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

August 2, 2018

Video Study

NTSB Case Number:
WPR18FA119

A. ACCIDENT

Location:	Scottsdale, Arizona
Date:	April 9, 2018
Time:	2048 MST
Aircraft:	Piper PA-24-260

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

On April 9, 2018, about 2048 mountain standard time, a Piper PA-24-260 airplane, N9456P, was destroyed when it impacted terrain shortly after takeoff from Scottsdale Airport (SDL), Scottsdale, Arizona. The airline transport pilot, student pilot, and 4 passengers were fatally injured. The airplane was registered to N9456P, LLC and operated by the pilots as a personal flight under the provisions of Title 14 Code of Federal Regulations Part 91. Night time visual meteorological conditions prevailed, and a flight plan was not filed. The flight was destined for North Las Vegas Airport (VGT), Las Vegas, Nevada.

D. DETAILS OF INVESTIGATION

The purpose of this study was estimating the trajectory and speed of the airplane. The airplane was captured on videos from several cameras. Three videos were used in this study. The first video was from a traffic camera at the intersection of East Frank Lloyd Wright Boulevard and North Greenway Hayden Loop. The camera was oriented approximately east along the boulevard. The second video was from the Scottsdale airport tower camera. It was oriented approximately along Runway 3. The third video was from the airport ASOS (Automated Surface Observing System) camera. This camera was only used for estimating the times when the airplane started moving and when it became airborne.

Camera Calibration

The analysis of this accident required calibrated mathematical models of the traffic camera optics and of the airport tower camera optics. The mathematical model of camera optics requires seven parameters. Three are the X, Y and Z camera location coordinates. Three are the yaw, pitch and roll camera orientation angles, and the seventh parameter is the camera horizontal field of view (HFOV). The approximate X, Y and Z coordinates of the two cameras were known. However, the accurate locations were required for analysis. Therefore, all seven parameters had to be estimated for both cameras.

The estimation was based on references that were visible both in aerial images and in video frames. The references used for the traffic camera calibration were road markings, curbs, light poles and traffic lights. The references used for the airport tower camera calibration were runway and taxiway markings and building corners. Both cameras were calibrated using daytime videos recorded by the two cameras.

A computer program that simulates camera optics was then used to project the references onto a frame from the video in an iterative process in which the seven parameters were varied so as to align the projected references with their images. When the projected references were aligned optimally with their images in the frame, values of the seven parameters were their optimal estimates. At that point, the model of the camera optics was calibrated.

Traffic Camera Video Analysis

Figure 1 shows a frame from the video acquired by the traffic camera. The video had 720x576 resolution and frame rate of 25 fps. Only the two airplane wingtip lights (the two white dots) are visible in this frame and in all the other frames that recorded the airplane. The two white dots are not sufficient for uniquely estimating the location of the airplane based on a video frame. It is so because there are infinitely many combinations of airplane distance from the camera, altitude, yaw angle and roll angle that place the two white dots at the same locations in a video frame.

Since it was not possible to uniquely estimate the airplane locations based on frames from the traffic camera video, five hypothetical ground track trajectories were examined. Figure 2 shows the geometry of the problem. The airplane took off along the runway and was flying above it. Then it turned to the left and crashed at the location marked with the red 'X'. It was assumed that the airplane ground track from the runway to the crash site was along a circular arc. Five arcs were considered, each tangent to the centerline of the runway and ending at the crash site. Each arc was specified by the center of the circle and the radius of the arc. One of the arcs, the 'optimal ground track,' is shown in red. It was determined to be the optimal arc based on information from the analysis of the airport tower camera that is described below.

Once one of the five circular ground tracks was selected, it was possible to uniquely estimate the location of the airplane (it had to be above the selected ground track) and the altitude of the airplane corresponding to each video frame. The estimation was performed in an iterative process using the calibrated camera optics model. Since the frame timing was known, speed could then be estimated based on airplane locations and the times when the analyzed video frames were acquired. Of particular interest were the speeds and altitudes at the time when the airplane entered the field of view of the traffic camera. These values were used for selecting the optimal ground track by correlating traffic camera estimates with airport tower camera estimates.

Figure 1. Frame from the Traffic Camera Video

Airport Tower Camera Video Analysis

Figure 3 shows a frame from the video acquired by the tower camera. The video had 1280x720 resolution and frame rate of 24 fps. As can be seen in Figure 3, only the tail light of the airplane is visible. The airplane tail light and the runway lights saturated the image sensor of the camera and, therefore, they appear in the video frame much larger than their real dimensions.

