

Ballistics analysis of a radar-recorded debris pattern emanating from TWA Flight 800's position when it lost electrical power

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July 16, 2008

Abstract

A detonation not associated with the National Transportation Safety Board's proposed center fuel tank explosion occurred within, or in the immediate vicinity of, TWA Flight 800 when it lost electrical power. The center fuel tank over-pressurization was most likely a secondary event resulting from this initial detonation. A straightforward ballistics analysis of a significant and early debris pattern recorded by FAA radar sites is presented.

Background

Flight 800 crashed off the coast of Long Island, NY on July 17, 1996. The National Transportation Safety Board (NTSB) ultimately concluded that a low-velocity fuel-air explosion or deflagration caused the crash. According to the NTSB, the energy released by this explosion caused the front wall of the tank to fail along its top and side attachment points while still connected at the bottom. This allegedly caused the front wall to rotate downward and create a hole in the belly of the plane. Federal investigators say this damage caused a chain reaction resulting in the jetliner's midair breakup.¹



Figure 1: A 747, cutaway to show the top of the center wing fuel tank, just beneath the passenger cabin.¹

¹ NTSB Final Report on the crash of TWA 800, release in August 2000. Details of the tank explosion begin on page 104.

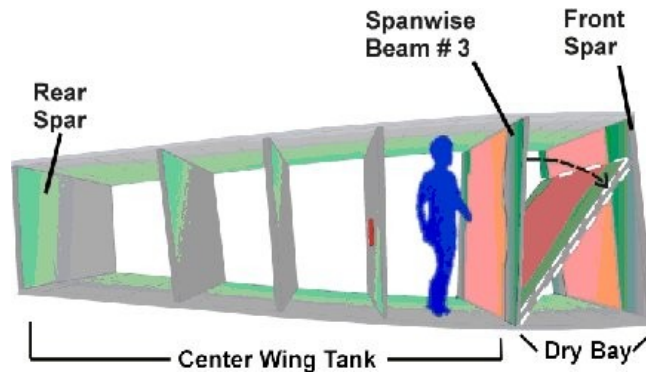


Figure 2: An NTSB image of the center wing tank, showing how its front wall failed.²

Consensus: low velocity fuel-air explosion (deflagration)

The NTSB hired Dr. Melvin Baer of Sandia Laboratories and Professor Joseph E. Shepherd of Cal-Tech's Explosion Dynamics Laboratory for their expertise in the field of explosions. Dr. Baer conducted full-scale computer modeling of tank explosions, and Dr. Shepherd conducted ¼ scale laboratory explosion tests.

Both Dr. Baer and Professor Shepherd concluded that the tank explosion deflagrated, meaning that it did not reach supersonic speeds or detonate. According to Baer, the tank would have been recovered in small pieces if it had detonated. Instead, the Navy recovered it in large sections. Even after being made aware of this analysis, Baer maintains that “nothing exited the CWT at high speed”.

Even if Dr. Baer and Professor Shepherd were wrong, and the fuel tank did detonate, the structure of the aircraft itself would absorb much of the energy from the explosion, and the resulting debris would still not reach the speed of the analyzed debris pattern, according to Baer.³

Time of explosion

According to the NTSB, the jetliner's cockpit voice recorder recorded the initial explosion at 8:31:11 PM EDT, and it was synchronized with the nearby FAA radar sites that recorded the jetliner and its associated debris descending to the ocean.⁴

X vs. Y radar plotting

The NTSB normalized the raw radar returns so that every data point had the MacArthur Islip Airport radar site at its origin. The Islip radar was the closest radar site to the crash. After this

² Image from NTSB Sequencing Group Chairman James Wildey's presentation during the final hearing on the crash of TWA Flight 800 in August of 2000, available at www.nts.gov

³ Private email communication between Dr. Melvin Baer, Sandia National Laboratories and Dr. Thomas Stalcup, NTSB Watch.

