NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

July 22, 2014

Video Study

Specialist's Study
By Sean Payne

1. EVENT

Location:	Santa Monica, California
Date:	September 29, 2013 18:20 Pacific daylight time (PDT)
Aircraft:	Cessna 525A, N194SJ
Operator:	Private
NTSB Number:	WPR13FA430

2. GROUP

A group was not convened.

3. SUMMARY

On September 29, 2013, at 1820 Pacific daylight time, a Cessna 525A Citation, N194SJ, veered off the right side of runway 21 and collided with a hangar at the Santa Monica Municipal Airport, Santa Monica, California. The private pilot and three passengers were fatally injured, and the airplane was destroyed by a post-crash fire. The airplane was registered to CREX-MML LLC, and operated by the pilot as a 14 *Code of Federal Regulations*, Part 91 flight. Visual meteorological conditions prevailed for the flight, which operated on an instrument flight rules flight plan. The flight originated at Hailey, Idaho, about 1614.

4. DETAILS OF INVESTIGATION

The NTSB Vehicle Recorder Division's Image Laboratory received two files containing images from 9 unique security camera feeds from the following device:

Recorder Manufacturer/Model:	**Bosch DIVAR 700 Series**
Recorder Serial Number:	**Unknown**

4.1. Recorder Description

The DVR[1] system that recorded the security camera feed was documented and identified as a Bosch DIVAR 700 series network recorder. The Bosch DIVAR 700 network recorder is a security camera DVR system that can record real time images in either 1080 HD[2], 720 HD, SD[3] or 4CIF[4] resolution streams. It can support up to 32 channels of IP and analog recording equipment simultaneously. The Bosch system utilizes the H.264[5] MP4[6] codec for high resolution compression and can support up to 8 TB (Terabytes) of recording space. The Bosch DIVAR 700 system utilizes Bosch Export Player and Bosch Video Client software to support playback and system configuration. The Bosch software package provides access to all operation and configuration features of the DIVAR 700 system in a graphical user interface.

4.2. Recorder Damage

The video recording system was a fixed based security camera system and was not destroyed or affected as a result of the accident.

4.2.1. Video Files

Two security camera files entitled "Divar700.20130817T111500-20130817T143100.dxa" and "Divar700.20130929T182000-20130929T200000.dxa" were sent to the Vehicle Recorder Laboratory. The first file, "Divar700.20130817T111500-20130817T143100.dxa", recorded 4 camera streams (cameras 7, 10, 13 and 14) and was determined to have not captured the accident due to the time interval provided. The second recording "Divar700.20130929T182000-20130929T200000.dxa" (200000.dxa) contained six camera streams and captured the accident sequence and subsequent ARFF[7] efforts. The six camera streams contained images from cameras 3, 4, 7, 8, 9 and 17, each of which captured the accident aircraft at some portion during its landing roll and subsequent impact with a hangar structure. The recording provided was 1 hour 40 minutes and 5 seconds in length. The beginning portion of the recording shows the landing roll and impact and the remainder of the files shows subsequent ARFF activities related to the accident.

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[1] DVR – Digital Video Recorder – A hardware electronic or software device that records video in a digital format to a type of disk drive.
[2] HD – High Definition – Any video format with more than 480 horizontal recording lines.
[3] SD – Standard Definition - Any video format with less than 480 horizontal recording lines.
[4] 4CIF – Common Intermediate Format – A format used to standardize horizontal and vertical resolutions in pixels. 4CIF = 704 x 480 pixels.
[5] H.264 Codec – A commonly used video compression format.
[6] MP4 – A multimedia container format used to store video and audio data.
[7] ARFF – Aircraft Rescue and Fire Fighting – A special category of firefighting that involves the response, hazard mitigation, evacuation and possible rescue or passengers and crew of an aircraft involved in a ground emergency.

“Divar700.20130817T111500-20130817T143100.dxa”

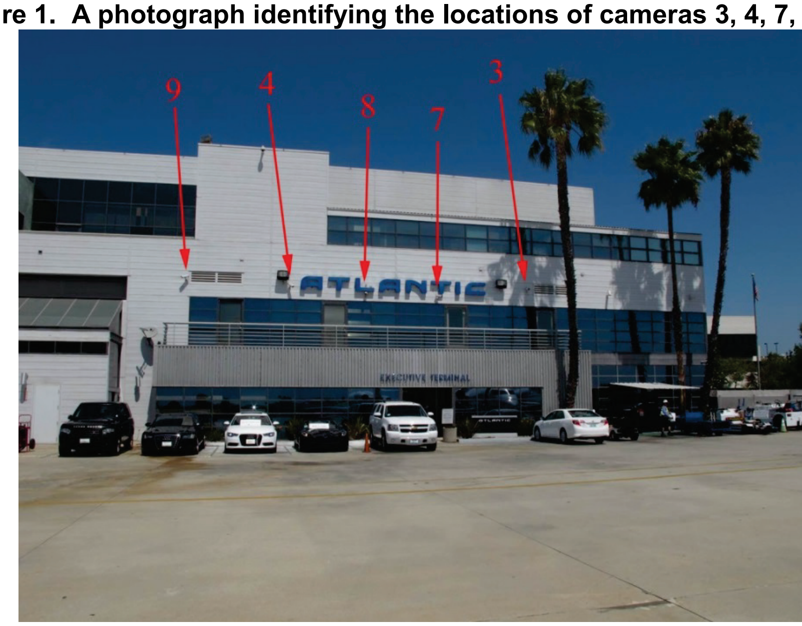
The time interval provided from this recording file does not capture the accident sequence.

“Divar700.20130929T182000-20130929T200000.dxa” (200000.dxa)

Images from this camera stream were recorded from cameras 3, 4, 7, 8, 9 and 17. The video file was provided by a local Fixed Base Operator (FBO) and the majority of the cameras (3, 4, 7, 8, and 9) were recorded from a cluster of locations near the FBO ramp entrance area. Camera 17 was mounted remotely on a different area of the airport property and was recorded in what appears to be 16 x 9 format[8]. The files were output from the security camera system in Bosch export player (.dxa) format at a frame rate of 4 FPS[9] and a 4CIF resolution of 704 x 480 pixels.

Images from the collection of cameras in this feed show a daytime view of portions of Runway 03/21 and the ramp area of one of the fixed base operators (FBO) at Santa Monica Municipal Airport (KSMO), Santa Monica, California. Cameras 3, 4, 7, 8 and 9 are oriented toward the southeast and show the ramp area and the center portion of Runway 03/21. Camera 17 is located in separate area from the initial cluster of cameras and looks southwest toward an aircraft parking area and a distant group of hangar structures on the boundary of the airport’s property. Figure 1 is a photograph of the camera locations on the FBO’s structure provided by the on-scene investigator. Figure 2 provides a map of the camera locations recorded on the feed in file 200000.dxa.

Figure 1. A photograph identifying the locations of cameras 3, 4, 7, 8, & 9.



[8] 16:9 Format – An aspect ratio with a width of 16 units and a height of 9.
[9] FPS – frames per second.

Figure 2. A map of camera locations and their direction of view from the 200000.dxa file.

4.3. Timing and Correlation

The multiple videos from the cameras in file 200000.dxa can be aligned using the common time stamp recorded on the DVR. Since the security system was recording to the same DVR, an assumption was made that a correlation can be made between the recorded camera streams in file 200000.dxa.

The timestamp is assumed to be correct between each video file since it was recorded commonly by the Bosch DIVAR 700 DVR. The security timestamp was recorded in local time (GMT -7:00[10]) in the format MM/DD/YYYY HH:MM:SS AM/PM. This output is present in the upper left corner of the provided image files when the option to display the timestamp in the DVR software is selected. Since the DVR's timestamp only records integer seconds, not enough timing information is available for a precise distance and position study of the aircraft's average groundspeed.

All camera streams were captured at a new 4 frames per second by the DVR system. The configuration displays the resolution and record rate for each camera stream.

Since the timestamp in the DVR system only has the resolution of a singular second, frames forward of the nearest integer second must be noted and recorded manually. Each frame after a whole integer second is referred to as a

[10] Occasionally, the camera timestamp displayed a local time of 1PM, an anomaly which is discussed later within this report.

carryover frame. The equation below defines time as the amount of whole integer seconds elapsed plus the amount of carryover frames. This total time value provides timing precision to the nearest quarter second due to the 4 Hz recording rate. For this study, a singular video frame aligns to .25 seconds of elapsed time.

4.4. Distance Position Study – File 200000.dxa

In agreement with the Investigator-In-Charge, a video group did not convene. Instead, this summary report and video study was prepared.

The camera locations in this report were evaluated in chronological order of the aircraft's appearance in each camera's field of view. The aircraft is first captured by Camera 7 as it moves toward the departure end of Runway 21. The aircraft is last captured in Camera 17 as it impacts the hangar structure. The aircraft was assumed to be on the centerline of Runway 03/21 until it is out of view of Camera 4.

Equations:

Time: S – The integer number of seconds displayed by the video program (HH:MM:SS display)
Carryover Frames: T_s – The number of frames carried over from the integer second
Total Time: T_t – The additive combination of Time (S) and Carryover Frames (T_s) in seconds
Total Frames: T_f – The total number of frames counted between perspective lines
Corrected Distance: d – The distance along the runway's centerline between camera perspective lines.
Average groundspeed: V_{gs} – The aircraft's calculated speed along the runway centerline.
Centerline Distance – D_{CL} – The distance measured virtually along the runway centerline between camera perspective lines.
Adjusted Fuselage Length –D_{FL} – The total amount of aircraft fuselage length at both camera perspective lines that appears to carry beyond a camera perspective line.

