NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

October 30, 2017

Video Study

NTSB Case Number:
DCA17FA109

A. ACCIDENT

Location:	Charleston, West Virginia (CRW airport)
Date:	May 5, 2017
Time:	6:51 am EDT
Aircraft:	Shorts SD3-30

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

On May 5, 2017 at 6:51 am eastern daylight time (EDT), Air Cargo Carriers flight 1260, a Shorts SD3-30, N334AC, crashed during landing on runway 5 at the Charleston Yeager International Airport, Charleston, West Virginia (CRW). The airplane was destroyed, and the two pilots suffered fatal injuries. The flight was a scheduled cargo flight from Louisville, Kentucky, operated under the provisions of 14 CFR 135.

The aircraft was executing a VOR-A approach to runway 5. At the time of the accident, weather was reported as an overcast ceiling at 500 ft. with 10 statute miles visibility and light winds.

D. DETAILS OF INVESTIGATION

This study had two goals. The first goal was estimating the cloud ceiling at the CRW airport based on a video. It was performed by estimating the airplane altitude when it was first seen in a video recorded by a surveillance camera installed on the top level of a Charleston garage building. The video had resolution of 1600x1200 and frame rate of 6 fps.

The second goal was estimating the speed of the airplane when it impacted the runway. It was performed by first estimating the airplane locations when it was above the runway and then estimating the speed based on the locations and the video frame rate. The video used for speed estimation was recorded by an airport camera installed on the control tower. It had resolution of 1706x1280 and image refresh rate, computed based on time stamps on the video frames, of 1/0.35=2.857 images per second.

Cloud Ceiling Estimation

Figure 1 shows the frame from the video when the descending airplane was seen for the first time. The airplane image is marked by the yellow circle. Five highway light poles, P1-P5, are also marked in Figure 1. These light poles are also visible and marked in the Google Earth aerial view shown in Figure 2.

Figure 1. Frame from the Garage Building Video

Figure 2 also shows the location of the camera on top of the garage building. Using the azimuth locations of the five light poles in Figure 2 with respect to the camera and knowing the resolution of the video frame in Figure 1, it was estimated that the horizontal field of view (HFOV) of the camera was 47º and that the camera yaw orientation was 52.8º east of north.

An estimate of altitude based on a video frame depends on the pitch angle of the camera with respect to horizontal. If it is assumed that the angle is zero and it is actually not zero, the estimate will be incorrect. In this case, for example, a 1º pitch orientation above horizontal results in altitude estimate that is 113 feet lower than the estimate derived assuming that the pitch angle is zero. Therefore, it was necessary to estimate the pitch angle of the camera and take its deviation from horizontal into account.

The camera pitch angle estimate was derived using a camera optics model that was based on the previously estimated HFOV of 47º, measurements of the parking space lines seen in Figure 1, and a measurement of the camera elevation above the floor of the top level of the parking garage. The camera optics model showed good match of the parking space lines with camera pitch angle close to zero. It was estimated that the camera pitch angle was in the range of ±0.3º with respect to the floor.

