DOCKET NO. **SA-522**

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

SPECIALIST'S REPORT OF INVESTIGATION
VIDEO STUDY

(24 Pages)

NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorders Division
Washington, D.C. 20594

April 2, 2002

Video Study

NTSB Accident Number:
DCA02MA001

by Douglass P. Brazy

A. ACCIDENT

Location:	Belle Harbor, NY
Date:	November 12, 2001
Time:	9:16 a.m. Eastern Standard Time
Aircraft:	Airbus A300-600, N14053
Operator:	American Airlines

B. GROUP

N/A

C. SUMMARY

On November 12, 2001, an Airbus 300-600 experienced a loss of control upon initial climb-out and crashed into a residential area in Belle Harbor, New York. Black-and-white video recordings recovered from a local surveillance system captured images of the accident airplane during a portion of the flight. The airplane can be seen in two different camera views, which are slightly overlapped. In the first view, the airplane can be seen as a small black dot moving from left to right across the sky, until it is obscured by a building in the foreground. Just at the time the airplane becomes obscured in the first view, it can be seen emerging from behind another obstruction in the second view. In this second view, the airplane can also be seen as a small dot initially flying from left to right, then starting to descend. During the descent, what appears to be a white "streak" can briefly be seen trailing behind the dot, before it descends behind a building and is obscured. About 40 seconds after the airplane descends behind the building, black smoke can be seen rising in the background.

D. DETAILS OF INVESTIGATION

Background information – tape and recording system

The Vehicle Recorders Division received a VHS videotape labeled "TBTA Video 11/12/01 NTSB copy". The tape was a copy of a recording from a video surveillance system installed by the Triborough Bridge and Tunnel Authority in New York, New York. The tape contained video captured from six different cameras at about the time of the accident. Two of these cameras were located at the Gill Hodges Marine Parkway Bridge toll plaza, and captured what is believed to be American Airlines Flight 587 during a portion of the flight. One camera was located in Lane 1 of the toll plaza; the other was located in Lane 5.

The surveillance system uses multiplexers (manufactured by Kalatel, Inc.; model Calibur CBR-16CDT) to combine the images from multiple cameras into a single video signal. This combined signal can then be recorded on a single videotape.

According to a representative from the Triborough Bridge and Tunnel Authority, the cameras in Lane 1 and Lane 5 were both connected to the same multiplexer (denoted "multiplexer B at Marine Park"), while all of the other cameras were connected to either one of two other multiplexers (either "multiplexer D at Marine Park" or "multiplexer D at Cross Bay bridge"). As a result, the cameras in Lane 1 and Lane 5 share a common time base. A single clock is used to "burn in" the time of day seen in the video frame for both views.

The video signal from each camera is not recorded continuously. Instead, the multipexer alternates between a number of cameras (up to 16) and captures “snapshots” from them. The specific rate and the order in which the cameras alternate can vary over time, and is based on the configuration of the multiplexer. Review of the video from both cameras indicates an approximate rate of 2-3 video fields (images) per second. However, when the video recording is demultiplexed, “real time” is maintained by padding the output signal with duplicate still images. The VHS tape received by the NTSB contained demultiplexed video signals for each camera view.

Other recorded data

The video recordings were examined in conjunction with data recorded from several other sources, each having their own distinct time base: [1]

1) The digital flight data recorder (DFDR) which stopped recording at 14:16:01.23 Coordinated Universal Time (UTC).

2) Radar Data recorded by the Federal Aviation Administration. The last secondary radar return was recorded at 14:16:01.82 UTC.

3) The cockpit voice recorder (CVR) which stopped recording at 14:16:14.77 UTC.

The airplane is visible in the video recordings from 14:15:54.48 to 14:16:12.08 UTC. The video data was synchronized in time with these other sources to establish an

[1] The time correlation among these additional data sources can be found in the Aircraft Performance Group Chairman’s Factual Report. Unless otherwise noted, all times in this report reflect FAA Air Traffic Control time in UTC.

overall timeline of events. The chart in Figure 1 gives an overview of the different data sources and their respective time periods.

