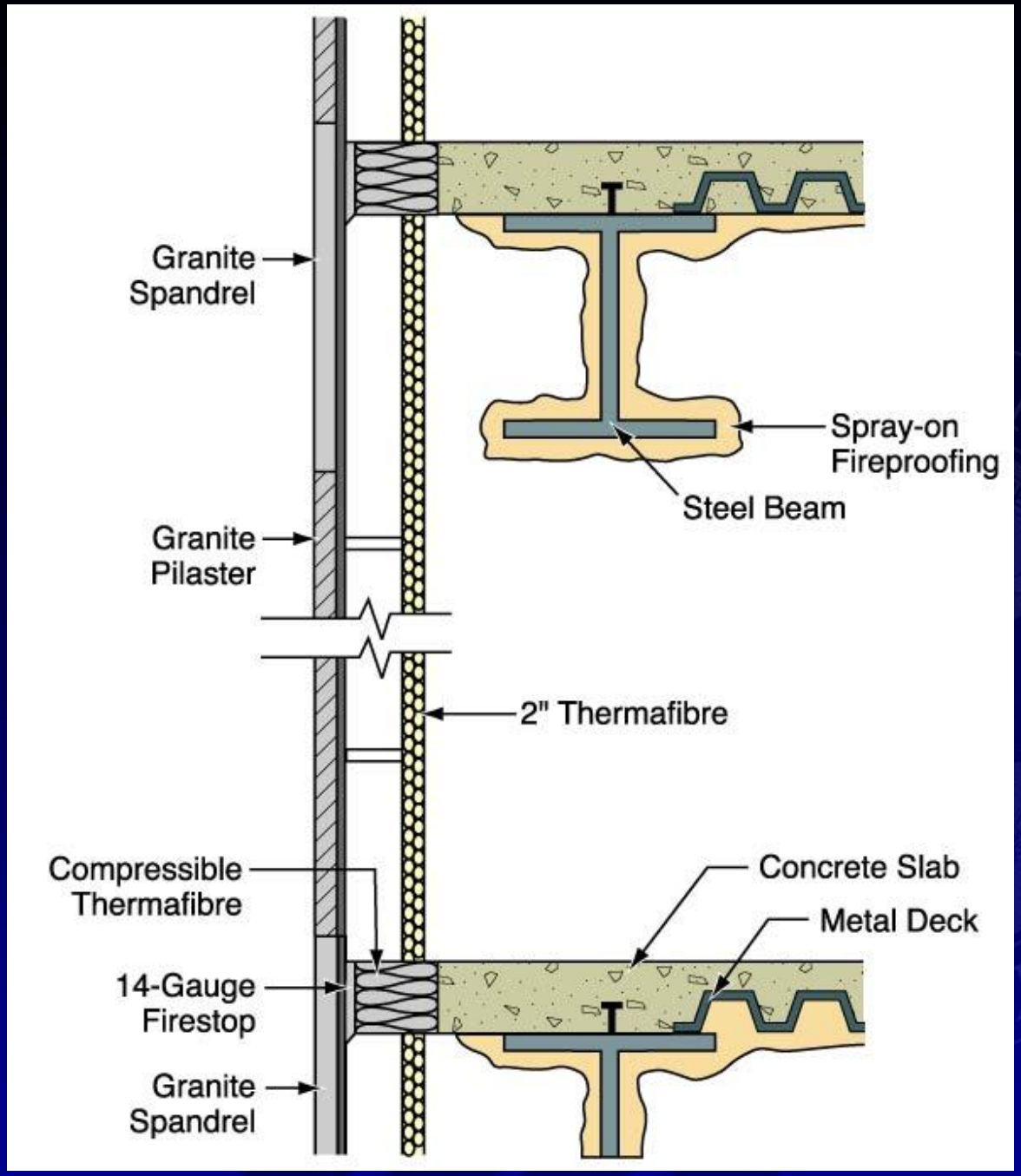

Truss 3
Cantilever
Transfer Girders
N
Floor 7
Floor 6
Floor 5
Floor 4
Core
Truss 1
Truss 2
Note: Some structural members omitted for clarity.

