The Instantaneous Free Fall of World Trade Center Building 7 and NIST's Attempt to Hide It

David Chandler[1]
Ted Walter[2]
Tony Szamboti[3]

Abstract

In its final report on the collapse of World Trade Center Building 7 (WTC 7), the National Institute of Standards and Technology (NIST) described three stages of downward motion in the first several seconds of WTC 7's descent: a Stage 1 in which the acceleration was less than that of gravity; a Stage 2 in which the building's north face descended at gravitational acceleration (i.e., in free fall); and a Stage 3 in which the acceleration decreased as the upper portion encountered resistance from below. NIST then claimed that these three stages were consistent with the results of its global collapse analyses. Whereas NIST measured the downward motion by tracking one point near the center of the north face roofline, we measure the downward motion by tracking four points across the entire width of the north face roofline. We also measure the downward motion of two additional points across the entire width of the west face roofline, the only other face that was captured on video. We find that NIST's Stage 1 mischaracterizes and obscures the true nature of WTC 7's downward motion. While a point near the center of the north face roofline did begin to experience minimal downward motion at the time NIST labels as "global collapse initiation," the rest of the north face and west face rooflines remained essentially motionless for about 1.4 seconds. After that, the entire north face and west face rooflines instantaneously transitioned to free fall. This instantaneous transition to free fall of the entire measurable roofline is conspicuously absent from NIST's description of the downward motion. We then show that the observed behavior is not consistent with NIST's global collapse analyses and conclude by offering a different hypothesis of the building failure that is consistent with the observed behavior.

[1] B.S., Physics, Harvey Mudd College, Claremont, CA. M.A., Education, Claremont Graduate University, Claremont, CA. M.S., Mathematics, California Polytechnic University, Pomona, CA. Board member of the International Center for 9/11 Justice, which is affiliated with the *Journal of 9/11 Studies*.
[2] Master of Public Policy, University of California, Berkeley, CA. Executive director of the International Center for 9/11 Justice, which is affiliated with the *Journal of 9/11 Studies*.
[3] B.S., Mechanical Engineering, Villanova University, Villanova, PA. Mechanical design engineer with over 30 years of structural design experience in the aerospace and communications industries.

1. Introduction

The collapse of the 47-story World Trade Center Building 7 (WTC 7) on September 11, 2001, was ostensibly the first-known instance of a steel-framed high-rise collapsing solely due to fire. Some members of the engineering community have long maintained that WTC 7's destruction was a fire-induced "progressive collapse" (which is when a building or a significant portion of a building collapses due to the spread of an initial local failure). However, more than 20 years after the event, there are multiple conflicting fire-based theories. The most recognized of those theories was put forth in 2008 by the National Institute of Standards and Technology (NIST) following its six-year investigation of the collapse, but NIST's theory is far from universally accepted. The author of another fire-based theory, Jose Torero, and his co-authors wrote in 2020: "After years of investigation by some of the world's leading experts in both fire and structural engineering, there remains multiple possible hypotheses without any consensus on how the building behaved and failed because of fire. . . . Despite occurring nearly twenty years ago, there is no real way to know what caused its failure" (Orabi et al, 2020, pp. 1, 10).

At the same time, a growing number of engineers, scientists, and technical professionals have argued that WTC 7 was destroyed by controlled demolition. One of the key pieces of corroborating evidence for WTC 7's demolition is that the building came down in absolute free fall for approximately 2.5 seconds of its descent over a distance of more than 100 feet, or 8 stories (Legge, 2006; Chandler, August 2008). Free fall is indicative of controlled demolition because in free fall, *all* of the energy of the falling body is being transformed into kinetic energy, so there is no energy left over to do work on anything else. Therefore, something other than the falling mass must be what is destroying the underlying structure.

How did NIST account for WTC 7's free fall? In its draft report issued in August 2008, NIST *denied* that WTC 7 underwent free fall. Then, after receiving critical public comments in response to its draft report, NIST acknowledged in its final report that the building did undergo free fall for approximately 2.25 seconds. However, NIST attempted to portray this period of free fall as a perfectly normal occurrence by claiming that it was preceded by a gradual build-up to free fall involving a natural sequence of column failures — what NIST calls "Stage 1" of the building's descent.

In a series of videos published in 2008 and 2009, one of the authors of this paper (Chandler) disputed NIST's claim of a gradual build-up to free fall, arguing based on his measurement of the downward motion of the roofline at the northwest corner that the building's transition from a state of rest to free fall was instantaneous. Then, in April 2020, two of the authors of this paper (Chandler and Walter) performed new measurements of WTC 7's downward motion by tracking three points along the north face roofline, finding that all three points entered free fall simultaneously and instantaneously (Architects & Engineers for 9/11 Truth, 2020).

In this paper we provide a more comprehensive characterization of WTC 7's downward motion by including measurements of additional points along the *north and west face rooflines* as well as of the north screen wall and the west penthouse. We then examine whether the observed behavior is consistent with the results of NIST's global collapse analyses, as claimed by NIST in

its final report. We argue that it is not, and we offer a different hypothesis for the building failure that *is* consistent with the observed behavior.

2. Background

In the first section of this paper, we will trace how NIST handled WTC 7's free fall and how criticism of this aspect of NIST's report has evolved from 2008 up to the present.

2.1 NIST's Initial Denial of Free Fall

In its draft report for public comment on the collapse of WTC 7 issued on August 21, 2008, NIST described the "collapse time" for the first 18 floors of descent as being 40% longer than the time it would have taken for the building to collapse in free fall. In a section of its draft report titled "Collapse Time," NIST stated:

> "NIST was interested in estimating how closely the time for WTC 7 took to fall compared with the descent time if the building were falling freely under the force of gravity. . . . The time the roofline took to fall 18 stories was 5.4 s, with an uncertainty of no more than 0.1 s. . . . [T]he estimated free fall time for the top of the north face to fall 18 stories was approximately 3.9 s. . . . Thus, the actual time for the upper 18 floors of the north face to collapse, based on video evidence, was approximately 40 percent longer than the computed free fall time. The actual collapse time of the upper 18 floors of the north face of WTC 7 (the floors clearly visible in the video evidence) was 40 percent greater than the computed free fall time. This was consistent with physical principles" (NCSTAR 1-9 Draft Report for Public Comment, pp. 595-596).

While the above passage *implies* that WTC 7 did not undergo free fall for any portion of its descent, NIST explicitly made this claim in the FAQs it published in conjunction with the release of its draft report, stating as follows:

> **[Question:] "In videos, it appears that WTC 7 is descending in free fall, something that would not occur in the structural collapse that you describe. How can you ignore basic laws of physics?**
>
> "WTC 7 did not enter free fall. According to NIST analysis of WTC 7 video, the building collapsed 18 stories in 5.3 [sic] seconds. If the building exhibited free fall, this process would have taken just 3.9 seconds. The actual collapse time exceeded the free fall time by 40 percent."

It is reasonable to deduce that NIST's superficial analysis of the "collapse time" was not a simple oversight but rather an intentional attempt to show that WTC 7 did not undergo free fall. The investigators at NIST must have known that simply examining the building's position at two points in time and assuming a constant rate of acceleration between those two points was not a scientifically valid way to characterize the building's motion. But rather than accurately measuring the downward motion and finding a way to accommodate the fact of free fall within their progressive collapse scenario, they took the approach of denying free fall altogether and

then using the alleged absence of free fall to dismiss any consideration of the argument that WTC 7 was demolished. By going out of its way to avoid acknowledging free fall, NIST was implying that free fall is not consistent with a natural progressive collapse.

The incompatibility of free fall with a natural progressive collapse was further suggested by NIST Lead Investigator Dr. Shyam Sunder during NIST's WTC 7 Technical Briefing on August 26, 2008. When responding to a question posed by Chandler asking how NIST could ignore the fact that WTC 7 underwent free fall, Sunder reiterated NIST's position that free fall did not occur and explained why it would not occur in a natural progressive collapse. Sunder stated:

> "The analyses show there's a difference in time between a free-fall time — **a free-fall time would be an object that has no structural components below it**. . . . What the collapse analysis shows, that same time that it took for the structural model to come down from the roofline all the way for those 17 [sic] floors to disappear is 5.4 seconds. It's about 1.5 seconds, or roughly 40 percent more time for that free fall to happen. **And that is not at all unusual because there was structural resistance that was provided in this particular case. And you had a sequence of structural failures that had to take place and where everything was not instantaneous.**" [Emphasis added.]

To summarize Sunder's words, free fall occurs when there are no structural components below an object. It does *not* occur when there *is* structural resistance and when a sequence of structural failures takes place over time. In the case of WTC 7, free fall could *not* have occurred, he claimed, because there *was* structural resistance and a sequence of structural failures had to take place over time.

2.2 NIST's Admission of Free Fall

After receiving critical public comments in response to its draft report, NIST, in its final report issued on November 20, 2008, abandoned its outright denial of free fall. The section of the report that NIST previously titled "Collapse Time" was now titled "Timing of Collapse Initiation and Progression." Rather than replacing its original "collapse time" analysis, NIST supplemented it with a second "more detailed analysis" that examined the downward motion over the entire 5.4 seconds, dividing it into a three-stage descent where the second stage is 2.25 seconds of free fall.

Note that the video NIST used was taken "from the vantage point of West Street near Harrison Street," i.e., northwest of WTC 7, and at street level, looking up at the building. As shown in Figure 5-186 of NCSTAR 1-9 presented below, NIST labeled this video "Camera 3." Below that, we present NIST's description of its analysis, edited for brevity and with **key language bolded**.

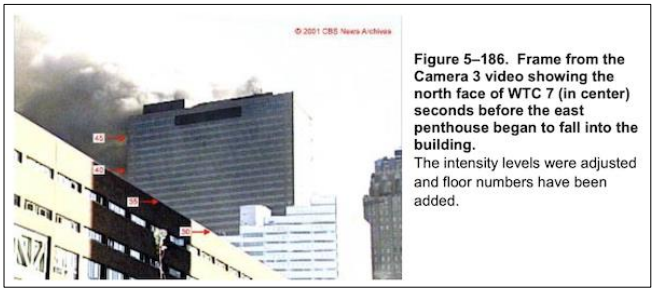

Figure 5–186. Frame from the Camera 3 video showing the north face of WTC 7 (in center) seconds before the east penthouse began to fall into the building.
The intensity levels were adjusted and floor numbers have been added.

"To obtain a better understanding of the vertical motion of the building in the first several seconds of descent, the motion of the north face was studied in more detail **by tracking the vertical position of a point near the center of the roofline** using the same video. . . .

"Figure 12–76 presents a plot of the downward displacement data shown as solid circles. . . . The fitted displacement function was differentiated to estimate the downward velocity as a function of time, shown as a solid curve in Figure 12–77. . . . **The slope of the velocity curve is approximately constant between about 1.75 s and 4.0 s. . . . The slope of the straight line, which represents a constant acceleration, was found to be 32.2 ft/s^2 (with a coefficient of regression $R^2 = 0.991$), equivalent to the acceleration of gravity *g*. . . .**

"For discussion purposes, three stages were defined, as denoted in Figure 12–77:

- **In Stage 1, the descent was slow and the acceleration was less than that of gravity. This stage corresponds to the initial buckling of the exterior columns in the lower stories of the north face**, as seen in Figure 12–62. By 1.75 s, the north face had descended approximately 7 ft. [Note: In NCSTAR 1A, NIST gave a displacement figure of "approximately 2.2 m (7 ft)."]

- In Stage 2, **the north face descended at gravitational acceleration, as exterior column buckling progressed and the columns provided negligible support to the upper portion of the north face.** This free fall drop continued for approximately 8 stories (105 ft), the distance traveled between times t = 1.75 s and t = 4.0 s.

- In Stage 3, the acceleration decreased somewhat as the upper portion of the north face encountered increased resistance from the collapsed structure and the debris pile below. Between 4.0 s and 5.4 s, the north face corner fell an additional 39.6 m (130 ft).

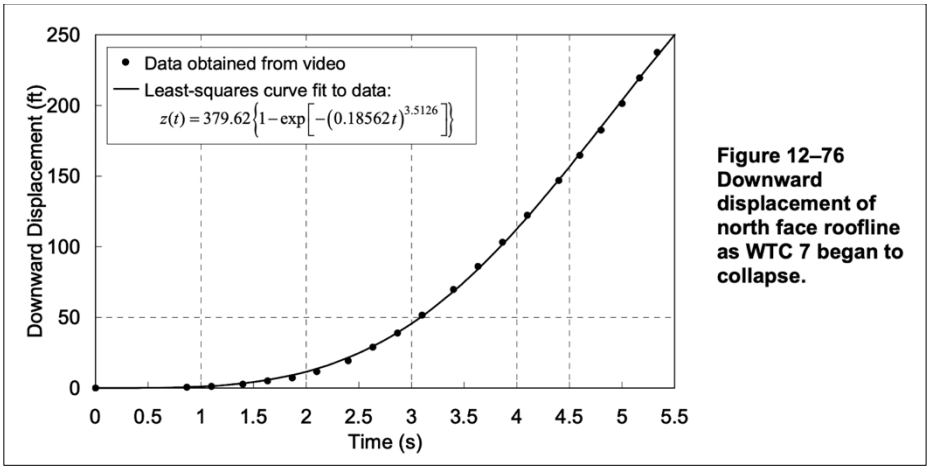

Figure 12–76
Downward displacement of north face roofline as WTC 7 began to collapse.

"As noted above, the collapse time was approximately 40 percent longer than that of free fall for the first 18 stories of descent. **The detailed analysis shows that this increase in time is due primarily to Stage 1, in which column buckling was just beginning and gradual increases in displacement and velocity were observed. The three stages of collapse progression described above are consistent with the results of the global collapse analyses discussed earlier in this chapter.**"

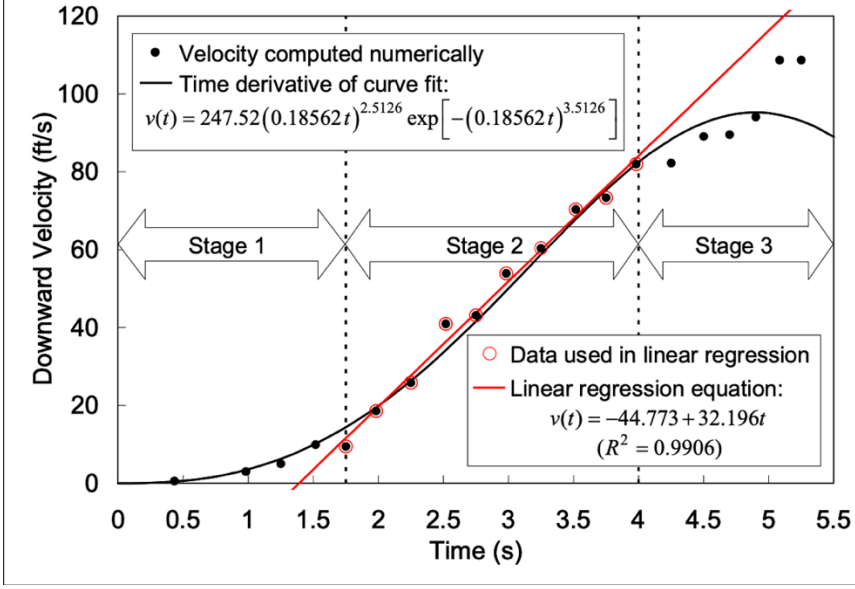

Figure 12–77 Downward velocity of north face roofline as WTC 7 began to collapse.

(NCSTAR 1-9, pp. 600-603)

Prior to its final report, NIST had taken the approach of denying free fall outright and implying that free fall was incompatible with a natural progressive collapse. It now accommodated the fact of free fall by claiming that it was preceded by a "Stage 1" in which "acceleration was less than that of gravity," involving "gradual increases in displacement and velocity" as "column buckling was just beginning." The smooth curve superimposed on the velocity points in Figure 12-77 above is NIST's attempt to graphically depict a gradual build-up to free fall. It has no physical significance. It is merely an interpolation curve that serves to create the impression of a smooth build-up to free fall.

The notion that WTC 7's transition to free fall was not instantaneous — but rather was preceded by a gradual build-up in "Stage 1" — was fundamental to NIST accommodating the occurrence of free fall without conceding that free fall undermined its progressive collapse scenario. By portraying a gradual build-up to free fall, NIST was attempting to make free fall seem more compatible with a natural progressive collapse. It was also a way of maintaining NIST's original claim of a collapse time 40% slower than a free-fall time.

As shown in the excerpt above, NIST then ended this section of its report by asserting, without explanation, that the three stages of descent were consistent with the results of its global collapse analyses. NIST also claimed in the preceding section of its report that "Given the complexity of

the modeled behavior, the global collapse analyses matched the observed behavior reasonably well. The global collapse analyses confirmed the leading collapse hypothesis, which was based on the available evidence" (NCSTAR 1-9, p. 600). These central claims in NIST's report will be scrutinized in the latter part of this paper.

2.3 Chandler's Early Challenge of NIST's Stage 1

One month after NIST's final report was released, Chandler published a three-part series of short videos titled *NIST Finally Admits Free Fall* in which he responded to NIST's admission of free fall. He challenged NIST's early start time, i.e., the beginning of NIST's Stage 1 or "global collapse initiation," and he argued that the building's transition to free fall was in fact instantaneous. This argument was based on his measurement of the downward motion of the roofline at the northwest corner using the video footage filmed by CBS News, pictured below. (This is a well-known clip in which CBS news anchor Dan Rather famously commented that WTC 7's collapse was "reminiscent of those pictures we've all seen too much on television before, when a building was deliberately destroyed by well-placed dynamite to knock it down.")

Figure 1: CBS News video of WTC 7's collapse featuring anchor Dan Rather.

In Part II of the series, Chandler specifically examined the building's lack of downward motion at the point NIST identified as the start of Stage 1 (i.e., "global collapse initiation"). He allowed for the possibility that NIST investigators may have detected a tiny movement at this point in time. Nevertheless, he surmised, they must have realized that this was not the true start of the building's downward motion. An excerpt from Part II is presented below:

> "The only rationale I can see for choosing Frame 16 to start the clock is to make the measurement come out to exactly 5.4 seconds to agree with the prediction of NIST's collapse model. But what if I'm wrong? What if they did see some tiny movement on a clearer version of the video? That tiny movement, whatever it might have been, did not last. It would have had to have been a glitch. And the scientists at NIST would recognize

it as a glitch, because there was no measurable difference of the height of the roofline for the next 20 to 30 frames. What can we conclude? You can draw your own conclusions. But I think it's pretty clear that the whole idea there was any kind of real 5.4-second collapse interval is a fiction" (Chandler, December 2008, at 4:27 to 5:10).

In Part III, Chandler analyzed the instantaneous nature of the transition to free fall versus NIST's attempt to portray the transition to free fall as a gradual build-up. An excerpt of Part III is presented below, together with a graph showing Chandler's measurement of the velocity versus NIST's velocity graph that Chandler was critiquing.

"The fact of free fall by itself is strong evidence of explosive demolition, but the evidence is even stronger than that. . . . What is particularly striking is the suddenness of onset of free fall. Acceleration doesn't build up gradually. The graph simply turns a corner. The building went from full support to zero support instantly.

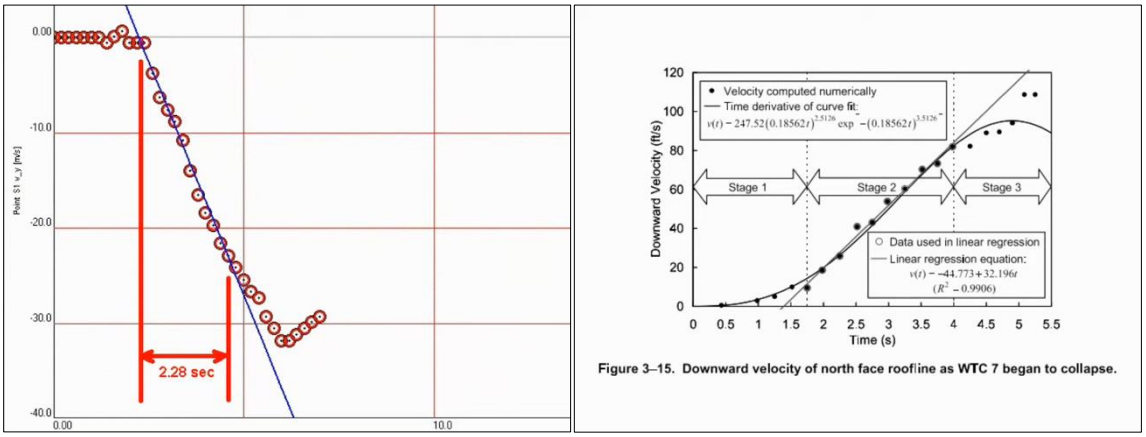

Figure 2: From *NIST Finally Admits Free Fall*. Left: Chandler velocity graph. Right: NIST velocity graph.

