Opening Statement
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Report on the Collapse of World Trade Center Building 7

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Good morning. I am here to summarize the findings from our three-year study of the collapse of World Trade Center Building 7.

The collapse of WTC 7 has been a source of extensive speculation. No planes hit the building. There was damage to the building from the collapse of World Trade Center Tower 1, which was about 370 feet to the south. Here you can see the location of WTC 7 on a map. But despite damage that severed seven exterior columns, Building 7 remained standing.

The debris from Tower 1, however, started fires on at least 10 floors of the building. The fires burned out of control on six of these ten floors for about seven hours.

The city water main had been cut by the collapse of the two WTC Towers, so the sprinklers in Building 7 did not function for much of the bottom half of the building. Nevertheless, other tall office buildings have burned for as long or longer in similar fires without collapsing—when sprinklers either did not exist or were not functional.

So we knew from the beginning of our study that understanding what happened to Building 7 on 9-11 would be difficult. It did not fit any textbook description that you could readily point to and say, yes, that's why the building failed.

In August of 2002—exactly six years ago today, with authority and funding from Congress, NIST started its building and fire safety investigation of all three World Trade Center building collapses. The study of Towers 1 and 2 was extremely complex, and as a result, we had to place our study of WTC 7 on hold. In September of 2005, with the study of the towers complete, we began the study of Building 7's collapse in earnest.

We conducted our study with no preconceived notions about what happened. We gathered evidence, we analyzed that evidence, we constructed computer models grounded in principles of physics and using detailed data on every aspect of the building's construction, detailed information on its contents, videos and photos of the event, and witness accounts. We drew conclusions and validated them against the video and photographic record.

Our investigation team for this building consisted of about 50 people with expertise in structures, fire science and engineering, metallurgy, explosives, blast analysis, evacuation and emergency response, and other technical fields. Our own technical staff was complemented by world-class private sector experts on contract.

We conducted this study without bias, without interference from anyone, and dedicated ourselves to do the very best job possible.

We have had only one single-minded goal during this entire effort. We wanted to determine the probable sequence of events that led to the collapse of Building 7 on 9-11, and then to share that information with the public in order to improve building and fire safety.

Before I tell you what we found, I'd like to tell you what we did not find. We did not find any evidence that explosives were used to bring the building down. We ran detailed computer simulations of blast scenarios. What you see in this slide are the expected air pressures from the smallest possible blast capable of crippling a critical column. This size blast would have produced an incredibly loud sound that was not recorded on videos of the collapse nor reported by witnesses.

The collapse was also not due to fires from the substantial amount of diesel fuel stored in the building. Such fires from ruptured fuel lines—or from fuel stored in day tanks on the lower floors—could not have been sustained long enough, would not have generated sufficient heat to weaken critical columns, and would have produced copious smoke that was not was not observed on 9-11.

What we found was that uncontrolled building fires—similar to fires experienced in other tall buildings—caused an extraordinary event, the collapse of World Trade Center 7.

This is the first time that we are aware of, that a building taller than about 15 stories has collapsed primarily due to fires.

We reached this conclusion by reconstructing the entire building, beam by beam, column by column, connection by connection into a computer model, a virtual WTC 7 Building. We then filled that virtual building with as much detail as possible about exactly what types of furnishings were on each floor. Then we set fire to those virtual offices on the floors where video and other visual evidence told us the fires burned.

We used a well-validated computer program developed at NIST, for studying the growth and spread of fires, to calculate temperatures throughout the building. On the right in this slide, for example, you see a detailed fire simulation showing the temperature of fires as they grew and spread on floor 12.

And we used well-established data on the properties of structural steel, the sprayed fire resistive material or fireproofing, and other building materials to determine how those temperatures affected the structure.

A typical fire simulation for a single floor of the building took up to two days with a state-of-the-art cluster of Linux computers. The structural model of the building components used to predict the subsequent fire-induced progressive collapse included more than 3 million separate elements and took about 7 to 8 months to complete a single run on some very powerful computers.

A critical factor that led to the initiation of collapse was thermal expansion of long-span floor systems located in the east side of the building. Here you see a photo of these long span beams in WTC 7 near a specific column involved in the collapse, column 79.

Anyone who has run a tight jar lid under hot water to help loosen it up knows that metal expands when it gets hot. Beyond expansion, heat also causes steel to lose strength and stiffness. In our investigation of the collapse of Towers 1 and 2, loss of strength and stiffness was more important. For WTC 7, thermal expansion was a critical factor. These effects occur at temperatures much lower than those required to reduce steel strength and stiffness.

These two posters show why thermal expansion was so important for the collapse of WTC 7. Here's a layout of the columns in the building. You see that on the east side of the building, these long beams are connected to a girder here and here, but there are no opposing support beams.

The exterior columns of the building were more closely spaced than the interior ones. When fires heated the floor system, thermal expansion of the floor beams caused damage to connections between the steel beams and concrete slab of the composite floor system. Some of the beams buckled. Others pushed the girders, causing some of them to buckle. A few girders lost their connections to columns, triggering floor failures.