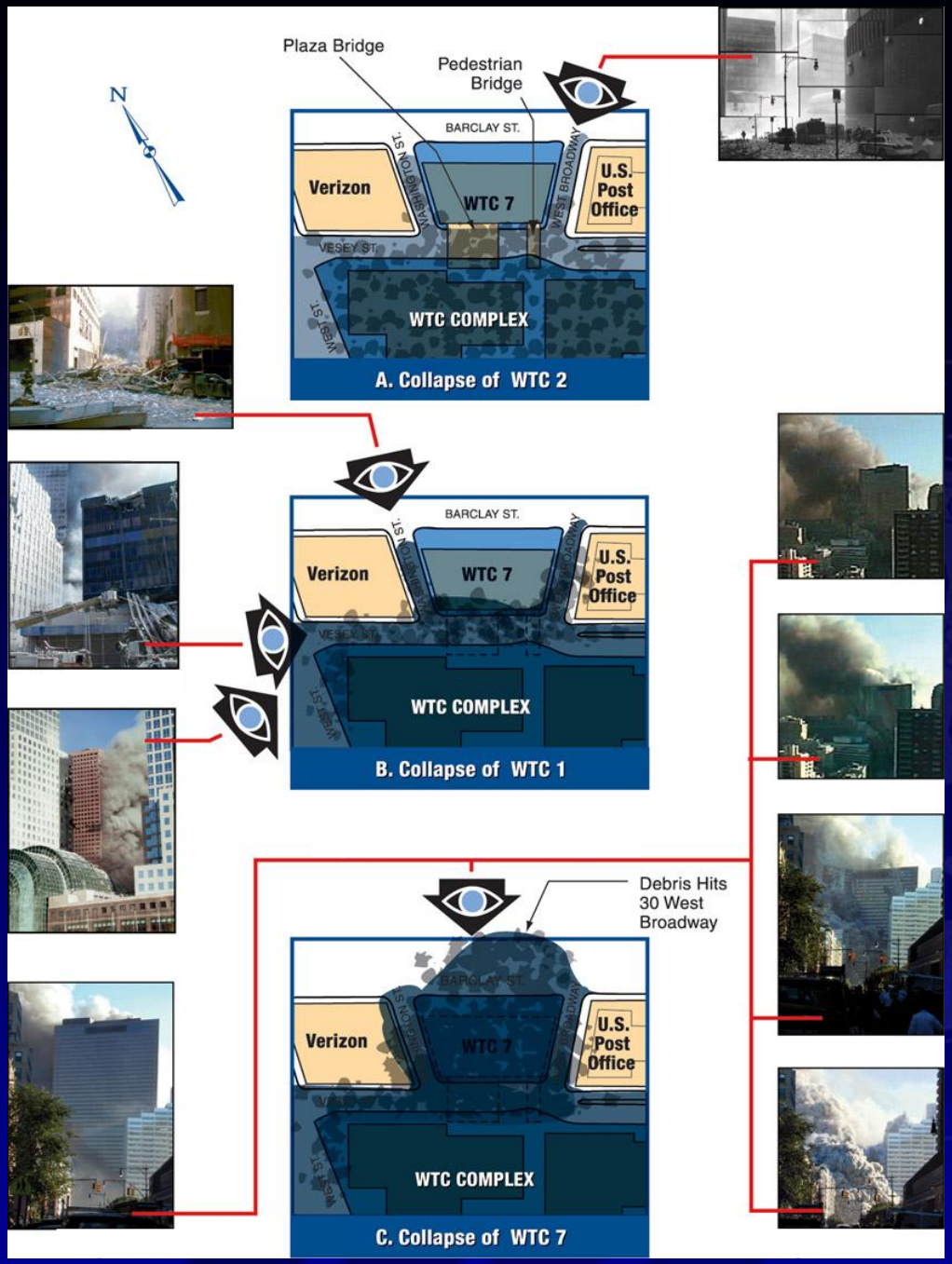

North Elevation - Perimeter Moment Frame
6'-9"
Columns Above
Columns Below
Column Above
North Core Elevation
Column Above
Columns Below
Truss 1
Column Below
Truss 3
Column Above
Truss 2
South Core Elevation
86'-6" Core
West Elevation - Moment Frame and Bracing
East Elevation - Moment Frame and Bracing
South Elevation - Perimeter Moment Frame
N
Truss
Eight Cantilever Transfer Girders
Four Transverse Core Elevations
Elevators

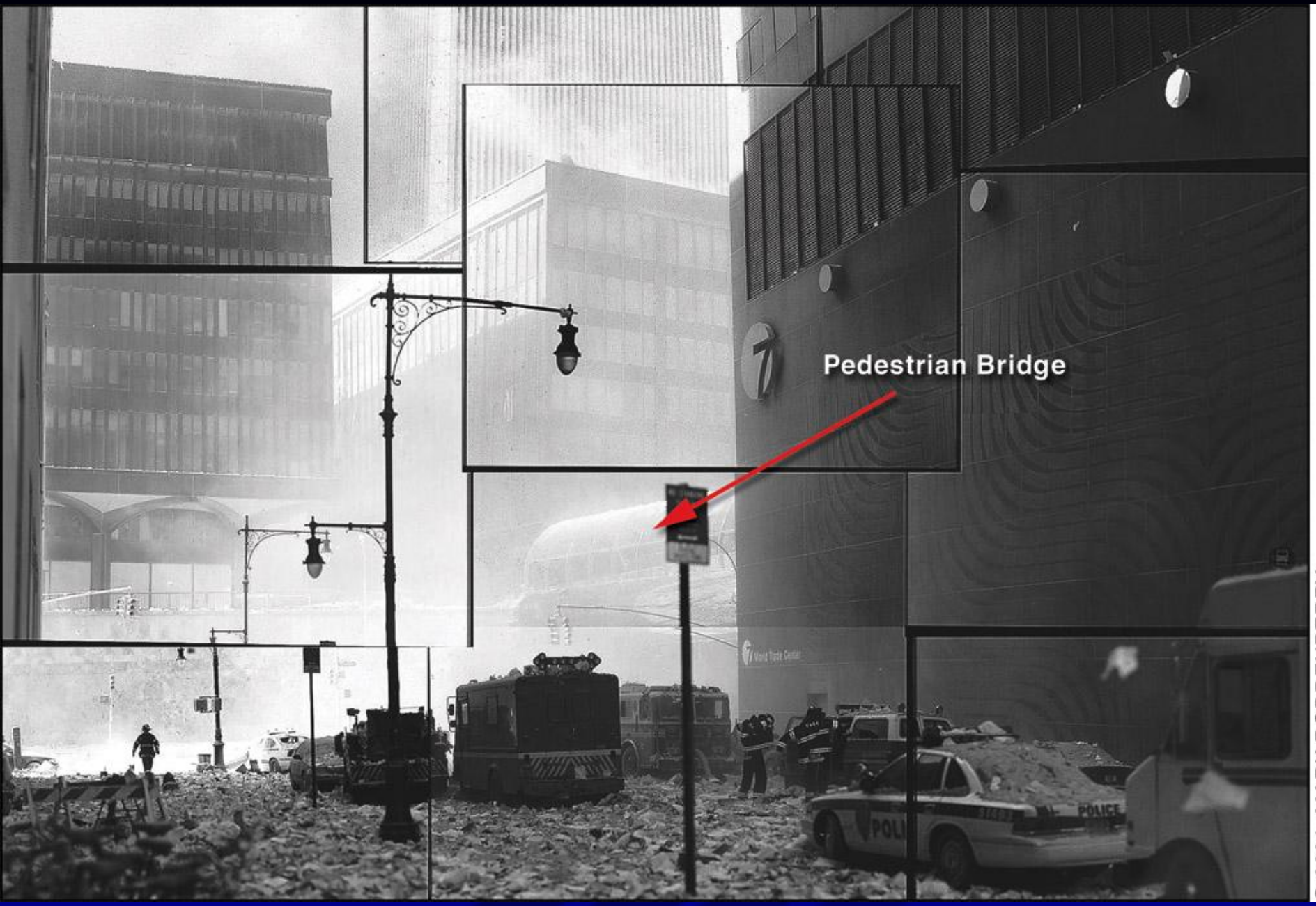

Centerline
Continuous
Column at Core
Centerline
Column
Above
West
East
7th Floor
W36x210
W24x55
W14x655
(Compression)
Splice
BPM (790 lb/ft)
(Compression)
6th Floor
W33x118
Splice
Splice
5th Floor
BPM (1,060 lb/ft)
(Tension)
Transfer
Girder