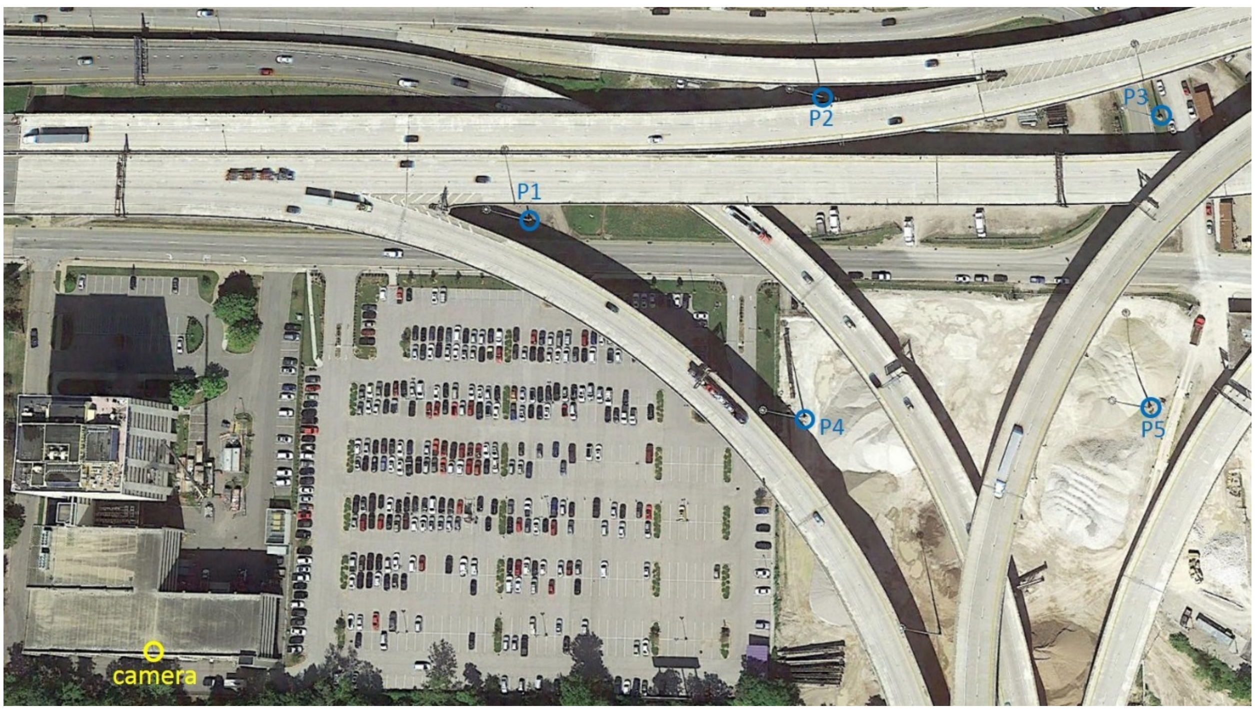

Figure 2. Aerial View Showing the Camera and the Poles Used for Calibration

The location of the airplane image in Figure 1, the video frame resolution of 1600x1200, the estimated HFOV and the camera yaw and pitch estimates result in a line-of-sight from the camera to the airplane that is 52.8º east of north and is elevated by 7.5º±0.3º above horizontal.

Figure 3 shows in red the ground track of the airplane estimated from radar returns as described in the *Airplane Performance Specialist Report* available in the docket for this accident. It also shows in yellow a line-of-sight from the camera that is oriented by the estimated 52.8º east of north. A white circle shows the intersection of the ground track with the line-of-sight. The ground-level distance from the camera to the intersection point is 7340 feet. Consequently, the elevation of the airplane above the camera is given by $7340 \times \tan(7.5^{\circ} \pm 0.3^{\circ}) = 966 \pm 40$ feet.

The ground near the parking garage is at the elevation of 591 feet above mean sea level (MSL), based on Google Earth. The camera was estimated to be 72 feet above ground level, i.e., at 663 feet MSL. This results in estimated nominal airplane altitude of 966+663=1629 feet MSL. The inaccuracy of this estimate was previously estimated as ±40 feet due to camera pitch angle uncertainty only. Adding to this inaccuracy ±20 feet to account for other sources of error, the estimated airplane altitude is 1629±60 feet MSL when it is seen first in the video.

Figure 3. Airplane Location Estimate

The elevation of runway 5 at CRW is 946 feet MSL. Therefore, the estimated cloud ceiling at the airport is 1629±60-946=683±60 feet. Note that this estimate is based on the limited information that was available. It is based on airplane location and cloud elevation at a location about 3800 feet west of the landing spot on runway 5. Additionally, it is based on video from a camera that is 7340 feet southwest of the location of the airplane.

The estimated cloud ceiling is also based on the ground track derived from radar data that is documented in the *Airplane Performance Specialist Report*. The ±60 feet tolerance of the estimated cloud ceiling in this report does not include a possible tolerance-increasing contribution due to uncertainty of the estimated ground track.

This video-based estimate of the altitude of the airplane (as it becomes visible breaking through the clouds) is consistent with the altitude indicated by the airplane transponder for the radar return nearest to the point marked by the yellow circle in Figure 3. The *Airplane Performance Specialist Report* shows the reported altitude as 1600±50 feet MSL.

Ground Impact Speed Estimation

Estimation of the speed of the airplane when it impacted the runway required a model of the camera optics. Figure 4 shows a frame from the control tower video. The camera used a wide-angle lens that caused significant barrel distortion. Figure 4 shows the video frame after the distortion was mathematically corrected.

Figure 4. Frame from the Airport Tower Video with Marked Reference Points

There are 17 reference points marked on the video frame in Figure 4. These reference points are also visible and marked in the aerial view of the airport shown in Figure 5. Parameters of a model of camera optics are camera location in a 3D coordinate system, its orientation angles with respect to ground, and its horizontal field of view (HFOV) angle. The 17 reference points were used to estimate these seven parameters.

Once the camera model parameters were known, the model could accurately map a point specified in the 3D camera field of view on the image of that point in a video frame.