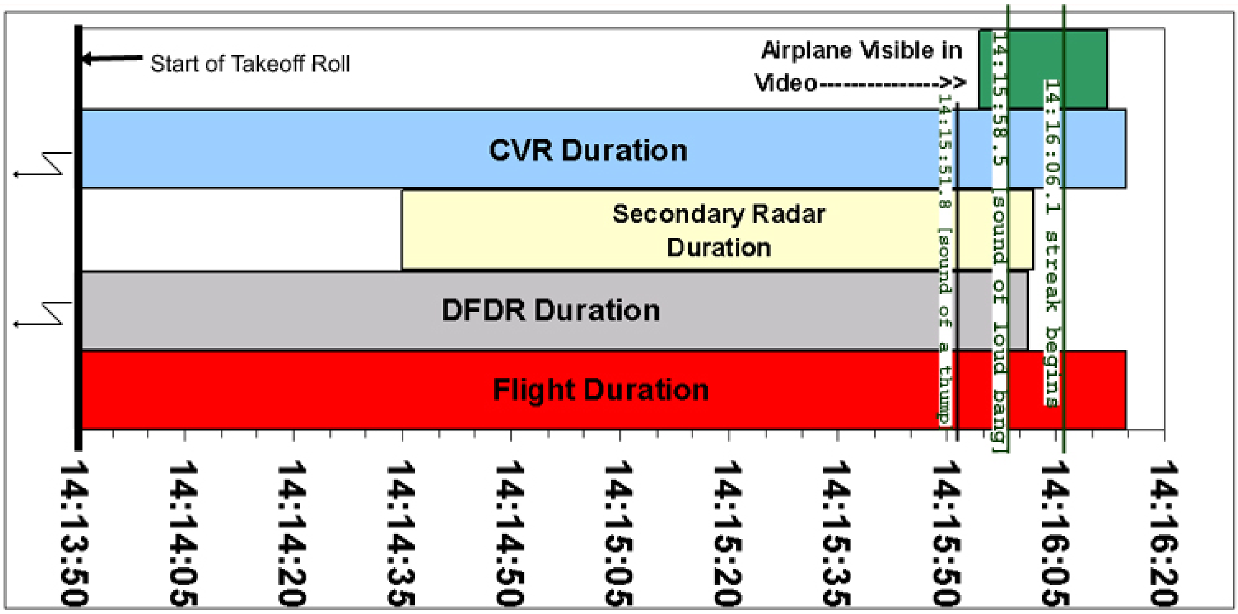

Figure 1. Recorded Data Sources in UTC

Study objectives

The video recording was examined in order to determine the following:

- Compare the elapsed time information from the video recording with that of the DFDR/CVR correlation, and determine if the CVR recorded up to the time of impact.
- Determine when and where the "streak" occurred in relation to other events recorded by the DFDR, CVR, and recorded radar data.
- Calculate the position of the airplane at several points after the loss of DFDR and radar data.

In order to accomplish these tasks, the video images and the airplane's ground track had to be oriented to a common frame of reference. Using the known location of the video cameras, and 7.5-minute topographical maps from the United States Geological Survey[2], an angular reference to true north was established using the roadway (Flatbush Avenue) that approaches the toll plaza. From the toll plaza, the heading along Flatbush Avenue was measured on the map to be 320°[3]. See Figure 2.

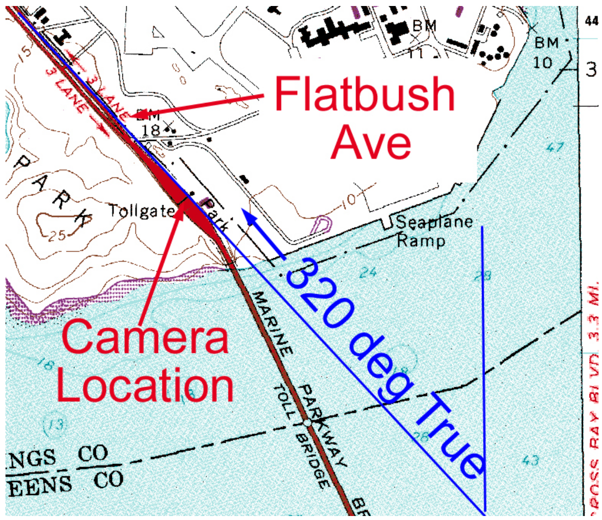

Figure 2. Azimuth Reference (Image not to scale) [4]

After establishing this reference, investigators conducted a site survey at the toll plaza. Using a Total Station surveyor's theodolite (Topcon model GTS-3), measurements were taken from the two camera positions to various landmarks visible in the video images. The Total Station was positioned immediately in front of each camera, and referenced to the 320° heading of Flatbush Avenue.[5]

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[2] Three 7.5-minute "quadrangle" maps were used. The map names are Far Rockaway, Coney Island and Jamaica, all located in the state of New York. These maps are available from the USGS.
[3] All heading and azimuth values referred to in this report are referenced to True North.
[4] All figures in this report are for illustrative purposes only, and are not intended for use in scale measurements. Actual measurements were taken from the original sources.
[5] During the site survey, the true heading of Flatbush Avenue was also measured to be 320° using a handheld GPS receiver.

Landmarks surveyed

Figure 3 is a still image taken from the video recorded by the camera located in Lane 1. The landmarks surveyed from this camera position are indicated in the figure.