Centerline
Continuous Column
Centerline
Column Above
Centerline
Continuous Column
West
East
W14x730
7th Floor
W33x118
Splice
Splice
W33x130
BPM (890 lb/ft)
(Compression)
BPM (890 lb/ft)
(Compression)
6th Floor
W21x62
W14x48
W14x82
(Tension)
5th Floor
Splice
Splice
BPM (1,060 lb/ft)
(Tension)

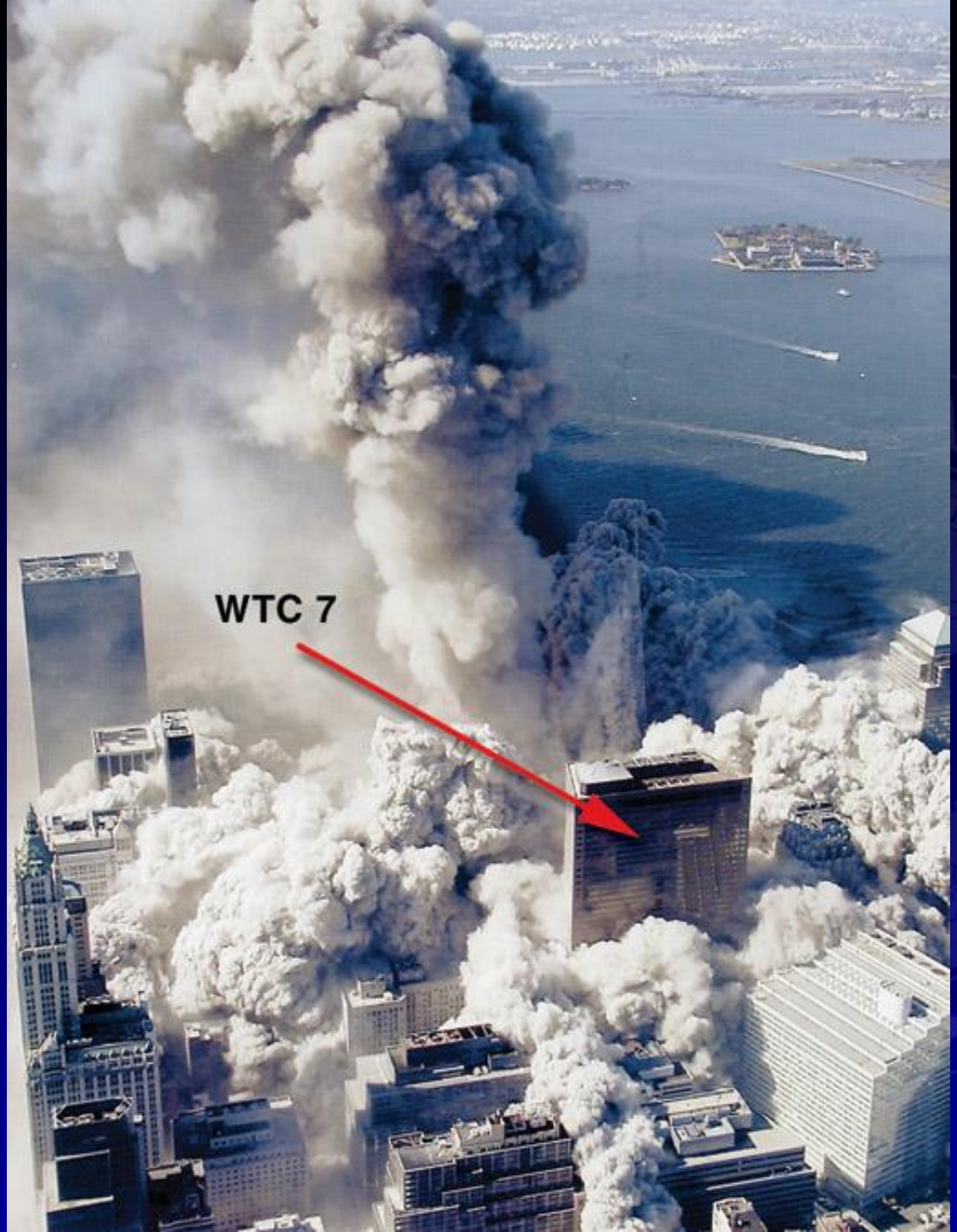

Centerline
Continuous Column
Centerline
Column Above
South
7th Floor
North
W14x342
W14x605
(Tension)
(Compression)
W14x605
W14x730
(Tension)
W14x730
W14x730
(Compression)
Continuous Column
6th Floor
W14x342
W14x455
W14x605
(Tension)
(Compression)
W14x605
W14x730
W14x730
W14x730
W14x500
(Compression)
(Tension)
5th Floor
W14x342
Columns Continue Down
Hanger Below


Granite Spandrel
Spray-on Fireproofing
Steel Beam
Granite Pilaster
2" Thermafibre
Compressible Thermafibre
Concrete Slab
Metal Deck
14-Gauge Firestop
Granite Spandrel


Plaza Bridge
Pedestrian Bridge
N
BARCLAY ST.
WASHINGTON ST.
WEST BROADWAY
Verizon
WTC 7
U.S. Post Office
VESEY ST.
WEST ST.
WTC COMPLEX
A. Collapse of WTC 2
B. Collapse of WTC 1
Debris Hits 30 West Broadway
C. Collapse of WTC 7