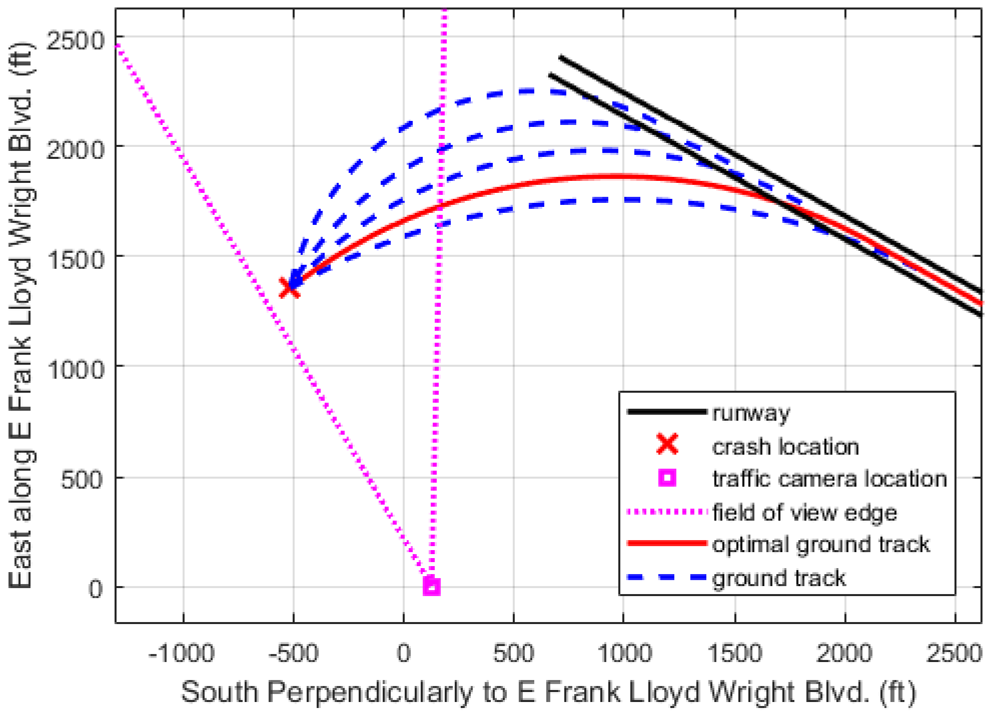

Figure 2. Accident Geometry Related to the Traffic Camera

Figure 4 shows the geometry of ground track estimation as it relates to the airport tower camera. Locations of both the airport tower camera and the traffic camera and their horizontal fields of view are marked in the figure. The ground track shown in the figure is the optimal ground track from Figure 2.

Runway 3 is 8249 feet long. The airport tower is located approximately half way along the runway and the tower camera is oriented approximately along the runway. Therefore, Figure 4 shows only the last 4600 feet of the runway. The tower camera location was set to be at the (0,0) coordinate in the figure.

The calibrated tower camera optics model was used in an iterative process where the locations and altitudes of the airplane were estimated at times corresponding to 14 video frames. Location estimates were then used to estimate speeds. Since only the tail light of the airplane was visible, it had to be assumed that the airplane was flying above an assumed ground track. The assumed ground track consisted of a straight segment above the runway and a circular segment that started tangentially to the runway centerline and ended at the crash site. The same five hypothetical ground tracks shown in Figure 2 were analyzed.