"NIST's graph is upside down relative to mine, but that's really not an issue. Their data is almost the same. What is dramatically different is the curve they superimpose on the data. This curve has no physical significance whatsoever. . . . The straight part fits the data reasonably well. What is totally misleading are the gradual transitions into and out of free fall. . . .

"The onset of free fall was not only sudden, it extended across the whole width of the building. My measurement of the acceleration of the building was based on the northwest corner. NIST's recent measurement confirming free fall was based on a point midway along the roofline. The fact that the roof stayed level shows that the building was in free fall across the entire width. The collapse we see cannot be due to a column failure or a few column failures or a sequence of column failures. All 24 interior columns and 58 perimeter columns had to have been removed over the span of 8 floors low in the building simultaneously to within a small fraction of a second and in such a way that the top half remained intact and uncrumpled" (Chandler, January 2009, at 1:57 to 3:58).

In the above excerpt, Chandler notes that his measurement was based on the northwest corner of the building and that NIST's measurement was based on a point near the center of the roofline. Chandler used these corresponding data points to deduce that WTC 7 was descending in free fall across its entire width. What Chandler did not comment upon at that time was whether both points *entered* free fall at precisely the same time — though, as he noted in Part II of *NIST Finally Admits Free Fall*, he could not detect any downward motion near the center of the north face roofline before the start of free fall at the northwest corner.

2.4 Updated Measurements for the 2020 Request for Correction

In subsequent years, Chandler continued to explore whether NIST's early start time was based on some tiny downward motion that NIST investigators had detected at the start of NIST's Stage 1 or whether there was no observational basis whatsoever.

In 2018, in an article published on the website Medium.com, Chandler hypothesized that NIST's early start time was derived by misinterpreting a vertical fold in the north face of WTC 7 as downward motion in the roofline due to the parallax of the Camera 3 view, which made it impossible to distinguish lateral and downward motion (Chandler, 2018). Figure 5-203 of NCSTAR 1-9, shown below, demonstrates how the lateral fold in the north face can appear as a downward kink in the roofline from the vantage point of Camera 3 (pictured on the right), which NIST used for its analysis of the descent. The video that NIST labeled "Camera 2" (pictured on the left), which is roughly level with the roofline, shows that the roofline remained largely straight during the descent, indicating that the apparent kink was actually a lateral fold (along a vertical axis) in the north face. Thus, NIST's use of Camera 3 to measure the downward motion introduced ambiguity sufficient to invalidate its measurements.

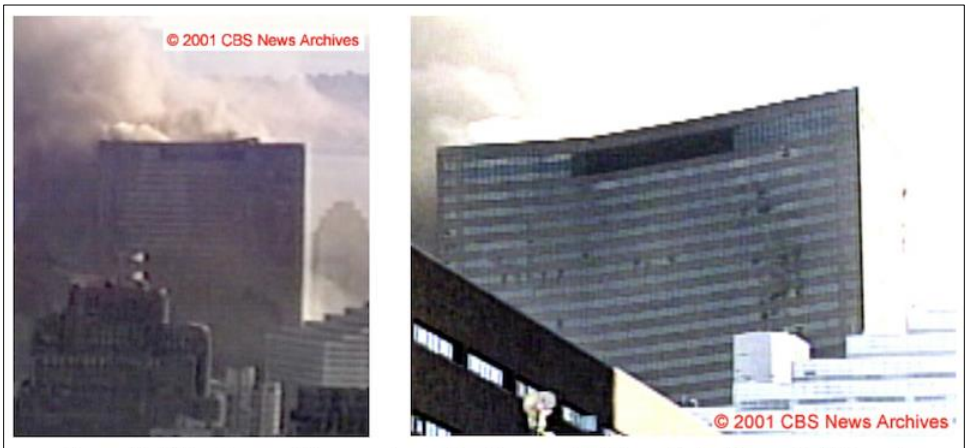

Figure 5–203. Cropped frames from the Camera 2 video clip in Figure 5–185 and the Camera 3 video clip in Figure 5–186, showing the north face of WTC 7 9.0 s ± 0.1 s after the east penthouse began to move downward.
The intensities have been adjusted.

Then, while preparing his contribution to a "request for correction" of the NIST WTC 7 report to be submitted to NIST in April 2020, Chandler updated his measurements of WTC 7's downward motion in collaboration with Walter (Architects & Engineers for 9/11 Truth, 2020). Instead of tracking the downward motion only at the northwest corner, Chandler and Walter tracked the

downward motion at three points across the entire width of the north face roofline: the northwest corner, the northeast corner, and a point near the center meant to approximate the point that NIST had tracked in its analysis, which was understood to be a point aligned with the east edge of the louvers on the 46th and 47th floors (the long black rectangle near the top of the north face).

In his earlier analyses, Chandler had used the CBS News footage featuring Dan Rather. For the request for correction, he used a different piece of CBS News footage — the video which NIST labeled "Camera 2" and is shown on the left in Figure 5-203 above. Chandler found the Camera 2 footage to be significantly more stable than the Dan Rather footage. Tracking a point at the corner of an adjacent stationary building showed only small random movement of no more than +/- 10 centimeters (a very stable shot for a camera a few miles away from WTC 7).

To Chandler and Walter's surprise, a small amount of downward motion near the center of the north face roofline could be detected during NIST's Stage 1. Specifically, between 6.9 and 8.2 seconds after the start of the east penthouse collapse (the start of the east penthouse collapse is the event that NIST used as zero in its timescale), the point near the center of the roofline dropped approximately half a meter, then stopped, and then dropped approximately one meter further. The start of downward motion near the center of the roofline at 6.9 seconds matches the start of NIST's Stage 1 or "global collapse initiation." However, between 6.9 and 8.2 seconds, the northwest and northeast corners remained essentially motionless — even though, according to NIST, global collapse had begun. Then, at about 8.2 seconds, within two-tenths of a second of one another, all three points along the roofline instantaneously transitioned to free fall. While the northeast corner became obscured by smoke partway into the descent, the center of the roofline and the northwest corner can be seen to continue in free fall for approximately 2.5 seconds. Graphs used in the request for correction to depict the downward velocity of all three points are presented below. In the timescale of these graphs, zero represents the time that NIST labeled as the start of Stage 1 or "global collapse initiation."

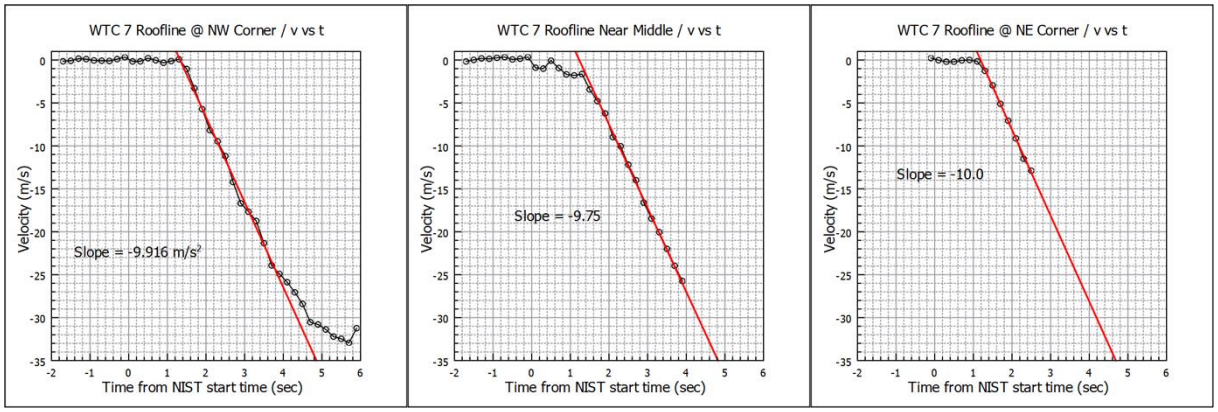

Figure 3: Left: Northwest corner velocity. Center: Center of roofline velocity. Right: Northeast corner velocity.

The request for correction also noted that NIST's own observations corroborated those of Chandler and Walter. For example, Figure 5-201 of NCSTAR 1-9, presented below, juxtaposes the position of WTC 7 at 5.0 seconds and at 7.5 seconds after the start of the east penthouse collapse (7.5 seconds is 0.6 seconds *after* the start of NIST's Stage 1 or "global collapse initiation"), with the white indicating how much displacement has occurred. The figure shows a

slight amount of displacement toward the center of the roofline and no displacement whatsoever at the northwest and northeast corners. NIST even remarked about the lack of displacement at 0.6 seconds after the supposed initiation of global collapse, stating: "Interestingly, little movement of the northeast and northwest corners of the building is indicated" (NCSTAR 1-9, p. 274).

Figure 5–201. Cropped difference frame at 7.5 s ± 0.1 s after the east penthouse began to move, created by subtracting the frame reproduced in Figure 5–199 from the Camera 3 video clip shown in Figure 5–200.
The intensity levels were adjusted.

Figure 5-205 of NCSTAR 1-9, part of which is presented below (the video frames after 8.8 s have been cropped out for brevity), corroborates Chandler and Walter's measurements over a longer stretch of time. It shows no displacement of the northwest and northeast corners at 7.3 seconds after the start of the east penthouse collapse, virtually no displacement at 7.8 seconds, and minimal displacement at 8.3 seconds, which is about 0.1 seconds after the instantaneous start of free fall across the north face roofline, according to Chandler and Walter's measurements.

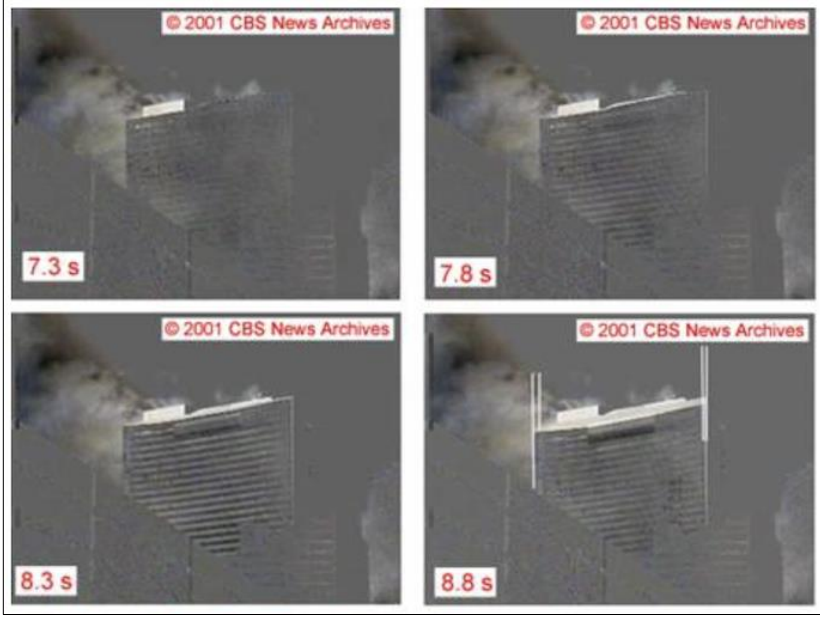

Figure 5–205. Difference images from the Camera 3 video clip showing the rotation of the northeast edge of WTC 7 during the global collapse.

Based on these new measurements, the request for correction noted three ways in which NIST's Stage 1 mischaracterized the downward motion. These are quoted below:

"1) It overstates by approximately half a second the period of time that the middle of the roofline experienced a "slow descent" before entering free fall, claiming that this period lasted 1.75 seconds when it was closer to 1.3 seconds;

2) It wrongly portrays the displacement of the middle of roofline during this 1.3 seconds as a smooth transition to free fall, when in fact it dropped approximately half a meter, stopped, and then dropped approximately 1 meter, before suddenly entering free fall;

3) Most importantly, it generalizes the downward motion of the middle of the roofline to represent the downward motion of the entire roofline, when in fact the northeast and northwest corners did not descend at all from 6.9 seconds to 8.2 seconds, and their transition from stasis to free fall was instantaneous and simultaneous . . . NIST's generalization of the entire roofline's behavior is exemplified in Figure 8-5 of NCSTAR 1-9, shown below, in which NIST states, "**Entire roofline** of north façade beginning to drop" "**about seven seconds** after the onset of collapse of the east penthouse" (emphasis added) (*see* NCSTAR 1-9, p. 327):

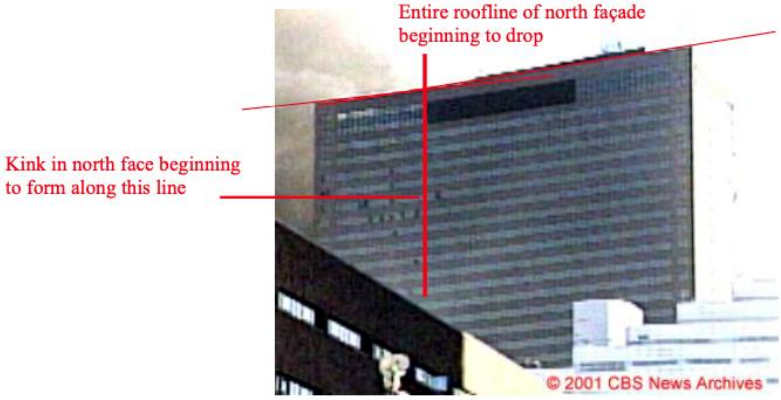

Figure 8–5. Global collapse of WTC 7 begins about seven seconds after the onset of collapse of the east penthouse.

Thus, the downward motion of WTC 7's north face roofline at the onset of global collapse is more accurately characterized as a sudden transition to free fall. Prior to the initiation of the entire roofline's free fall, the middle of the roofline dropped approximately half a meter, then stopped, and then dropped approximately 1 meter further, before entering into free fall along with the entire roofline" (Architects & Engineers for 9/11 Truth, 2020, p. 39).

In its response to the request for correction, NIST completely ignored the specific request for NIST to revise its report to reflect that the north face roofline actually underwent an instantaneous transition to free fall (NIST, 2020, p. 6).

3. New Measurements of WTC 7's Downward Motion

In the present paper, we provide updated measurements of the downward motion of the north face roofline, adding an additional point on the roofline for a total of four fairly evenly spaced points. Also, for the first time, we measured the downward motion of the west face roofline using video footage taken from the west, which enables us to characterize the downward motion of two sides of the building. The west face is especially significant because, as we will discuss in the next section, NIST claims the sequence of exterior column failures that allegedly culminated in the global collapse began at the southwest corner and spread northward along the west face before progressing to the north face. We also for the first time measured the downward motion of the north screen wall and the west penthouse, both located on the roof of WTC 7 and supported by the building's core columns.

The goal of these new measurements was to produce a comprehensive characterization of WTC 7's downward motion that could then be examined for its consistency with the results of NIST's global collapse analyses and be used to develop and evaluate other, more valid hypotheses.

3.1 Points Tracked

The four points we tracked across the north face roofline in the Camera 2 video as well as the point on the north screen wall and the point on the west penthouse are shown below in Figure 4. Note that the east penthouse has already collapsed into the building at this point.

Figure 4: Neon green: Northeast corner. Blue: East center roofline (NIST's point). Orange: West center roofline (new point). Red: Northwest corner. Dark green: North screen wall. Light blue: West penthouse.

For a better understanding of the north screen wall and west penthouse structures, Figure 5-9 of NCSTAR 1-9 is presented below. Note that the north screen wall is one of two walls that ran

between east and west penthouses, providing an open enclosure for the mechanical equipment located therein.

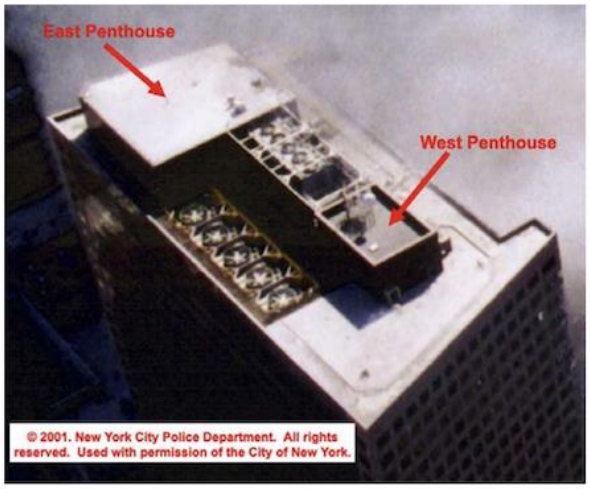

Figure 5–9. Cropped photograph taken from the northwest around 12:00 p.m. on September 11 showing the mechanical systems and penthouses on the roof of WTC 7.

To measure the downward motion of the west face roofline, we used video footage taken from the west and slightly north of WTC 7, shown below in Figure 5. This video footage was released by an anonymous source in the fall of 2008, just as NIST was completing its WTC 7 report. Prior to that, there was no footage we are aware of that clearly showed the west face of WTC 7. The specific version we used was stabilized by Nathan Flach and posted on his YouTube channel (Flach, 2013). Since the camera panned and zoomed in and out substantially during the event, we could not reliably track the downward motion using this video alone, even with it stabilized. However, because we knew the timing and rate of downward motion of the northwest corner from the Camera 2 video, we could correlate the two other points on the west face roofline with the northwest corner and determine the start time of their descent.

Figure 5: Red: Northwest corner. Green: Center of west face roofline. Blue: Southwest corner.

3.2 Results of New Measurements

Our new measurements confirm our 2020 measurements and expand our understanding of the downward motion through the information provided by the additional points we tracked.

The key observation is that every point along the north face *and* west face rooflines instantaneously entered free fall within two-tenths of a second of each other between 8.0 and 8.2 seconds after the start of the east penthouse collapse. There was no gradual build-up to free fall and no apparent progression of exterior column failures, which will be discussed further in the next section.

As for the north screen wall and the west penthouse, their descent began about 0.6 seconds after the minimal downward motion in the north face roofline and 0.6 to 0.8 seconds before the instantaneous transition to free fall of the north face and east face rooflines. The north screen wall and the west penthouse fell at a constant downward acceleration of about two-thirds of the acceleration of gravity until they became obscured by the roofline. This indicates that the resistance was significantly reduced but not eliminated.

Table 1 below presents the start times of all major events. In Appendix A, we provide graphs and detailed numerical figures for the displacement and velocity of each tracked point. We also provide instructions, archival video files with good resolution, calibration data, and a link to the Tracker software so that anyone who wishes to reproduce our measurements can do so.

Table 1: Start Times of Major Events in Downward Motion of WTC 7

Event	Start Time
Start of east penthouse collapse	0.0 s
East center of roofline minimal downward motion (NIST's Stage 1)	6.8 s*
North screen wall descent (at ~2/3 of gravity)	7.4 s
West penthouse descent (at ~2/3 of gravity)	7.4 s
Northeast corner free fall	8.0 s
East center roofline free fall	8.2 s
West center roofline free fall	8.2 s
Northwest corner free fall	8.2 s
Center of west face free fall	8.2 s
Southwest corner free fall	8.2 s

*Given the margin of error and our tracking the motion in intervals of 0.2 seconds on the even decimal values, this timing is consistent with NIST's timing of 6.9 seconds.

Two additional observations from our new measurements are discussed below:

- Like the northwest and northeast corners, the newly added point labeled "west center roofline" remained essentially motionless for more than a second after the point labeled

"east center roofline" began to exhibit minimal downward motion. This observation is consistent with NIST's Figure 5-201 above. Upon close inspection, Figure 5-201 shows that the displacement on the west side of the building at 7.5 seconds was the descent of the north screen wall and the west penthouse.

This suggests that the minimal downward motion in the north face roofline starting at 6.8 seconds was largely confined to the area of the roofline that aligned with the east end of the louvers on the 46th and 47th floors. As NIST noted in its report, this is where the lateral fold in the north face developed. Describing the state of the building at 9.0 seconds after the start of the east penthouse collapse, NIST observed: "The rotation of the east edge of the north face has become more evident, and **a distinct kink has begun to develop just to the left of the east end of the louvers on the 46th and 47th floors**. This location is close to perimeter Column 47" (NCSTAR 1-9, p. 276). [Emphasis added.]

From this, we deduce that the minimal downward motion exhibited at the point labeled "east center roofline" was probably a small vertical component of the mostly lateral motion of the fold that was developing in the north face, which was likely due to local disruption in the interior pulling the north face inward. There is no evidence that the downward motion was due to buckling in the lower stories of the exterior columns, as claimed by NIST. Conversely, when this point suddenly transitioned to free fall, along with the rest of the north face and west face rooflines, such a simultaneous global failure probably *was* due to catastrophic failures of the exterior columns in the lower stories. Thus, the minimal downward motion prior to free fall and the subsequent free fall motion appear to have been independent from each other.