© 2001, MARK RODDENBERRY


WTC 7

GEORGE MILLER / NYCTA

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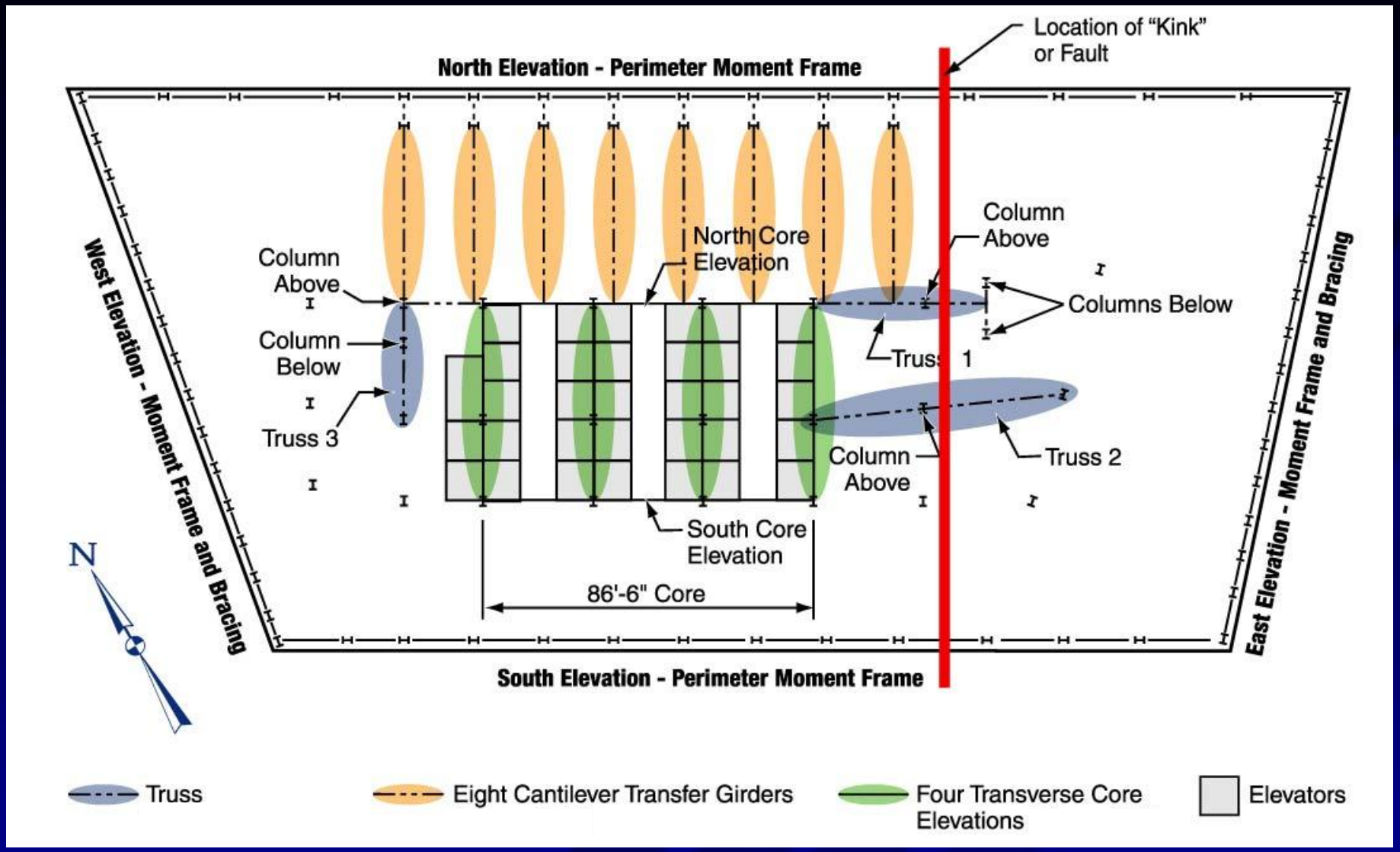
Location of "Kink" or Fault
North Elevation - Perimeter Moment Frame
West Elevation - Moment Frame and Bracing
East Elevation - Moment Frame and Bracing
South Elevation - Perimeter Moment Frame
Column Above
Column Below
Truss 3
North Core Elevation
South Core Elevation
86'-6" Core
Column Above
Columns Below
Truss 1
Truss 2
Column Above
N
Truss
Eight Cantilever Transfer Girders
Four Transverse Core Elevations
Elevators