The following process was used for estimating the speed of the airplane when it impacted the runway. A wireframe model of the Shorts SD3-30 airplane was constructed, consisting of points on the nose, tail and wings. The wireframe model was then iteratively positioned and rotated in the field of view of the simulated camera until the points on the wireframe model that were mapped onto the video frame coincided optimally with their images in the video frame. At that time, the position and orientation of the wireframe model was the optimal estimate of the position and orientation of the real airplane at the time the analyzed video frame was acquired.

Figure 5. Aerial View of Airport with Marked Reference Points

There were four frames in the video that were taken before the fuselage contacted the runway. Locations and orientations of the airplane were estimated at the four times corresponding to these video frames. Figure 6 shows the ground track distances traveled by the airplane between the first and the fourth frame. The distance traveled at time zero was set to zero. The slope of the distance vs. time curve in Figure 6 is constant and corresponds to ground speed of 89.0 knots.

The airplane nose altitude was decreasing at the rate of approximately 22.8 knots (2309 feet/minute) between the first and the fourth locations. The vector sum of the ground speed and the vertical speed is $(89.0^2+22.8^2)^{1/2}=91.9$ knots. To account for estimation errors, a tolerance must be assigned to the nominal speed estimate. With the tolerance, the estimated ground impact speed is 92±4 knots. This is the estimated magnitude of the three-dimensional velocity vector of the airplane nose when it contacted the runway.

The use of the wireframe model allowed the estimation of the airplane orientation angles at time of ground impact. Just before the left wing contacted the runway, the left-wing-down roll angle was approximately 42º and the nose-down pitch angle was approximately 14º.

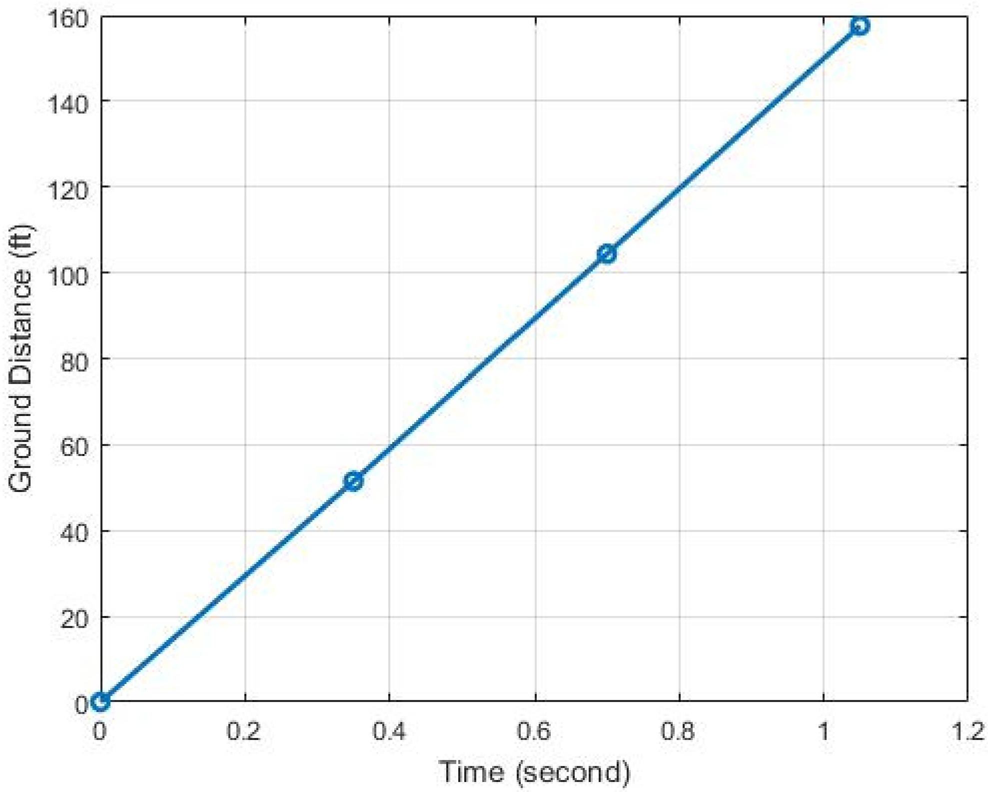

Figure 6. Distance along Ground Path vs. Time

E. CONCLUSIONS

The cloud ceiling at an airport was estimated based on a video from a surveillance camera installed on a garage building. The estimated ceiling was set to the altitude of a descending airplane when it became visible in the video for the first time. The estimated cloud ceiling was 683±60 feet above airport ground level.

An airport camera video was used for estimating the speed with which the airplane impacted the runway. The estimated speed was 92±4 knots. The left wing contacted the runway first because the left-wing-down roll angle was approximately 42º. The fuselage was at an approximate 14º nose-down pitch angle at that time.