- The 0.2-second variation in the start time of free fall for the six measured points along the roofline is almost certainly caused by artifacts of the limited resolution of the measurements. However, even if the differences were taken to be real, rather than simply measurement artifacts, note that the northeast and southwest corners, which are about 100 meters apart, have start times that are synchronized to within 0.2 seconds. As we will discuss in the next section, this undermines the notion of a progression of exterior column failures, which would have taken time to move from one side of the building to the other.

In summary, our new measurements show that WTC 7's instantaneous transition to free fall did not occur only across the north face roofline of the building. It occurred virtually simultaneously across the entire measurable roofline on the visible north and west sides of the building. Moreover, the minimal downward motion that NIST characterized as the start of a Stage 1 or "global collapse initiation" was confined to a limited area of the north face roofline.

4. NIST's Global Collapse Analyses

Now that we have a more accurate and comprehensive characterization of WTC 7's downward motion, we will examine the validity of NIST's twin claims that the observed behavior was consistent with the results of NIST's global collapse analyses and that the global collapse analyses "matched the observed behavior reasonably well" and thus "confirmed the leading collapse hypothesis."

First, we will examine NIST's sequence of column failures for its consistency with the observed behavior. Then we will examine NIST's global collapse animation for how well it visually matches the observed behavior.

Note that we are not examining the alleged initiating failure and subsequent sequence of events that supposedly led to the buckling of Column 79, which NIST claims caused the observed collapse of the east penthouse. Criticism of that part of NIST's probable collapse sequence can be found in the 2020 request for correction and the sources cited therein. This analysis focuses on the alleged sequence of core and exterior column failures that supposedly occurred *after* the buckling of Column 79 and culminated in the global collapse.

Also, note that NIST conducted four different simulations of the global collapse: the first with debris impact damage from the collapse of WTC 1 and with 4 hours of fire-induced damage; the second with debris impact damage and with 3.5 hours of fire-induced damage; the third *without* debris impact damage and with 4 hours of fire-induced damage; and the fourth without any debris impact damage or fire-induced damage, where NIST simply removed a portion of Column 79. Our discussion will focus on the simulation *with* debris impact damage and with 4 hours of fire-induced damage, which NIST claimed "better matched the video observations of the global collapse" and which constitutes NIST's final probable collapse sequence (NCSTAR 1-9, p. 613).

4.1 Consistency of NIST's Column Failure Sequence with the Observed Behavior

NIST's sequence of column failures seems fairly straightforward at first glance, but it is actually quite complicated and self-contradictory in subtle ways when one carefully studies all three of NIST's WTC 7 reports (NCSTAR 1A, NCSTAR 1-9, and NCSTAR 1-9A).

Certain passages in each of the reports would lead one to conclude that NIST is claiming a cohesive progression of core column failures traveled from east to west, and this in turn triggered a progression of exterior column failures that started at the southwest corner and traveled in both directions from column to column around the perimeter of the building.

However, careful review of NCSTAR 1-9 and NCSTAR 1-9A reveals that NIST's sequence of core column failures was not actually a cohesive east-to-west progression originating solely from the failure of Column 79. Rather, a "secondary collapse" originated almost simultaneously in the western side of the core, triggered by a combination of earlier debris impact damage from the collapse of WTC 1 (claimed by NIST but not supported by photographic or video evidence) and "global motions and load redistributions" caused by the buckling of Columns 79, 80, and 81 on the opposite side of the core. In addition, the progression of exterior column failures actually began at the southwest corner *before* the progression of core column failures was complete, as it was triggered by the secondary collapse in the western core that was occurring at the same time as the primary east-to-west collapse progression.

To clarify NIST's sequence of column failures, we used Figure 2-4 of NCSTAR 1-9, presented as Figure 6 below, and inserted the reported time of buckling for each of the columns according to NIST's rather fragmented description of the column failure sequence. Note that the failure

times written in red are times that NIST gave explicitly, and the times written in green are inferred from NIST's description. For anyone wishing to check the failure times presented below, the most clear and succinct description of the column failure sequence is contained in Section 4.3.2 of NCSTAR 1-9A. Section 12.4.4 of NCSTAR 1-9 and Sections 4.3.4 and 4.3.5 of NCSTAR 1-9A describe the column failure sequence in more detail, giving exact times for many of the individual column failures, but the information in those sections is more fragmented.

Note that in the timescale used by NIST, 0.0 seconds is the start of the east penthouse's collapse into the building. In NIST's scenario, the buckling of Column 79 preceded the start of the east penthouse collapse by 1.3 seconds. Therefore, it is represented as -1.3 s.

In addition, note that 6.3 seconds after the start of the east penthouse collapse is the time of "global collapse initiation" in NIST's global collapse analysis, whereas 6.9 seconds is the time of "global collapse initiation" according to NIST's observations. (Note that we have established that the downward motion of WTC 7's entire measurable roofline actually began at about 8.2 seconds.) The discrepancy of 6.3 seconds in the global collapse analysis versus 6.9 seconds in the video observations is not a problem per se. In fact, the difference in timing is remarkably small. Rather, the problem is the overall inconsistency of NIST's column failure sequence with the observed behavior.

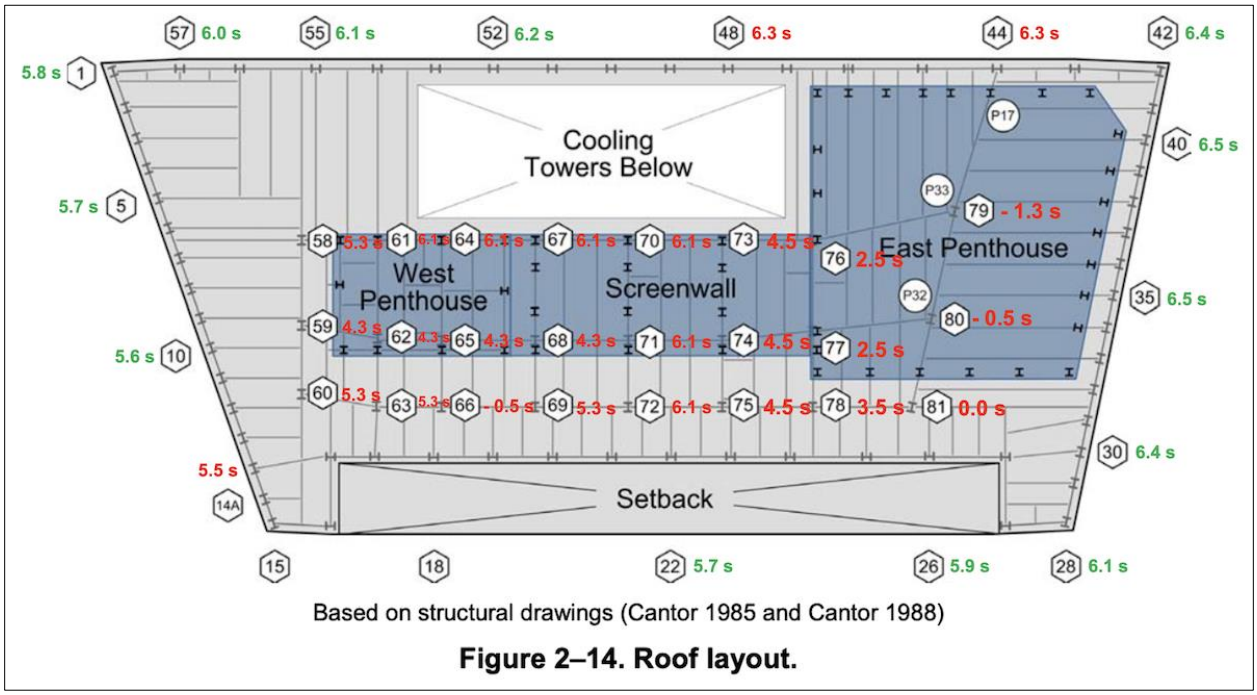

Figure 6: The timing of NIST's column failure sequence. 0.0 is the start of the east penthouse collapse.

The obvious takeaway from the above figure is that if the progression of exterior column failures initiated at the southwest corner — specifically at Column 14 as claimed by NIST — and traveled along the west and south faces first before spreading to the north and east faces, there should have been some visible sign of the west face roofline descending first, since buckling causes shortening, which would cause immediate downward motion.

Take the example of Column 79's downward motion. NIST states that according to its global collapse analysis, "after Column 79 buckled, it started moving downward at the roof level 0.2 s later" (NCSTAR 1-9, p. 575).

Why then would Column 14 and the rest of the columns on the west face take more than a second after buckling to begin moving downward? And why would the first downward motion occur on the east side of the north face, which allegedly buckled nearly a second *after* the columns in the southwest corner did? NIST claims that the minimal downward motion at 6.9 seconds (i.e., the start of its Stage 1) "corresponds to the initial buckling of the exterior columns in the lower stories of the north face" (NCSTAR 1-9, p. 602). Why then was there no downward motion in the rest of the north face and in the west face corresponding with shortening due to the buckling of those columns (in the case of the west face, a second *prior* to the east side of the north face buckling, according to NIST)?

In its description of its column failure sequence, NIST paints a picture of the building's entire exterior shell hovering motionlessly until column buckling had spread almost all the way around the building. For example, NIST states: "When all the exterior columns had buckled . . . the entire building above the buckled-column region moved downward as a single unit, resulting in the global collapse of WTC 7" (NCSTAR 1-9, p. 588). But the notion that the buckled west and south faces would remain motionless until the eastern side of the north face also buckled is physically implausible. Just like Column 79 in NIST's global collapse analysis, the west and south faces should have begun to move downward *as* the buckling occurred.

Moreover, NIST claims that after "the east side of the north face roofline began moving downward" at 6.3 seconds, "Global vertical motion spread across to the west side of the north face roofline" from 6.5 seconds to 7.5 seconds (NCSTAR 1-9A, p. 76). But this was not observed in the videos. Rather, as demonstrated in the first part of this paper, the initiation of downward motion was instantaneous and virtually simultaneous across the entire measurable roofline, with the distant, opposite northeast and southwest corners starting to descend within 0.2 seconds of each other. Furthermore, why would the downward motion start on the east side of the north face and travel westward when the sequence of exterior column failures had allegedly come from the west and spread eastward?

As for NIST's sequence of core column failures, a superficial reading would suggest that the north screen wall and the west penthouse (which were supported by core columns 58, 59, 61, 62, 64, 65, 67, 68, 70, 71, 73 and 74) should have descended one after the other in a westward sequence and at least two seconds prior to any downward motion of the exterior. However, since NIST's column failure sequence was not a cohesive east-to-west progression that completed prior to the buckling of the exterior columns — rather, it occurred simultaneously on the east and west and overlapped with the sequence of exterior column failures — the timing does align with the observed behavior. With that said, the notion of "primary" and "secondary" collapse progressions occurring simultaneously because "global motions and load redistributions" from buckling core columns on the east side caused core columns on the west side to begin buckling is dubious and entirely dependent on NIST's *estimates* of debris impact damage in the western core from the collapse of WTC 1.

4.2 The Consistency of NIST's Global Collapse Animation with the Observed Behavior

Whereas NIST's column failure sequence is a story that can be compared with the observed behavior using logic and understanding of physics, the animation of NIST's global collapse analysis is a video that can be analyzed and compared with the observed behavior visually.

Through careful review of NIST's global collapse animation, we identified multiple ways in which the global collapse analysis completely fails to match the observed behavior and actually predicts fundamentally different behavior (NIST, Case B West View, 2008). **In our view, the behavior predicted by NIST's global collapse analysis is so fundamentally different from the observed behavior that it not only fails to confirm NIST's collapse hypothesis, it actually provides strong evidence against NIST's collapse hypothesis.** This is especially the case when we consider that this was NIST's best attempt to match the observed behavior and that NIST presumably did everything possible to make the model produce the observed behavior.

The ways in which NIST's global collapse analysis fails to match the observed behavior can be organized into three categories, which we will discuss in the following order: (1) Exterior Deformation; (2) Southward Tipping; and (3) Initial Downward Motion.

4.2.1 Exterior Deformation

The most striking feature of NIST's global collapse animation is the significant amount of deformation that develops in the building's exterior both before and after "global collapse initiation." Such deformation is completely absent from the building's actual observed behavior, as corroborated by NIST's own observations discussed earlier in this paper. (For example, Figure 5-201 of NCSTAR 1-9 indicates "little movement of the northeast and northwest corners" at 0.6 seconds into the global collapse, according to NIST.)

NIST obscures and downplays the exterior deformation in various ways. For example, NCSTAR 1A, which is NIST's summary report on WTC 7, features no figures showing the global collapse analysis from the exterior other than a zoomed-in view of the lower exterior columns buckling in Figure 3-14, shown below.

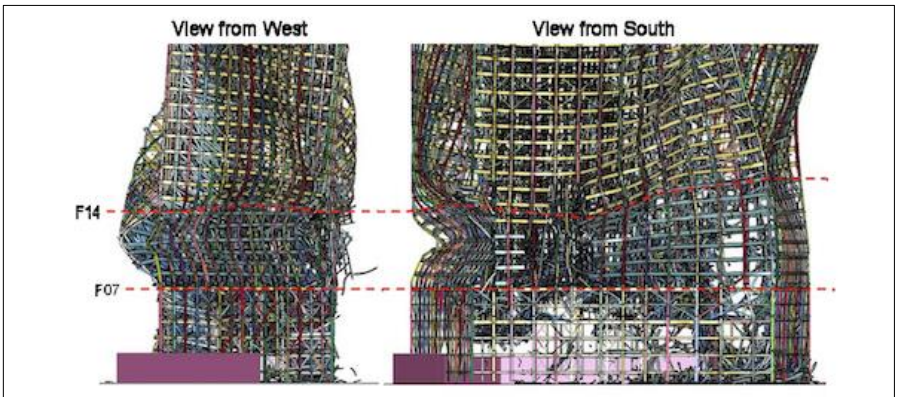

Figure 3-14. Buckling of the lower exterior columns within 1 s of Figure 3–13.

Meanwhile, NCSTAR 1-9, which is NIST's main report on WTC 7, includes just one figure depicting the global collapse analysis from the exterior. And even this figure, Figure 12-62 presented below, shows the collapse only from the west and south. While the significant deformation of the east wall is visible in the "View from South," one must look at it carefully to see the deformation and realize how much it differs from the observed behavior. A cursory review of the figure gives the impression of a fairly straight, undeformed building.

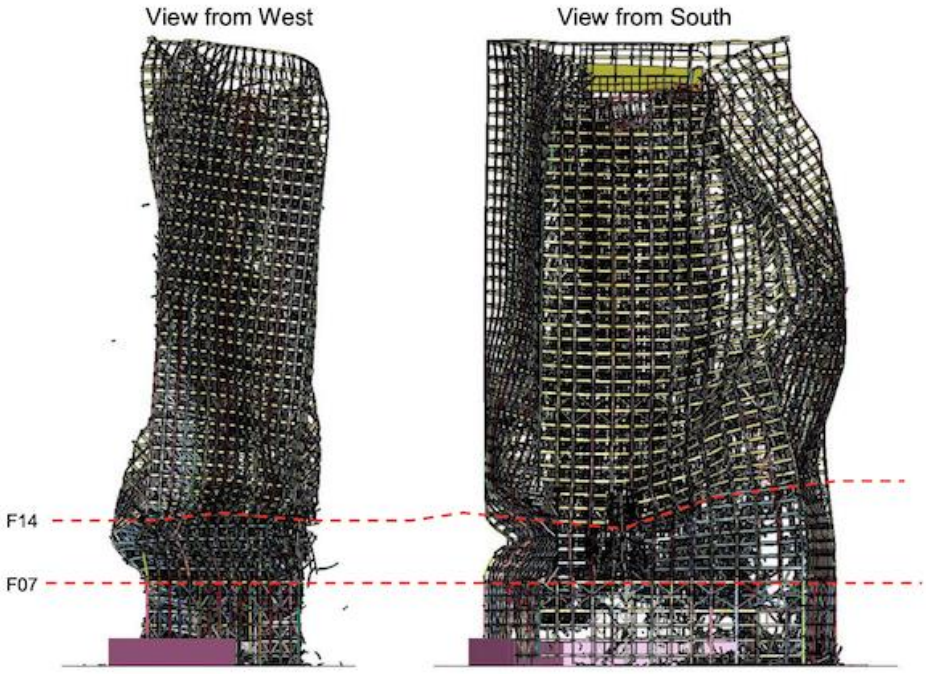

Figure 12–62. Exterior column buckling after initiation of global collapse with debris impact and fire-induced damage (slabs removed from view).

To get a clear picture of just how dramatic the exterior deformation in the global collapse animation really is, one must delve into NCSTAR 1-9A, which is NIST's global structural analysis report. It shows a series of animation figures where the building's behavior differs markedly from the observed behavior. Figures 4-44, 4-45 and 4-46, which provide northeast and southwest views of the building at 3.5, 6.5, and 8.6 seconds after the start of the east penthouse collapse, respectively, are presented below. NIST says of these figures:

> "Figure 4-44 shows the **lateral displacements that developed in the east face** [by 3.5 s]. Also shown is the start of the **southward global motion** that developed as the east interior region collapsed. Figure 4-45 illustrates the **increase of lateral deflections of the east face** and the start of exterior column buckling in Floors 7 and 14, which began in the southwest corner at 5.5 (21.5) s. Figures 4–46 and 4–47 show the buckling of the exterior columns as the global collapse began" (NCSTAR 1-9A, p. 96). [Emphasis added.]

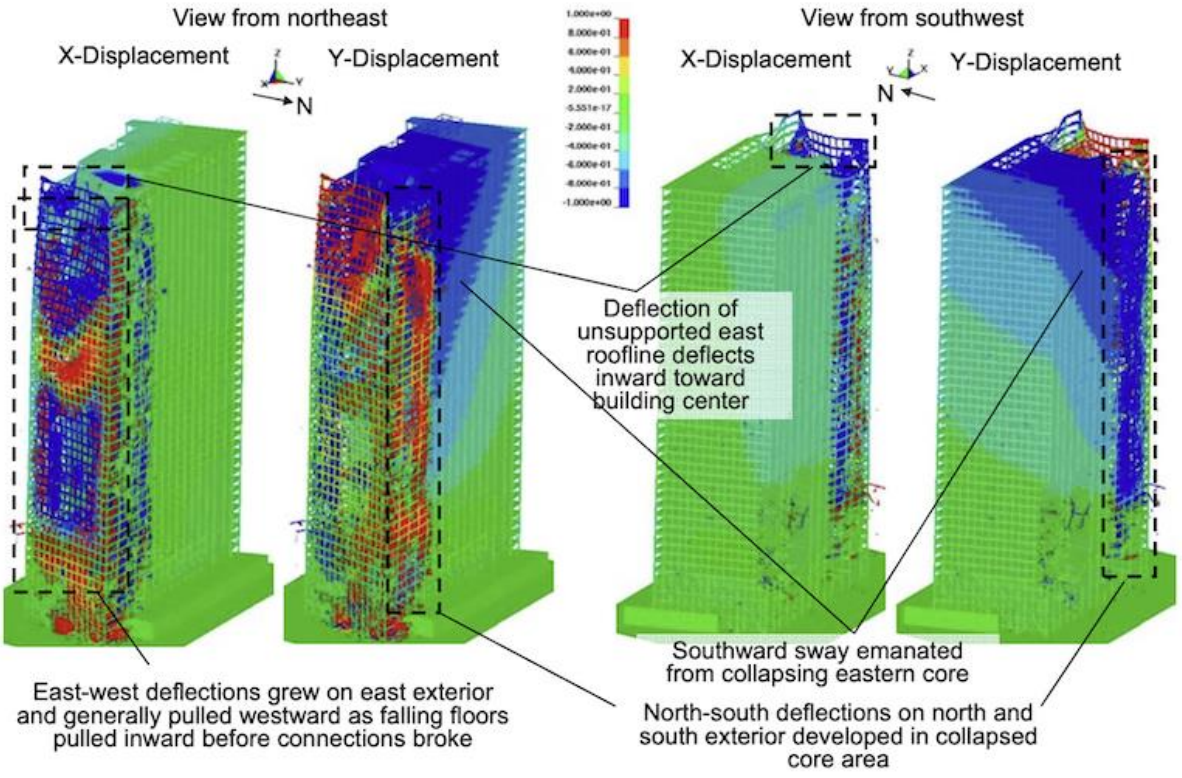

Figure 4-44. Global model with lateral displacement contours (-1 m to 1 m) at 3.5 (19.5) s.