⁴ NTSB Exhibit 13A, NTSB Public Docket on TWA Flight 800, available at www.nts.gov

analysis, radar records from various FAA sites, including Islip, JFK Airport, and the White Plains facility, could be viewed on a single plot.³

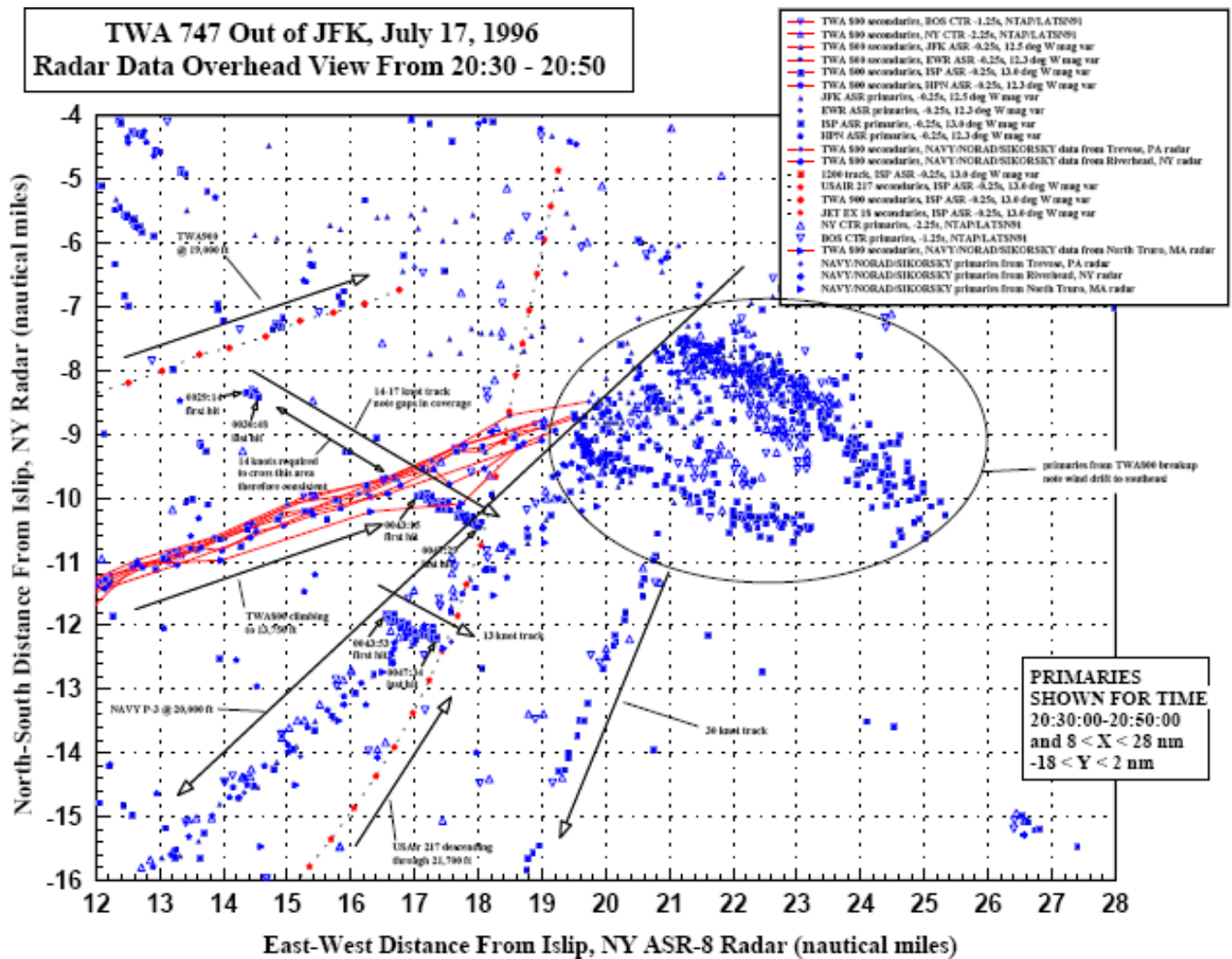


Figure 3: An NTSB plot of several FAA radar sites that recorded the crash. The red lines are from when Flight 800 still had electrical power. The circled area is radar tracked debris after the initial explosion.³