For determining Total Time (T_t) in seconds:

$$S + \left(\frac{Ts}{4}\right) = Tt$$

For determining Average groundspeed (G_s) in Knots:

$$Vgs = \left(\frac{d}{Tt}\right)$$

$$Vgs = \left(\frac{d}{Tt}\right)\left(\frac{3600sec}{1hour}\right)\left(\frac{1nm}{6076.12feet}\right)$$

For determining corrected distance (d) in feet:

$$d = D_{CL} - D_{FL}$$

For this DVR System (Ts) in seconds:

$$\left(\frac{1sec}{4\,frames.}\right) = 0.25\ sec./frame$$

A correction must be made when noting the position of the aircraft in front of a chosen geographic camera perspective line. Given the low frame rate of the camera and the lack of distinguishing features available in the background, it is unlikely that the nose of the aircraft crosses the exact position of a chosen camera perspective line at a recorded frame. This error is corrected for by subtracting the amount of the aircraft's fuselage that had appeared to cross over a chosen camera perspective line. The resolution of the video limits the estimation of the amount of the aircraft's fuselage that may fall over the chosen perspective line. For this study, ¼ aircraft fuselage length was defined as a resolvable amount of correction for the amount of the aircraft that had crossed over a camera perspective line. Given the length of the Cessna Citation 525A is approximately 43 feet, the value for the adjusted fuselage length (D_{FL}) is given in quarters of fuselage rounded to the nearest whole foot (approximately 11 feet). The estimated D_{FL} is then subtracted from the measured centerline distance between two perspective lines (D_{CL}) to arrive at a value for total distance in feet (d).

For determining distance (d) in feet:

$$d = D_{CL} - D_{FL}$$

Camera 7

The aircraft first appears in the upper left corner of the frame as the cockpit area of the fuselage is shown behind an open hangar structure. Figure 3 shows the aircraft in this position at a recorded timestamp of 6:20:45 AM and two carryover frames (45.50 seconds). The amount of adjusted fuselage length was established as ¼ or approximately 11 feet.

Figure 3. The position of the aircraft as it enters the field of view for Camera 7.

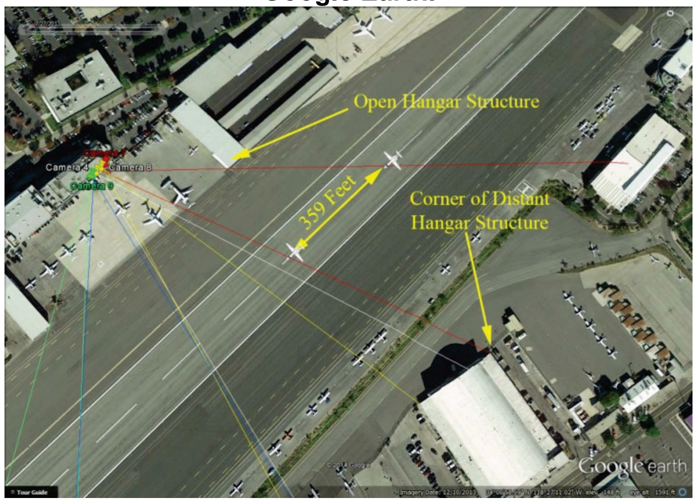
Shortly after, the cockpit area of the accident aircraft becomes aligned with the corner of a hangar structure on the far side of Runway 03/21. Figure 4 shows the accident aircraft in this position. The timestamp reads 6:20:48 and zero carryover frames (48.00 seconds). The adjusted fuselage length was estimated as zero.

Figure 4. The position of the aircraft as it exits the field of view for Camera 7.

The time calculated between the aircraft's position in Figure 3 and Figure 4. Using the equation in Section 4.3., was 2.50 seconds

Figure 5 shows the two positions of the aircraft in Figure 3 and 4 represented on Google Earth. Assuming the aircraft was on the centerline of Runway 03/21, a distance of 359 feet was measured. The adjusted fuselage length was subtracted in the amount of 11 feet. The total distance traveled was calculated to be 348 feet.

Figure 5. The distance between the aircraft's position in Figure 3 and 4 as measured on Google Earth.

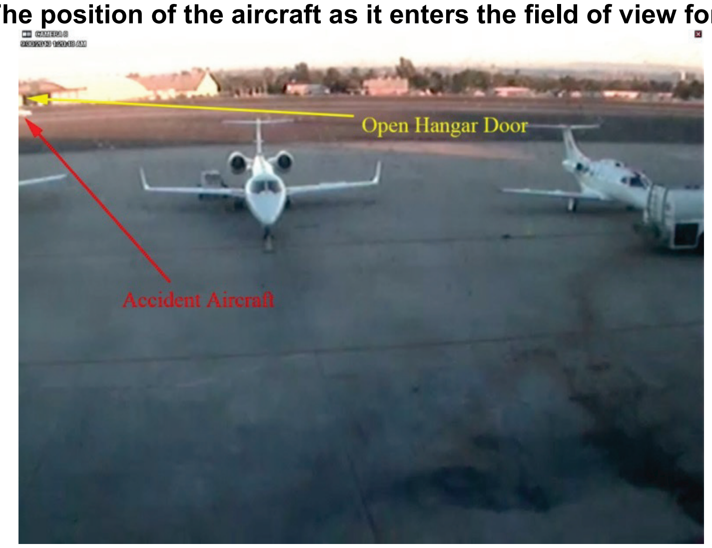


Using the equation for average groundspeed in the beginning of this section, an average groundspeed of 82.5 knots was obtained for this segment.

Camera 8

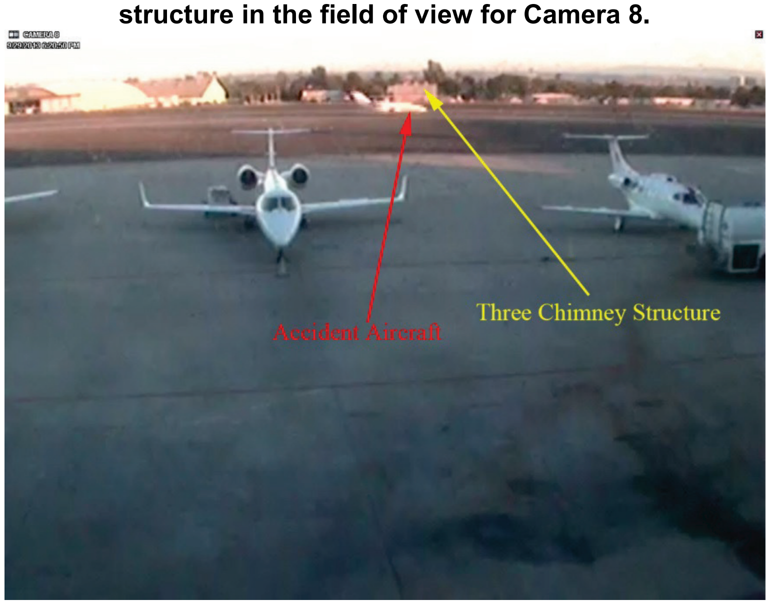
The aircraft first appears in the upper left corner of the frame as the cockpit area of the fuselage is shown in front of an open hangar door on the far side of Runway 03/21. Figure 6 shows the aircraft in this position at a recorded timestamp of 1:20:48 AM, likely a glitch representing 6:20:48 PM. One carryover frame was counted at this position resulting in a total time of 48.25 seconds. The camera perspective line was able to be established at this position shown in Figure 6 so no adjusted fuselage length was utilized.

Figure 6. The position of the aircraft as it enters the field of view for Camera 8.



Shortly after, the cockpit area of the accident aircraft becomes aligned with a vented structure on the far side of Runway 03/21. Figure 7 shows the accident aircraft in this position. The timestamp reads 1:20:50 AM and 1 carryover frame (50.25 seconds). The amount of adjusted fuselage length was established as ¼ or 11 feet.

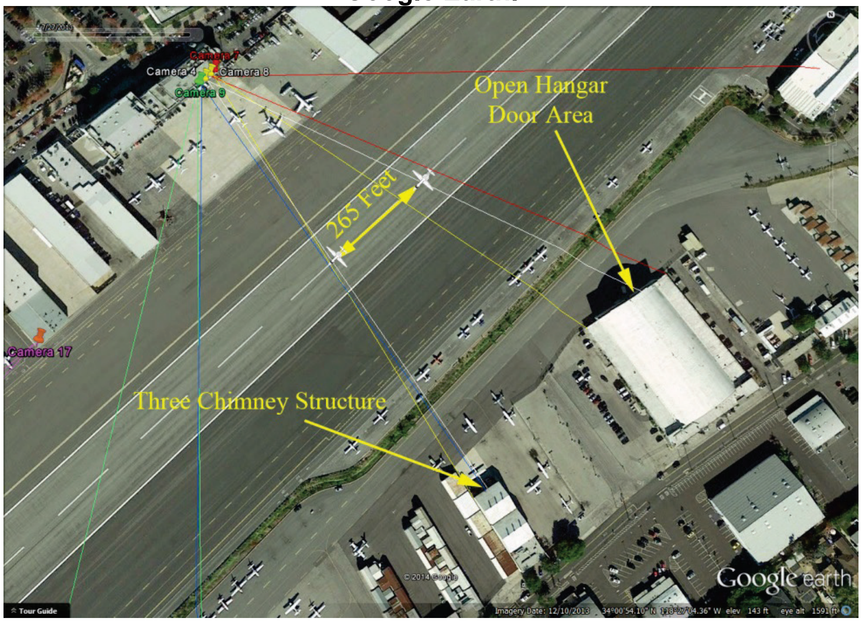
Figure 7. The position of the aircraft as it aligns with the center of a three chimney structure in the field of view for Camera 8.



Using the equation in Section 4.3., this time was calculated to be 2.0 seconds.

Figure 8 shows the two positions of the aircraft in Figure 6 and 7 represented on Google Earth. Assuming the aircraft was on the centerline of Runway 03/21, a distance of 265 feet was measured. The adjusted fuselage length was subtracted in the amount of 11 feet. The total distance traveled was calculated to be 254 feet.

Figure 8. The distance between the aircraft's position in Figure 6 and 7 as measured on Google Earth.