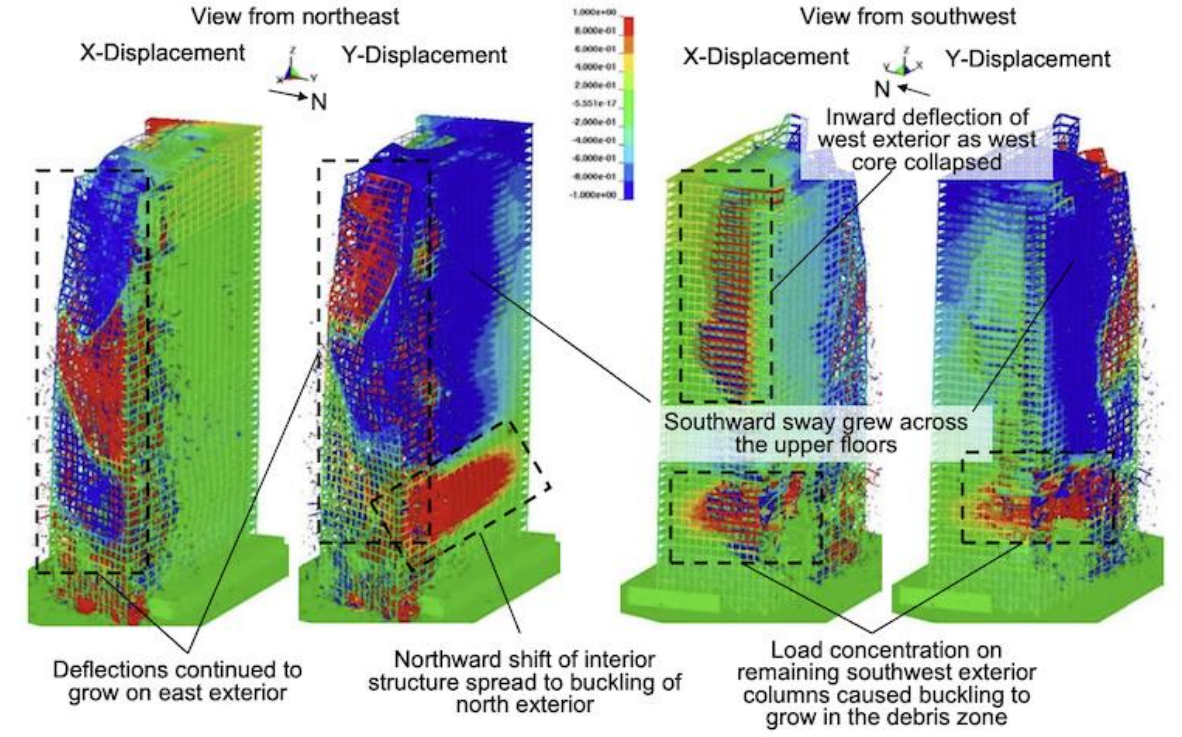

Figure 4-45. Global model with lateral displacement contours (-1 m to 1 m) at 6.5 (22.5) s.

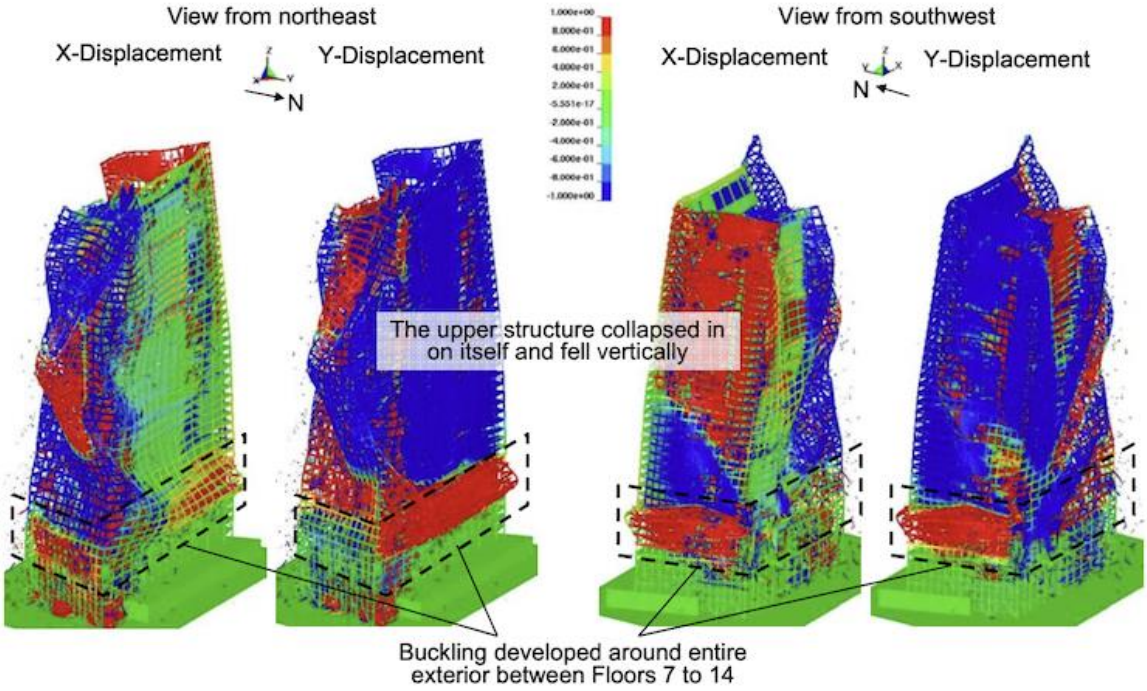

Figure 4-46. Global model with lateral displacement contours (-1 m to 1 m) at 8.6 (24.6) s.

NIST comments that by 7.3 seconds in its global collapse animation, "the north exterior wall appears generally intact, while most of the structure behind the north face is collapsing" (NCSTAR 1-9A, p. 77). But as we know, in reality, the north and west face rooflines began to descend simultaneously and remained level well into the building's descent. Furthermore, the core columns continued to support the north screen wall and the west penthouse until 7.4 seconds. These structures were still visible at the start of the roofline's free fall and did not sink below the roofline until 9.0 seconds and 9.3 seconds, respectively (NCSTAR 1-9, pp. 276, 282).

Another way NIST downplays the exterior deformation in its global collapse analysis is by claiming in its WTC 7 FAQs that the deformation occurred only *after* global collapse initiation. Specifically, NIST states: "Only in the later stages of the animation, after the initiation of global collapse, do the upper exterior wall deformations from the NIST analysis differ from the video images." Yet NIST itself contradicts this claim in NCSTAR 1-9A, both in the figures above and by stating that from 0.7 seconds onward in the animation, "The east face near the top of the building deflected westward as floors surrounding Columns 79 to 81 pulled the exterior wall inward" (NCSTAR 1-9A, p. 76).

NIST's global collapse animation also plainly contradicts the claim in NIST's WTC 7 FAQs. Figure 7 below overlays NIST's global collapse animation just before the start of the east penthouse collapse with the animation at 6.3 seconds (the point of "global collapse initiation" in the global collapse analysis). Overlaying the two frames shows the east wall, the northeast corner, and the eastern part of the north wall to have had already undergone significant deformation prior to global collapse initiation. This is in stark contrast to the observed behavior,

which — consistent with NIST's own observation in Figure 5-201 of NCSTAR 1-9 — involved *zero* deformation or displacement of the northeast corner until its instantaneous transition to free fall at 8.0 seconds.

Figure 7: NIST's global collapse animation at 6.3 seconds after the start of the east penthouse collapse laid over the animation at 0.1 seconds before the start of the east penthouse collapse.

4.2.2 Southward Tipping

Contrary to NIST's own observations of the collapse, NIST's global collapse animation exhibited southward tipping. But nowhere in NCSTAR 1A or NCSTAR 1-9 can one find any mention of southward tipping in the animation. To discover this fact, one must delve into NCSTAR 1-9A with a fine-tooth comb and carefully study the global collapse animation video.

In the statement regarding Figure 4-44 of NCSTAR 1-9A quoted above in Section 4.2.1, NIST describes the "start of the southward global motion" at 3.5 seconds. Then, in Figure 4-44, NIST states: "Southward sway emanated from the collapsing eastern core." Also, in Figure 4-45, which shows the building at 6.5 seconds, NIST states: "Southward sway grew across the upper floors."

Careful review of the global collapse animation video also indicates significant southward tipping. Figure 8 below overlays NIST's global collapse animation just before the start of the east penthouse collapse with the animation at 8.6 seconds, which is the point at which NIST terminated the global collapse analysis, 2.3 seconds after "global collapse initiation." As discussed further in the next section, we tracked two points in every animation frame, one at the

northwest corner and one approximating NIST's east center roofline point. Below that, in Figure 9, we provide the same analysis of the Camera 3 video over the first 2.3 seconds of descent. Although it is difficult to distinguish downward motion from lateral motion in the animation, it is obvious that the building in the animation is tipping while the building in the video is descending vertically. By 2.3 seconds into the global collapse, the top of the building has tipped southward by as much as half of its north-south width.

Figure 8: The final frame of NIST's global collapse animation, at 8.6 seconds after the start of the east penthouse collapse, laid over the animation at 0.1 seconds before the start of the east penthouse collapse. Blue dots track the motion at the east center roofline point. Red dots track the motion of the northwest corner.

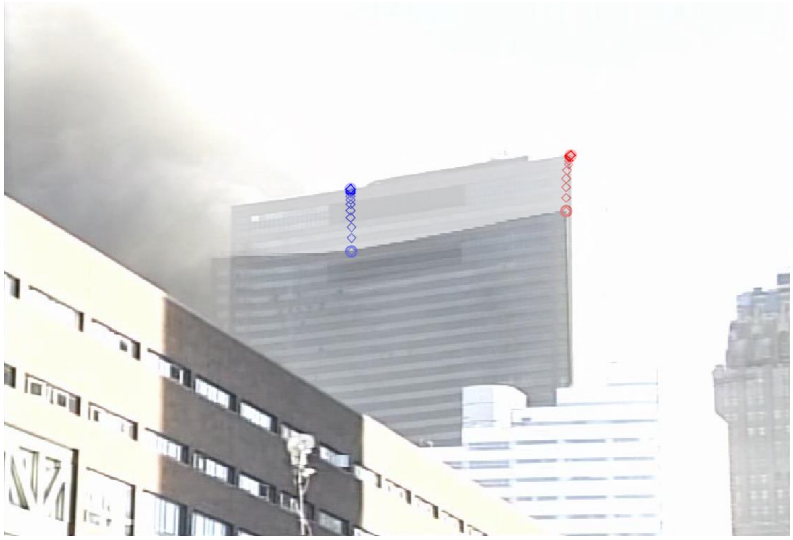

Figure 9: A frame from Camera 3 at 2.3 seconds into the downward motion laid over a frame just before the start of downward motion.

In addition, the "View from West" in Figure 12-62 of NCSTAR 1-9, presented in Section 4.2.1 above, shows the southward tipping in NIST's model at about 1.2 seconds into global collapse. At this point, the top of the building appears to have tipped southward approximately one-quarter of the north-south width of the building. (Note: NIST doesn't provide a time for Figure 12-62. However, Figure 3-14 of NCSTAR 1A, which is the same shot zoomed in on the lower exterior columns, states that this shot is "within 1 s of Figure 3-13." Figure 3-13 is a depiction of the building's interior at 6.5 seconds. Thus, Figure 12-62 shows the building at about 7.5 seconds or 1.2 seconds after "global collapse initiation" in the global collapse analysis.)

Whereas NIST's global collapse analysis predicts "southward global motion" or "sway," according to NIST's own observations, the northeast edge of WTC 7 in fact tilted to the *north*, while the northwest edge also tilted to the north before it "settled back to its original line and fell **nearly vertically**" (NCSTAR 1-9, p. 277). [Emphasis added.] NIST based this observation on the analysis in Figure 5-205 of NCSTAR 1-9, presented below in its entirety (earlier in the paper we presented this figure with the bottom five frames cropped out).

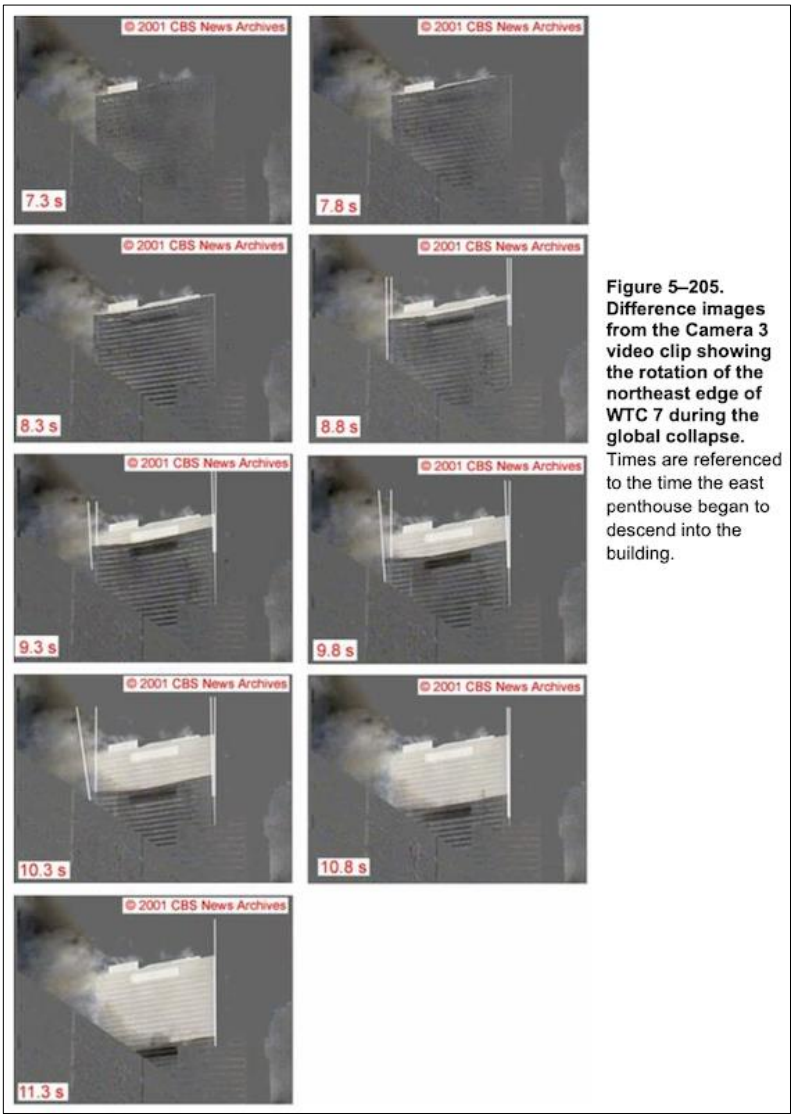

Figure 5–205. Difference images from the Camera 3 video clip showing the rotation of the northeast edge of WTC 7 during the global collapse. Times are referenced to the time the east penthouse began to descend into the building.

Note that in the last frame of Figure 5-205 — which is 4.4 seconds after NIST's "global collapse initiation" (at 6.9 seconds) and 3.1 seconds after the actual start of downward motion (at 8.2 seconds) — the northwest edge of WTC 7 is still falling "nearly vertically." In contrast, the tracked motion in Figure 8 and Figure 12-62 of NCSTAR 1-9, both presented above, show the building tipping considerably just one to two seconds into the global collapse. One can imagine how much more the building would have tipped southward had NIST allowed the analysis to run a few seconds longer.

4.2.3 Initial Downward Motion

We now come to assessing whether the observed downward motion of WTC 7 is consistent with the results of NIST's global collapse analysis, as NIST claimed in its final report.

To examine NIST's global collapse animation with precision, we used the same method of tracking multiple points along the north face roofline, measuring the downward motion frame by frame. Since the northeast corner undergoes significant deformation early and becomes obscured, it could not be tracked. However, we did track the northwest corner and a point approximating NIST's east center roofline point (tracking a second point near the center of the roofline seemed unnecessary for the purposes of measuring an animation). The two points we tracked are shown in Figure 8 in the previous section.

Below, in Figures 10 to 13, we present graphs showing the position vs. time and velocity vs. time for each point. Appendix B provides detailed numerical data for each point.

Both points reached a constant rate of acceleration slightly less than free fall at about 7.5 seconds after the start of the east penthouse collapse — or 1.2 seconds after the time NIST identified as "global collapse initiation" in its global collapse analysis. This rate of acceleration lasted about 1.1 seconds, until the analysis was terminated at 8.6 seconds. The rate of acceleration of the east center roofline point was 8.70 m/s^2 (slightly less than free fall) while the rate of acceleration of the northwest corner was 8.38 m/s^2 (also slightly less than free fall). Although the final rates of acceleration were less than free fall, their proximity to free fall is the only way the global collapse animation comes close to matching the observed downward motion seen in videos.

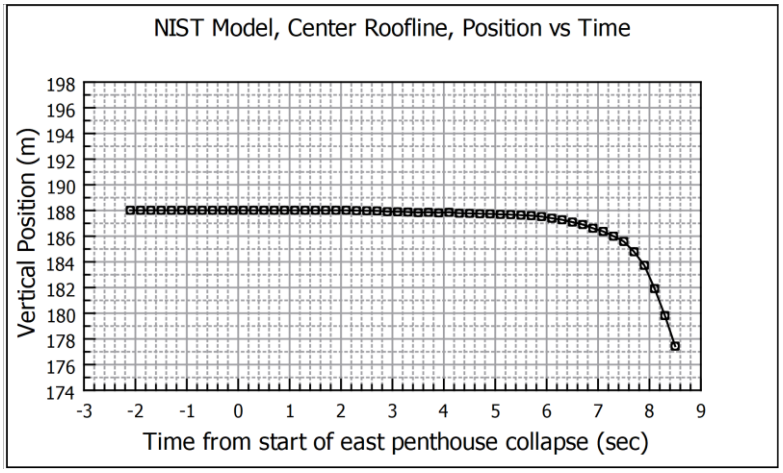

Figure 10: Vertical position vs. time for the east center roofline.

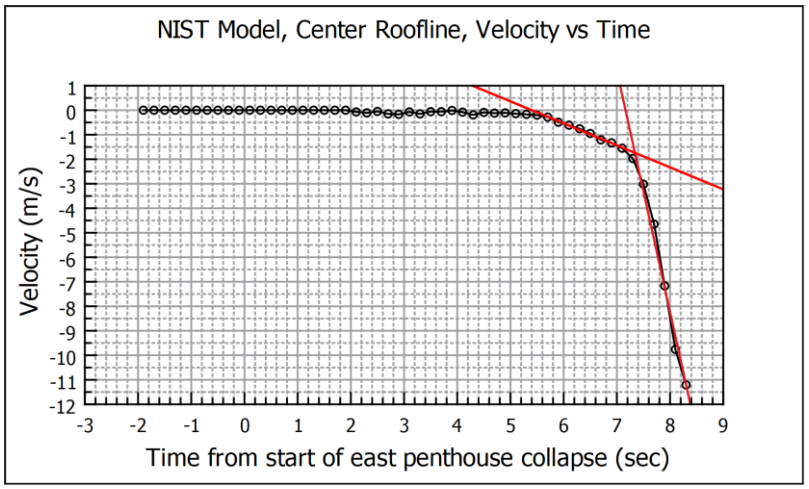

Figure 11: Vertical velocity vs. time for the east center roofline. Transitional acceleration = -0.898 m/s^2. Final acceleration = -8.70 m/s^2.

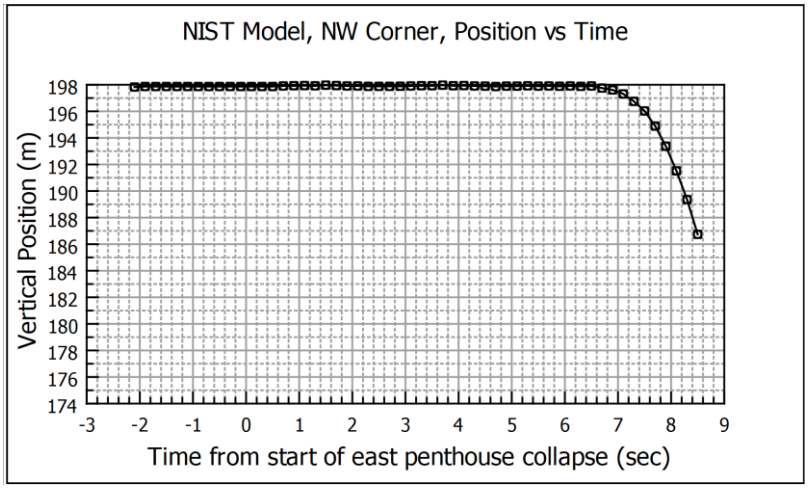

Figure 12: Vertical position vs. time for the northwest corner.