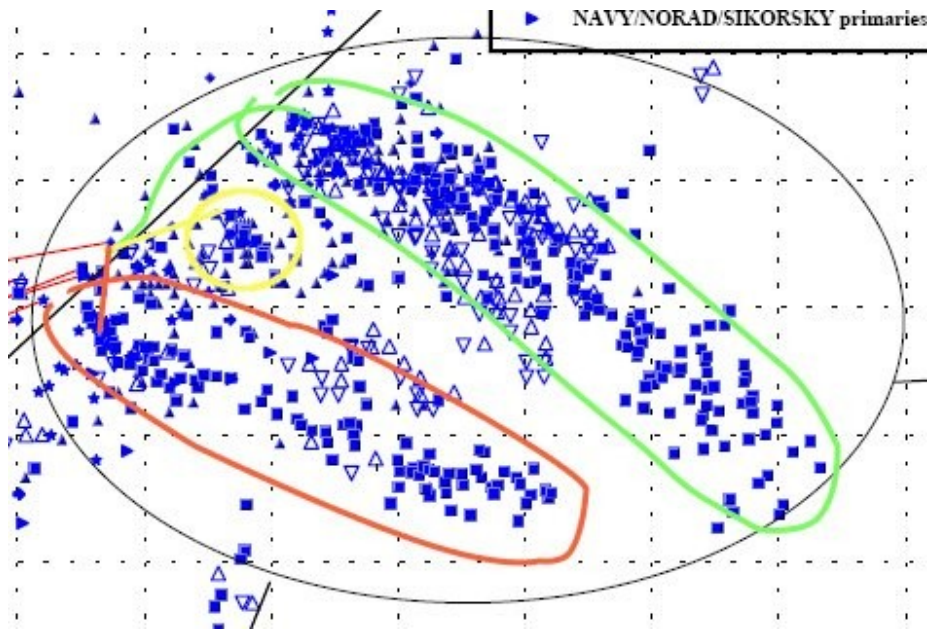


Figure 4: A close-up of the radar-tracked debris after the initial explosion, highlighting areas of clearly defined events. The red band is debris from the initial explosion, the yellow circle is debris from the nose of the plane after separation, and the green band is from the main wreckage, when one or both of its wings detached. The green line represents the approximate path of the main wreckage, including the wings. The yellow line represents the path of the nose section, which separated within four seconds of the initial detonation. The red line represents the path of debris from the initial detonation.

Notice that in figure 4 the two best-defined radar events are the red and green bands. The red band was created by the initial detonation, which in seconds launched debris approximately one half mile south of the flight path. Heavier debris from this detonation would have continued down to the ocean in an arc while lighter debris drifted to the southeast with the wind.

The radar-tracked wind drift of lighter debris appears as a distinctive band shape when all the X vs. Y data is plotted together over a period of time. NTSB radar analysts show this in exhibit 13A of their crash investigation docket. Figure 3 above is taken directly from this exhibit.

The radar returns in the green band in figure 4 were recorded when one or both of the wings separated from the main fuselage. This was by far the most visible event on radar and to eyewitnesses. Hundreds of individuals up and down Long Island, NY reported seeing a waterfall of flames as the fuel released by the recently filled wing tanks erupted. As can be seen, the green band likely contained the lightest debris, which continued to drift with the wind long after TWA Flight 800 hit the ocean.

The radar returns in the yellow circle were from the nose of the aircraft, which federal investigators say fell to the water more or less intact while the rest of the fuselage continued on a northward-turn.

FBI report addresses high-speed debris pattern

Radar consultant Michael O'Rourke was hired by the FBI to analyze the radar evidence and was one of the first experts to highlight this debris. His report to the FBI concluded that "some portion or component of the aircraft kicked out to the right nearly immediately after the loss of the transponder signal." O'Rourke expressed interest in the debris' identity after not seeing it listed in the official NTSB debris field database.⁵