Fires on Floors 7 through 9 and 11 through 13 were particularly severe. Long-span steel beams on the lower floors of the east side of the building, expanded significantly due to these fires, damaging the floor framing on multiple floors. Eventually, a girder on Floor 13 lost its connection to a critical interior column that provided support for the long span floors on the east side of the building. The displaced girder, and other local fire-induced damage, caused Floor 13 to collapse. This began a cascading chain of failures of eight additional floors—many of which already had been at least partially weakened by the fires in the vicinity of the critical column. With the support of these floors gone, column 79 buckled, which initiated the fire-induced progressive collapse of the building.

Here's a close up from the structural computer model we developed showing how the floor failures lead to an unsupported column on the far right and then buckling of that column.

This in turn caused the failure of nearby columns 80 and 81 and floor failures up to the roof line. These images show how the failure of column 79 matches up with a still frame from a video of the event. As the building starts to fall in the video, which I will show shortly, a kink occurs at the top of the building as the east penthouse falls. At the same time, the video shows windows breaking on the east side of the building.

When you overlay the layout of the penthouse with the diagram of the building floor framing, you can see how the girders between column 79, 80, and 81 line up with the kink seen in the penthouse.

As the roof line begins to fall adjacent columns buckle as well.

In quick succession, the remaining interior columns failed from east to west across WTC 7, until the entire core began moving downward. Finally, the remaining outer shell or façade of the building fell.

Here's a video taken on 9/11 that shows WTC 7 collapsing.

Note the kink in the east penthouse and the progression of the screening wall and the west penthouse collapsing from east to west.

Here's our structural model showing the building collapsing, which matches up quite well with the video of the event.

World Trade Center 7 was generally consistent with local building code in place at the time of its construction. If water had been available, it is likely that sprinklers in the lower floors of the building would have worked and the building would still be here today. The estimated 4,000 occupants of WTC 7 on 9/11 were evacuated without any fatalities or serious injuries.

In general, tall buildings are very safe. We have decades upon decades of real-life experience to prove this. This was a rare event.

This study has identified thermal expansion as a new phenomenon that can cause structural collapse. For the first time we have shown that fire can induce a progressive collapse.

In the building community the term "progressive collapse" means the spread of local damage from a single initiating event, from structural element to element, eventually resulting in the collapse of an entire structure or a disproportionately large part of it.

Currently thermal expansion effects are not explicitly considered in design practice for fire resistance ratings.

No design professional is assigned the explicit responsibility for ensuring the adequate fire safety performance of a building's structural system.

Architects typically use catalogued test data to specify fireproofing thickness to meet the fire ratings in the building code. Structural engineers design buildings to withstand its weight and to resist earthquake and wind loads, but are not required to consider fire as a load condition in structural design. Fire protection engineers design the active fire protection systems in buildings—such as sprinklers, fire alarms, and smoke management systems. They may or may not be called upon to assist the architect with the design of the passive fire protection system—such as fireproofing and compartmentation.

WTC 7, which included floor spans as long as 54 feet, had a structural system design that is in widespread use in other tall buildings. The length of floor spans is important. Longer beams can be subject to proportionally greater thermal expansion effects, but such effects may also be present in buildings with shorter span lengths depending on the design of the structural system.

We strongly recommend that building owners, operators, and designers evaluate buildings to ensure the adequate fire performance of the structural system. Of particular concern are the effects of thermal expansion in buildings with one or more features such as: long-span floor systems, connections not designed for thermal effects, asymmetric floor framing, and/or composite floor systems.

If thermal effects concerns are raised by this evaluation, possible retrofits may include strengthening connections, strengthening floor framing, increasing structural redundancy, and adding additional fireproofing to vulnerable areas. There clearly are ways available to address any concerns that arise from this analysis, but this situation should be analyzed by owners, operators, and designers for each structure on a case-by-case basis.

Our take-home message today is that the reason for the collapse of World Trade Center 7 is no longer a mystery. WTC 7 collapsed because of fires fueled by office furnishings. It did not collapse from explosives or from diesel fuel fires.

It collapsed because fires—similar to those experienced in other tall buildings—burned in the absence of water supply to operate the sprinklers, and burned beyond the ability of firefighters to control fires. It fell because thermal expansion, a phenomenon not considered in current building design practice, caused a fire-induced progressive collapse.

We urge the building community to explicitly address all the effects of fire in the design of structural systems, especially thermal expansion, by strengthening building codes, standards, and practices. Specifically, building codes and standards must be strengthened beyond the current intent to achieve life safety by preventing structural collapse in building fires—where sprinklers do not function, do not exist, or are overwhelmed by fire.

We will be accepting public comments on our final report until September 15, 2008. Directions for submitting these comments are provided on our web site at wtc.nist.gov.

At this point, I'll be happy to take your questions.

Thank you.