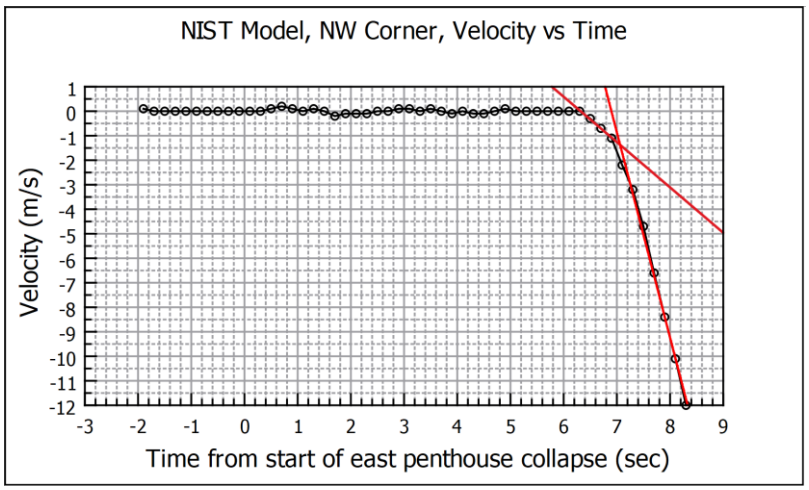

Figure 13: Vertical velocity vs. time for the northwest corner. Transitional acceleration = -1.85 m/s^2. Final acceleration = -8.38 m/s^2.

First, in the case of the east center roofline point, downward motion can be detected well in advance of "global collapse initiation" at 6.3 seconds (see the numerical results in Appendix B in addition to Figures 10 and 11 above). Specifically, the east center roofline point was completely steady until 2.1 seconds and then gradually descended 0.74 meters between 2.1 seconds and 6.3 seconds (which is NIST's "global collapse initiation"). In the Camera 2 video, there was no downward motion whatsoever anywhere along the north face roofline, including at the east center roofline point, until 6.8 seconds. A descent of 0.74 meters may seem small, but motionlessness versus consistent downward motion over several seconds, even if small, is not a negligible difference. We are seeing two qualitatively different types of behavior.

Second, the east center roofline point and the northwest corner in the global collapse animation each experienced their first significant drop — which we considered to be at least 0.1 meters — 0.6 seconds apart. Specifically, the east center roofline dropped 0.12 meters at 5.9 seconds, and the northwest corner dropped 0.16 meters at 6.5 seconds. Thus, the start of significant downward motion across the width of the north face roofline is not virtually simultaneous, which contradicts the observed behavior in the Camera 2 video.

The third and most significant way in which NIST's global collapse analysis fails to match the observed downward motion is that both points experience a gradual build-up to their final rates of acceleration — not a gradual increase in speed, but a gradual increase in acceleration — and these final rates of acceleration are less than free fall. Specifically, the east center roofline, as shown in Figure 11 above, exhibited a fairly constant transitional downward acceleration of 0.90 m/s^2 from 5.5 seconds to 7.1 seconds and then increased to 8.70 m/s^2 (slightly less than free fall) by about 7.5 seconds. Meanwhile, the northwest corner's transition to free fall was of a shorter duration than the other point, but the northwest corner still exhibited a transitional downward acceleration of about 1.85 m/s^2 from 6.3 seconds to 6.9 seconds before increasing to 8.38 m/s^2 (slightly less than free fall) by 7.3 seconds, as shown in Figure 13 above.

The fact that the build-up to free fall is gradual in NIST's global collapse animation is not surprising, since it is simulating a natural progressive collapse, and as we have argued, a building cannot instantaneously transition to free fall in a natural progressive collapse. According to its global collapse animation, NIST apparently agrees.

We must also note that NIST terminated its analysis at about 1.1 seconds after the final acceleration of each point was reached, so we do not know if the descent slowed shortly after termination or if the building tipped over completely. We can reasonably assume that the building would have experienced further deformation and tipping had the analysis not been terminated at that point.

In addition, we are unable to examine what inputs NIST made to its global collapse analysis that enabled it to mimic the observed behavior to the limited extent that it did — or enabled the building to collapse at all, for that matter — since NIST has refused to release its modeling data on the dubious ground that doing so "might jeopardize public safety" (Gallagher, 2009).

Regardless, what we do know is that NIST's best attempt to match the observed behavior of WTC 7 failed on every count. By depicting a highly deformed, southward tipping building, which experienced a gradual build-up to a final acceleration that was less than free fall, NIST's global collapse analysis not only fails to match the observed behavior, it provides strong evidence against NIST's own hypothesis.

5. A Column Failure Sequence that Explains the Observed Behavior

In Figure 14 below, using the same diagram as in Figure 6, we offer a hypothesized sequence of column failures that realistically explains the key observed behavior. The estimated failure times are merely *reasonable guesses* as to the *approximate* times of failure. The key observed behavior can be summarized as follows:

1) The collapse of the east penthouse into the building starting at 0.0 seconds, accompanied by scattered window breakage as low as 15 stories down from the roofline but no visible deformation or downward displacement anywhere in the building's exterior.

2) The collapse of the north screen wall and the west penthouse at 7.4 seconds.

3) The instantaneous transition to free fall of the entire measurable roofline at 8.2 seconds.

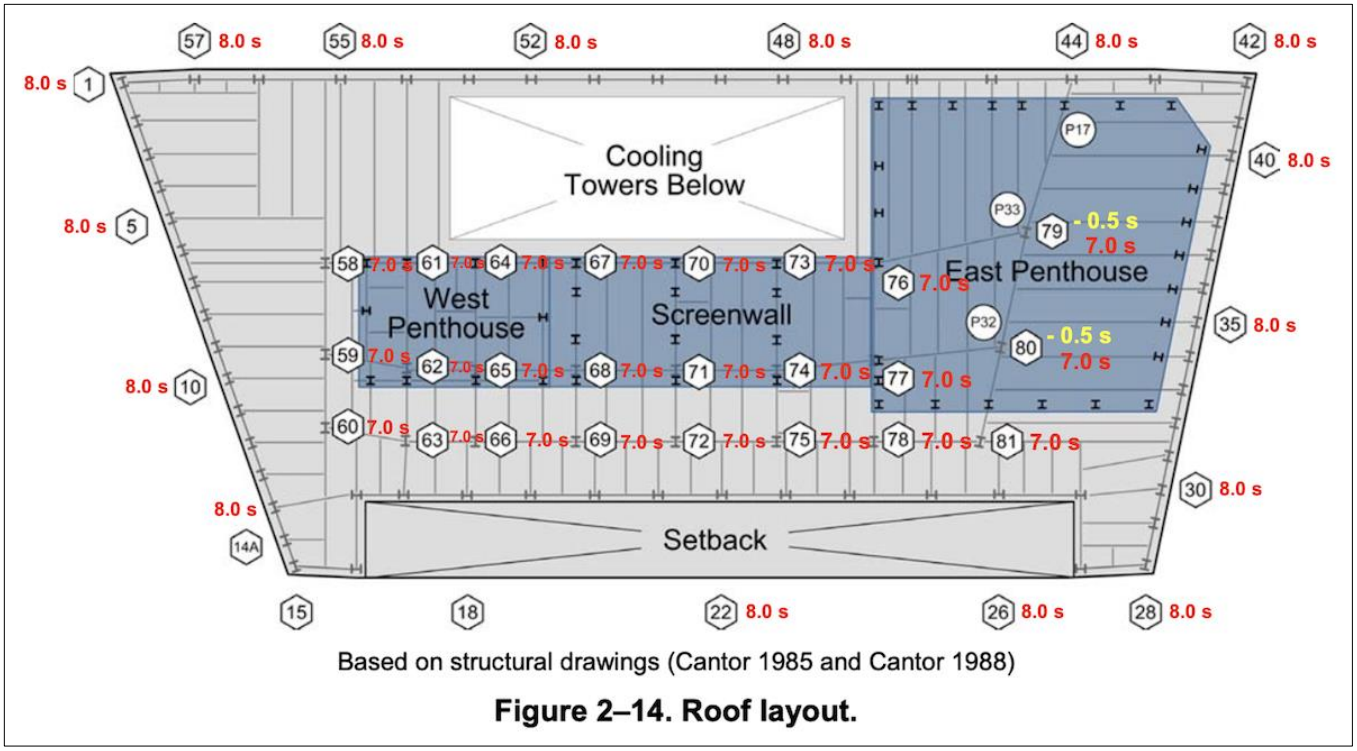

Figure 14: Hypothesized column failure sequence with estimated approximate failure times. Yellow indicates column failures high in the building. Red indicates column failures low in the building.

As depicted in the figure above, our estimated failure time for all of the exterior columns is 0.2 seconds prior to when downward motion was observed in the roofline. For the core columns, our

estimated failure time is approximately 0.5 seconds prior to when downward motion was observed in the north screen wall and west penthouse.

For Columns 79 and 80, which supported the east penthouse, we have estimated two separate failure times: The first is when we hypothesize Columns 79 and 80 failed high in the building (notated in yellow) — which has no plausible natural mechanism since there were no fires in that part of the building — causing the east penthouse to collapse into the building. The second is when the remaining length of the columns failed low in the building (notated in red). We estimated the failure of Columns 79 and 80 high in the building to be 0.5 seconds prior to the start of the east penthouse collapse. This is consistent with audio evidence suggesting the occurrence of an explosion approximately 0.5 seconds before the start of the east penthouse collapse, to be discussed below. Our hypothesis that the initial failure of Columns 79 and 80 occurred high in the building will be discussed further in Section 5.2.

The only plausible means by which this pattern of column failures could have been achieved is through a controlled demolition process over a period of about eight seconds.

5.1 Seismic, Audio, and Eyewitness Evidence

The detonation of demolition devices over a period of about eight seconds is supported by seismic, audio, and eyewitness evidence as well as by the "severe erosion" found in "several beams" from WTC 7 (FEMA, 2002, Appendix C), indicating the use of thermite-based devices.

In Appendix B of NCSTAR 1-9, NIST documents two seismic events recorded at the Lamont-Doherty Earth Observatory 34 kilometers away from Lower Manhattan: one at 5:20:42 PM, corresponding roughly to the collapse of the east penthouse, and one eight seconds later at 5:20:50 PM, corresponding roughly to the initiation of global collapse. An abridged version of Table B-4 from Appendix B is presented below, showing NIST's listing of these seismic events.

Table B-4. Summary of seismic events recorded 8:46 to 17:21 on Sept. 11, 2001.

Origin Time, EDT (hh:mm:sec)	Event ID	Latitude (°N)	Longitude (°E)	Depth (km)	Magnitude (M_L)	Event Type
17:20:42	5	40.71	-74.01	0	0.6	WTC 7 collapse initiation
17:20:50	5'	40.71	-74.01	0	0.6	WTC 7 perimeter wall collapse

NIST attributes the first seismic signal to "interior debris falling to the lower floors of WTC 7 on the east side, which transmitted loads to the foundation," and the second seismic signal to "the fire-damaged and buckled floors [moving] downward as a single unit, transmitting impact loads to the foundation." These explanations strain credulity.

As geophysicist Andre Rousseau testified for the 2020 request for correction, the notion that interior debris falling to the lower floors inside one corner of the building could generate seismic activity sufficient to propagate 34 kilometers is simply impossible. It also contradicts NIST's

own claims about the seismic activity generated during the collapse of WTC 1 and 2, where NIST asserts that the collapsing structures — much greater in mass and force — generated no seismic activity until the debris started hitting the ground (NCSTAR 1-5A, pp. 22-24). (In reality, neither of NIST's explanations for the recorded seismic activity — in the case of WTC 1 and 2, debris impacting the ground, or in the case of WTC 7, debris impacting the lower floors of the building — have been found to be sound (MacQueen, 2009; Rousseau 2012).)

Indeed, NIST is unable to explain why scattered falling debris, whether inside or outside the building, would generate sudden, powerful spikes of seismic activity when it involves a gradual, diffuse percussive force. NIST itself points to the oddity of the second signal being generated specifically at the onset of global collapse and not after, stating:

> "One would have expected seismic signals from this second phase of collapse to be generated over this entire episode (which lasted approximately 14 s) since debris was continuously impacting the ground either unobserved within the core or externally as seen from the videos of the perimeter walls. However, because the total energy dissipated by the impact was distributed over a long period of time, the strength of the signal at any given time was small and difficult to interpret" (NCSTAR 1-9, p. 675).

In fact, in the case of the second seismic signal, its timing of 5:20:50 PM actually precedes NIST's best estimate, based on television broadcasts, of when WTC 7's downward motion began, which was at 5:20:52 PM (NCSTAR 1-9, p. 90). Why would a seismic signal be generated *prior* to the initiation of global collapse when the majority of the collapsing structure impacting the ground *after* global collapse initiation would be expected to generate much more seismic activity? A seismic event immediately preceding WTC 7's downward motion is far more consistent with the synchronized detonation of demolition devices. A seismic event corresponding to the collapse of the east penthouse eight seconds earlier is also far more consistent with the detonation of demolition devices than with debris falling to the lower floors of the building (Architects & Engineers for 9/11 Truth, 2020, Section F and Exhibit B).

The seismic evidence is corroborated by various eyewitness and audio evidence of explosions at the onset of and during WTC 7's collapse. Two examples of eyewitness reports that were given on the day of 9/11, immediately after the event, are provided below. The first report is notable because the witness explicitly identified the event as an explosion and she confirmed her account to one of the authors of this paper (Walter) in 2021. The second report is notable because it is consistent with the approximately eight-second demolition process indicated by the video and seismic evidence.

1) NY1 reporter Gigi Stone Woods, who at the time of WTC 7's collapse at 5:20 PM was stationed at the intersection of West Broadway and Reade Street, approximately 360 meters north of WTC 7, reported at 6:30 PM:

   > "…possibility that the fire was going to get worse. All of a sudden, a loud, incredibly loud explosion. And we have the video to show you" (NY1, 2001).

   Ms. Woods confirmed her account in an email to Walter in January 2021, stating:

> "Yes I am the reporter in that video. All I remember is that we were reporting near building 7 [sic] heard a loud explosion and people yelling to run and we all did. Except for a very brave cameraman Basche who stayed put and videotaped the building going down."

2) NYU medical student Darrell, who was interviewed twice on 1010 WINS Radio shortly after the event, stated:

> "Yeah, so I was just standing there. We were watching the building actually because it was on fire. The bottom floors of the building were on fire. And, you know, we heard this sound that sounded like a clap of thunder. Turned around. We were shocked to see that the building was — well, it looked like there was a shockwave ripping through the building, and the windows all busted out. It was horrifying. Then, you know, about a second later the bottom floor caved out. And the building followed after. We saw the building crash down all the way to the ground."
>
> ___
>
> "We were just standing there. All of a sudden, out of nowhere, you hear this clap, sounds like thunder. The building had shockwaves going through it. You could see a shockwave go up the — the windows blast out. You know, I thought I was watching a movie. I mean, I can't believe this is happening. It's really ridiculous. But, you know, it came down floor by floor. The structure stayed intact until it all hit the ground" (1010 WINS, 2001).

The most notable piece of eyewitness and audio evidence for the purpose of corroborating our hypothesized timing of the column failure sequence is contained in a video recording of MSNBC's Ashleigh Banfield witnessing the collapse (MNSBC, 2001). According to NIST, which examined this clip in its report, this footage was filmed at the corner of West Broadway and Leonard Street, approximately 650 meters north of WTC 7 (NCSTAR 1-9, p. 280).

Figure 15: Ashleigh Banfield and a woman being interviewed turn toward WTC 7 roughly 650 meters to the south.

In the video, Banfield and others around her hear a loud sound — from more than seven football fields away — that causes them to quickly and involuntarily turn toward WTC 7. She then exclaims, "Oh my god. Look behind us. Please pan in this way. Be careful of your baby. This is it!" A man in the background then says, "That's the building coming down," just as the crowd noise quickly crescendos, which can be interpreted as the approximate time that WTC 7 begins to descend. Analysis of the video's audio track performed by Chandler in 2010 revealed what appear to be nine separate explosions — first two initial explosions, relatively spaced out, and then seven more explosions regularly spaced over a span of 2.5 seconds (Chandler, 2010).

The roof of WTC 7 cannot be seen in the distance in the Banfield video, but by correlating the Banfield video with the video that NIST labels "Camera 4" — which was filmed at the same intersection and shows the global collapse but does not show the collapse of the east penthouse — we were able align the crescendo in the crowd noise heard in both videos. From there, we were able to deduce the exact time in the Banfield video that WTC 7 begins to descend, which then allowed us to identify the times that each explosion and Banfield's reaction were recorded in relation to the start of the descent. Then, to determine an origin time of the sounds, we added 1.92 seconds to account for the time the sound took to travel 650 meters. (NIST performed this same analysis but reached a different time for Banfield's reaction in relation to the start of the east penthouse collapse, approximately two seconds earlier than our time. We suspect this is because NIST assumed a 6.9-second interval between the start of the east penthouse collapse and the start of the roofline's downward motion — as opposed to the correct 8.2-second interval — and because NIST may have failed to account for the one-second lag between the start of downward motion and the crescendo in the crowd noise. Although NIST studied this video, it did not identify the series of nine explosions identified by Chandler in his 2010 analysis.)

From the above analysis, we determined that the first explosion picked up on the Banfield video, accounting for the travel time of the sound, occurred 0.52 seconds prior to the start of the east penthouse collapse (corresponding to our estimated failure time for Columns 79 and 80); the second explosion occurred 0.22 seconds prior to the start of the east penthouse collapse; and the series of seven evenly space explosions occurred from 0.84 to 2.68 seconds after the start of the east penthouse collapse. Meanwhile, Banfield began to turn toward WTC 7 at 3.37 seconds after the start of the east penthouse collapse (not at 1.3 seconds, as claimed by NIST). Accounting for 1.92 seconds of sound travel, Banfield and the people around her must have been responding to the explosions that occurred in the range from 0.52 seconds before to 1.45 seconds after the start of the east penthouse collapse.

NIST's Camera 3 video also picked up an apparent explosion that preceded the east penthouse collapse. Approximately one second prior to the start of the east penthouse collapse, a low but concussive boom, with a sudden acoustic onset, can be heard on the audio track. Accounting for a sound travel time of approximately 1.88 seconds, this apparent explosion occurred about 2.91 seconds prior to the start of the east penthouse collapse. We do not know why this apparent explosion was picked up by NIST's Camera 3 but apparently not by the Banfield camera (we did examine the Banfield video for signs of earlier booms), nor do we know why the series of explosions picked up by the Banfield camera was not picked up by Camera 3. We find it entirely

reasonable that different explosions would be picked up by different cameras, and we note that there may have been explosions that were not picked up at all.

Table 2 below presents the origin times of the apparent explosions captured in both videos in relation to the start of the east penthouse collapse, the north screen wall and west penthouse collapse, and the global collapse.

Table 2: Times of Apparent Explosions in Relation to Collapse Events

Event	Start Time
Camera 3 Explosion	-2.91 s
First Banfield Video Explosion	-0.52 s
Second Banfield Video Explosion	-0.22 s
Start of East Penthouse Collapse	**0.0 s**
Start of Seven-Explosion Sequence in Banfield Video	0.84 s
End of Seven-Explosion Sequence in Banfield Video	2.68 s
Start of Ashleigh Banfield's Turn Toward WTC 7	3.37 s
Start of North Screen Wall and West Penthouse Downward Motion	**7.4 s**
Start of WTC 7 Downward Motion (Free Fall)	**8.1 s***
Start of Crescendo in Crowd Noise	9.27 s

*8.1 s is the start of downward motion derived from the Camera 3 footage, which we then applied to the Camera 4/Banfield camera analysis.

Overall, the interval between the origin time of the first detected explosion in the Banfield video and WTC 7's downward motion was approximately 8.6 seconds, while the interval between the origin time of the explosion in the Camera 3 video and WTC 7's downward motion was approximately 11 seconds. Accounting for the likelihood that the final explosions occurred just prior to global collapse, this means the series of explosions lasted up to 10 seconds. Keeping in mind the margin of error inherent in all of the various measurements and the fact that an explosion does not necessarily produce seismic activity or observable structural behavior, the apparent series of explosions lasting up to 10 seconds is substantially consistent with the video observation of the east penthouse and the roofline beginning to descend 8.2 seconds apart and with two seismic signals being generated approximately eight seconds apart.

5.2 The Collapse of the East Penthouse and the Lack of Deformation

One question not addressed up to this point is how the east penthouse collapsed into the building without any deformation occurring in the nearby walls, apart from limited window breakage. As discussed in the previous section, NIST's global collapse analysis predicts significant deformation of the east wall, the northeast corner, and the north wall due to Columns 79, 80, and 81 on the east side of the core buckling low in the building and pulling the walls inward. Since there was no deformation evident in the nearby walls in the video, NIST's global collapse analysis contradicts NIST's hypothesis that Column 79 failed low in the building just prior to the collapse of the east penthouse.

