The Downward Motion of World Trade Center Building 7
(A kinematics lab with significant social implications)

Introduction

Everyone is well aware that the North and South Towers of the World Trade Center in New York City (each 110 stories high) were hit by commercial Boeing 767 airliners on 9/11/2001. Less well publicized is another building in the World Trade Center complex, Building 7 (or WTC 7) that was not hit by a plane but collapsed suddenly and completely at 5:20 pm on the same day.

A movement has arisen which challenges the official account of 9/11, calling itself the "9/11 Truth Movement." There is a scientific wing to this movement, represented by such organizations as Architects and Engineers for 9/11 Truth, Scientists for 9/11 Truth, and Scholars for 9/11 Truth and Justice. The scientific wing of the movement has focused on physical evidence which they believe proves that the buildings were brought down by explosives.

One piece of evidence cited by the dissenting scientists is that the buildings came down far too rapidly than would be expected due to natural causes. In particular, from even casual observation, Building 7's collapse looked very much like a controlled demolition. The National Institute of Standards and Technology (NIST, the government agency tasked with analyzing the building collapses) concluded that fires in WTC 7 started by the falling debris from the North Tower, burned through the day and eventually caused the collapse. In their final draft, pending public comment, they asserted that the time for the building to fall through the first 18 stories (the part visible from the camera angle they used) took "40% longer than freefall time." At the technical briefing conference on August 2008, when challenged by a high school physics teacher who asserted that measurements show the building came down very close to freefall, Shayam Sunder, the lead investigator for NIST stated:

"[A] free fall time would be an object that has no structural components below it. . . . the time that it took . . . for those 17 floors to disappear [was roughly 40 percent longer than free fall]. 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 everything was not instantaneous."

In essence, NIST said the building could not have been in freefall because that would not be physically possible. The high school physics teacher said freefall actually occurred because he had measured the actual acceleration. His question was how such a "publicly visible, easily measurable quantity" could be set aside.

* * * * *

This brings us to the substance of the lab. The goal is to resolve the dispute between the high school physics teacher and NIST.

Video footage exists which shows a level view with a stationary video camera of WTC 7 as it falls. The rows of windows on the building mark the floors. Page 41 of the preliminary NIST document released in August 2008 gives the height of the top of the windows of the 29th floor and the height of the top of the parapet (i.e. the roofline). When those two levels are identified on the video, the video can be calibrated, so that pixel measurements can be translated into real world measurements in meters. The frame rate of the camera is 29.97 (~30) frames per second. Given the position and time measurements for a corner of the building as it falls, the instantaneous velocity can be computed by numerical differentiation, which is done automatically by the Tracker software, and velocity can be plotted as a function of time. The slope of the velocity vs time graph gives the acceleration. If the building is falling with a constant downward acceleration, the velocity vs time graph would be linear, and the slope of the linear portion of the graph would give the rate of acceleration. This could then be compared with the acceleration of gravity, which for New York City is 9.803 m/s^2.

Materials Needed

All of the materials needed to perform this measurement have been collected together as a “kit” and are available for download: wtc7-lab.zip. The zip file contains

- A suitable video clip: a level view taken by a stationary camera. A video named DistantViewWTC7.avi, is included in the kit that meets these criteria. Two other clips from closer perspectives, but less suitable for measurement (Camera3.wmv and wtc70002.mov), are included for comparison.
- Data for the height of two points on the building for calibration purposes. The data we need is found on p. 41 of the document, NIST_NCSTAR_1A_for_public_comment_unlocked copy.pdf, which is in the kit. The heights that are given are for the 29th floor and the roofline (top of the parapet, the safety wall around the roof, not the top of the penthouse). These are given in feet and inches. The difference needs to be converted to meters for use as a calibration measurement.
- A way to identify the 29th floor, which is one of the calibration points. The building is 47 stories high. The rows of windows are hard to see in the video, but a still frame (WTC7-Windows.png) was extracted and brightness and contrast were increased (WTC7-Windows-High-Contrast.png) to make the rows visible. A second video (named Camera3.wmv, included in the kit), looking up at the building from a much closer distance, is helpful for comparison for identifying the windows of the 47th floor. To help with the window count, the extracted and enhanced image was imported into Geogebra (free download from geogebra.org, not in the kit itself) and a tool was constructed in Geogebra which consists of a stretchable row of equally spaced dots (like beads on a rubber band) which can be stretched to match the rows of windows. The Geogebra file with the ready-made tool and imported image (Window Counter.ggb) is included in the kit. Also the final resulting image (CountedWindows.png) with the row of dots already in place is included, so the work in this step is optional.
- Tracker software. The high school teacher who confronted NIST originally used a more primitive tool called Physics Toolkit, but Tracker is much easier to use and can produce more reliable results. Tracker is part of the Open Source Physics project and can be downloaded from https://www.cabrillo.edu/~dbrown/tracker/ . It is free and cross platform, written in Java, so your computer will also have to have Java installed. A YouTube video with a brief Tracker tutorial is available here: https://www.youtube.com/watch? Another video (named BigBallDrop.avi) is included in the Extra Materials folder for practice using Tracker.