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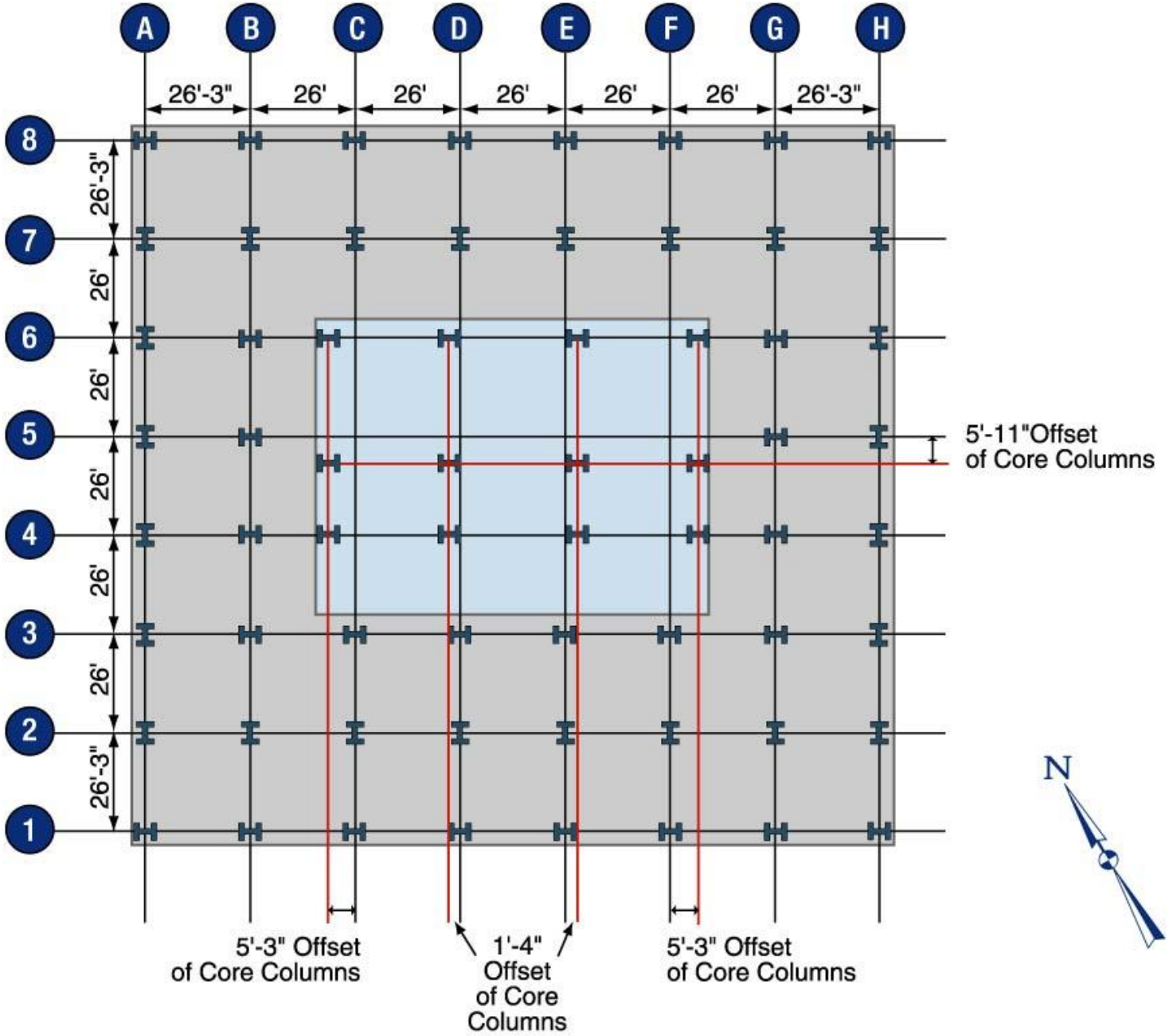
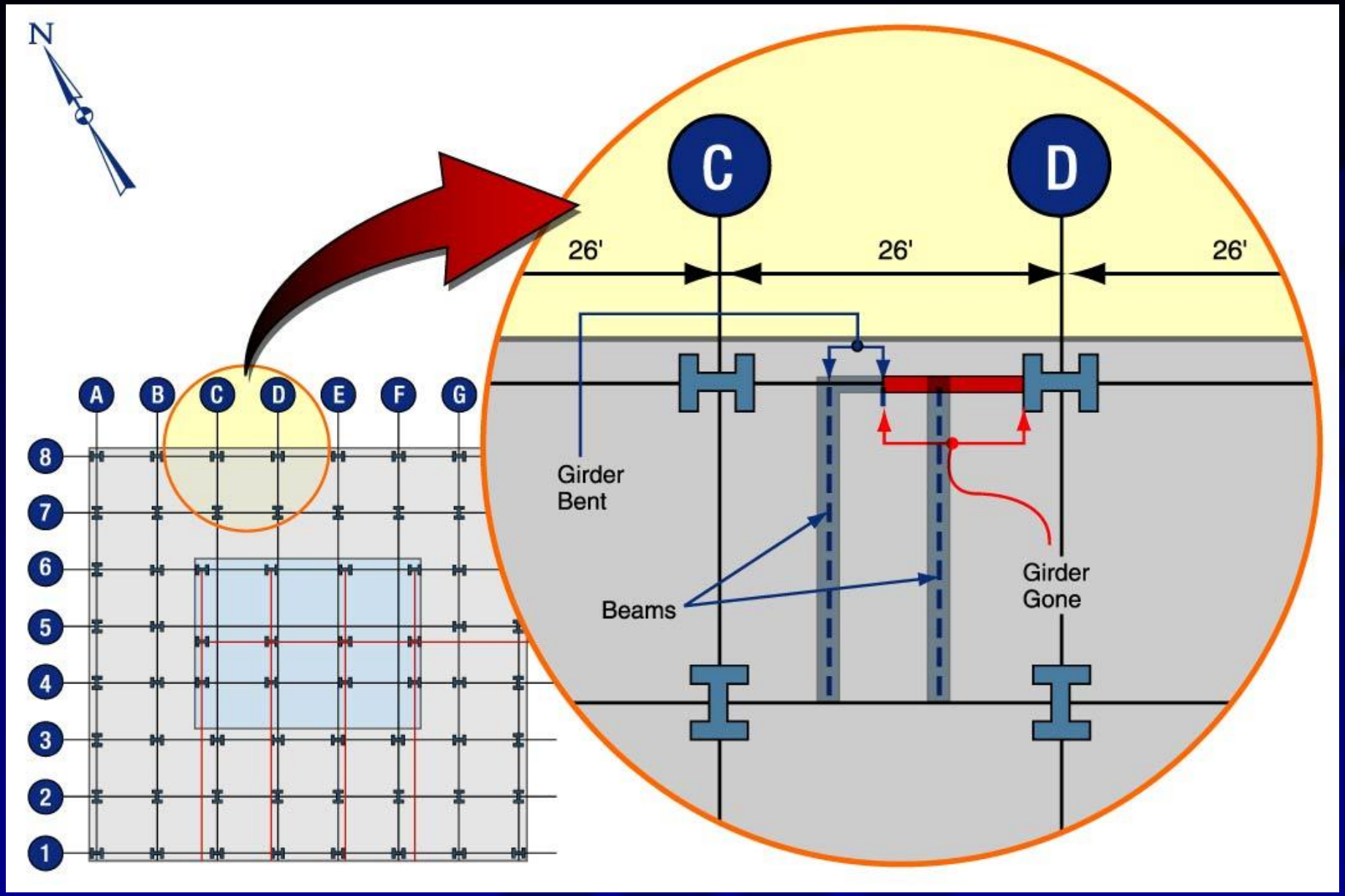
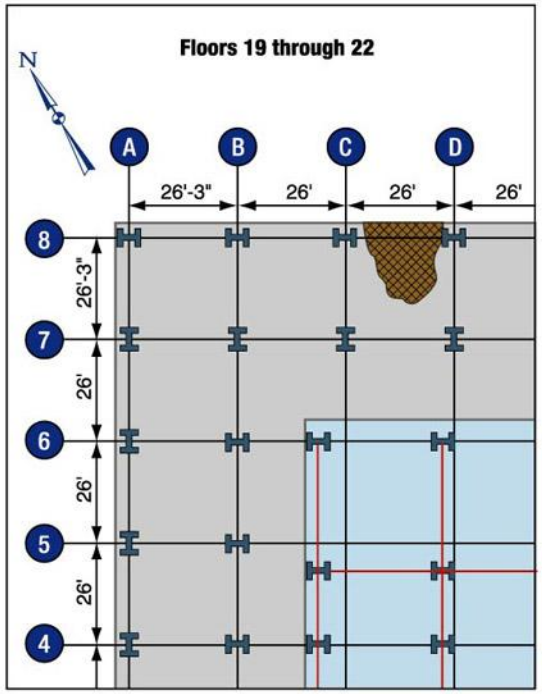
30 West
Broadway
Irving Trust
N
Verizon
WTC 7
U.S. Post Office
WTC 6
WTC 5