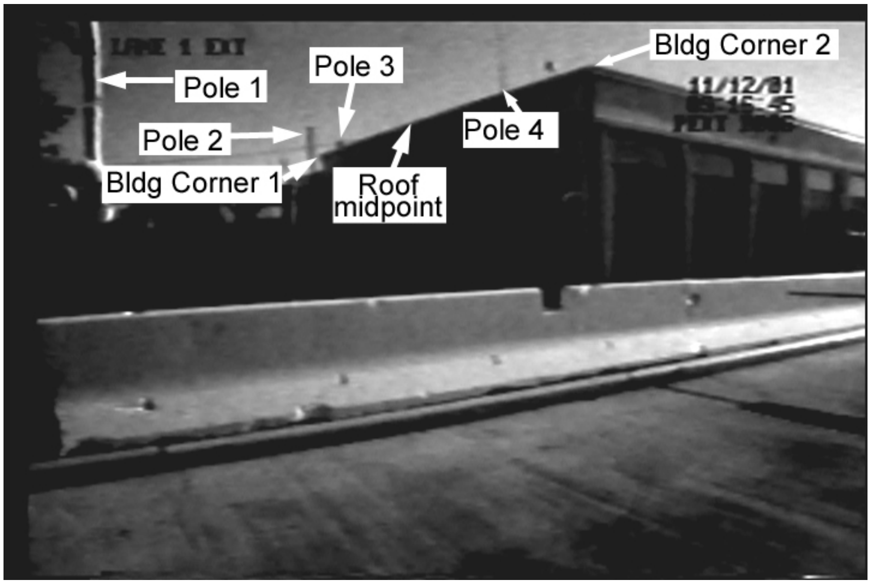

Figure 3
Camera View from Lane 1 - Landmarks surveyed

Poles 1, 2, and 3 were not readily accessible, and therefore the distance to each pole was not surveyed. However, the heading (azimuth) to the pole from the camera was measured for these landmarks. The distance from the camera to the "Roof midpoint" landmark was determined by measuring the length of the roof with a tape measure, and positioning the surveyor's prism at the center of the roofline.

Figure 4 is a still image taken from the video recorded by the camera located in Lane 5. The landmarks surveyed from this camera position are indicated in the figure.

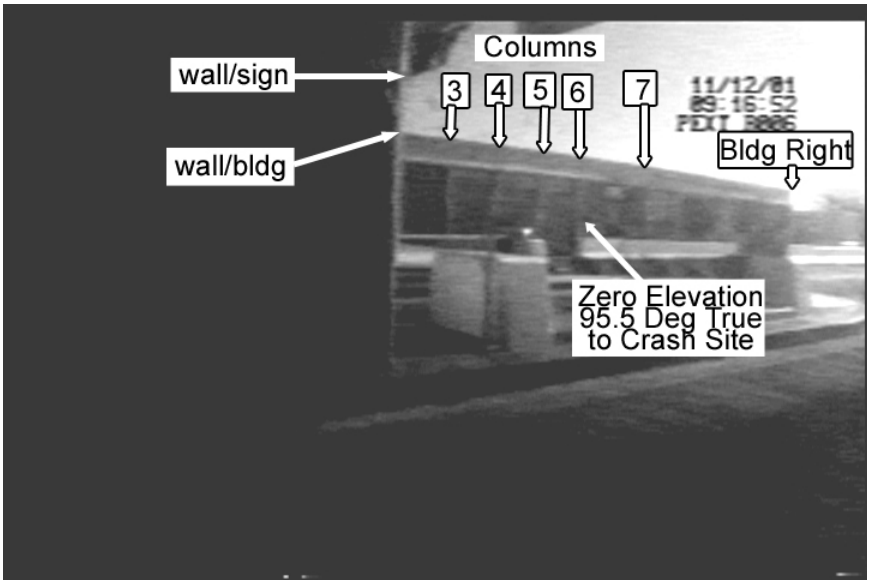

Figure 4.

Camera View from Lane 5 - Landmarks Surveyed

Most of the landmarks in this image were easily accessible, and were surveyed with distance measuring equipment. Positions (range, azimuth, elevation angle) were determined for each of these points relative to the camera location. Columns 3 through 7 were surveyed along the roofline directly above each column. Also depicted in the figure is the direction to the crash site at a zero elevation angle.

The data collected during the sight survey made it possible to orient the camera views and the landmarks to the flight path of the airplane. This was done by combining information from the tollbooth videotape, recorded radar, DFDR, and CVR data onto the topographical maps.

Figure 5 is a scanned image of the topographical maps depicting the area of interest. The blue line denotes the ground track of the airplane as defined by the last three recorded radar positions. The crash site was plotted using GPS coordinates of the impact area, which were obtained by the on-site investigation team. The yellow line is the straight-line assumption of the ground track after the radar data end. The data collected during the toll plaza survey was used to project lines (representing the landmarks) from the camera position to where they intersect the ground track of the airplane.