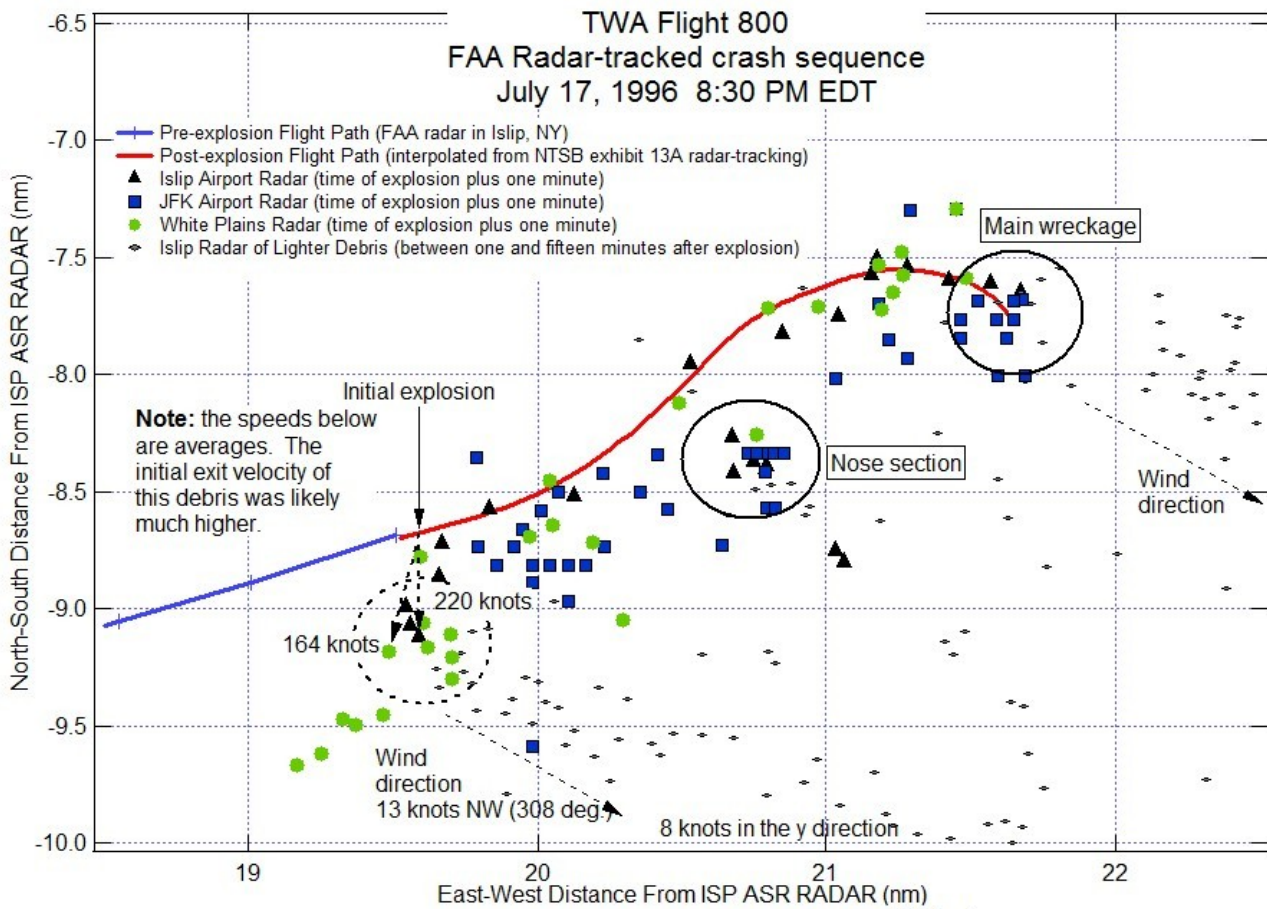


Figure 5: X vs. Y plot of FAA radar data showing average ground velocities of wreckage items.

Eight seconds after the initial explosion, the Islip radar recorded a debris item nearly half a mile south of the flight path. Its average speed over eight seconds, relative to Flight 800, was 625 knots or just under Mach 1 at Flight 800's altitude. The average speed of this wreckage relative to the ground was 220 knots.

The White Plains radar picked up this or an adjacent debris item moments later at a similar speed, further down range. Its average ground speed was 164 knots, consistent with air resistance slowing down the debris as time passed. The Islip and White Plains radar sites continued to detect these debris items as they fell to the ocean and as lighter items drifted in the wind.

⁵ FBI report available in the attachments of the Flight 800 Independent Researchers Organization's petition to the NTSB here: http://flight800.org/FIRO_pet_attach.pdf

It is important to note that the speeds listed on the above plot are *averages* over a period of eight seconds or more. This amount of time is a relative eternity for debris ejected from instantaneous detonations. The extreme forces of air resistance will slow high-speed debris to a fraction of its speed in just a few seconds, making the average speed over many seconds far lower than the speed at which this debris was ejected. Therefore, the initial speed relative to the jet liner was well over Mach 1 or supersonic. To calculate a range of possible ejection velocities, a ballistics analysis is necessary.