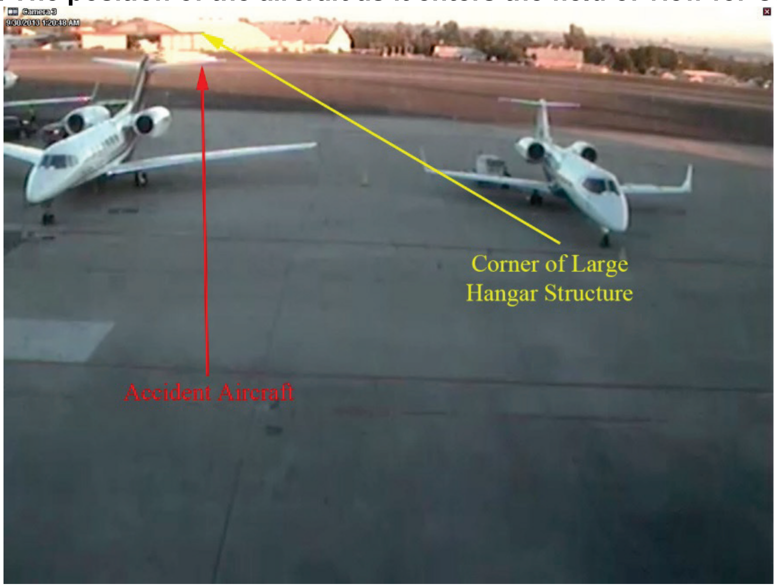


Using the equation for average groundspeed in the beginning of this section, an average groundspeed of 75.2 knots was obtained for this segment.

Camera 3

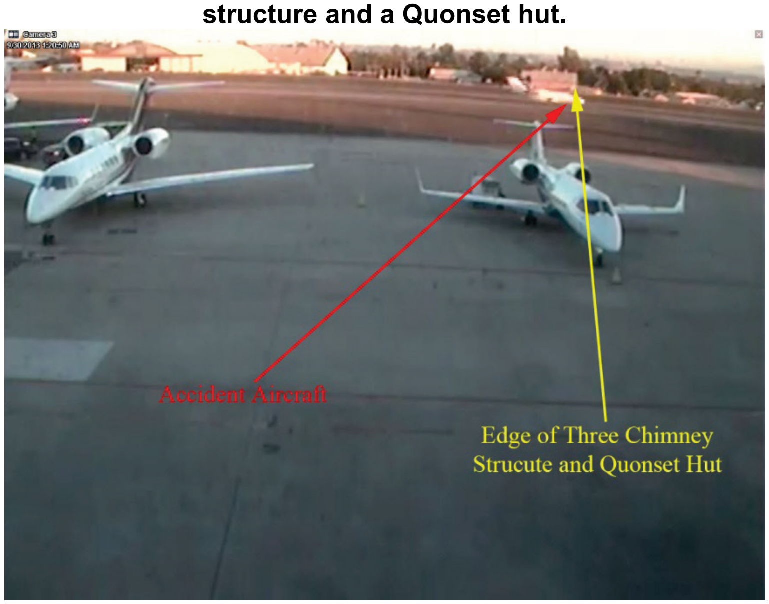
The aircraft first appears in the upper left corner of the frame as the cockpit area of the fuselage is shown in front of the corner of a large hangar structure on the far side of Runway 03/21. Figure 9 shows the aircraft in this position at a recorded timestamp of 1:20:48 AM and two carryover frames (48.50 seconds). The amount of adjusted fuselage length at this position was established as ¼ or 11 feet.

Figure 9. The position of the aircraft as it enters the field of view for Camera 3.



Shortly after, the cockpit area of the accident aircraft becomes aligned with the edge of a vented structure and a small Quonset hut on the far side of Runway 03/21. Figure 10 shows the accident aircraft in this position. The timestamp reads 1:20:50 and one carryover frame (50.25 seconds). No adjustment was made for fuselage length at this position.

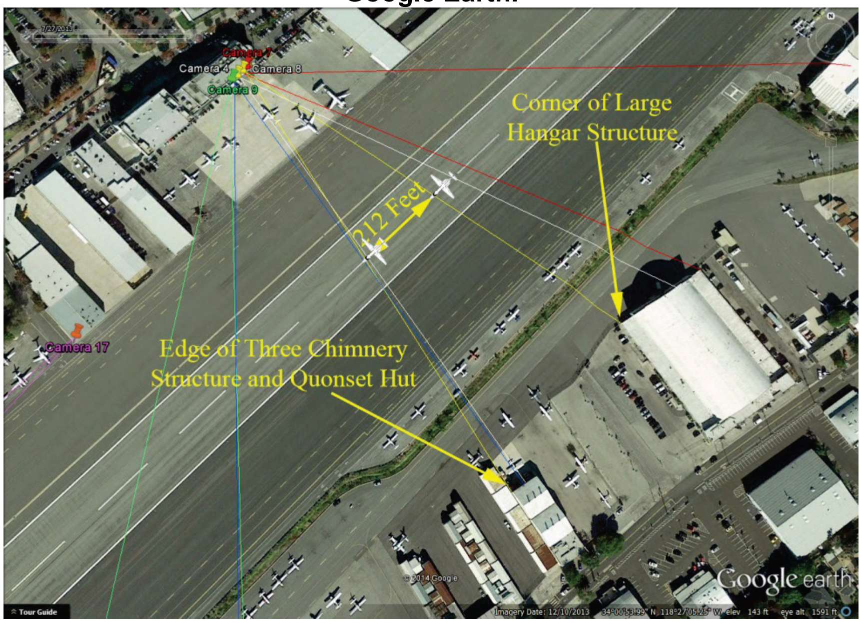
Figure 10. The position of the aircraft as it aligns with the edge of a three chimney structure and a Quonset hut.



Using the equation in Section 4.3., this time was calculated to be 1.75 seconds.

Figure 11 shows the two positions of the aircraft in Figure 9 and 10 represented on Google Earth. Assuming the aircraft was on the centerline of Runway 03/21, and the amount of adjusted fuselage length was subtracted (11 feet) from a measured distance of 212 feet. 201 feet was calculated for this segment.

Figure 11. The distance between the aircraft's position in Figure 9 and 10 as measured on Google Earth.

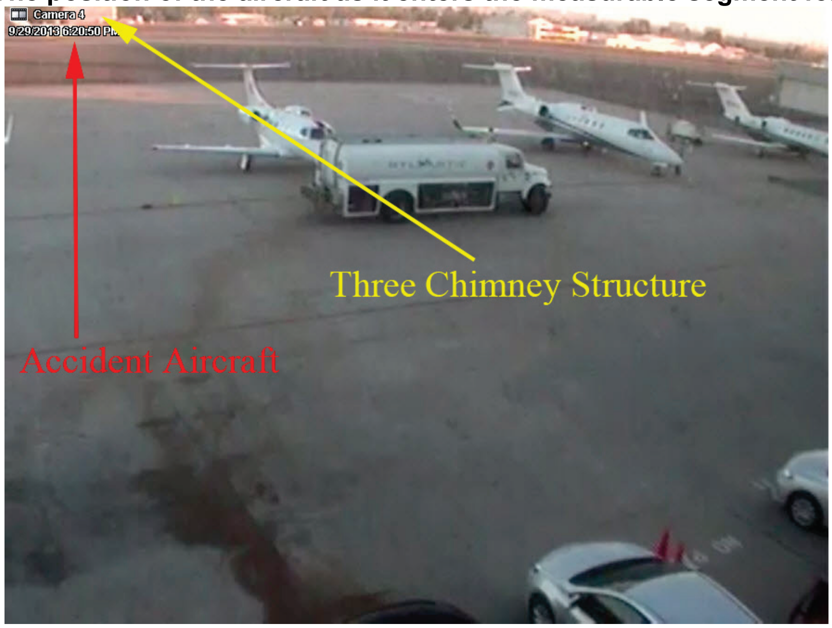


Using the equation for average groundspeed in the beginning of this section, an average groundspeed of 68.1 knots was obtained for this segment.

Camera 4

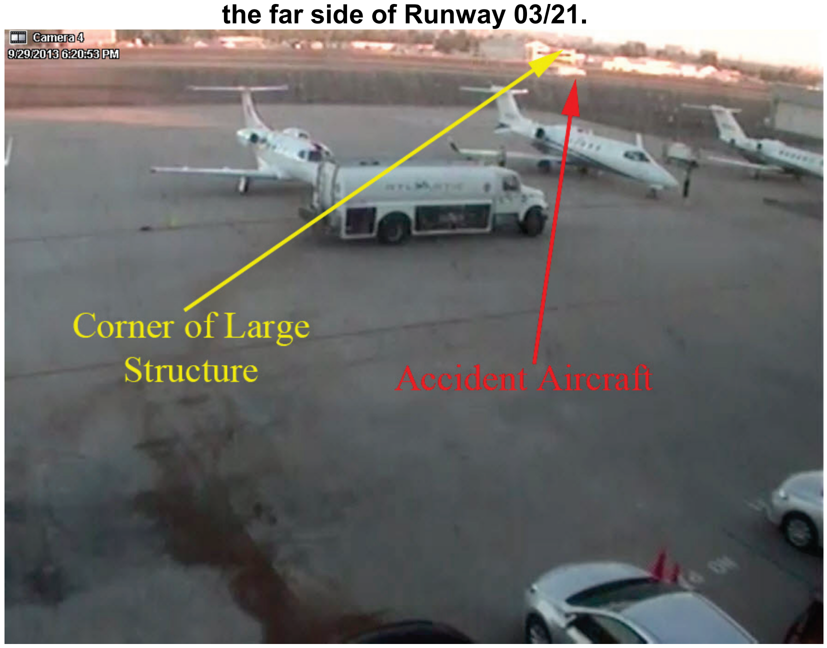
The aircraft first appears in the upper left corner of the frame as the cockpit area of the fuselage is shown in front of the three chimney structure on the far side of Runway 03/21. Figure 12 shows the aircraft in this position at a recorded timestamp of 1:20:50 PM and one carryover frames (50.25 seconds). No adjusted fuselage length was made at this position.

Figure 12. The position of the aircraft as it enters the measurable segment for Camera 4.



Shortly after, the cockpit area of the accident aircraft became aligned with the far corner of a large structure on the far side of Runway 03/21at a timestamp of 1:20:53 and no carryover frames (53.00 seconds). Figure 13 shows the accident aircraft in this position. No adjustment for fuselage length was made at this position.

Figure 13. The position of the aircraft as it aligns with the far corner of a large structure on the far side of Runway 03/21.



Using the equation in Section 4.3., this time was calculated to be 2.75 seconds.

Figure 14 shows the two positions of the aircraft in Figure 12 and 13 represented on Google Earth. Evidence collected on scene suggests that the accident aircraft was not on centerline at this time. Using information provided by the Investigator-in-Charge (IIC) and Figure 20 and 21, an estimate of the aircraft's path was made. When plotted on Google Earth this measurement was established as 328 feet.