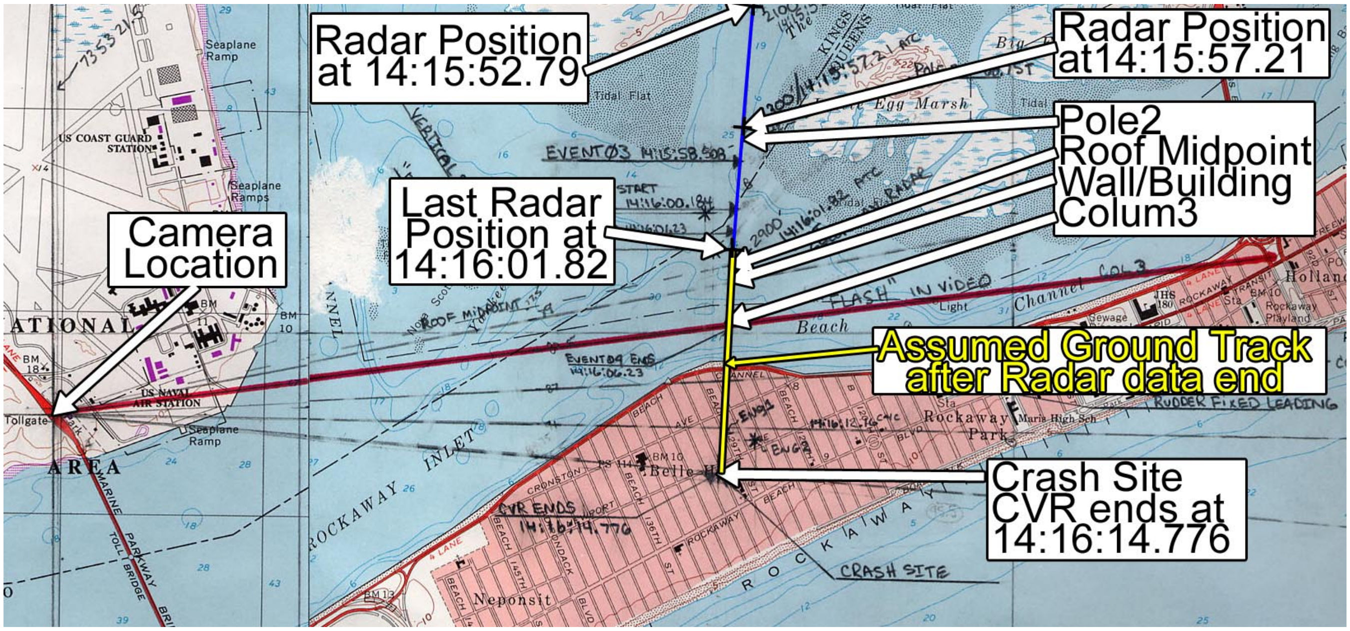

Figure 5. Video Landmarks / Radar Data

(image not to scale)

The combination of data in Figure 5 provides a relationship between the toll plaza video and the other recorded data sources. As a result, an event noted in one of the data sources (video, DFDR, Radar, or CVR) can be compared to the data in another source, at the same point in time.

<u>Comparison of Video and DFDR/CVR timing correlation</u>

The toll plaza video data and the DFDR/CVR timing correlation were examined to determine if the CVR continued to record up to the time of impact. This was done by comparing the amount of time it took for the airplane to fly a specific segment of the flight, both in the video and according to the radar data/CVR correlation. The portion of the flight considered was from the moment the airplane was positioned over Pole 2 (as seen in the view from lane 1), to the point of impact with the ground.

Video Elapsed Time

The video from both cameras were imported into a digital video editing system, and synchronized in time using the imprinted time-of-day clock seen in the upper right corner of both views. It was assumed that the demultiplexed video from both camera views maintains a "real time" basis as they are played back.

In the view from Lane 1, as the airplane is directly over Pole 2, the time reference on the digital video system ("dv time") was noted as 01:33.83 (minutes:seconds) elapsed time.[6]

In the view from Lane 5, the impact time could not be directly measured because the impact occurred behind a building in the foreground and was not in the camera view. Instead the time of impact had to be calculated based on the flight path depicted in Figure 6 below.

[6] "dv time" is an arbitrary elapsed time reference similar to a counter on a VCR.

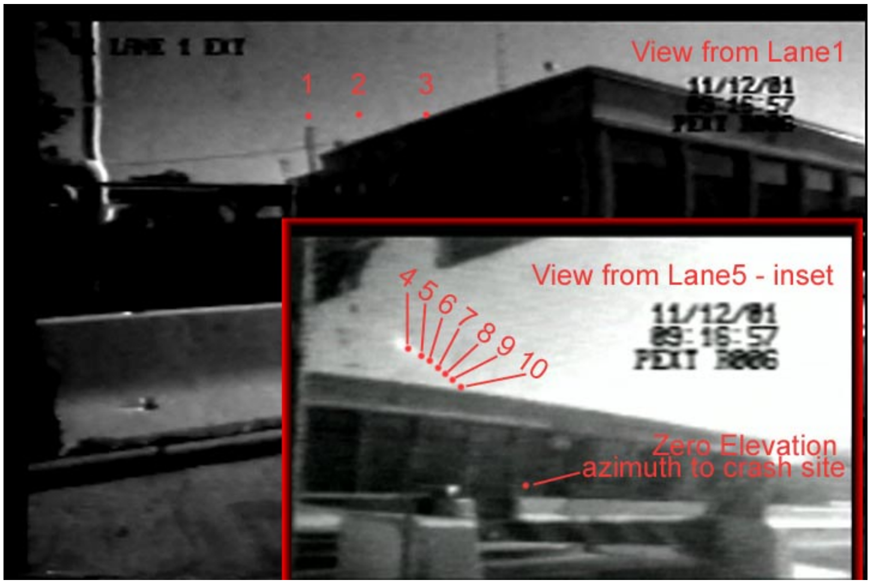

Figure 6. Views from lane1 (background image) and Lane 5 (inset image)

Figure 6 is comprised of a still image from each camera, with an overlaid sequence of positions of the airplane as seen in the video. The red dots numbered 1 through 10 mark the location of the airplane at selected times. The zero elevation azimuth to the crash site (point of impact) is also depicted in the lower center area of the view from lane 5.[7]

To determine impact time (according to the video data, i.e. "dv time"), the average speed of the airplane was calculated between points 5 and 9. This was done by measuring the distance between the points plotted on the video monitor and noting the times for each position. The calculated average speed was 1.35 units (on an engineer's 20 scale) per second. It was assumed that the airplane maintained this average speed up to the time of impact. Using this assumed speed, and the measured linear distance from position 10 to the point of impact, the time of the impact was calculated to be 01:51.35 dv time.