Measurements required

- After watching the Tracker tutorial, import the video, DistantViewWTC7.avi into Tracker.
- Identify the top of the parapet (roofline of the main building) and the 29th floor. Calibrate the view using the data found on page 41 of NIST_NCSTAR_1A_for_public_comment_unlocked

copy.pdf.

- Create a marker with suitable "footprint" to use for tracking the corner point. You will be tracking the motion of the top right corner of the building. We are looking generally southward, so this is the top NW corner of the building.
- Use the video properties setting (the icon looks like a frame of film) to choose a suitable spacing of the measurements. If every frame is used, the motion from one frame to the next is very small, so the inevitable random measurement errors tend to overwhelm the data. (This is a "signal to noise ratio" issue.) This problem is partially alleviated by choosing a longer time interval between measurements. Try skipping to every third position (for a 0.1 second interval) or every 6^{th} position (for a 0.2 second interval) to get less noisy results. Do several runs and choose the best balance of precision and clean data.
- While placing the marks, turn off the trail of previous marks. Use the magnifying glass tool to zoom in to precisely position the points. After a first pass at placing the points the positions can be adjusted under magnification to get better precision. Alternatively, read the documentation and learn how to let the program automatically position the points for you.
- On the Plot panel (usually on the right side of the screen), click on the axis labels to select the y component of velocity on the vertical axis and time on the horizontal axis.
- When you are finished collecting data, be sure you are displaying y-velocity vs time, then hover on the Plot panel, right click (if using Windows or Linux; Ctrl-click if you are using a Mac with a 1-button mouse) and select "Analyze." This takes you to a large window with the data graph. (Be sure you are plotting y-velocity vs time.) Click the Analyze tab, select Curve Fits, and at the bottom select Line as the Fit Name, and check Autofit. Now select a range of points over which the graph appears linear. The Fit Equation box shows the equation of the line. The coefficient of t is the slope. Read the slope in the box to the right. (If the number is in the form 1.23E4 the E stands for the power of 10, so this number would be 1.23×10^4, or 12300.)

Results

- What is the duration of essentially constant downward acceleration? What is that acceleration?
- By what % does the measured result differ from 9.803 m/s^2, the acceleration of gravity in New York City?
- Does your result come out on the high or low side of *g*? Do you think the difference is real or an artifact of the measurement? What are possible systematic errors in the measurement?
- Do you think, given the results of this measurement, the term "freefall" is justified?
- What distance of fall corresponds with the time of fall in freefall?
- What are the implications of freefall in terms of the physics? ...in light of Shayam Sunder's statement and the NIST report?
- What do you think are the implications of freefall for interpreting the events of the day of 9/11?

Follow-up

NIST changed their final report after being confronted on the issue of the measured freefall of WTC 7. Two (of many) official "requests for correction" and NIST's final report (released just after the 2008 presidential election) are included in the kit in the Extras folder. Videotaped exerpts of the technical briefing conference can be seen here: http://www.youtube.com/view_play_list?p=206C1F5EDFC83824 .

Read the section of the report dealing with the freefall of WTC 7 in the final report and compare it with Shayam Sunder's statements, the comparable section of the preliminary report, and the example requests for correction. Search the preliminary report and the final report for the phrase, "consistent with physical principles." Explain in your own words how the final report deals with the freefall of WTC 7.