Figure 14. The distance between the aircraft's position in Figure 12 and 13 as measured on Google Earth.

Using the equation for average groundspeed in the beginning of this section, an average groundspeed of 70.7 knots was obtained for this segment.

Camera 9

The aircraft first appears in the upper left hand corner of the recording as the fuselage is shown traveling down Runway 03/21. The aircraft fuselage appears to be aligned with the corner of a large structure on the other side of Runway 03/21. Figure 15 shows the aircraft in this position at a recorded timestamp of 1:20:53AM and zero carryover frames (53.00 seconds). No adjustment for fuselage length was made at this position.

Figure 15. The position of the aircraft as it enters the measurable segment for Camera 9.

Shortly after, the cockpit area of the accident aircraft becomes aligned with the corner of a hangar structure near the FBO's ramp as it crosses out of view of the camera's image. Figure 16 shows the accident aircraft in this position. The timestamp reads 6:20:54 PM[11] and two carryover frames (54.50 seconds). An adjusted fuselage length of ½ (22 feet) was noted at this position.

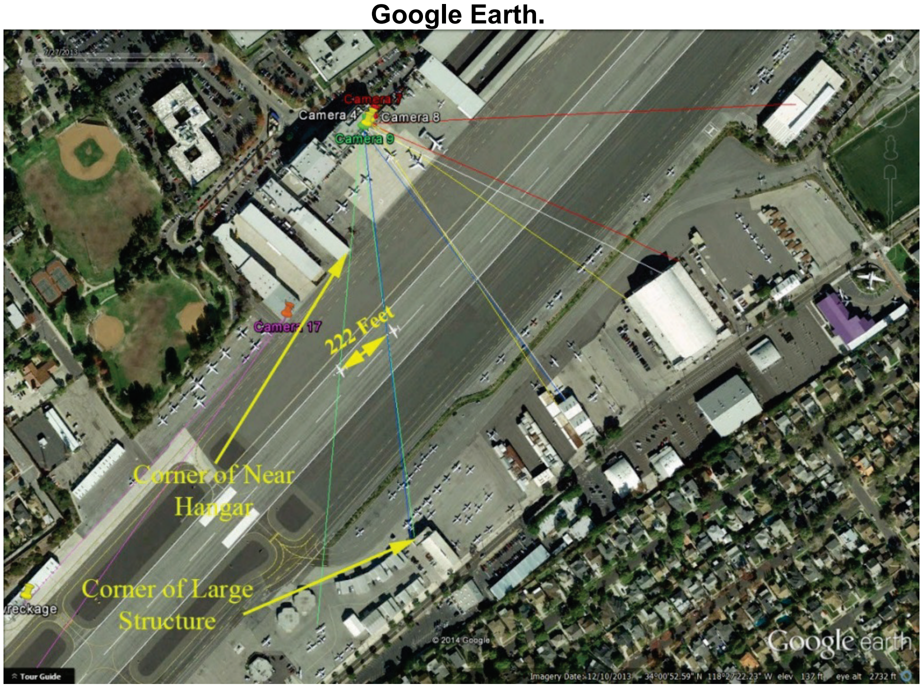
Figure 16. The position of the aircraft as the cockpit it aligns with the corner of a hangar structure near the FBO's ramp area.

Using the equation in Section 4.3., this time was calculated to be 1.50 seconds.

[11] The camera's time format had changed from displaying an hour value of 1 PM back to 6 PM for unknown reasons.

Figure 17 shows the two positions of the aircraft in Figure 15 and 16 represented on Google Earth. Evidence collected on scene suggests that the accident aircraft was not on centerline at this time. Using information provided by the Investigator-in-Charge and Figure 20 and 21, an estimate of the aircraft's path was made. When plotted on Google Earth this measurement was established as 222 feet. When the adjusted fuselage length is accounted for this measurement becomes 200 feet.

Figure 17. The distance between the aircraft's position in Figure 12 and 13 as measured on Google Earth.



Using the equation for average groundspeed in the beginning of this section, an average groundspeed of 79.0 knots was obtained for this segment.

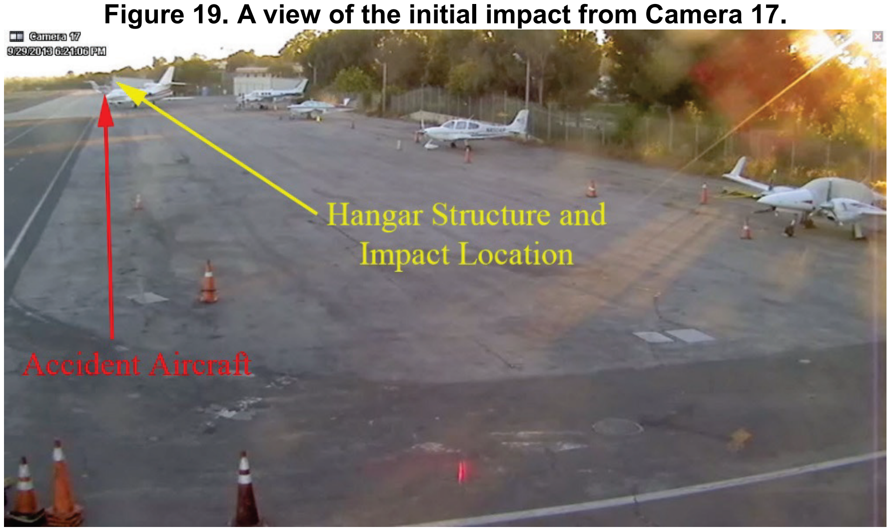
Camera 17

The aircraft first appears in the upper left hand corner of the recording as the nose of the aircraft is shown veering towards a tarmac area between Runway 03/21 and the intersection of Taxiway A1 and Taxiway A. There are limited background landmark features to align the aircraft at this moment. The closest fit was a line drawn from the camera location to the intersection of two different color tarmac surfaces near the area of Taxiway A2 and Taxiway A. Figure 18 shows the aircraft in this position at a recorded timestamp of 6:21:04 PM and one carryover frame (4.25 seconds). A trajectory was estimated using photographs from the on-scene portion of the investigation which showed witness marks from the aircraft's tires as it moved toward the impact location. This trajectory was used to calculate the overall distance the aircraft traveled through the measureable segment. No adjustment for fuselage length was made at this frame.

Figure 18. The position of the aircraft as it enters the measurable segment for Camera 17.

The cockpit area of the accident aircraft is then shown impacting a hangar structure near the edge of Taxiway A. Figure 19 shows the accident aircraft during first portion of impact with the hangar structure. At this moment, approximately half the fuselage appears to be inside the hangar (approximately 22 feet). The timestamp reads 1:21:06 AM and three carryover frames (6.75 seconds).

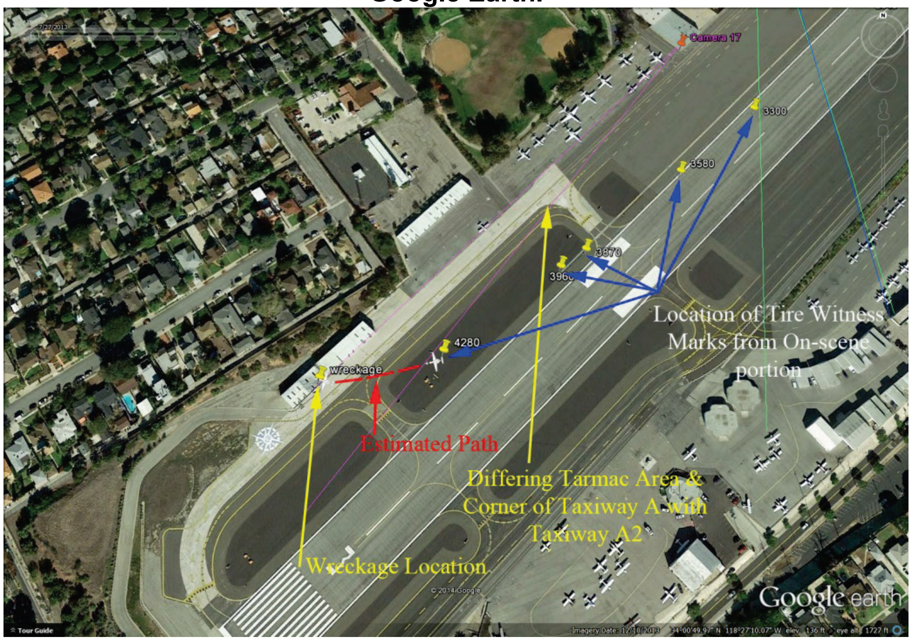
Figure 19. A view of the initial impact from Camera 17.



Using the equation in Section 4.3., this time was calculated to be 2.5 seconds.

Figure 20 shows the two positions of the aircraft in Figure 18 and 19 represented on Google Earth. A distance of 235 feet was calculated as an approximation based on the aircraft's trajectory across the ground provided by tire mark evidence collected on scene. Additionally, the frame at time of impact shows roughly have the aircraft impacting the structure during the 2.5 second measured time interval. Due to this, half the length of the aircraft (22 feet) was subtracted. The resultant total distance traveled along the estimated path becomes 213 feet.

Figure 20. The distance between the aircraft's position in Figure 18 and 19 as measured on Google Earth.