[7] The positions shown in figure 5 are for illustrative purposes only. The actual positions were marked and measured on a video monitor. The azimuth to the crash site was determined to be 95.5° using the topographical maps. During the site survey, the Total Station was sighted to this azimuth and a zero elevation angle, and the location on the building was noted.

Therefore, based on the timing information in the video, the elapsed time from when the airplane was above Pole 2 and the point of impact was calculated to be 17.5 seconds.

Radar/DFDR/CVR Elapsed Time

The elapsed time for the same portion of the flight was calculated using the radar data and the correlated DFDR/CVR data. Using the topographical map, a line was extended from the camera location at the toll plaza along the measured azimuth of 68.75° (to Pole 2), to where it intersected the ground track of the airplane. This intersection is noted in Figure 5 above.

The Air Traffic Control (ATC) time at this position was interpolated (using the two known times of the surrounding radar positions) to be 14:15:57.44 (hours:minutes:seconds). The CVR ends at time 14:16:14.776. Therefore, based on the Radar/DFDR/CVR timing information, the calculated elapsed time from when the airplane was over Pole 2 to the end of the CVR is 17.3 seconds.

<u>Time and Location of the "streak"</u>

In the video from lane 5, the airplane emerges from behind a wall just below the "wall/sign" landmark denoted in Figure 4. As the airplane travels from left to right, the first indication of the streak occurs when the airplane is directly above "Column 3". The streak appears as a white smoke-like trail that can be seen trailing behind the "dot". The corresponding position of the airplane can be seen in Figure 5, at the intersection of the yellow and red lines, denoted as "Column 3". Using the elapsed time between the last radar position (14:16:01.82) and the impact (14:16:14.776 – the end of the CVR recording) as a scale, the time that the streak began was calculated to be 14:16:06.14, or about 4.3 seconds after the last recorded radar return. The calculated position of the airplane at this time is described in the next section.

Calculated Airplane Positions

An effort was made to determine the position (lateral location and altitude) of the airplane at several points in time after the DFDR and Radar data ends. The lateral location of the airplane (with respect to the landmarks seen in the video) could be readily determined using the map depicted in Figure 5. This was done by locating the intersections of the lines extending from the landmarks with the plotted ground track of the airplane. The altitudes were calculated using the data gathered from the site survey, the still images captured from the video, and an architectural drawing of the building in the camera view. The positions are listed in Table 1 below. See Appendix 1 for details on the calculations and estimated accuracy for altitude determinations.

Landmark	Time (ATC)	Latitude	Longitude	Altitude (MSL)
Roof Midpoint	14:16:02.263	40 35 10.9	73 50 58.5	2398
Over Column 3	14:16:06.14	40 35 01.2	73 50 59.5	2428
Over Column 4	14:16:09.38	40 34 52.34	73 51 00.00	2012
Roofline at Column 5	14:16:12.08	40 34 44.9	73 51 0.5	1470

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Attachment I – Calculations

Video - Elapsed Time from Pole 2 to Impact

The following measurements and calculations were used to determine elapsed time from “over Pole 2” to the impact in the toll plaza video:

- Position 5 – 01:43.133 dv time[8]
- Position 9 – 01:45.133 dv time
- Position 10 – 01:45.57 dv time
- Distance measured on video monitor between positions 5 and 9 – 2.7 units on engineer’s 20 scale ruler.
- Distance measured on video monitor between position 10 and the zero elevation azimuth to crash site: 7.8 units on engineer’s 20 scale ruler.

Establish the average speed between positions 5 and 9:

$$\frac{2.7\ \text{units}_{20}}{2.0\ \text{seconds}} = \frac{1.35\ \text{units}_{20}}{1\ \text{second}}$$

Elapsed time from position 10 to impact:

$$\left(7.8\ \text{units}_{20}\right) \times \frac{1\ \text{second}}{1.35\ \text{units}_{20}} = 5.78\ \text{seconds}$$

Time of impact = (Time at position 10) + 5.78 seconds

= 01:45.57 + 5.78

= **01:51.35 dv time**

[8] “dv time” is an elapsed time reference indicated on the digital video machine which was used to review the re-

Video elapsed time from Pole 2 to Impact:

= (Time at Impact) – (Time at Pole2)

= 01:33:83 – 01:51.35

= **17.52 seconds**

Radar/DFDR/CVR Correlation - Elapsed Time from Pole 2 to impact

Time at Pole 2:

- Intersection of azimuth line (from camera through Pole 2) and the airplane's ground track lies between two radar positions:

  14:15:57.21 (2nd to last radar position)

  14:16:01.82 (last radar position)
- ∆Time between these two radar positions = 4.61 seconds
- Distance measured between these two radar positions = 2.0 units on 20 scale
- Distance measured from the 2nd to last radar position to the azimuth line = 0.1 units on 20 scale.
- CVR ends at 14:16:14.776

$$\frac{2.0\ \text{units}_{20}}{4.61\ \text{seconds}} = \frac{0.434\ \text{units}_{20}}{1\ \text{second}}$$

$$(0.1\ \text{units}_{20}) \times \frac{1\ \text{second}}{0.434\ \text{units}_{20}} = 0.23\ \text{seconds}$$

Time at Pole 2:

= 14:15:57.21+0.23

= **14:15:57.44**

Radar/DFDR/CVR elapsed time from Pole2 to impact:

cording. The absolute values of these times are arbitrary. Time is displayed in minutes:seconds.