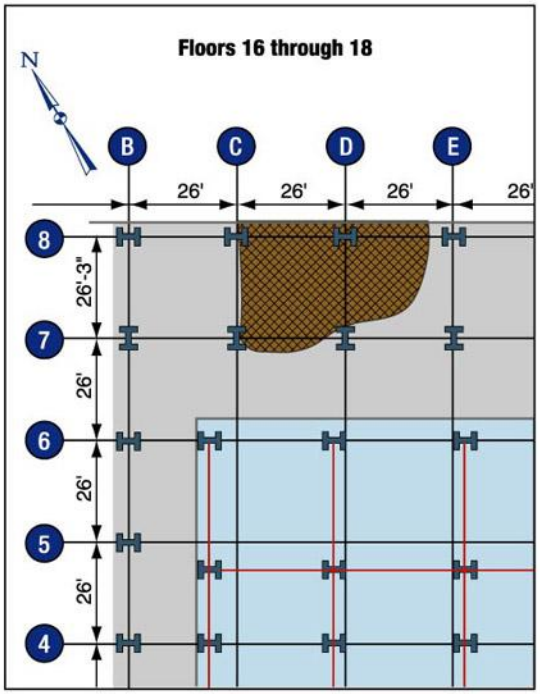
Recommendations

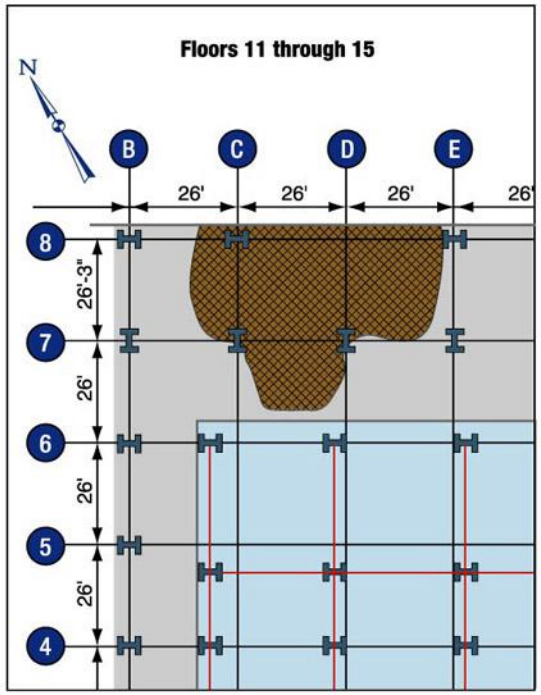
- Collect additional data to confirm the extent of the damage to the south face of WTC 7 caused by falling debris.
- Determine the specific fuel loads, especially at the lower levels, to identify possible fuel supplied to sustain the fires for a substantial duration. Areas of interest include storage rooms, file rooms, spaces with high-density combustible materials, and locations of fuel lines. The control and operation of the emergency power system, including generators and storage tanks, needs to be thoroughly understood. Confirm the ability of the diesel fuel pumps to continue to operate and send fuel to the upper floors after a fuel line is severed.
- Examine the anticipated temperatures and duration of the fires and the effects of the fires on the structure, with an emphasis on the behavior of transfer systems and their connections.
- Study and confirm suggested mechanisms for a progressive collapse. Determine how the collapse of an unknown number of gravity columns brought down the whole building.
- Explain the role that the axial capacity between the beam-column connection and the relatively strong structural diaphragms may have had in the progressive collapse.
- Study the level of fire resistance and the ratio of capacity-to-demand required for structural members and connections deemed to be critical to the performance of WTC 7. The collapse of some structural members and connections may be more detrimental to the overall performance of the building than other structural members. Also study the adequacy of current design provisions for members whose failure could result in large-scale collapse.

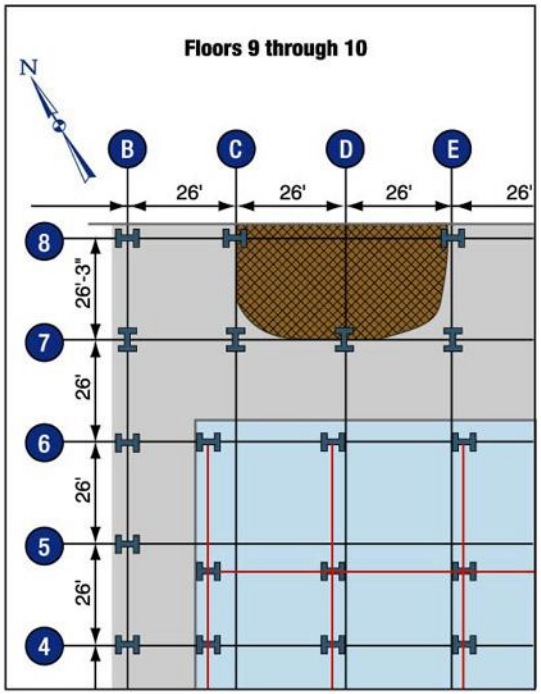

A
B
C
D
E
F
G
H
26'-3"
26'
26'
26'
26'
26'
26'-3"
8
7
6
5
4
3
2
1
26'-3"
26'
26'
26'
26'
26'
26'-3"
5'-11"Offset
of Core Columns
5'-3" Offset
of Core Columns
1'-4"
Offset
of Core
Columns
5'-3" Offset
of Core Columns
N