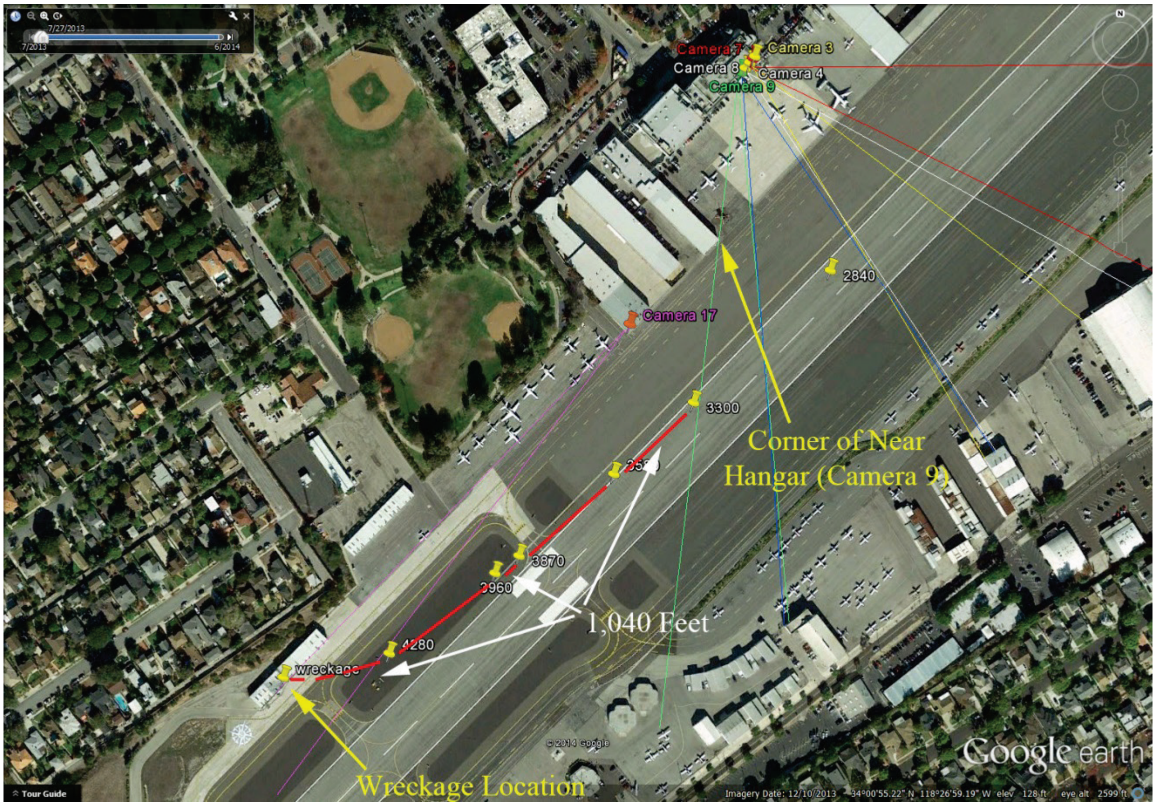


Using the equation for average groundspeed in the beginning of this section, an average groundspeed of 50.5 knots was obtained for this segment.

Average Speed Between Camera 9 and Camera 17

The accident aircraft's speed can be averaged throughout a portion of Runway 03/21 that is not covered by security camera footage. Figure 16 shows an image from camera 9 in which the aircraft is shown passing behind a hangar structure near the FBO's ramp area at a recorded common timestamp of 6:20:54 and 2 carryover frames (6:20:54.50). The nose of the accident aircraft appears 9.75 seconds later at a recorded common timestamp of 6:21:04 and 1 carryover frame (6:21:04.25) on the recording from Camera 17. Figure 21 shows a map of Runway 03/21 in this area which includes the location of tire witness marks recorded on the tarmac during the on-scene portion of the investigation. The distance measured using Google Earth resulted in approximately 1,040 feet.

Figure 21. The distance measured between likely locations of the aircraft from camera 9 and 17 video recordings. The distance was measured to be 1,040 feet. The value next to the plotted tire witness marks are the distance value in feet measured from the Runway 21 threshold.



Using the equation for average groundspeed, an average groundspeed of 63.2 knots was obtained for this segment.

4.5. Summary

Table 4.1 shows a collection of distance/position data as result of this study in relation to the overall length of the Runway 03/21 as measured from the Runway 21 threshold. The format of Section 4.4 of this report was structured in the same order in which each camera captured the accident aircraft during its ground roll along the selected measureable distances. The order of Table 4.1 is presented in the same chronological order as the structure of Section 4.4. The first 2,057 feet of available runway was not covered by security cameras. Data for any portion of the accident aircraft's ground roll during the first 2,057 feet of available runway is unavailable.

Table 4.1. A summary of the distance/position study for all cameras in relation to the distance measured from Runway 21's threshold.

Camera Segment	Runway Distance Start (ft)	Runway Distance (ft)	Centerline Distance – D_{cl} (ft)	Adjusted Fuselage Length – D_{fl} (ft)	Corrected Distance - d (ft)	Time (sec.)	Average groundspeed (kt)
None	0	2057	2057	N/A	Unknown	Unknown	Unknown
7	2057	2416	359	11	348	2.5	82.5
8	2458	2723	265	11	254	2	75.2
3	2520	2732	212	11	201	1.75	68.1
4	2735	3094	359(328)	0	328	2.75	70.7
9	3094	3341	247(222)	22	200	1.5	79.0
9 to 17	3341	Near 4500' marker	N/A	0	1040	9.75	63.2
17	Near 4500' Marker	Near 4500' marker	N/A	22	213	2.5	50.5

To obtain error margins for the average groundspeed study, fluctuations in the calculation of distance and the precision of the time measurement between geographic points were examined. For errors in distance, recall the minimum resolvable distance when the aircraft crossed a geographic reference point was discussed as being ¼ length of the aircraft's fuselage length (about 11 feet). For errors in timing precision, the minimum resolvable time is 0.25 seconds (the duration of a frame). An equation for average groundspeed, V_{gs}(error), is as follows: D_{cl}

$$\mathrm{Vgs(error)} = \left(\frac{d \pm \Delta d}{Tt \pm \Delta Tt}\right)\left(\frac{3600sec}{1hour}\right)\left(\frac{1nm}{6076.12feet}\right)$$

Where, $d(error) = D_{CL} - (D_{FL} \pm 11\ feet)$

And $\mathrm{Tt(error)} = (Tt \pm (Tt \pm 0.25seconds))$

Table 4.2 represents V_{gs}(error) when $\mathrm{Vgs(error)} = \left(\frac{\mathrm{Dcl} - (Dfl - 11)}{Tt + (Tt + 0.25sec)}\right)$. In this condition, the distance is maximized by the largest possible error and the time value is minimized by the largest possible error. This produces a value for V_{gs} at a maximum for each camera/distance segment.

Table 4.2. A summary of the distance/position study for all cameras in relation to the distance measured from Runway 21's threshold with values for V_{gs} maximized.

Camera Segment	Runway Distance Start (ft)	Runway Distance (ft)	Centerline Distance - D_{cl} (ft)	Adjusted Fuselage Length – D_{fl} (ft)	Corrected Distance – d (ft)	Time (sec.)	Average groundspeed (kt)
None	0	2057	2057	N/A	Unknown	Unknown	Unknown
7	2057	2416	359	11	359	2.25	94.5
8	2458	2723	265	11	265	1.75	89.7
3	2520	2732	212	11	212	1.5	83.7
4	2735	3094	359(328)	0	339	2.5	80.3
9	3094	3341	247(222)	22	211	1.25	100.0
9 to 17	3341	Near 4500' marker	N/A	0	1051	9.5	65.5
17	Near 4500' Marker	Near 4500' marker	N/A(235)	22	224	2.25	99.6

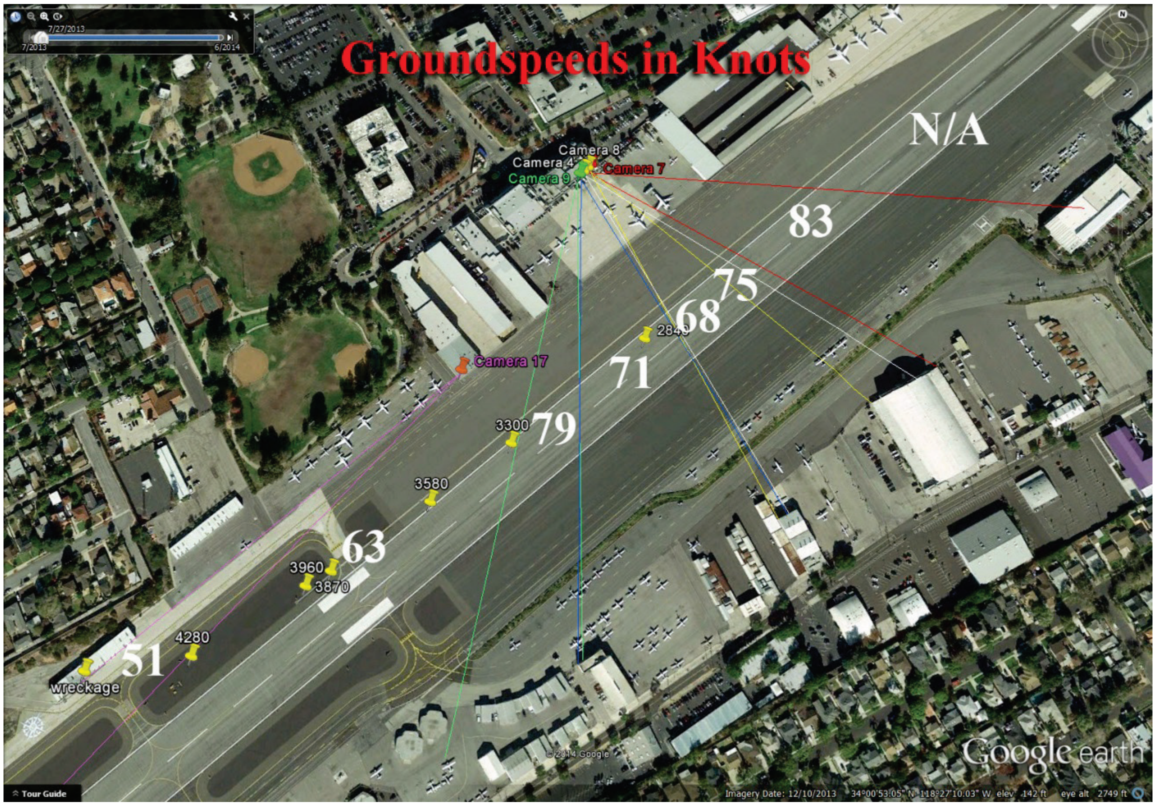
Table 4.2 represents V_{gs}(error) when $\mathrm{Vgs(error)} = \left(\frac{\mathrm{Dcl}-(Dfl+11)}{Tt-(Tt-0.25sec)}\right)$. In this condition, the distance is minimized by the largest possible error and the time value is maximized by the largest possible error. This produces a value for Vgs at a minimum throughout.