= (14:16:14.776) - (14:15:57.44)

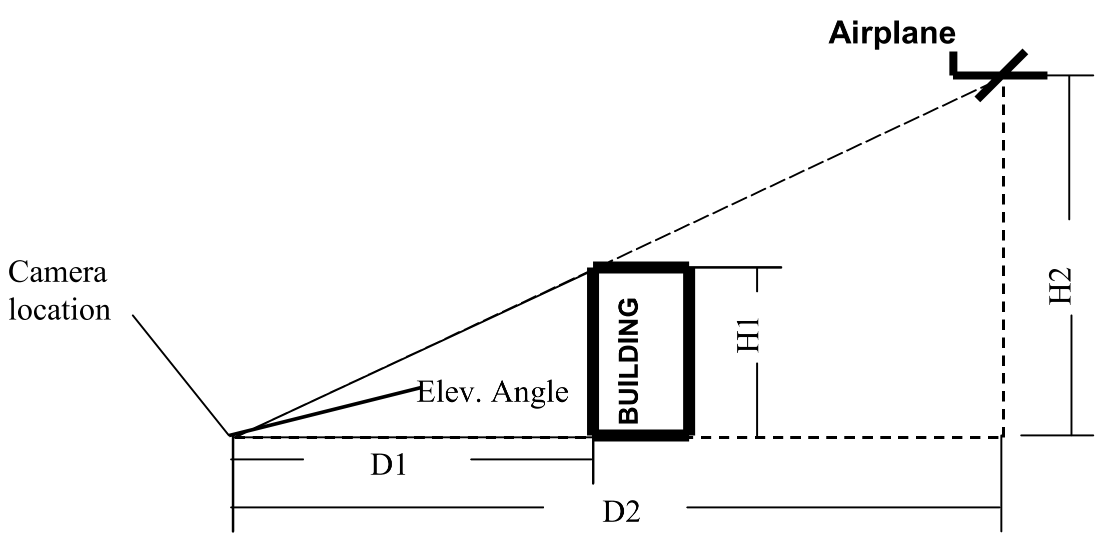
= **17.34 seconds**

Calculation of Airplane Positions after DFDR/Radar data end

The lateral locations were measured directly from the topographical maps at the intersections of the landmark azimuth lines and the ground track. For several locations, the altitude of the airplane was also calculated. The method of calculating altitude is described below.

Roof Midpoint

In the camera view from lane 1, the airplane passes behind the building's roof at about the midpoint of the roofline. During the site survey, the position (azimuth, elevation angle, distance) of the roof midpoint relative to the camera position was measured. The altitude of the airplane at the time it appeared to intersect the roofline was calculated by solving two similar triangles.



For the Roof Midpoint:

Elev. Angle = **11.7597 degrees**

D1 = **42.775 feet**

D2 = **11,450 feet** (measured from the camera position to the known ground track on the topographical map).

H2 (height of airplane above the camera) can then be solved for with the following equation:

$$TAN(11.7597) = \frac{H2}{11{,}450}$$

or;

H2 = **2384 feet**

The camera height is 4.8 feet from the ground, and the ground elevation is estimated to be 10 feet (based on the topographical map).

Therefore the estimated altitude:

= 2384 + 4.8 + 10

= **2398 feet MSL.**

<u>Roofline at Column 5</u>

In the view from lane 5, the airplane is descending as it passes behind the building's roofline directly above Column 5. The altitude at this point was calculated in the same manner as described above. The parameters are:

Elev. Angle = 7.5388

D1 = 67.895 feet

D2 = 11,000 feet

$$TAN(7.5388) = \frac{H2}{11{,}000}$$

H2 = 1456 feet

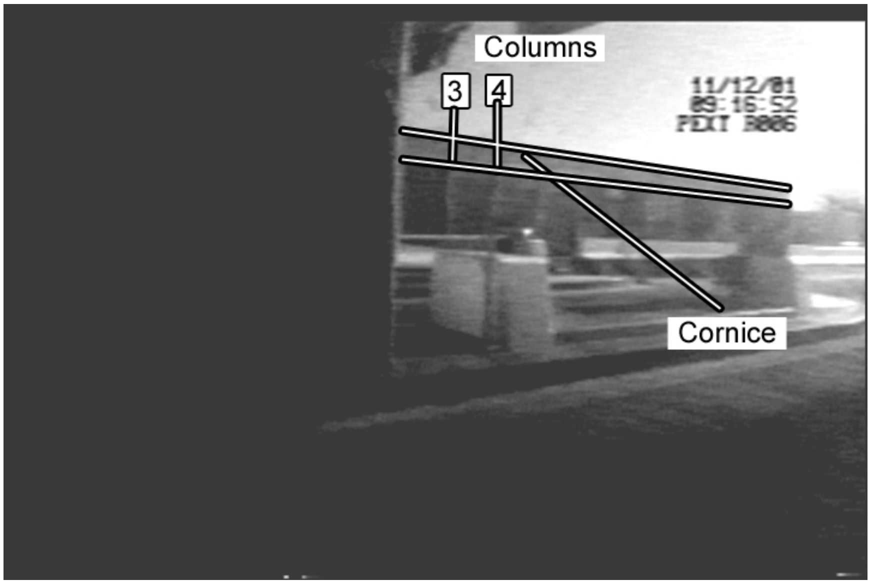
Camera Height = 4.25 Feet

Ground Elevation = 10 Feet

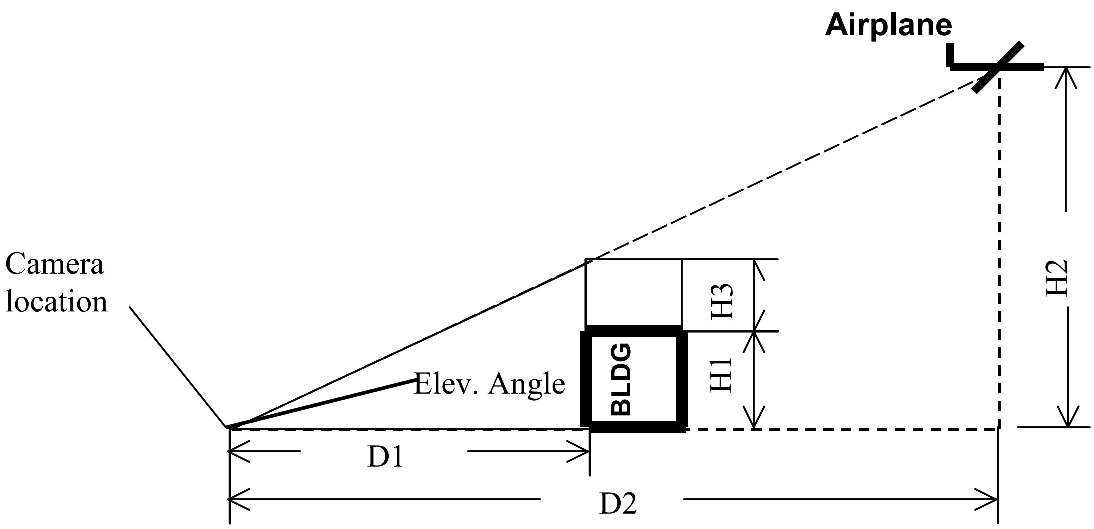
ALT = 1470 feet

Over Columns 3 and 4

The method for determining the altitude when the airplane was seen flying over columns 3 and 4 was somewhat different than the previous two. At these positions, the airplane did not pass behind any landmarks that could be surveyed at the toll plaza. As a result, the elevation angle to the airplane could not be directly measured. Instead, the altitude was estimated by measuring the distance from the airplane to known survey points in the still image. This was done as the airplane was positioned directly over the surveyed points for Columns 3 and 4. In order to use these measurements, the scale of the image had to be determined. This was done by measuring the cornice feature of the building, outlined in the figure below.



The actual height of the cornice was measured to be 3.08 feet tall on an architectural drawing of the building provided by the Triborough Bridge and Tunnel Authority. In the still image seen above, the height of the cornice appears to decrease from left to right, because the building is at an oblique angle to the camera. As a result, the scale of the building (and cornice) in the image is varying from left to right. The following diagram was used to determine the image scale, height of the airplane above the roofline in the image, and the estimated altitude of the airplane.



Altitude when the airplane is over Column 3:

Measured on the still image from the video:

The height of the cornice at column 3 = 0.95 units on engineer's 30 scale

Height of airplane above roofline at column 3 = 1.25 units on engineer's 30 scale.

Actual height of the cornice from architectural drawing = 3.08 feet. Therefore, H3 in the diagram above is given by:

$$\frac{0.95\text{ units}_{30}}{3.08\text{ feet}} = \frac{1.25\text{ units}_{30}}{\text{H3 (in feet)}}$$

H3 = 4.05 feet

From the site survey:

H1 (The height of the roofline)

= **9.035** feet above the camera height.

D1 (Horizontal Distance from the camera to the building)
= **60.7 feet**.

From the topographical map (depicted in Figure 5 of the report):

D2 = **11,200 feet**

The elevation angle from the camera to the airplane is given by:

$$\text{TAN(elev angle)} = \frac{H1 + H3}{D1} = \frac{13.085}{60.7} = 0.21556$$

$TAN^{-1}(0.21556)$ = **12.17°**

The height of the airplane above the camera (H2) can then be calculated by:

H2 = TAN(12.17) x D2
= 0.21566 x 11,200
= **2414 feet**

The calculated altitude of the airplane is then:

ALT = H2 + Camera Height + Elevation of the ground at the camera
= 2414 + 4.25 + 10
= 2428 feet MSL

Altitude when the airplane is over Column 4:

The altitude for this position was calculated in the same manner as that of the Column 3 position described above. The parameters were:

Height of cornice at column 4 = **0.90 units** on engineer's 30 scale.
Height of airplane above the roofline at column 4 = **0.75 units** on engineer's 30 scale.