As mentioned above, we hypothesize that instead of buckling low in the building, Column 79 and Column 80 were severed high in the building (where there were no fires throughout the day) in order to drop the east penthouse into the building before the demolition of the rest of the building proceeded. This may have been done to ensure that the large east penthouse fell within the building's footprint. With the initial failure of Columns 79 and 80 limited to the top few stories of the building, there would be little inward pull on the east and north walls. In addition, there is other observational evidence that Columns 79 and 80 were severed high up in the building. This includes:

1) After the collapse of the east penthouse, daylight was visible only in the two uppermost stories. If the entire eastern interior had collapsed, daylight would have been visible lower down, as there was still plenty of daylight. Corroborating this observation, NIST states:

> "A bright area is evident in the windows on the 46th and 47th floors. This bright area appeared as the east penthouse disappeared into the building, likely due to sunlight shining onto the windows through the opening created in the roof of WTC 7 by the collapsing penthouse" (NCSTAR 1-9, p. 271).

2) Window breakage occurred only throughout the top 10 to 15 stories. If the collapse had initiated low in the building, then windows lower down would have broken first. Corroborating this observation, NIST states that at 5.0 seconds:

> "Open windows are visible at multiple locations from the 37th floor to the 43rd floor" (NCSTAR 1-9, p. 273).

3) There was a shock wave that traveled down the building from the top. This may have been due to the east penthouse impacting the top stories as it fell into the building or due to the explosion or series of explosions that precipitated the east penthouse collapse. If the collapse had begun low in the building and then traveled upward, there would have been nothing for the east penthouse to impact, since the material below it would have fallen slightly before it, thus there would have been no shock wave emanating from the upper part of the building. Corroborating the observation of a shockwave traveling down the building, NIST states:

> "In this same frame [at 3.5 seconds], a faint tear-drop-shaped brighter area is also apparent, spread over multiple floors on the eastern side of the north face. This area extends downward to near the 33rd floor. When this video clip was scrubbed (played back and forth at varying rates), it was possible to observe this lighter area moving downward on the face following the penthouse descent. It appeared near the top of the building at the same time the east penthouse disappeared into the building (Figure 5–194 through Figure 5–196) and moved downward in a single continuous motion, disappearing from view behind the building in the foreground, roughly 5 s after the penthouse began to descend. The same motion could be seen in the Camera 1 video clip from which the more distant view shown in Figure 5–184 was taken.

> "Since the majority of the window glass in the area of the movement was still intact, it is probable that the lighter area was the result of changing light reflections due to distortions of the façade, similar to those discussed earlier. Such distortions could be due to physical movement of the face or perhaps to pressure changes within the building. Whatever the cause, it seems clear that some type of disturbance began to move downward in the building at the same time as the east penthouse started descending" (NCSTAR 1-9, p. 271).

4) No dust was observed being expelled from the eastern windows of the building until after the beginning of WTC 7's descent. If Column 79 had failed lower down — with the interior columns failing in a progressive manner from east to west, prior to the collapse of the exterior columns — windows would have broken and dust would have been expelled from those windows during that process. Rather, the only smoke or dust seen emanating from the building prior to global collapse was a "flow of what appears to be dark smoke" that came from an unknown location apparently near the base of the building, including on the western side of the north face. Corroborating this observation, NIST states:

> "Perhaps the most interesting feature of Figure 5–187 [taken at 3.7 seconds] is the flow of what appears to be dark smoke across the visible part of the northeast corner as high as the 23rd floor. The actual composition of the material is not known" (NCSTAR 1-9, p. 272).
>
> "Figure 5–189 was taken by Camera 6 a few tenths of a second after the global collapse started and before the images in Figure 5–200 were taken. It provides a view of the center of the north face, down to the 15th floor. Heavy smoke and/or dust are visible flowing across portions of the north face. The smoke and/or dust nearly reach to the 25th floor at the northeast corner. It is likely that this flow is a continuation of the heavy smoke and/or dust flow first observed in Figure 5–187, i.e., prior to the initiation of apparent global collapse" (NCSTAR 1-9, p. 274).
>
> "The façade damage on the west side of the face has increased [at 9.0 seconds] and seems to extend over most of the visible floors between Columns 54 and 55. **What appears to be dust has begun to flow from the open windows**" (NCSTAR 1-9, p. 276). [Emphasis added.]
>
> "Figure 5–191 [at 8.8 seconds] and Figure 5–192 [at 9.4 seconds] showed views of the north face of WTC 7 taken looking up Greenwich Street that were recorded just prior to and just after those shown in Figure 5–203 and Figure 5–207, respectively. The dust cloud is prominent in both images. It appears to extend down close to the ground" (NCSTAR 1-9, p. 281).
>
> "Camera 2 and Camera 3 views, recorded 10.0 s following the start of downward movement for the east penthouse, are shown in Figure 5–208. The West Street view shows a large amount of dust flowing from open windows on the face. **This**

> **dust first appeared around 9.2 s after the east penthouse started moving**" (NCSTAR 1-9, pp. 281-282). [Emphasis added.]
>
> "Figure 5–209 shows a frame from Camera 6 of the north face of WTC 7 recorded **10.0 s** after the east penthouse began to collapse. **Dust trails are flowing from the open windows on the east and west sides of the building**" (NCSTAR 1-9, p. 282). [Emphasis added.]

In summary, our hypothesis that Columns 79 and 80 failed high in the building is consistent with all of the available evidence, while NIST's hypothesis that Column 79 failed low in the building is inconsistent with the available evidence and is undermined by NIST's own global collapse analysis.

Similarly, the column failure sequence we propose is entirely consistent with the observed behavior and other corroborating evidence, while the column failure sequence proposed by NIST is not. Note that there is yet more evidence consistent with a controlled demolition scenario that we have not discussed, such as the "severe erosion" found in "several beams" from WTC 7, including one which was found to have undergone sulfidation and intergranular melting (FEMA, 2002, Appendix C), nor the certain foreknowledge by government officials, up to six hours in advance, that WTC 7 would collapse later in the day (MacQueen, 2008).

6. Conclusion

In an apparent attempt to make the remarkable free fall of WTC 7 seem compatible with a natural progressive collapse, NIST obscured the building's instantaneous transition to free fall by claiming that global collapse initiated earlier than it actually did and asserting a gradual build-up to free fall between the early start time and the actual start of downward motion. Our measurements, however, indicate that the entire measurable roofline of WTC 7 entered free fall instantaneously and simultaneously to within two-tenths of a second. This occurred more than a second after the time NIST calls "global collapse initiation" or the start of its Stage 1.

NIST then claimed in its final report that its global collapse analysis was consistent with the observed behavior. But careful review of NIST's global collapse analysis reveals this claim to be false. NIST's alleged column failure sequence is incompatible with the observed behavior, while its global collapse animation predicts such fundamentally different behavior that it provides strong evidence *against* NIST's hypothesis. The only column failure sequence that is consistent with the observed behavior and readily explains the other available evidence is the near-simultaneous failure of all interior columns low in the building followed about a second later by the near simultaneous failure of all exterior columns low in the building — in other words, a classic controlled demolition. This conclusion was shared by researchers at the University of Alaska Fairbanks based on their computer modeling of WTC 7's collapse (Hulsey, 2020).

Jose Torero and his co-authors claimed there is "no real way" to know what caused the collapse of WTC 7. We disagree. All one needs to do is reject theories that have no basis in reality and follow the evidence where it leads.

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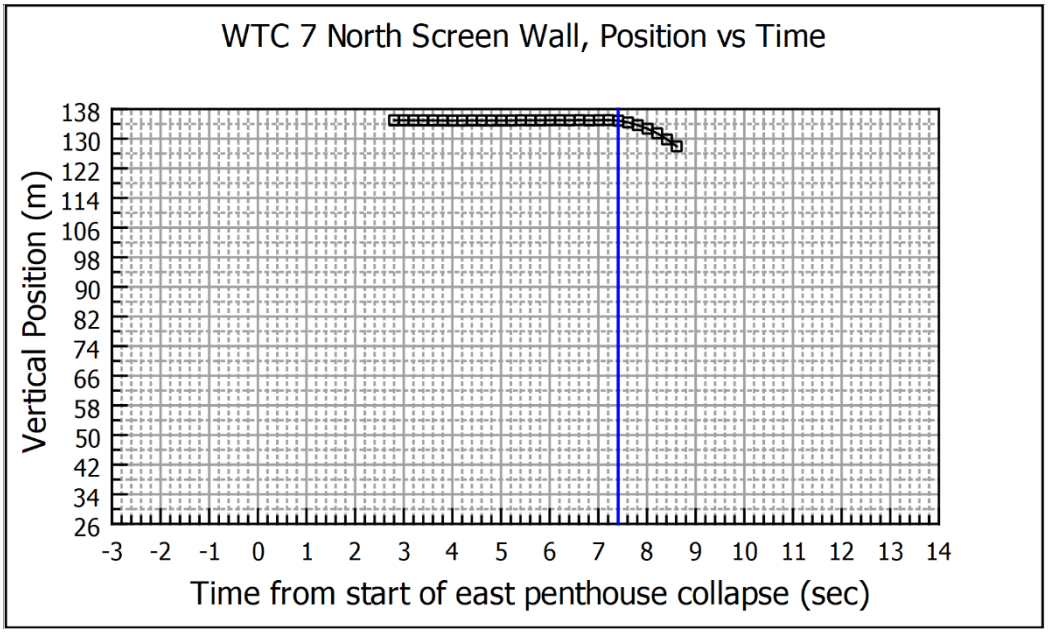
Appendix A – Downward Motion of North Screen Wall, West Penthouse, and Roofline

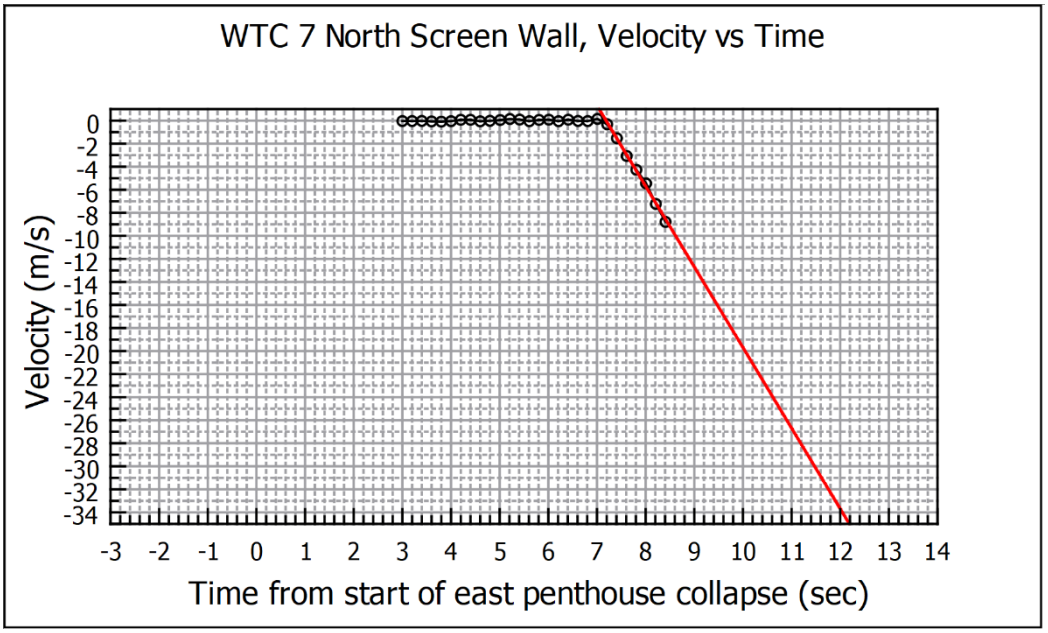
Camera 2 Measurements

North Screen Wall (Dark Green Point in Figure 4): Vertical Position vs. Time



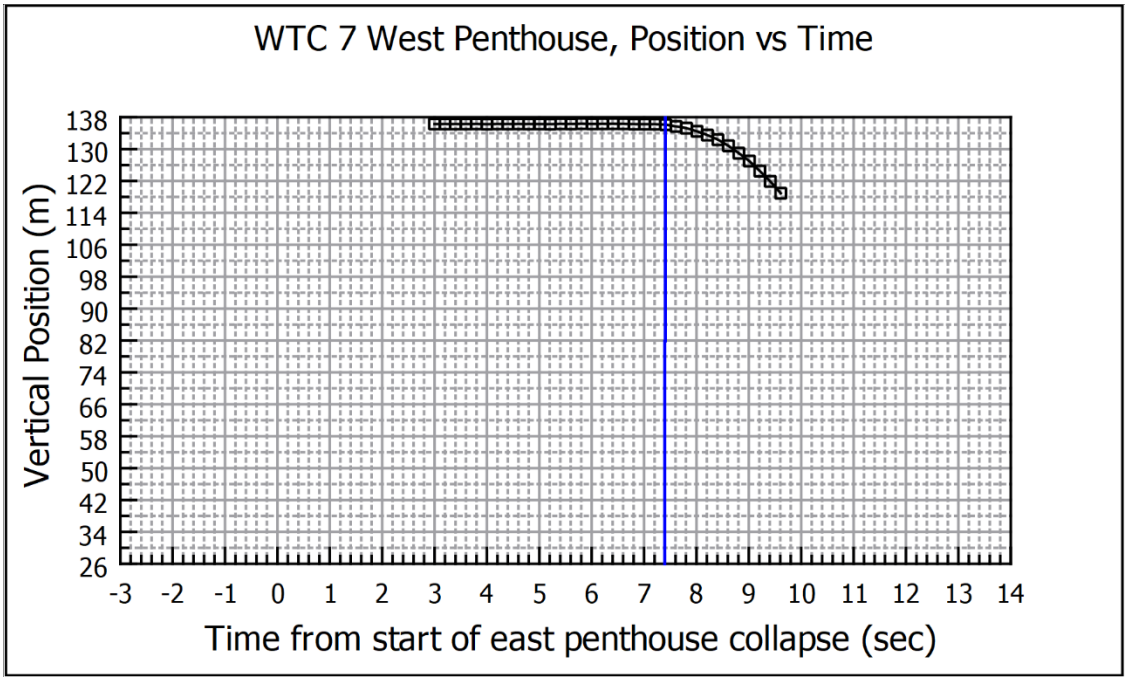
Start time of descent: 7.4 s.

North Screen Wall (Dark Green Point in Figure 4): Vertical Velocity vs. Time



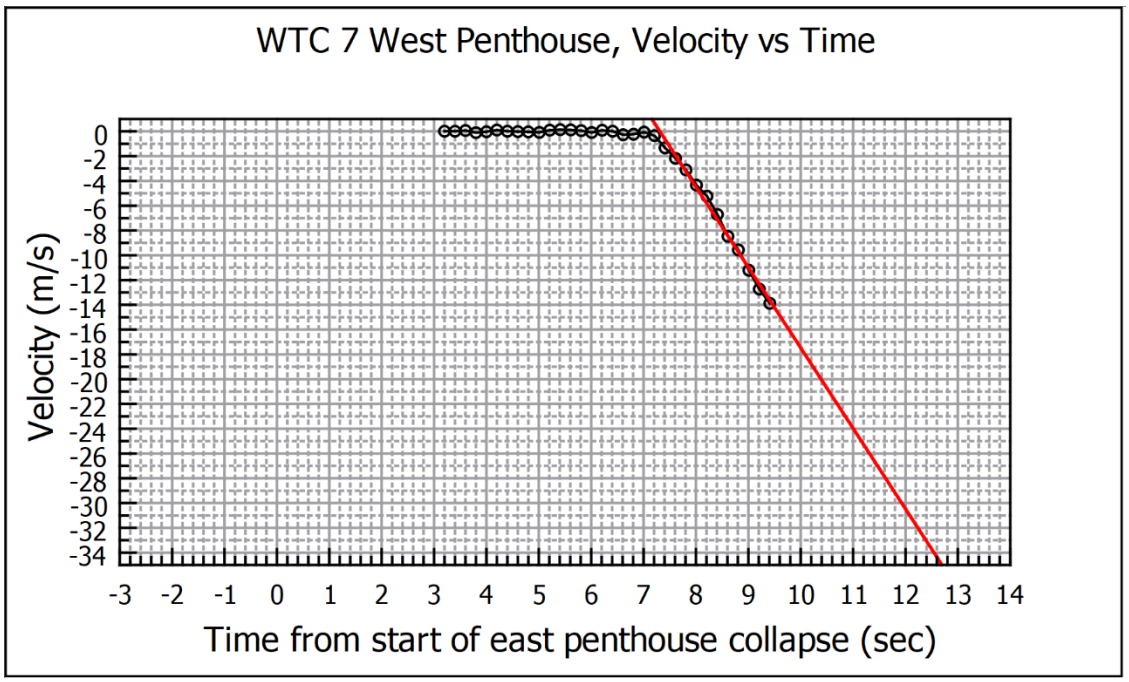
Rate of downward acceleration: 7.00 m/s^2.

West Penthouse (Light Blue Point in Figure 4): Vertical Position vs. Time



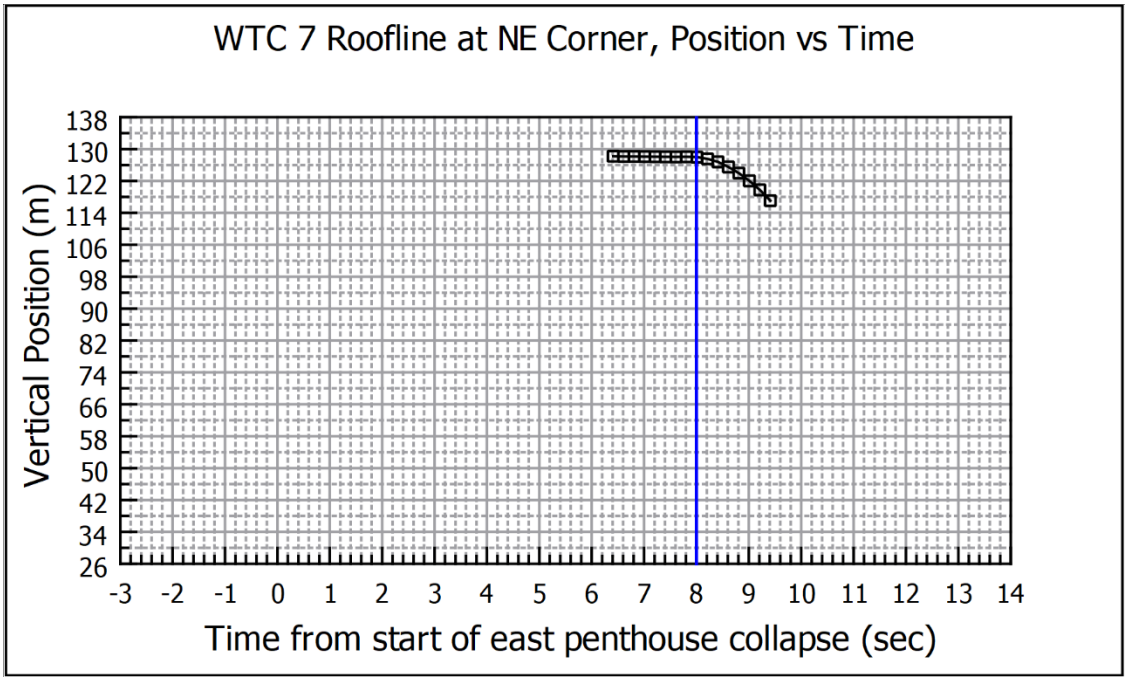
Start time of descent: 7.4 s.