Table 4.3. A summary of the distance/position study for all cameras in relation to the distance measured from Runway 21's threshold with values for V_{gs} minimized.

Camera Segment	Runway Distance Start (ft)	Runway Distance (ft)	Centerline Distance (ft)	Adjusted Fuselage Length – D_{fl} (ft)	Corrected Distance (ft)	Time (sec.)	Average groundspeed (kt)
None	0	2057	2057	N/A	Unknown	Unknown	Unknown
7	2057	2416	359	11	337	2.75	72.6
8	2458	2723	265	11	243	2.25	64.0
3	2520	2732	212	11	190	2	56.3
4	2735	3094	359(328)	0	348	3	68.7
9	3094	3341	247(222)	22	214	1.75	72.5
9 to 17	3341	Near 4500' marker	N/A	0	1029	10	61.0
17	Near 4500' Marker	Near 4500' marker	N/A(235)	22	202	2.75	43.5

Figure 22 is a graphical representation of average groundspeeds from Table 4.1. It shows the calculated average groundspeed of the accident aircraft as related to its position on Runway 03/21 at KSMO. The values are shown rounded to the nearest knot.

Figure 22. A graphical summary of the distance/position study for all cameras. Speeds are rounded to the nearest knot.



4.6. Examination of Flap Position for N194SJ

Exported still images from each camera position were examined to attempt to make a determination of the accident aircraft's flap position. The still images selected for this report were exported at what the author felt was the best examples of potential flap position recognition.

Figure 23 shows the sun's azimuth and altitude in relation to the airport property at the time of the accident, September 29, 2013, at 6:20 PM PDT. The direction of the sun was from an azimuth of 264 degrees with an altitude of +3.6 degrees. The sun's direction was quartering the right front of the accident aircraft, allowing only limited reflection of the aircraft's rear flap surfaces.

Figure 23. The position of the sun at the time of the accident. The arrow indicates the sun's vector at the time of the accident.

Camera 7

Figure 24 is an exported still from 6:20:47 PM. The position of the aircraft's flap position is inconclusive. Figure 25 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 24. An exported still image from camera 7 at 6:2047 PM.

Figure 25. An enhanced image from camera 7 at 6:20:47 PM.

Camera 8

Figure 26 is an exported still from 6:20:50 PM. The position of the aircraft's flap position is inconclusive. Figure 27 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 26. An exported still image from camera 8 at 6:20:50 PM.

Figure 27. An enhanced image from camera 8 at 6:20:50 PM.

Camera 3

Figure 28 is an exported still from 6:20:51 PM. The position of the aircraft's flap position is inconclusive. Figure 29 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 28. An exported still image from camera 3 at 6:20:51 PM.

Figure 29. An enhanced image from camera 3 at 6:20:51 PM.

Camera 4

Figure 30 is an exported still from 6:20:50 PM. The position of the aircraft's flap position is inconclusive. Figure 31 is the same image, enhanced to attempt to recognize the aircraft's flap position.

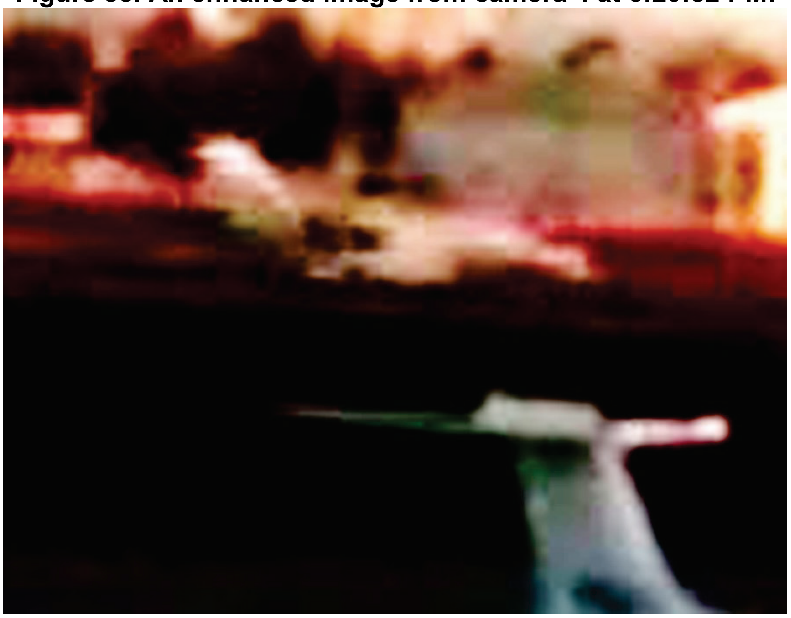
Figure 30. An exported still image from camera 4 at 6:20:50 PM.

Figure 31. An enhanced image from camera 4 at 6:20:50 PM.

Figure 32 is a second exported still from 6:20:52 PM. The position of the aircraft's flap position is inconclusive. Figure 33 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 32. An exported still image from camera 4 at 6:20:52 PM.

Figure 33. An enhanced image from camera 4 at 6:20:52 PM.



Camera 9

Figure 34 is an exported still from 6:20:53 PM. The position of the aircraft's flap position is inconclusive. Figure 35 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 34. An exported still image from camera 9 at 6:20:53 PM.

Figure 35. An enhanced image from camera 9 at 6:20:53 PM.

Camera 17

Figure 36 is an exported still from 6:21: 05 PM. The position of the aircraft's flap position is noted as in an unquantified extended position. Figure 37 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 36. An exported still image from camera 17 at 6:21:05 PM.

Figure 37. An enhanced image from camera 17 at 6:21:05 PM. The flap position is in an unquantified extended position.

Summary of Flap Position Findings

Table 4.2 summarizes the findings from the flap position study

Table 4.2. A summary of flap position examination from the recordings.

Camera Number	Time	Flap Position
7	6:20:47 PM	Inconclusive
8	6:20:50 PM	Inconclusive
3	6:20:51 PM	Inconclusive
4	6:20:50 PM	Inconclusive
4	6:20:52 PM	Inconclusive
9	6:20:53 PM	Inconclusive
17	6:21:05 PM	Unquantified extended Position

5. Examination of Other Cessna 525 Landings at KSMO

5.1. Distance/Position Study of Other Cessna 525 Landings at KSMO

Other Cessna 525 landings conducted at KSMO were requested to be captured on the airport's DVR system and provided to the NTSB. KSMO provided three batch recordings from the Bosch DVR system for landings that occurred between April 7, 2015, and April 10, 2015. The three batch files show similar camera views of three successful Cessna 525 landings.

Individual distance and position studies of the three landings were created using the same method as described in the report for the accident scenario. Due to lighting conditions and camera movement, it was not possible to quantify speeds of the exemplar aircraft for certain camera views. It is difficult to factually compare the additionally studied landings as the touchdown point and aircraft performance characteristics for each landing are largely unknown. An error margin was not examined for the following situations.

Batch File 1
File: Divar700.20150407T085630-20150407T085800.dxa
Time: April 7, 2015 – Approximately 8:56 AM

Table 5.1 shows the results of a distance and position study performed for Bosch batch file Divar700.20150407T085630-20150407T085800.dxa.

Table 5.1. Calculated speeds from the recordings taken on April 7, 2015.

Camera Number	Corrected Distance – d (ft)	Time (sec)	Speed (kts)
7	N/A	N/A	N/A
8	243	1.5	96.0
3	212	1.5	83.7
9	199	2.25	52.4

Batch File 2
File: Divar700.20150409T093159-20150409T093600.dxa
Time: April 9, 2015 – Approximately 9:32 AM

Table 5.2 shows the results of a distance and position study performed for Bosch batch file Divar700.20150409T093159-20150409T093600.dxa.

Table 5.2. Calculated speeds from the recordings taken on April 9, 2015.

Camera Number	Corrected Distance – d (ft)	Time (sec)	Speed (kts)
7	N/A	N/A	N/A
8	N/A	N/A	N/A
3	145	1.25	68.7
9	188	2.25	89.1

Batch File 3
File: Divar700.20150410T170159-20150410T170403.dxa
Time: April 10, 2015 – Approximately 5:02 PM

Table 5.3 shows the results of a distance and position study performed for Bosch batch file Divar700.20150410T170159-20150410T170403.dxa

Table 5.3. Calculated speeds from the recordings taken on April 10, 2015.

Camera Number	Corrected Distance – d (ft)	Time (sec)	Speed (kts)
7	N/A	N/A	N/A
8	N/A	N/A	N/A
3	167	2	49.5
9	210	2.5	49.8

5.2. Examination of Flap Positions from Other Cessna 525 Landings at KSMO

Batch File 1
File: Divar700.20150407T085630-20150407T085800.dxa
Time: April 7, 2015 – Approximately 8:56 AM

Figure 38 shows the sun's azimuth and altitude in relation to the airport property at the time of the recording of the exemplar batch file on April 7, 2015 at 8:56 AM PDT. The direction of the sun was from an azimuth 101.7 degrees with an altitude of +28.6 degrees. The sun's direction was quartering the left rear of the exemplar aircraft, allowing some reflection of the aircraft's rear flap surfaces.

Figure 38. The position of the sun at the time of recording of batch file 1.