N
A
B
C
D
E
F
G
8
7
6
5
4
3
2
1
C
D
26'
26'
26'
Girder
Bent
Beams
Girder
Gone


Floors 19 through 22
N
A
B
C
D
26'-3"
26'
26'
26'
8
7
6
5
4
26'-3"
26'
26'
26'

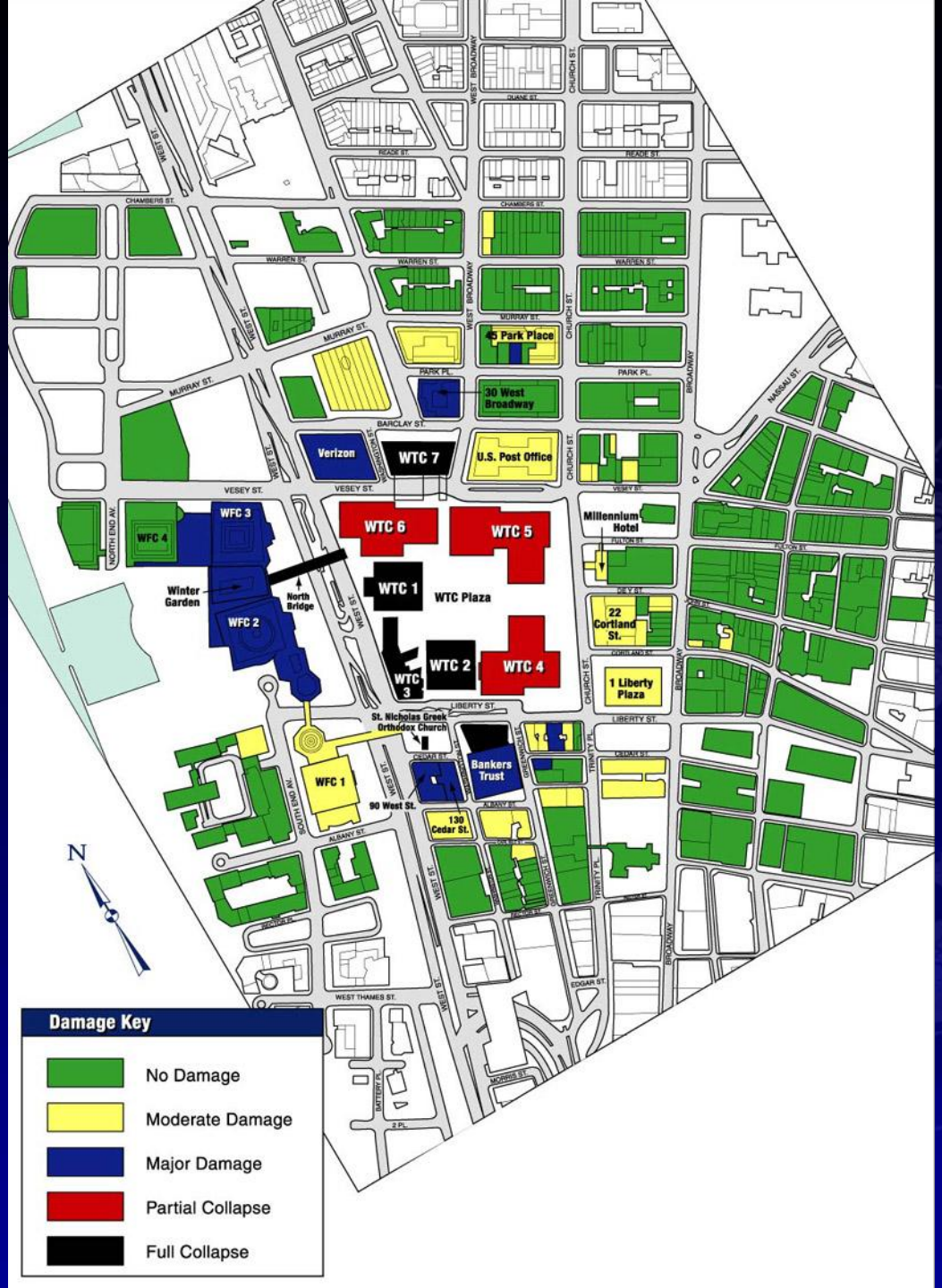

Floors 16 through 18
N
B
C
D
E
26'
26'
26'
26'
8
7
6
5
4
26'-3"
26'
26'
26'


Floors 11 through 15
N
B
C
D
E
26'
26'
26'
26'
8
7
6
5
4
26'-3"
26'
26'
26'


Floors 9 through 10
N
B
C
D
E
26'
26'
26'
26'
8
7
6
5
4
26'-3"
26'
26'
26'

Recommendations

- Determine whether the observed damage in the column flange, and not at the beam flange, of the moment frames top connection plates is due to high restraint in the welds.
- Conduct further studies as to why the bottom flange welded connection has typically failed at the fillet weld to beam interface and not at the fillet weld to seat plate interface.
- Examine the impact response of various moment-connected details.
- Determine if composite construction would reduce local collapse zones. (There were no shear connectors to provide composite action between the floor beams and slab. Composite construction would have increased the capacity of the members and may have dissipated more of the impact energy; however, it may have also pulled a greater extent of the adjoining regions into the collapse zone.)
- Conduct further studies as to whether perimeter rebar in the slabs could improve the structural response by providing catenary action and tensile force resistance in the slabs to reduce local collapse zones.
- Determine whether the partial-strength connections permitted members to break away from the structure, thereby limiting the extent of damage. (If the moment connections had been designed for the capacity of the sections, as opposed to fully rigid partial strength based on design load and stiffness requirements, the building performance is likely to have been different.)
- Determine whether the collapse zone would have been limited if the spandrels on the 16th, 17th, and 18th floors had not been so grossly distorted through twisting.