H3 = **2.56 feet**
H1 = **9.04 feet**
D1 = **64.34 feet**
D2 = **11,075 feet**

The calculated altitude is:

ALT = **2012 feet MSL**

Estimated accuracy in altitude calculations – Over Columns 3 and 4

It is assumed that the measurements taken from the still images, topographical maps, and architectural drawing could be accurately measured to within ½ of a graduation on the scale used. The accuracy of the calculated altitudes due to measurement tolerance alone (not considering any other factors such as lens distortion, camera tilt angle, or variance of the airplane's path from the assumed ground track etc), was estimated to be about +/- 65 feet, based on a compounded error in the calculations described above.

Attachment II – Data

Survey Measurements From Camera in Lane 1:

		Az	az	az	Az	**az TRUE**	elev	elev	elev	elev	**elev**				
seq	name	deg	min	sec	dd		deg	min	sec	dd	**"true"**	slope	**horiz**	vert	Rod Ht
1	Pole1	89	45	25	89.757	**49.757**									
4	Pole2	108	45	10	108.75	**68.753**									
5	buuilding 2 corner1	109	24	5	109.4	**69.401**	81	32	55	81.549	**8.451**	60.74	**60.08**	8.925	0
6	Pole3	111	24	30	111.41	**71.408**									
7	roof mid	117	35	45	117.6	**77.596**	78	14	25	78.24	**11.76**	43.69	**42.775**	8.905	0
8	Pole4	127	33	10	127.55	**87.553**	74	49	25	74.824	**15.18**	33.61	**32.38**	9.01	0
9	Building2 corner2	136	21	35	136.36	**96.36**	72	12	5	72.201	**17.8**	29.09	**27.7**	8.89	0
	Theo HT:	4.8													
	0 Ref :	320													

Survey Measurements From Camera in Lane 5:

seq	name	az	az	az	az	az	elev	elev	elev	elev	elev	slope	horiz	vert	Rod Ht
		deg	min	sec	dd	**TRUE**	deg	min	sec	dd	**"true"**				
1	wall/building	119	7	45	119.129	**79.129**	81	11	40	81.194	**8.8056**				
2	wall/sign?	119	9	5	119.151	**79.151**	75	1	30	75.025	**14.975**				
3	Building Right	152	56	45	152.946	**112.95**	85	19	55	85.332	**4.6681**				
4	col3	122	36	50	122.614	**82.614**	81	32	0	81.533	**8.4667**	61.37	60.7	9.035	0
5	col4	127	11	0	127.183	**87.183**	81	59	40	81.994	**8.0056**	64.795			0
6	col5	131	13	20	131.222	**91.222**	82	27	40	82.461	**7.5389**	68.485	67.895	8.985	0
7	col6	134	48	50	134.814	**94.814**	82	50	25	82.84	**7.1597**	72.53	71.965	9.04	0
8	col7	140	51	55	140.865	**100.87**	83	34	30	83.575	**6.425**	81.275	80.765	9.065	0
	zero Elev crash														
	Description of location on buliding:														
	two bricks Right of column 6, two bricks down from window														
	Theo HT:	4.25													
	0 Ref :	320													

Data provided by Aircraft Performance Group Chairman:

Radar Data:

jfk asr data									
HH	MM	SS (ATC TIME)	ALT	LATD	LATM	LATS	LOND	LONM	LONS
14	14	34.56	-400	40	38	11.01552	73	47	23.78711
14	14	39.18	-100	40	38	16.90747	73	47	39.00356
14	14	43.92	100	40	38	23.05875	73	47	52.57636
14	14	48.66	300	40	38	28.23426	73	48	7.21038
14	14	53.07	500	40	38	31.45769	73	48	22.57367
14	14	57.89	700	40	38	31.27873	73	48	37.4568
14	15	2.43	800	40	38	28.92934	73	48	54.17487
14	15	7.04	900	40	38	23.71963	73	49	10.87471
14	15	11.67	900	40	38	15.2866	73	49	28.06124
14	15	16.16	1000	40	38	4.400883	73	49	41.13919
14	15	20.66	1000	40	37	50.61814	73	49	52.91598
14	15	25.21	1100	40	37	35.79229	73	50	3.177698
14	15	29.92	1200	40	37	19.85814	73	50	12.67874
14	15	34.31	1300	40	37	3.445955	73	50	21.61715
14	15	38.82	1400	40	36	46.38618	73	50	30.80413
14	15	43.56	1700	40	36	28.79383	73	50	41.05
14	15	48.17	1900	40	36	11.3726	73	50	47.89028
14	15	52.79	2100	40	35	52.13756	73	50	54.11032
14	15	57.21	2300	40	35	32.81001	73	50	56.19741
14	16	1.82	2900	40	35	12.69356	73	50	58.55746

GPS Coordinates for impact site:

40 34 37.59N

73 51 01.305W

CVR End Time:

14:16:14.776 UTC