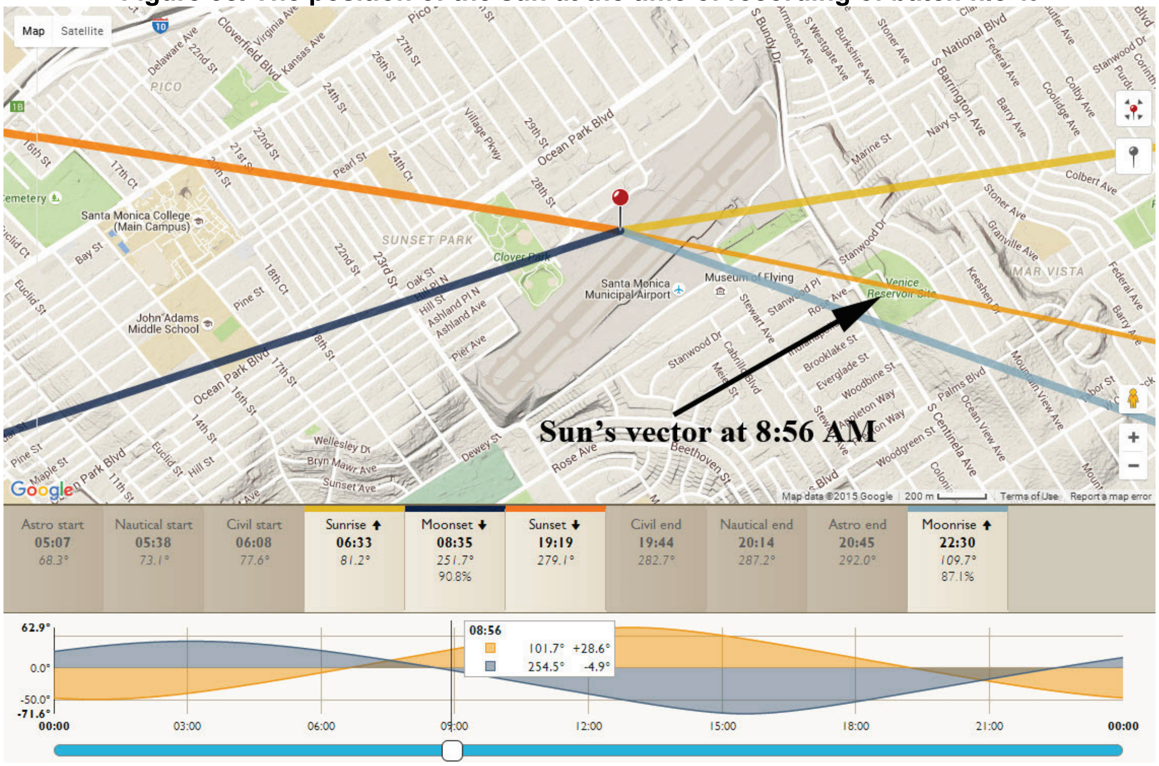


Figure 39 is an exported still from camera 8 8:56:58 AM. The position of the aircraft's flap position is in an unknown extended position. Figure 40 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 39. An exported still image from camera 8 at 8:56:58 AM.

Figure 40. An enhanced image from camera 8 at 8:56:58 AM.

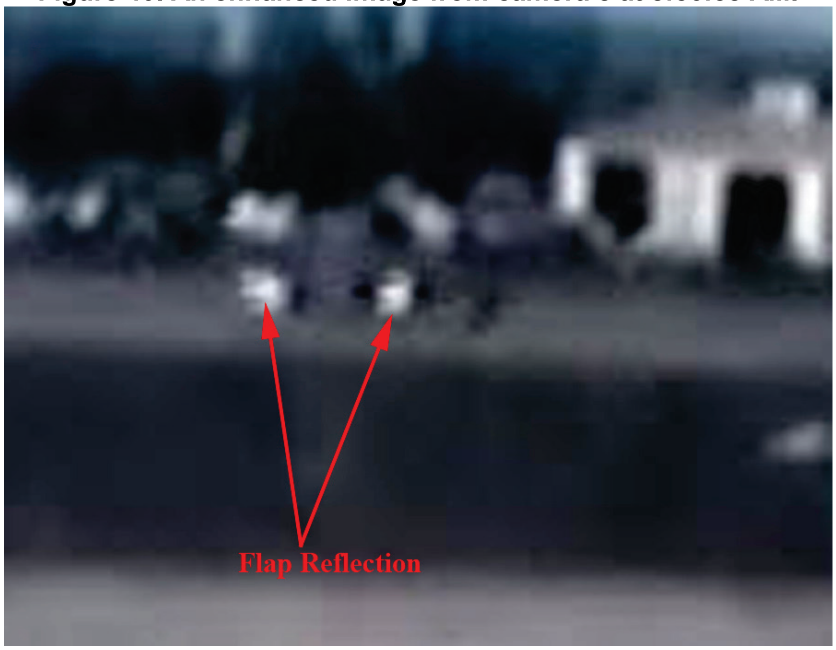


Figure 41 is an exported still from camera 9 8:56:59 AM. The position of the aircraft's flap position is in an unknown extended position. Figure 42 is the same image, enhanced to attempt to recognize the aircraft's flap position.

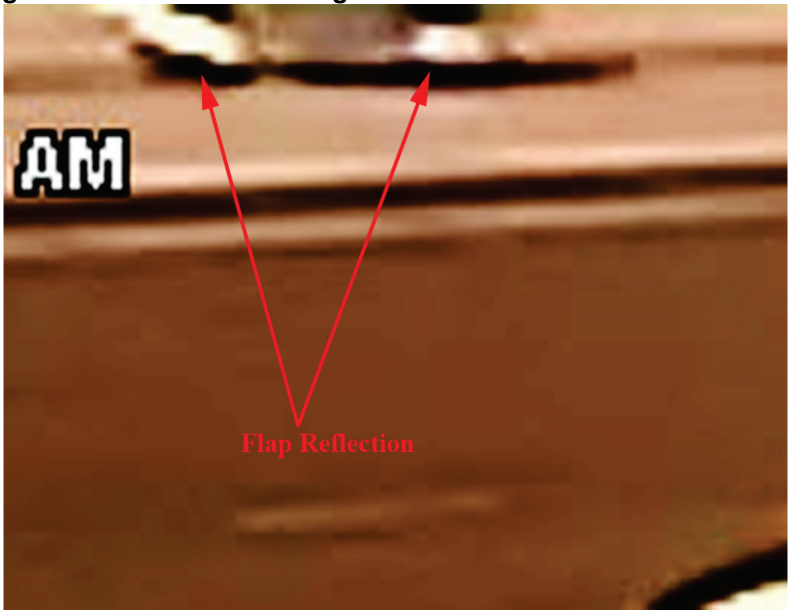
Figure 41. An exported still image from camera 9 at 8:56:59 AM.

Figure 42. An enhanced image from camera 9 at 8:56:59 AM.

Figure 43 is an exported still from camera PTZ 16 take at 8:57:00 AM. This camera view did not capture the accident sequence on September 29, 2013 The camera at this location shows the flaps of the exemplar aircraft in an unknown extended position. It was captured within two seconds of cameras 8 and 9. Figure 44 is an enhancement of the image in figure 43.

Figure 43. An exported still image from camera PTZ 16 at 8:57:00 AM.

Figure 44. An enhanced image from camera PTZ 16 at 8:57:00 AM.



<u>Batch File 2</u>
File: Divar700.20150409T093159-20150409T093600.dxa
Time: April 9, 2015 – Approximately 9:32 AM

Figure 45 shows the sun's azimuth and altitude in relation to the airport property at the time of the recording of the exemplar batch file on April 9, 2015 at 9:32 AM PDT. The direction of the sun was from an azimuth 107.3 degrees with an altitude of +36.4 degrees. The sun's direction was quartering the left rear of the exemplar aircraft, allowing some reflection of the aircraft's rear flap surfaces.

Figure 45. The position of the sun at the time of recording of batch file 2.

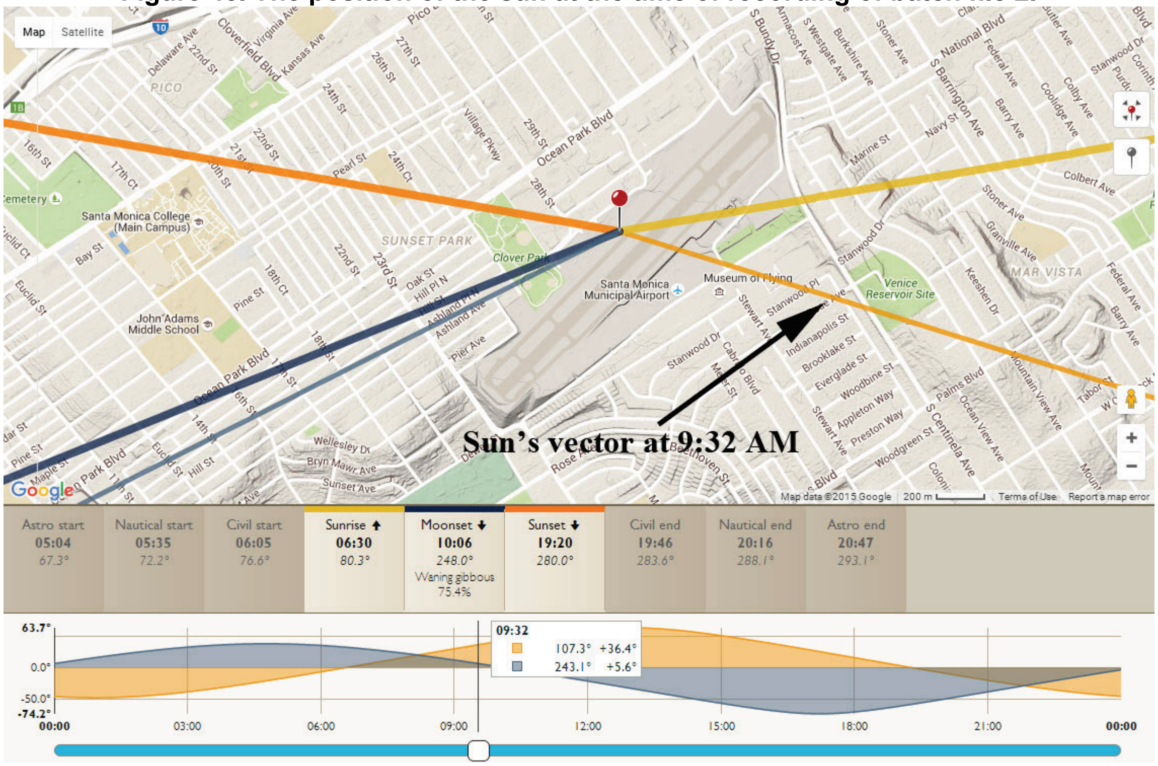


Figure 46 is an exported still from camera 8 9:32:10 AM. The position of the aircraft's flap position is in an unknown extended position. Figure 47 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 46. An exported still image from camera 8 at 9:32:10 AM.

Figure 47. An enhanced image from camera 8 at 9:32:10 AM.