Damage Key
No Damage
Moderate Damage
Major Damage
Partial Collapse
Full Collapse
N
WTC 1
WTC 2
WTC 3
WTC 4
WTC 5
WTC 6
WTC 7
WFC 1
WFC 2
WFC 3
WFC 4
WTC Plaza
Verizon
U.S. Post Office
30 West Broadway
45 Park Place
Millennium Hotel
22 Cortland St.
1 Liberty Plaza
Bankers Trust
130 Cedar St.
90 West St.
St. Nicholas Greek Orthodox Church
Winter Garden
North Bridge
WEST BROADWAY
CHURCH ST.
BROADWAY
WEST ST.
NORTH END AV.
SOUTH END AV.
WEST THAMES ST.
EDGAR ST.
MORRIS ST.
BATTERY PL.
2 PL.
TRINITY PL.
GREENWICH ST.
NASSAU ST.
CHAMBERS ST.
WARREN ST.
MURRAY ST.
PARK PL.
BARCLAY ST.
VESEY ST.
FULTON ST.
DEY ST.
CORTLAND ST.
LIBERTY ST.
CEDAR ST.
ALBANY ST.
DUANE ST.
READE ST.

No.	Block	Lot	Address	Name	Building Color Code[2]	Building Rating
1	16	100	395 South End Ave.	Gateway	Yellow	Moderate Damage
2	16	120	120 West St.	1 WFC Tower A	Yellow	Moderate Damage
3	16	120	120 West St.	South Bridge	Yellow	Moderate Damage
4	16	120	120 West St.	1-2 WFC Link Bridge	Yellow	Moderate Damage
5	16	125	125 West St.	2 WFC Tower B	Blue	Major Damage
6	16	140	200 Vesey St.	3 WFC Tower C - Annex	Blue	Major Damage
7	16	140	201 Vesey St.	Winter Garden Building	Blue	Major Damage
8	48	1	2 Wall St.		Yellow	Moderate Damage
9	49	2	111 Broadway		Yellow	Moderate Damage
10	51	14	125 Greenwich St.		Yellow	Moderate Damage
11	51	15	90 Trinity Pl.		Yellow	Moderate Damage
12	52	10	120 Cedar St.		Blue	Major Damage
13	52	15	110 Trinity Pl.		Yellow	Moderate Damage
14	52	21	120 Liberty St.		Yellow	Moderate Damage
15	52	22	124 Liberty St.	Fire Station	Yellow	Moderate Damage
16	52	30	106 Liberty St.		Yellow	Moderate Damage
17	52	7501	110 Liberty St.		Yellow	Moderate Damage
18	52	7502	114 Liberty St.	Engineering Building	Blue	Major Damage
19	53	23	5 Carlisle		Yellow	Moderate Damage
20	53	28	1 Carlisle		Yellow	Moderate Damage
21	53	33	110 Greenwich St.		Yellow	Moderate Damage
22	54	1	130 Liberty St.	Bankers Trust	Blue	Major Damage
23	56	1	130 Cedar St.		Blue	Major Damage
24	56	20	155 Cedar St.	Greek Orthodox Church	Black	Collapse
25	56	4	90 West St.		Blue	Major Damage
26	58		WTC 1	North Tower	Black	Collapse
27	58		WTC 2	South Tower	Black	Collapse
28	58		WTC 3	Marriott International Hotel	Black	Collapse
29	58	1	WTC 4	South East Plaza	Red	Partial Collapse
30	58	1	WTC 5	North East Plaza	Red	Partial Collapse
31	58	1	WTC 6	Custom House	Red	Partial Collapse
32	84		WTC 7		Black	Collapse
33	62	1	1 Liberty Plaza		Yellow	Moderate Damage
34	63	1	10 Cortland St.		Yellow	Moderate Damage
35	63	3	22 Cortland St.		Yellow	Moderate Damage
36	63	6	27 Church St.	Century 21	Yellow	Moderate Damage
37	63	13	189 Broadway		Yellow	Moderate Damage
38	63	15	187 Broadway		Yellow	Moderate Damage
39	65	10	9 Maiden Ln.	Jeweler's Building	Yellow	Moderate Damage
40	65	16	174 Broadway		Yellow	Moderate Damage
41	80	4	47 Church St.	Millennium Hotel	Yellow	Moderate Damage
42	84	1	140 West St.	Verizon	Blue	Major Damage
43	86	1	90 Church St.	Post Office	Yellow	Moderate Damage
44	88	2	12 Vesey St.		Yellow	Moderate Damage
45	88	8	26 Vesey St.		Yellow	Moderate Damage
46	88	10	28 Vesey St.		Yellow	Moderate Damage
47	88	13	14 Barclay St.		Yellow	Moderate Damage
48	125	20	100 Church St.		Yellow	Moderate Damage
49	126	2	110 Church St.		Yellow	Moderate Damage
50	126	9	45 Park Pl.		Blue	Major Damage
51	126	27	120 Church St.		Yellow	Moderate Damage
52	127	1	30 West Broadway		Blue	Major Damage
53	127	18	75 Park Pl.		Yellow	Moderate Damage
54	128	2	224 Greenwich St.		Yellow	Moderate Damage
55	136	15	60 Warren St.		Yellow	Moderate Damage
56	136	16	128 Chambers St.		Yellow	Moderate Damage

5th Floor
4th Floor
3rd Floor

5th Floor
4th Floor
3rd Floor
2nd Floor

CAUTION
CAUTION

Bankers Trust
WFC 1
90
West
130
Cedar

Recommendations

- Utilize the known data and conditions of the perimeter structures after the impact damage as a basis for calibration, comparison, and verification of existing software intended to predict such behavior, and for the development of new software for the prediction of the ability of structures to sustain localized and global overload conditions.

Overall Recommendations

- Conduct detailed modeling of the aircraft impacts into WTC 1 and WTC 2 to provide understanding of the probable damage state immediately following the impacts.
- Conduct detailed modeling of the fires and combine with structural modeling to develop specific failure modes likely to have occurred.
- Conduct detailed modeling of the floor framing systems and their connections to understand the effects of localized overloads and failures to determine ultimate failure modes. Other types of common building framing should also be examined for these effects.
- Conduct studies of the fire-performance of steel trusses with spray-applied fire protection, and with end restraint conditions similar to those present in the two towers.
- Conduct tests of spray-applied fireproofing materials to understand how well they withstand mechanical damage and to determine whether it is appropriate and feasible to improve their resistance to such damage.
- Conduct studies to determine, given the great size and weight of the two towers, whether there are feasible design and construction features that would permit such buildings to arrest or limit a collapse, once it began.