West Penthouse (Light Blue Point in Figure 4): Vertical Velocity vs. Time



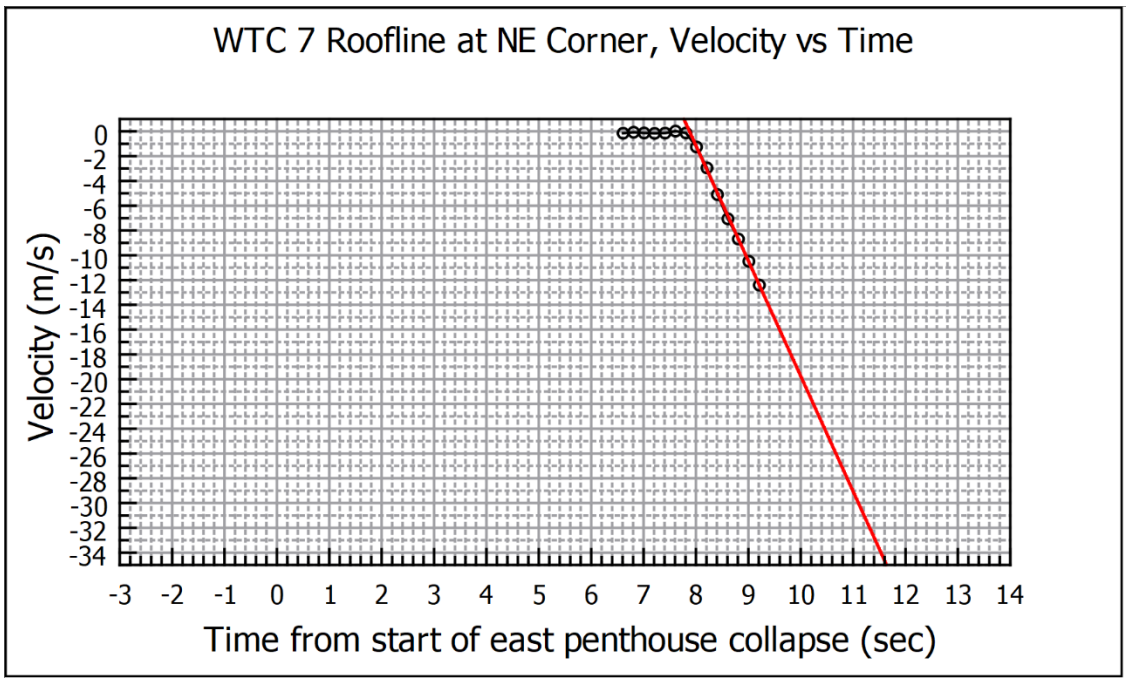
Rate of downward acceleration: 6.50 m/s^2.

Northeast Corner (Neon Green Point in Figure 4): Vertical Position vs. Time



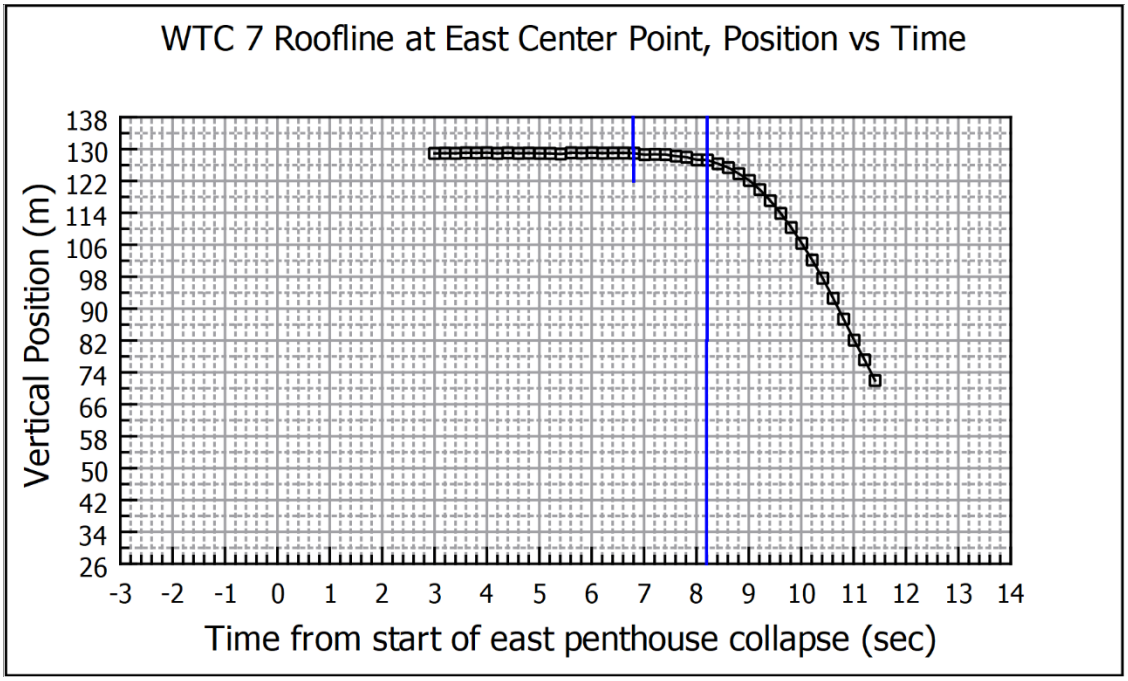
Start time of descent: 8.0 s.

Northeast Corner (Neon Green Point in Figure 4): Vertical Velocity vs. Time



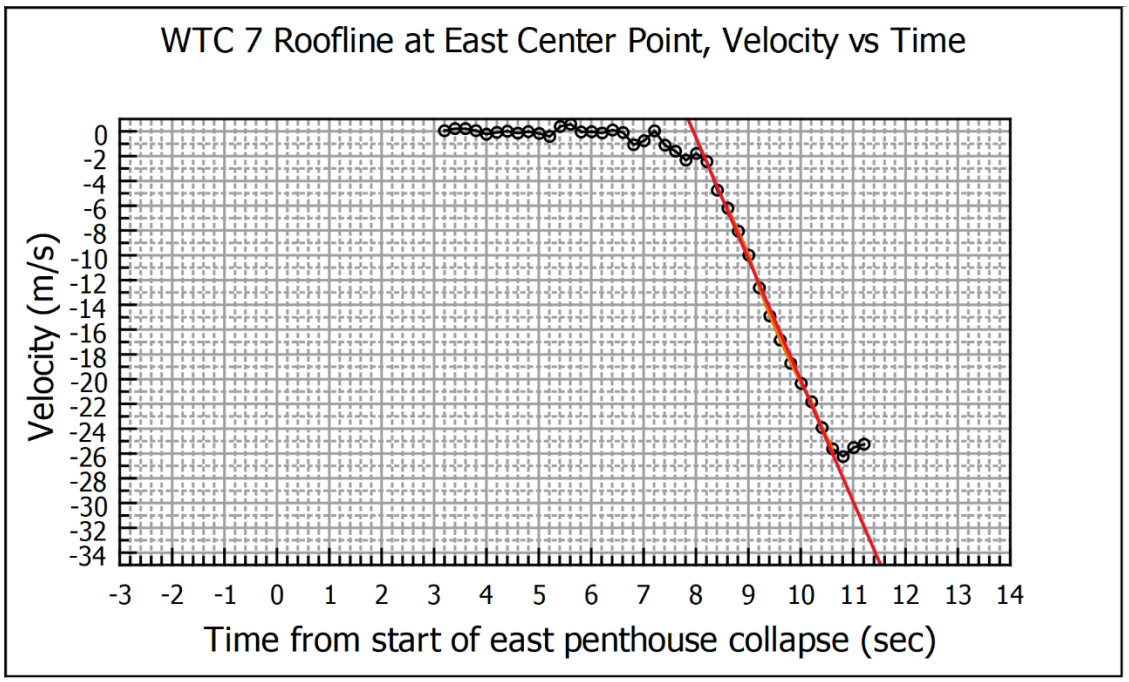
Rate of downward acceleration: 9.30 m/s^2.

East Center Roofline (Blue Point in Figure 4): Vertical Position vs. Time



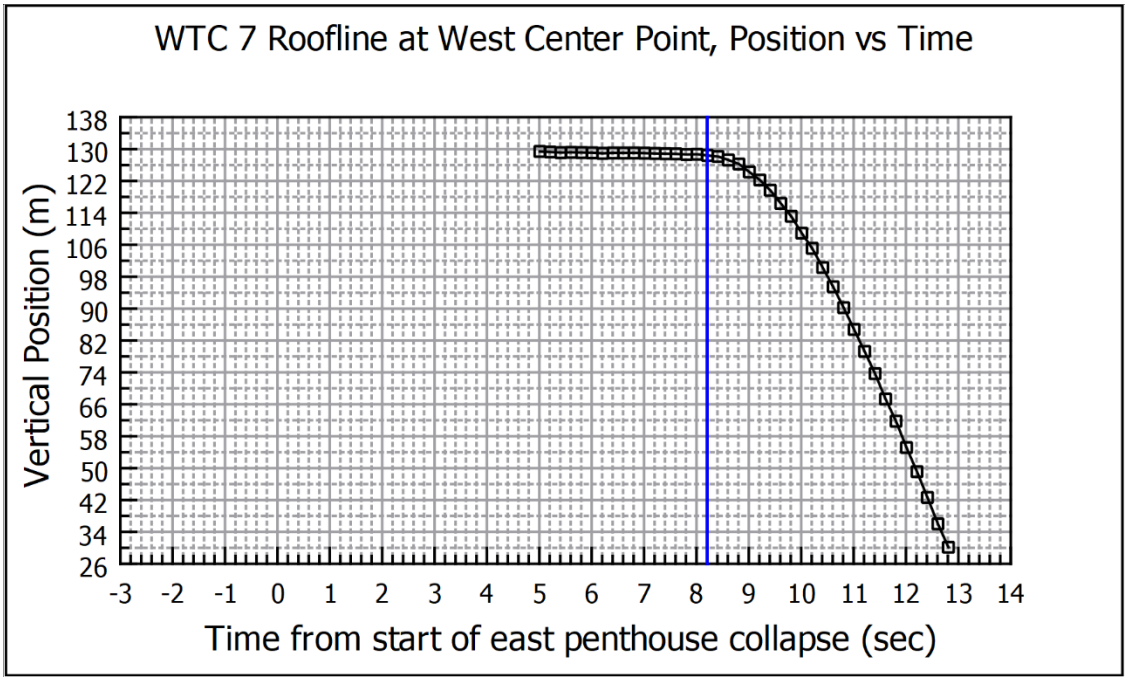
Start time of minimal downward motion: 6.8 s. Start time of free fall descent: 8.2 s.

East Center Roofline (Blue Point in Figure 4): Vertical Velocity vs. Time



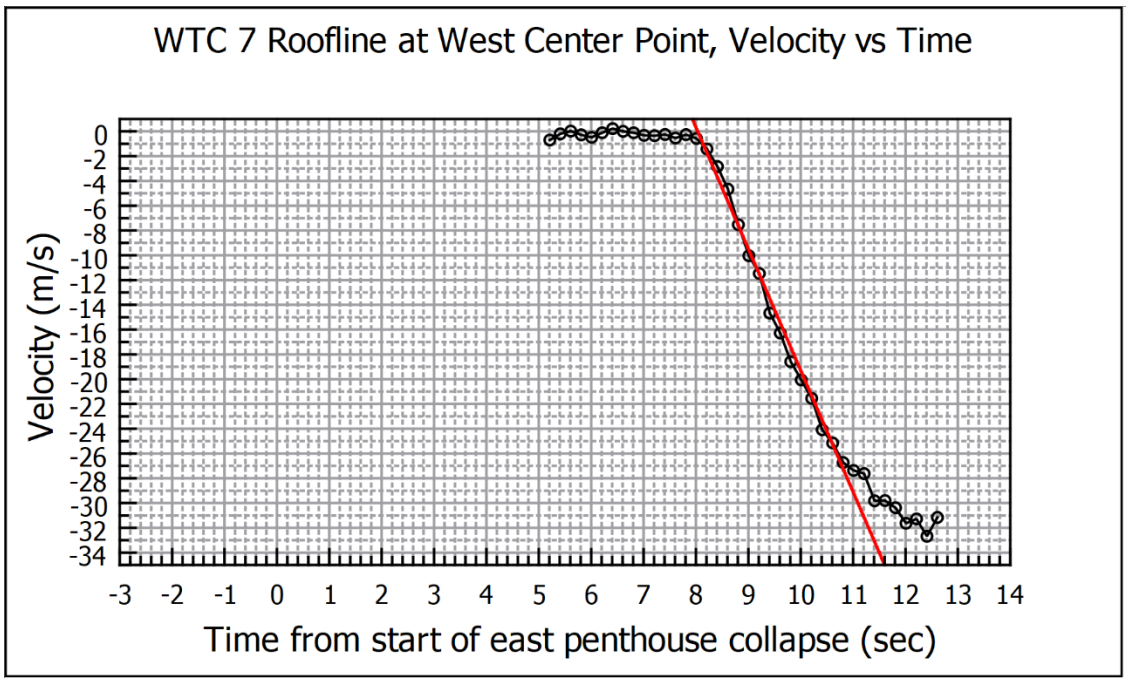
Rate of final downward acceleration: 9.79 m/s^2.

West Center Roofline (Orange Point in Figure 4): Vertical Position vs. Time



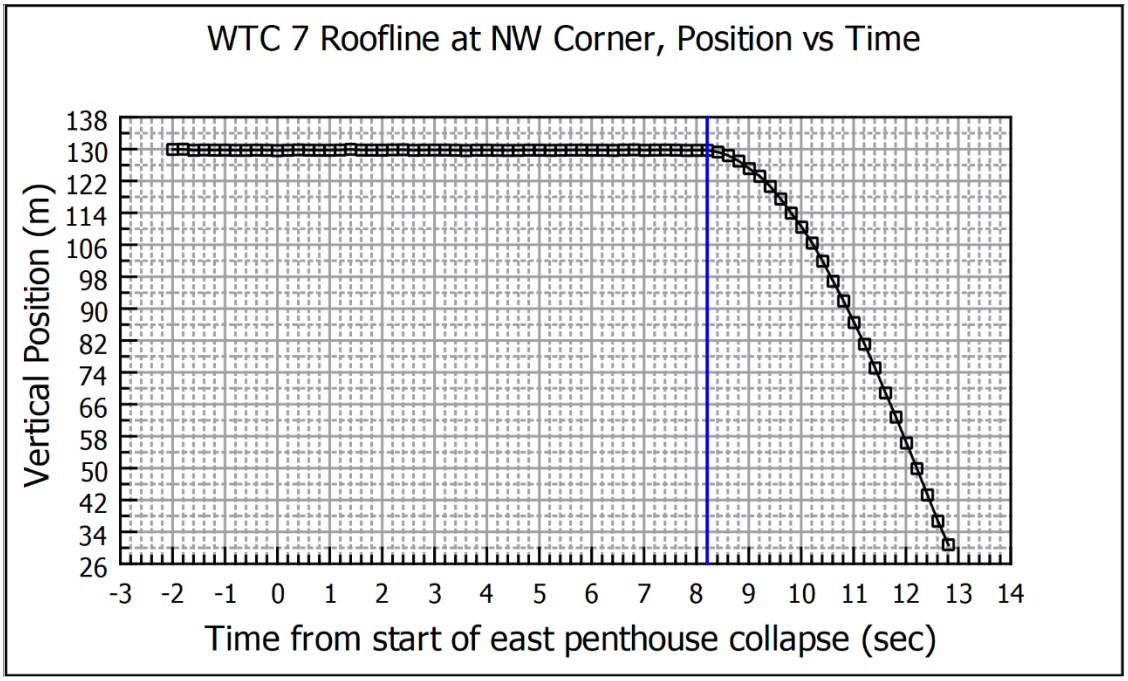
Start time of descent: 8.2 s.

West Center Roofline (Orange Point in Figure 4): Vertical Velocity vs. Time



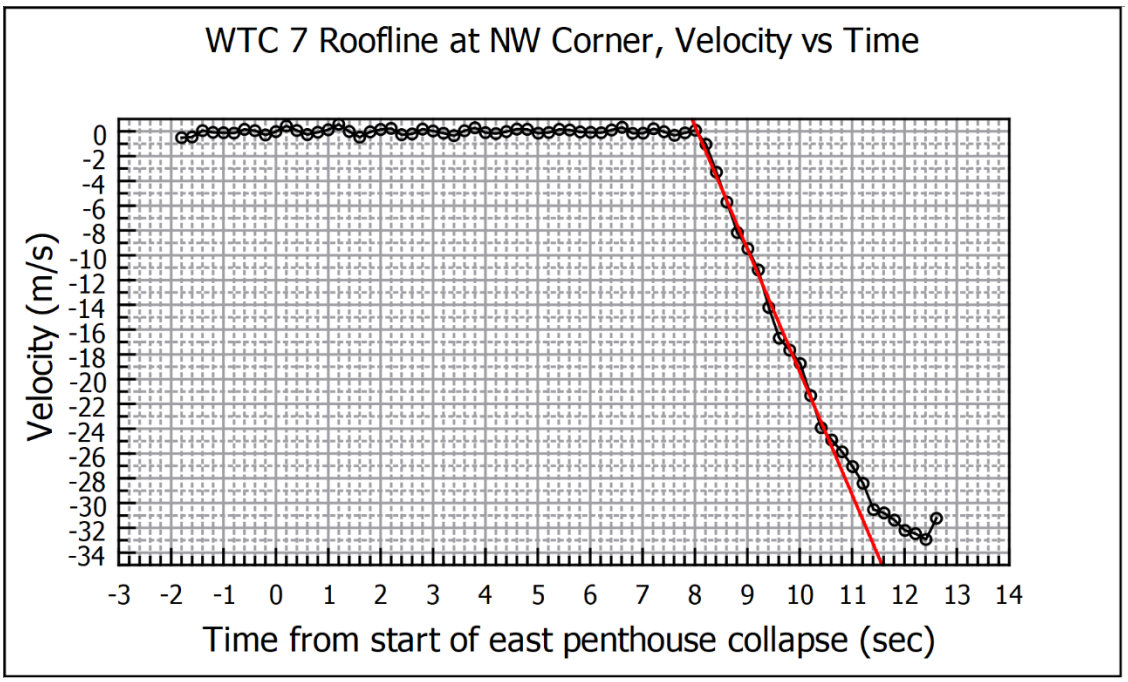
Rate of downward acceleration: 9.81 m/s^2.

Northwest Corner (Red Point in Figure 4): Vertical Position vs. Time



Start time of descent: 8.2 s.

Northwest Corner (Red Point in Figure 4): Velocity vs. Time



Rate of downward acceleration: 9.92 m/s^2.