Figure 48 is an exported still from camera 9 9:32:12 AM. The position of the aircraft's flap position is in an unknown extended position. Figure 49 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 48. An exported still image from camera 9 at 9:32:12 AM.

Figure 49. An enhanced image from camera 9 at 9:32:12 AM.

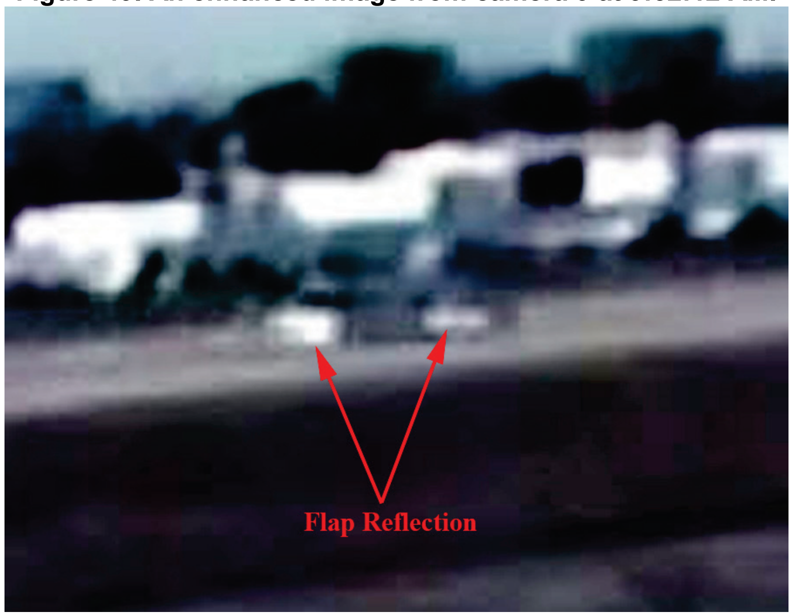
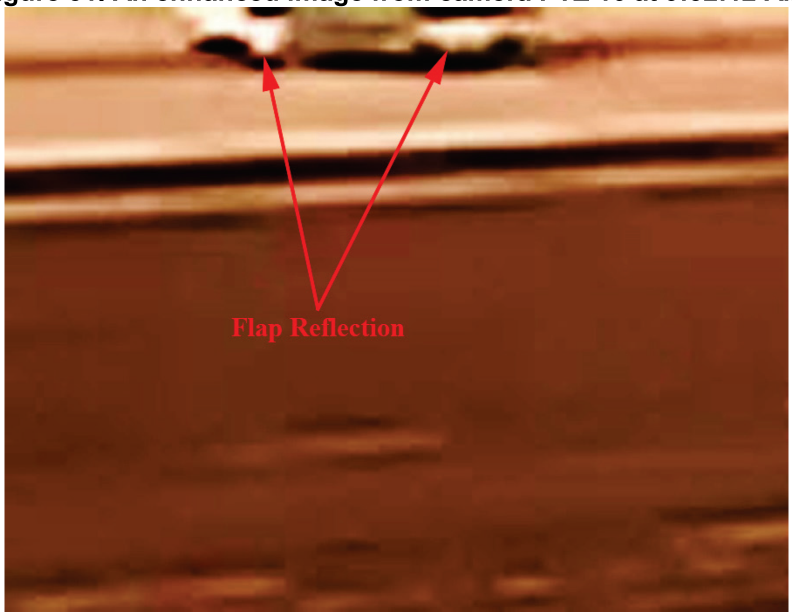


Figure 50 is an exported still from camera PTZ 16 taken at 9:32:12 AM. This camera view did not capture the accident sequence on September 29, 2013. The camera at this location shows the flaps of the exemplar aircraft in an unknown extended position. It was captured within two seconds of cameras 8 and at approximately the same moment as camera 9. Figure 51 is an enhancement of the image in figure 50.

Figure 50. An exported still image from camera PTZ 16 at 9:32:12 AM.

Figure 51. An enhanced image from camera PTZ 16 at 9:32:12 AM.



Batch File 3
File: Divar700.20150410T170159-20150410T170403.dxa
Time: April 10, 2015 – Approximately 5:02 PM

Figure 52 shows the sun's azimuth and altitude in relation to the airport property at the time of the recording of the exemplar batch file on April 10, 2015, at 5:02 PM PDT. The direction of the sun was from an azimuth of 260.5 degrees with an altitude of +27.9 degrees. The sun's direction was quartering the left rear of the exemplar aircraft, allowing some reflection of the aircraft's rear flap surfaces.

Figure 52. The position of the sun at the time of recording of batch file 2.

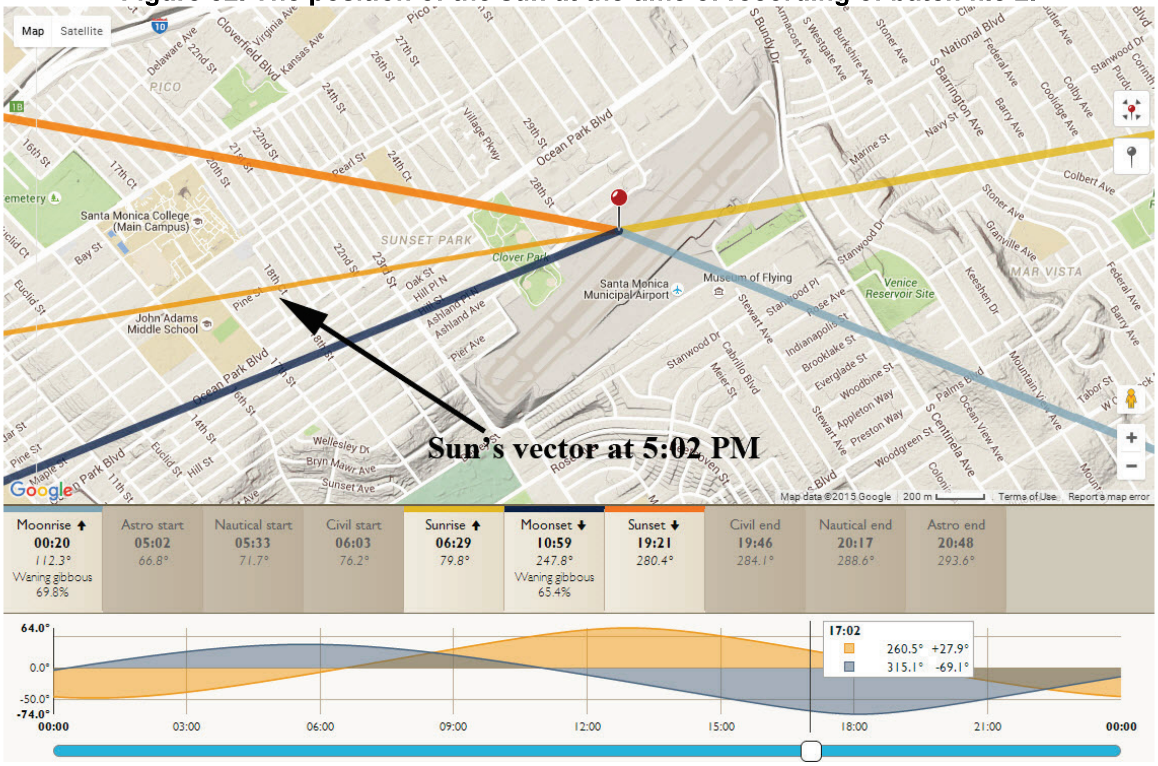


Figure 53 is an exported still from camera 8 5:02:20 PM. The position of the aircraft's flaps are inconclusive. Figure 54 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 53. An exported still image from camera 8 at 5:02:20 PM.

Figure 54. An enhanced image from camera 8 at 5:02:20 PM.

Figure 55 is an exported still from camera 9 5:02:24 PM. The position of the aircraft's flaps are inconclusive. Figure 56 is the same image, enhanced to attempt to recognize the aircraft's flap position.

Figure 55. An exported still image from camera 9 at 5:02:24 PM.

Figure 56. An enhanced image from camera 9 at 5:02:24 PM.

Compared to the results from Section 5.1 and 5.2, the azimuth and altitude of the sun at the time of the accident recording in relation to the location of the security cameras resulted in difficulty resolving the accident aircraft's flap position at the time of the accident recordings.

6. Uncertainty and Assumptions

A number of assumptions had to be made to conduct this study which led to varying amounts of uncertainty in the calculations.

For this study it was assumed that barrel distortion[12] did not affect the images from any of the cameras. The recorded images do appear to have a small amount of barrel distortion evident in the outer regions of the recorded capture. Unfortunately, since the cameras were not looking directly at the runway, the runway and aircraft appear on the edges of the image. Since the study was evaluated using the aircraft's alignment with visible airport features, this error was mitigated.

Difficulties were also presented when trying to identify landmarks in the accident video that were used to conduct the study. The selection of the background structures as geographic references was challenging and had a small degree of uncertainty. Supplemental photographs taken after the accident were used to make a correlation between the landmarks in the camera's field of view and their position on geographical mapping software. If an incorrect landmark was chosen, the output results could have been skewed by an unknown amount. For this study, it is assumed that all geographical background objects were chosen correctly and their positions were identified with certainty. Similarly, the security camera locations were evaluated in the same manner. No

[12] Barrel distortion – a lens effect which causes images to be spherized or "inflated" as if the image were mapped around the surface of a barrel. The effect is typically associated with wide angle lenses.

error in placement of the security camera recording locations at the time of the accident was accounted for. This was assumed to be correct.

To calculate the distance traveled, camera perspective lines originating from the camera's center of lens were extended through the image field and across the runway where they intersected landmark features. To calculate an average speed for a measured segment, a distance was measured using Google Earth along the runway's centerline. Physical evidence locating the aircraft's position with tire marks were accounted for in cameras 4, 9 and 17. In all other camera views, an assumption was made that the accident aircraft was traveling along the runway's centerline. For recorded images from cameras 7, 8 and 3, the accident aircraft was assumed to be traveling along the runway centerline.

The study also assumes for the distance time calculation in section 4.4 between cameras 9 and 17 that the DVR's timestamp expresses timing information precisely across all camera recordings. The study assumes that the timestamping information between camera 9 and 17 were in sync with no errors. The accuracy of the DVR's time stamping method between two camera feeds was not explored.