The NTSB did not list this debris on their official debris field charts, and their final report does not contain an analysis of its radar-recorded trajectory. Although radar printouts in NTSB Exhibit 13A show that the pattern created by this debris was the second most luminous event on radar (second only to the separation of one or both of the aircraft's wings), the NTSB apparently did not conduct a ballistics analysis or consider the implications of its timing, displacement, or velocity.

Ballistics analysis

Debris velocities are impossible to discern from an X vs. Y plot alone, but when the time of each radar point is applied to the data, the average speed of the wreckage can be determined. For example the speeds shown in figure 5 were determined after dividing the distance of each radar return from the initial explosion by the time elapsed after that explosion.

We explained above how the south-bound debris that moved away from Flight 800 at an average speed close to Mach 1 over eight seconds shows that a supersonic explosion caused the crash. But we didn't quantify how much over Mach 1 this debris traveled. Now, with well-established ballistics formulas, a range of possible exit velocities for the debris can be obtained.

Whether or not an individual understands the formulas associated with ballistics, we are all familiar with its effects. Ask a friend to throw a styrofoam cup at a tree twenty yards away, and you'll get funny look. Ask a friend to hit the tree with a rock, and you both know it's possible.

When you put your hand out a window in a car going sixty miles an hour on the highway, you feel a strong force of air pushing against it. But don't ever stick your arm outside a moving commercial jet's window. It's traveling ten times faster and the force on your arm would be one hundred times stronger.

The reason for this is because the force of air resistance on your arm is proportional to the square of your velocity through the wind, as follows:

$$\mathbf{F}_d = -\frac{1}{2}\rho v^2 AC_d \hat{\mathbf{v}}$$

(1)

F_d is the drag force, ρ is air density and v is velocity. 'A' is the cross-sectional area of your arm exposed to the air stream and C_d is the drag coefficient. The negative sign and the unit vector symbol mean that the force will oppose your arm's motion through the air stream.

This means objects that separate from an aircraft during midair breakups typically decelerate quickly and directly behind the main fuselage. In the present, NTSB-proposed theory for the crash, this is what the radar sites should have recorded. However, they actually show debris being thrown very far, very fast, well off the flight path. This is something that can't happen with just a center wing tank explosion.

Since the laws that apply to your arm also apply to this debris, they can be used to extract important information regarding the detonation. By plotting the radar data in distance vs. time plots, ballistics curves can be fit to the data to obtain a range of possible exit velocities and drag coefficients.

First we have to consider a large range of possible ejection velocities, which means adjusting equation 1. That equation stops being useful at speeds greater than Mach 2, where the drag force becomes more linear with speed. Therefore, a computer program can be generated to calculate ballistics curves, as described by Marion and Thornton's text on classical dynamics.⁶

Such a program computed the following ballistics curves for the high-speed debris pattern recorded on radar. This program calculated position and time coordinates of probable ballistics curves over five millisecond intervals, using Marion and Thornton's drag force data.

For simplicity, we set the origin to the position at which Flight 800 recorded the initial explosion and converted the units to metric.

Objects of various shapes and sizes were likely ejected from the initial detonation. Each slowed down at a different rate, creating the wide, red band of radar returns in figure 4. This means that there are multiple forces acting on these objects, which allows for multiple ballistics curves fitting the data.

⁶ Classical Dynamics of Particles and Systems, Third Edition, Jerry B. Marion and Stephen T. Thornton, Harcourt Brace Jovanovich, Inc, 1988, page 65.