All Camera 2 Points Vertical Positions and Velocities vs. Time

	Ref Building		E Penthouse		N Screen Wall		W Penthouse		NE Corner		EC Roofline		WC Roofline		NW Corner	
t	x	y	y	v	y	v	y	v	y	v	y	v	y	v	y	v
-1.0	42.82	90.50	135.18	-0.03											129.74	-0.11
-0.8	42.71	90.52	135.18	0.04											129.68	-0.14
-0.6	42.85	90.49	135.19	0.02											129.68	0.16
-0.4	42.86	90.48	135.19	-0.02											129.74	0.06
-0.2	42.83	90.47	135.18	0.04											129.70	-0.29
0.0	42.83	90.43	**135.20**	**-0.14**											129.62	-0.02
0.2	42.86	90.46	135.12	-0.50											129.70	0.44
0.4	42.85	90.49	135.00	-1.42											129.80	0.07
0.6	42.76	90.50	134.56	-2.02											129.73	-0.26
0.8	42.94	90.38	134.19	-2.97											129.70	-0.07
1.0	42.85	90.47	133.37	-3.97											129.70	0.13
1.2	42.76	90.55	132.60	-5.21											129.75	0.57
1.4	42.82	90.49	131.28	-6.35											129.92	-0.01
1.6	42.85	90.46	130.06												129.74	-0.47
1.8	42.78	90.56													129.73	-0.04
2.0	42.79	90.50													129.73	0.15
2.2	42.74	90.47													129.79	0.24
2.4	42.82	90.51													129.82	-0.27
2.6	43.12	90.49													129.69	-0.21
2.8	42.68	90.49			134.98										129.74	0.18
3.0	42.83	90.47			134.98	-0.04	136.28				128.92				129.76	0.03
3.2	42.82	90.49			134.96	-0.04	136.28	0.01			128.97	0.05			129.75	-0.15
3.4	42.83	90.47			134.96	-0.03	136.28	0.01			128.94	0.22			129.70	-0.35
3.6	42.78	90.48			134.95	-0.07	136.28	0.07			129.06	0.22			129.62	0.05
3.8	42.81	90.49			134.93	-0.09	136.31	-0.10			129.03	0.06			129.72	0.29
4.0	42.82	90.49			134.91	-0.05	136.24	-0.03			129.08	-0.23			129.73	-0.10
4.2	43.02	90.48			134.91	0.07	136.30	0.11			128.93	-0.08			129.68	-0.18
4.4	42.72	90.48			134.94	0.07	136.28	0.01			129.05	0.01			129.66	-0.02
4.6	42.82	90.51			134.94	-0.06	136.30	-0.02			128.94	-0.14			129.67	0.18
4.8	42.84	90.49			134.92	-0.02	136.28	-0.04			128.99	-0.02			129.73	0.16
5.0	42.86	90.46			134.93	0.05	136.29	-0.08			128.93	-0.17	129.40		129.73	-0.15
5.2	42.81	90.48			134.93	0.14	136.24	0.10			128.92	-0.41	129.27	-0.70	129.67	-0.09
5.4	42.75	90.53			134.99	0.09	136.33	0.14			128.76	0.40	129.12	-0.20	129.70	0.16
5.6	42.75	90.55			134.97	-0.05	136.30	0.12			129.08	0.57	129.18	0.02	129.74	0.11
5.8	42.83	90.52			134.97	0.06	136.37	0.06			128.99	-0.05	129.13	-0.28	129.74	-0.05
6.0	43.02	90.48			135.00	0.08	136.32	-0.09			129.06	-0.03	129.07	-0.48	129.72	-0.08
6.2	42.83	90.46			135.00	-0.05	136.34	0.09			128.98	-0.13	128.94	-0.11	129.71	-0.11
6.4	42.66	90.56			134.98	0.08	136.36	0.01	128.20		129.01	0.11	129.03	0.22	129.67	0.11
6.6	42.81	90.54			135.03	-0.03	136.34	-0.27	128.14	-0.15	129.02	-0.09	129.02	0.00	129.76	0.33
6.8	42.87	90.48			134.96	-0.04	136.25	-0.23	128.14	-0.07	**128.97**	**-1.08**	129.03	-0.11	129.80	-0.16
7.0	42.77	90.48			135.01	0.15	136.25	-0.06	128.11	-0.13	128.59	-0.76	128.98	-0.32	129.69	-0.15
7.2	42.84	90.50			135.03	-0.32	136.23	-0.35	128.08	-0.16	128.67	0.04	128.90	-0.35	129.74	0.21
7.4	42.74	90.47			**134.88**	**-1.53**	**136.11**	**-1.33**	128.05	-0.14	128.60	-1.12	128.84	-0.25	129.77	-0.03
7.6	42.88	90.46			134.41	-3.07	135.69	-2.18	128.03	0.02	128.22	-1.60	128.80	-0.54	129.73	-0.32
7.8	42.79	90.47			133.66	-4.27	135.24	-3.11	128.06	-0.13	127.96	-2.32	128.63	-0.26	129.65	-0.12
8.0	42.82	90.48			132.70	-5.45	134.45	-4.34	**127.98**	**-1.26**	127.29	-1.78	128.69	-0.57	129.68	0.09
8.2	42.83	90.49			131.47	-7.23	133.50	-5.23	127.55	-2.95	**127.25**	**-2.44**	**128.40**	**-1.42**	**129.68**	**-1.04**
8.4	42.86	90.47			129.81	-8.79	132.36	-6.71	126.79	-5.10	126.31	-4.75	128.13	-2.84	129.26	-3.29
8.6	42.85	90.45			127.95		130.82	-8.47	125.51	-7.06	125.35	-6.20	127.26	-4.66	128.36	-5.71
8.8	42.81	90.47					128.97	-9.57	123.97	-8.69	123.83	-8.06	126.26	-7.53	126.98	-8.17
9.0	42.84	90.42					126.99	-11.21	122.03	-10.49	122.12	-9.99	124.25	-10.04	125.09	-9.47
9.2	42.83	90.50					124.48	-12.73	119.77	-12.41	119.83	-12.63	122.24	-11.47	123.18	-11.19
9.4	42.93	90.46					121.89	-13.88	117.06		117.06	-14.90	119.66	-14.67	120.61	-14.21
9.6	42.78	90.48					118.92				113.87	-16.85	116.37	-16.28	117.49	-16.69
9.8	42.82	90.49									110.32	-18.73	113.14	-18.59	113.93	-17.66
10.0	42.79	90.54									106.37	-20.35	108.92	-20.06	110.42	-18.74
10.2	42.87	90.43									102.17	-21.83	105.11	-21.55	106.43	-21.33
10.4	42.81	90.47									97.62	-23.92	100.29	-24.08	101.88	-23.92
10.6	42.73	90.54									92.59	-25.62	95.47	-25.15	96.85	-24.91
10.8	42.74	90.58									87.36	-26.25	90.23	-26.73	91.91	-25.87
11.0	42.82	90.56									82.08	-25.52	84.76	-27.37	86.49	-27.06
11.2	42.73	90.55									77.15	-25.25	79.27	-27.62	81.07	-28.41
11.4	42.80	90.43									71.97		73.70	-29.82	75.11	-30.53
11.6	42.82	90.46											67.33	-29.80	68.85	-30.80
11.8	42.92	90.43											61.77	-30.38	62.78	-31.38
12.0	42.90	90.57											55.16	-31.63	56.29	-32.21
12.2	42.81	90.46											49.11	-31.28	49.88	-32.47
12.4	42.82	90.44											42.64	-32.68	43.29	-32.94
12.6	42.80	90.51											36.02	-31.16	36.69	-31.23
12.8	42.96	90.39											30.16		30.78	

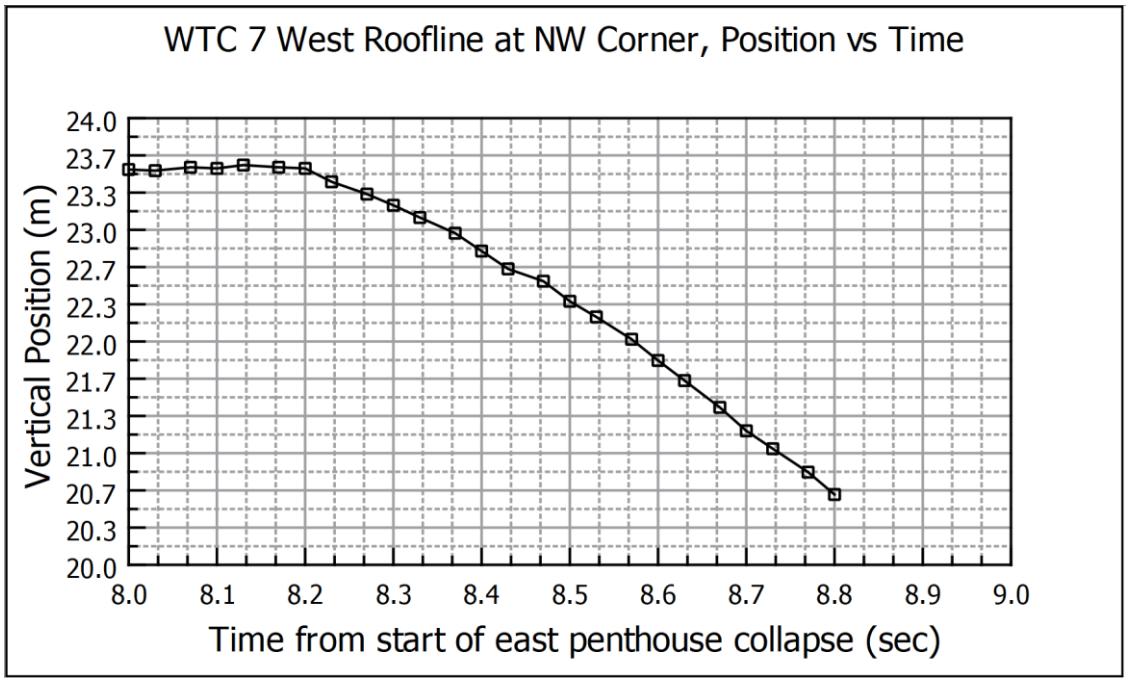
Start times of descent are bolded and outlined.

Western Camera Measurements

Methodology

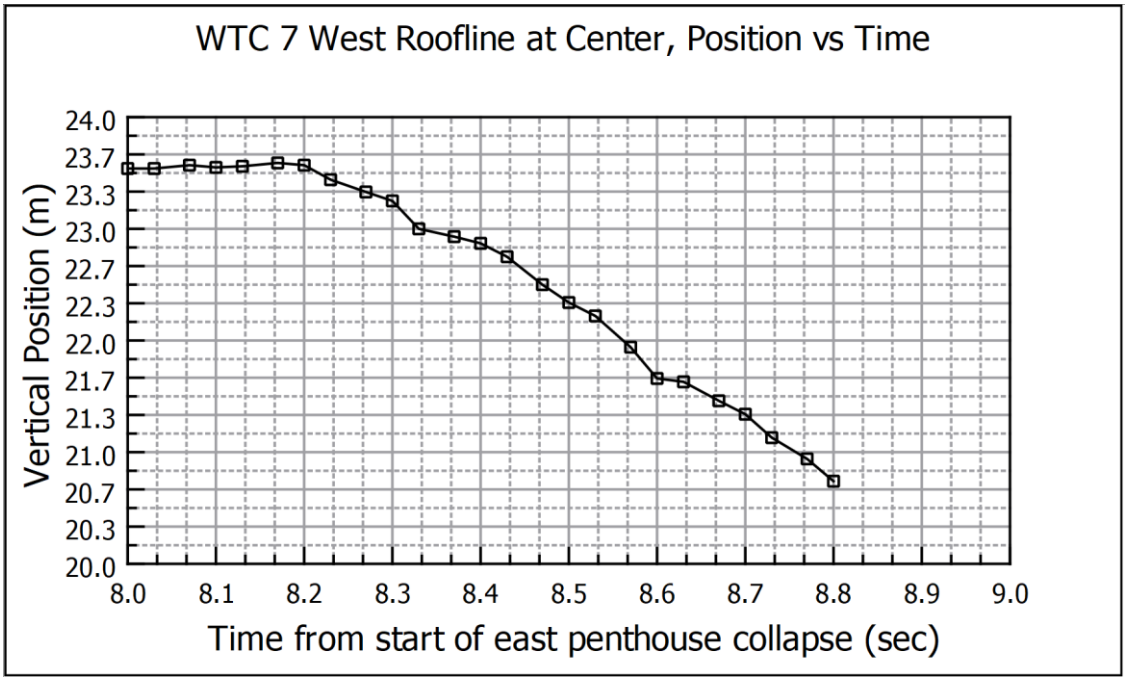
The camera that recorded the west wall of WTC 7 was hand-held. It panned and zoomed in and out several times immediately before and during the collapse of WTC 7. We used a copy of the video that was partially stabilized by Nathan Flach, but it was not stabilized enough to do reliable quantitative tracking. Therefore, a stationary reference point on a neighboring building was tracked, and the positions of the points of interest were measured relative to the reference point. We used the west wall measurements only to estimate the start time of the downward motion and not for computing the velocity or acceleration. The start times for these points are based on the known timing of the descent of the northwest corner (one of the three points in these calculations), which was already accurately measured in the Camera 2 footage. The fact that the upper section appears to remain rigid as it falls is a good indication that the points along the west wall share the same downward acceleration as the north wall.

West Face View, Northwest Corner (Red Point in Figure 5): Position vs. Time



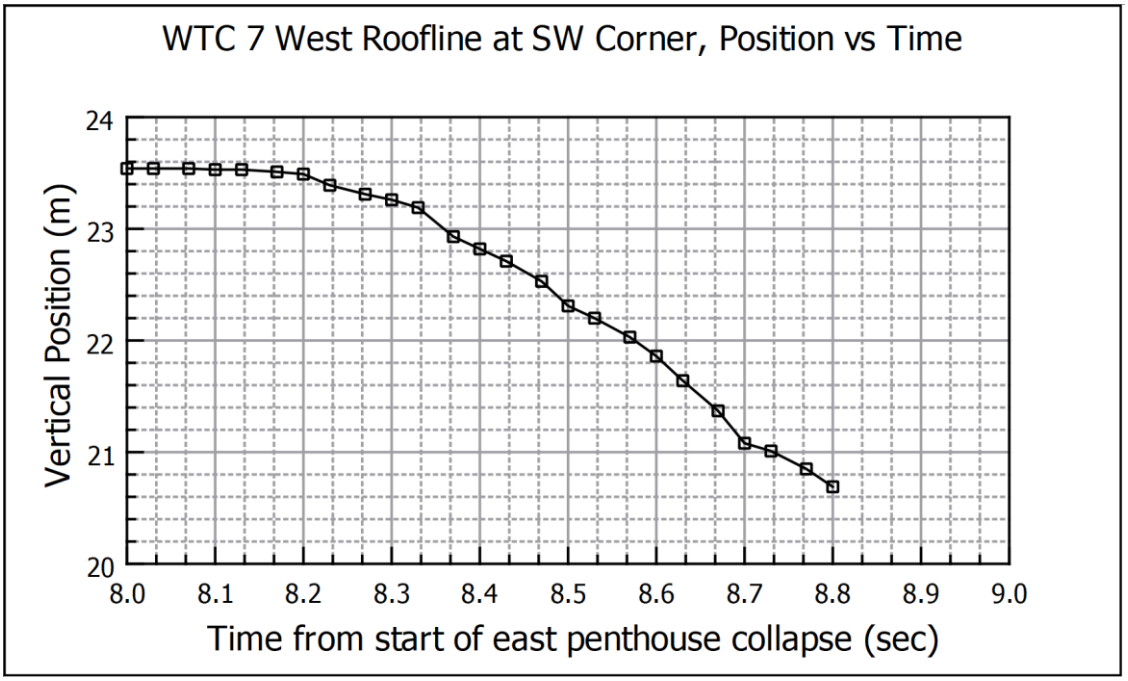
Start time of descent: 8.2 s.

West Face View, Center (Green Point in Figure 5): Position vs. Time



Start time of descent: 8.2 s.

West Face View, Southwest Corner (Blue Point in Figure 5): Position vs. Time



Start time of descent: 8.2 s.

All Western Camera Points Vertical Positions vs. Time

	Reference Point	NW Corner		Center			SW Corner		
t	y	y	relative y	y	relative y	adjusted y	y	relative y	adjusted y
8.00	29.16	52.71	23.54	48.38	19.22	23.54	44.47	15.30	23.54
8.03	29.14	52.67	23.53	48.35	19.21	23.54	44.44	15.30	23.54
8.07	29.11	52.67	23.56	48.36	19.24	23.57	44.42	15.30	23.54
8.10	29.10	52.65	23.55	48.33	19.23	23.55	44.39	15.29	23.53
8.13	29.10	52.69	23.58	48.34	19.24	23.56	44.39	15.29	23.53
8.17	29.09	52.65	23.56	48.36	19.27	23.59	44.36	15.27	23.51
8.20	29.08	**52.63**	**23.55**	**48.33**	**19.25**	**23.57**	**44.34**	**15.26**	**23.49**
8.23	29.07	52.50	23.43	48.18	19.11	23.44	44.23	15.16	23.39
8.27	29.06	52.38	23.32	48.06	19.00	23.33	44.13	15.07	23.31
8.30	29.05	52.27	23.22	47.97	18.92	23.25	44.08	15.03	23.26
8.33	29.05	52.15	23.11	47.72	18.67	23.00	44.00	14.95	23.19
8.37	29.05	52.02	22.97	47.65	18.60	22.93	43.74	14.69	22.93
8.40	29.06	51.87	22.81	47.61	18.55	22.87	43.64	14.58	22.82
8.43	29.03	51.68	22.65	47.45	18.42	22.75	43.49	14.47	22.71
8.47	28.99	51.53	22.54	47.17	18.18	22.50	43.28	14.29	22.53
8.50	28.96	51.32	22.36	46.97	18.01	22.34	43.02	14.07	22.31
8.53	28.91	51.13	22.22	46.81	17.90	22.22	42.88	13.97	22.20
8.57	28.87	50.89	22.02	46.49	17.61	21.94	42.67	13.79	22.03
8.60	28.83	50.66	21.83	46.17	17.34	21.66	42.46	13.62	21.86
8.63	28.78	50.43	21.65	46.08	17.30	21.63	42.18	13.40	21.64
8.67	28.76	50.18	21.41	45.90	17.13	21.46	41.90	13.13	21.37
8.70	28.74	49.95	21.20	45.76	17.02	21.34	41.59	12.85	21.08
8.73	28.64	49.68	21.04	45.44	16.80	21.13	41.41	12.77	21.01
8.77	28.62	49.45	20.83	45.23	16.62	20.94	41.23	12.61	20.85
8.80	28.55	49.18	20.63	44.96	16.41	20.74	41.00	12.45	20.69

Relative y: Position in relation to reference point. Adjusted y: Position in relation to reference point adjusted to a uniform roofline height. Start times of descent are bolded and outlined.

Materials for Reproducing the Measurements

The videos, the calibration data, and a video tutorial for using the Tracker software are provided as a freely downloadable kit at David Chandler's 9/11 website at https://911speakout.org/physics-lab. The Tracker software itself is available for free at https://physlets.org/tracker. It comes with documentation, and additional tutorials for its use can be found on the internet.

- NIST Camera 2: https://drive.google.com/file/d/1RGWHdqt_PO_Z-KlWhXza0QBq909BEGmC/view?usp=sharing
- NIST Camera 3: https://drive.google.com/file/d/1wXvPywYMO1BWO6Q9aCkB2fNYQJQo6-JW/view?usp=sharing
- NIST Camera 4: https://drive.google.com/file/d/1niXMKt-ERf2fnneUmLn8yeT5o2Reyzbi/view?usp=sharing

Appendix B – Downward Motion of NIST Global Collapse Animation

	E Penthouse		EC Roofline		NW Corner	
t	y	v	y	v	y	v
-2.1	193.28		188.02		197.83	
-1.9	193.28	0.00	188.02	0.00	197.87	0.09
-1.7	193.28	0.00	188.02	0.00	197.87	0.00
-1.5	193.28	0.00	188.02	0.00	197.87	0.00
-1.3	193.28	0.00	188.02	0.00	197.87	0.00
-1.1	193.28	-0.04	188.02	0.00	197.87	0.00
-0.9	193.26	-0.17	188.02	0.00	197.87	0.00
-0.7	193.21	-0.47	188.02	0.00	197.87	0.00
-0.5	193.07	-0.76	188.02	0.00	197.87	0.00
-0.3	192.90	-0.68	188.02	0.00	197.87	0.00
-0.1	192.80	-0.51	188.02	0.00	197.87	0.00
0.1	192.70	-1.10	188.02	0.00	197.87	0.00
0.3	192.36	-2.03	188.02	0.00	197.87	0.00
0.5	191.89	-2.71	188.02	0.00	197.87	0.11
0.7	191.28	-3.55	188.02	0.00	197.91	0.15
0.9	190.47	-5.56	188.02	0.00	197.93	0.07
1.1	189.06		188.02	0.00	197.94	0.00
1.3			188.02	0.00	197.92	0.07
1.5			188.02	0.00	197.97	0.04
1.7			188.02	0.00	197.94	-0.16
1.9			188.02	0.00	197.91	-0.08
2.1			**188.02**	**-0.07**	197.91	-0.08
2.3			187.99	-0.11	197.88	-0.08
2.5			187.98	-0.05	197.88	0.01
2.7			187.97	-0.15	197.88	0.04
2.9			187.91	-0.17	197.89	0.08
3.1			187.90	-0.07	197.91	0.08
3.3			187.88	-0.15	197.93	0.04
3.5			187.84	-0.06	197.93	0.11
3.7			187.86	-0.06	197.97	0.00
3.9			187.82	-0.01	197.93	-0.08
4.1			187.86	-0.08	197.94	-0.04
4.3			187.79	-0.19	197.91	-0.10
4.5			187.78	-0.09	197.90	-0.11
4.7			187.75	-0.12	197.87	0.00
4.9			187.74	-0.11	197.90	0.09
5.1			187.70	-0.14	197.90	0.04
5.3			187.68	-0.17	197.92	-0.01
5.5			187.64	-0.20	197.90	-0.03
5.7			187.60	-0.28	197.91	-0.02
5.9			**187.53**	**-0.49**	197.89	0.00
6.1			187.40	-0.61	197.91	-0.03
6.3			187.28	-0.76	197.88	0.01
6.5			187.10	-0.95	**197.91**	**-0.33**
6.7			186.91	-1.21	197.75	-0.74
6.9			186.62	-1.33	197.61	-1.09
7.1			186.37	-1.55	197.31	-2.15
7.3			186.00	-1.97	**196.75**	**-3.20**
7.5			**185.59**	**-3.02**	196.03	-4.65
7.7			184.79	-4.65	194.89	-6.62
7.9			183.73	-7.17	193.38	-8.43
8.1			181.92	-9.76	191.52	-10.07
8.3			179.82	-11.21	189.36	-11.96
8.5			177.44		186.74	

The start times listed below are bolded and outlined in the table above.

- NIST's start of east penthouse collapse: 0.0 s
- Start of gradual downward motion of east center roofline: 2.1 s
- Start of significant downward motion of east center roofline: 5.9 s
- NIST's global collapse initiation: 6.3 s
- Start of significant downward motion of northwest corner: 6.5 s
- Final acceleration of northwest corner (8.70 m/s^2) reached: 7.3 s
- Final acceleration of east center roofline (8.38 m/s^2) reached: 7.5 s