Figure 3. Frame from the Airport Tower Camera Video

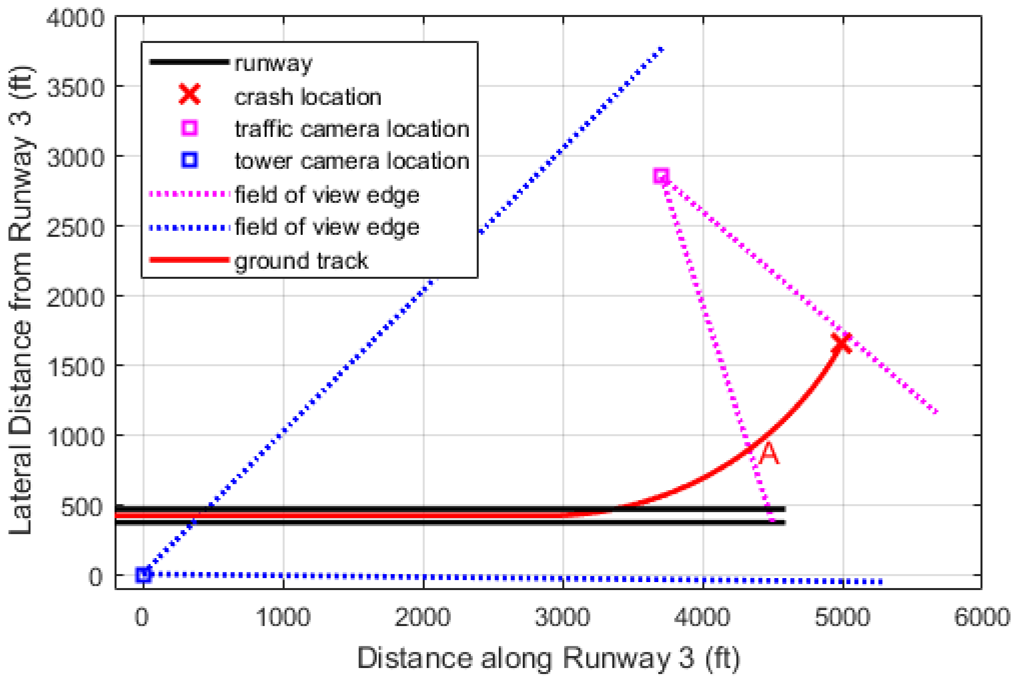

Figure 4. Accident Geometry Related to the Airport Tower Camera

Of particular interest was point A on the ground track that is marked in Figure 4. At that point, estimates of speed and altitude were available both from the traffic camera and from the airport tower camera. The circular ground track segment in Figure 4 and the 'optimal ground track' shown in red in Figure 2 generated close agreement between the two speed estimates and the two altitude estimates. Therefore, this hypothetical track was determined to be the closest to the actual ground track of the accident airplane.

Once the ground track was known, the airport tower camera was used to plot the ground distance traveled by the airplane versus time. Figure 5 shows the plot. Time zero in the plot corresponds to the first analyzed point. That point is above the runway centerline, just after the airplane crossed into the field of view of the tower camera. It could be determined with certainty that the airplane was above the runway up to time 25 seconds in Figure 5. During these 25 seconds, its estimated ground speed was 75±4 knots. It could be determined with certainty that the airplane was above the circular ground track segment after time 36 seconds. The estimated speed between time 36 seconds and time 45 seconds was 50±4 knots, a significant decrease from the speed above the runway. Note that the last point, at 46 seconds, indicates speed decreasing below 50 knots. The airplane impacted the ground at about time 52 seconds. Between time 25 seconds and time 36 seconds, the airplane was beginning to turn left but was still close to the runway. Since the camera was looking along the runway and only the tail light was visible, accurate airplane location estimates could not be derived in this segment. Therefore, this segment in Figure 5 is drawn as a broken line.