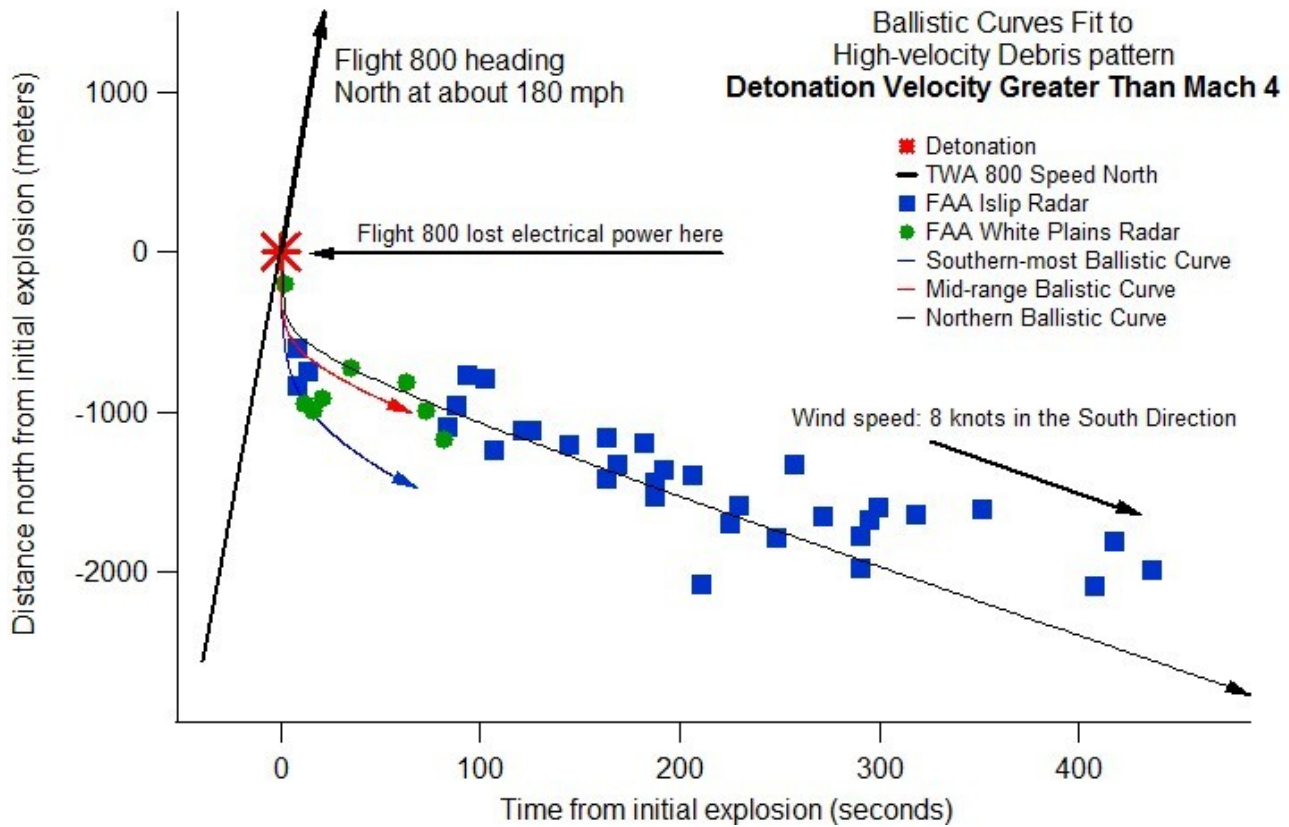


Figure 6: Three ballistics curves fit to north-south position vs. time data from the high-velocity debris pattern captured by the Islip and White Plains radar sites. Note that this plot only shows the north-south distances and speeds. Flight 800 was heading ENE at 385 knots.

Using our computer program, three ballistics curves were found to fit the data very well. Speeds in excess of Mach 4 fit the data best. Speeds lower than that did not fit the data well, regardless of the ballistics coefficient (BC) generated. Below Mach 4, curves with high BC values would not decelerate fast enough and curves with low BC values would not travel far enough.

Discussion

A straightforward ballistics analysis of the radar evidence shows that a supersonic explosion ejected debris from the vicinity of TWA Flight 800. Extreme forces of air resistance quickly slowed down the debris, following physical laws within the field of aerodynamics.

It is clear to see this high-speed event on radar. It was recorded by nearly every radar site that recorded the crash, including the Islip Airport, JFK Airport, White Plain's Airport, New York Center, Boston Center, and the Navy's radar facility in Truro, MA.

This report does not address the possible reasons for why this debris was never received by the National Transportation Safety Board, nor does it address why, in its final report on the crash, the NTSB did not provide their own analysis of this debris pattern or reference an FBI

report that highlighted it.

The officially proposed, low-velocity fuel-air explosion could not have caused the high-velocity debris pattern captured on radar and displayed above. The only way to explain the data is to either 1) reject the official radar records from all of the radar facilities listed above or 2) reconsider the official probable cause determination, which contains no physical processes to create the analyzed debris pattern.