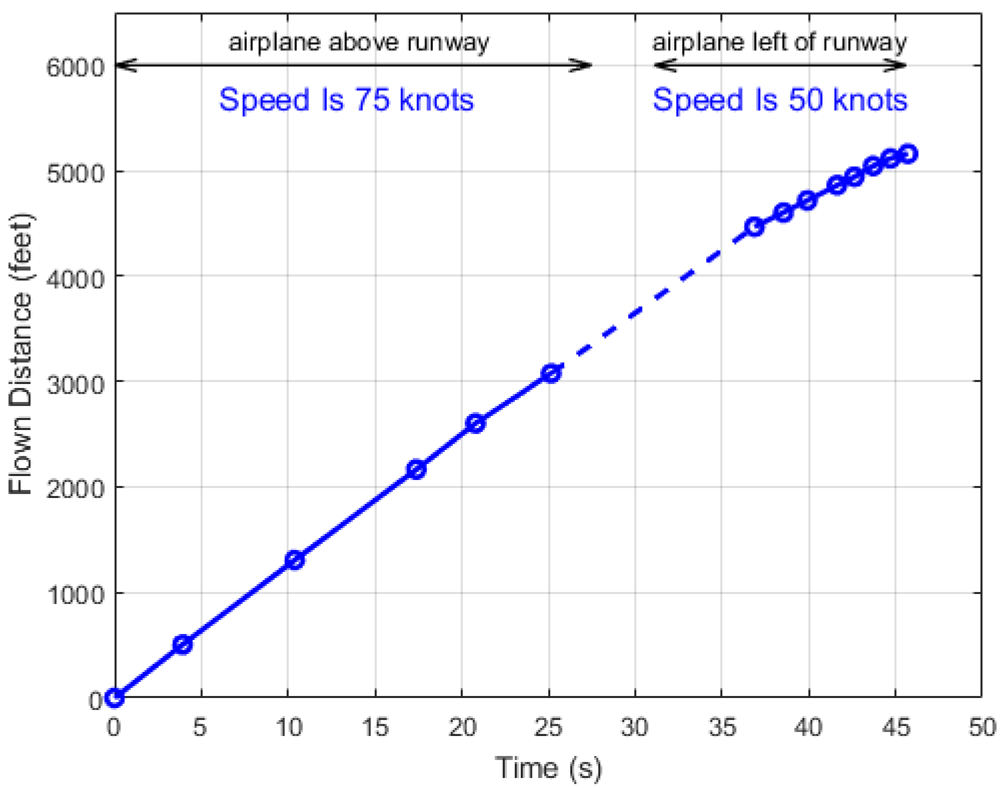

Figure 5. Estimated Distances and Ground Speeds

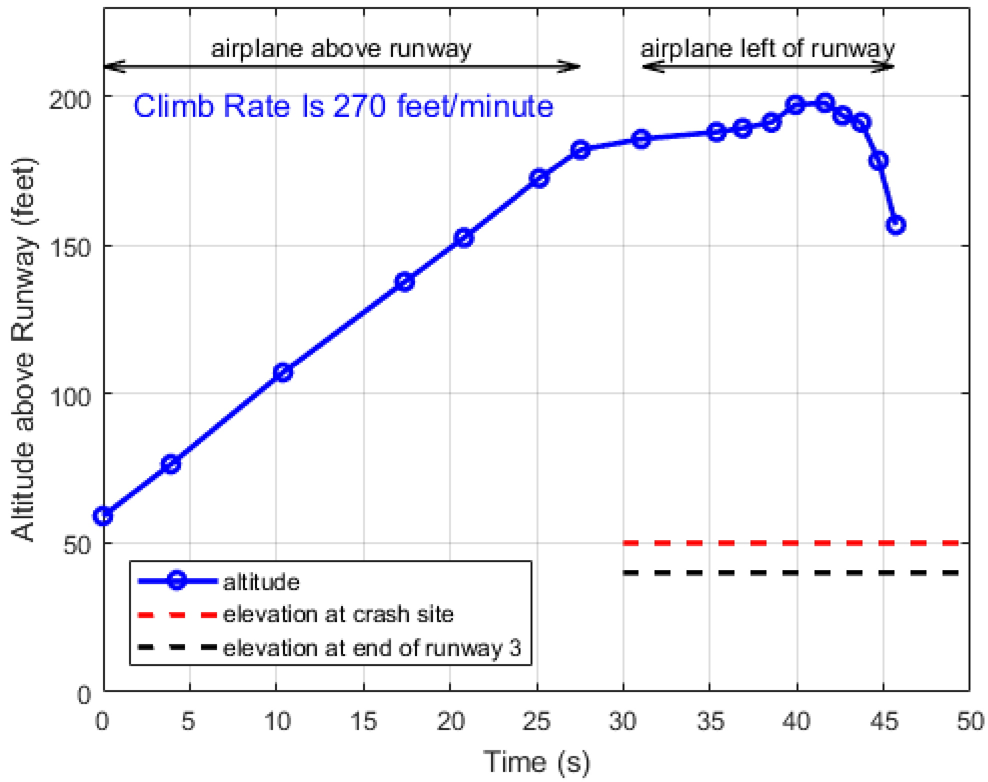

Figure 6. Estimated Altitude of the Airplane

Figure 6 shows the estimated altitude of the airplane above runway elevation at the location of the tower. The elevation of the runway at the location of the tower is set to zero in the figure. The airplane entered the field of view of the tower camera when it was already airborne. Therefore, at time zero, its altitude was already 59 feet above the runway. Its climb rate over the first 27 seconds was low, only 270 feet/minute. Past time 27 seconds, it virtually stopped climbing, never exceeding altitude of 200 feet. At time 42 seconds, the airplane started a rapid descent and impacted the ground at about time 52 seconds.

Runway 3 has a gradient of 0.8%. Due to the gradient, the runway elevation at the end of the runway is about 40 feet higher than its elevation at the tower location. The elevation at the crash site is about 50 feet higher than the runway elevation at the tower location. Figure 6 shows the elevations at the end of the runway and at the crash site. These elevations are with respect to the zero elevation that was assigned to the runway at the tower location.

The time in Figure 5 and in Figure 6 was set to zero shortly after the airplane entered the field of view of the tower camera and the first video frame was analyzed. The Airport ASOS camera recorded the airplane when it started its takeoff roll and when it became airborne. The image of the airplane was partially obscured by runway and taxiway lights that saturated the camera sensor, but approximate times could be estimated. Takeoff roll started approximately 45 seconds before time zero in Figure 5 and Figure 6 and the airplane became airborne approximately 18 seconds before time zero. The flight, from becoming airborne to ground impact, lasted approximately 70 seconds.

E. CONCLUSIONS

Videos captured by a traffic camera and an airport tower camera were used for estimating trajectory and speed of an airplane that crashed shortly after takeoff. It was estimated that the airplane ground speed was 75±4 knots shortly after takeoff when it was still above the runway. Its climb rate was only 270 feet/minute. As the airplane ground track approached the end of the runway, the airplane turned to the left. Twelve seconds later its speed was down to 50±4 knots and it started losing altitude. The airplane impacted the ground several seconds later. The airplane was airborne for only about 70 seconds.