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

December 29, 2017

Video Study

NTSB Case Number:
CEN17LA192

A. ACCIDENT

Location:	Canon City, Colorado
Date:	May 20, 2017
Time:	1340 MDT
Aircraft:	Robinson R66 helicopter

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

On May 20, 2017, about 1340 mountain daylight time, a Robinson R66 helicopter, N778TL, impacted terrain following a loss of control on approach to landing near Canon City, Colorado. The commercial pilot and four passengers were not injured, and the helicopter sustained substantial damage. The helicopter was registered to Hynes Aviation Industries, Inc. and operated by Colorado Vertical under provisions of Title 14 *Code of Federal Regulations* Part 91 as a local air tour flight. Visual meteorological conditions prevailed and a company flight plan was filed for the local flight. The flight originated at a private helipad near Canon City about 1335.

D. DETAILS OF INVESTIGATION

The goal of this study was estimating the forward speed and vertical speed of the helicopter shortly before the hard landing based on a video recorded by a camera installed on the helicopter. The video was recorded by a GoPro HERO3 Silver Edition camera that was mounted on the helicopter windshield facing inward. The video had resolution of 1280x960, frame rate of 60 fps, and the field of view (FOV) was set to Wide.

Because of the wide FOV, the video frames were distorted. The distortion was mathematically removed before the video was analyzed. Figure 1 shows a typical frame from the video after distortion removal. The gray area masks the images of the pilot and the four passengers, to protect their privacy. The analysis in this study is based only on reference points visible through the helicopter windows so that the unmasked area of Figure 1 is typical of the information that was available for analysis.

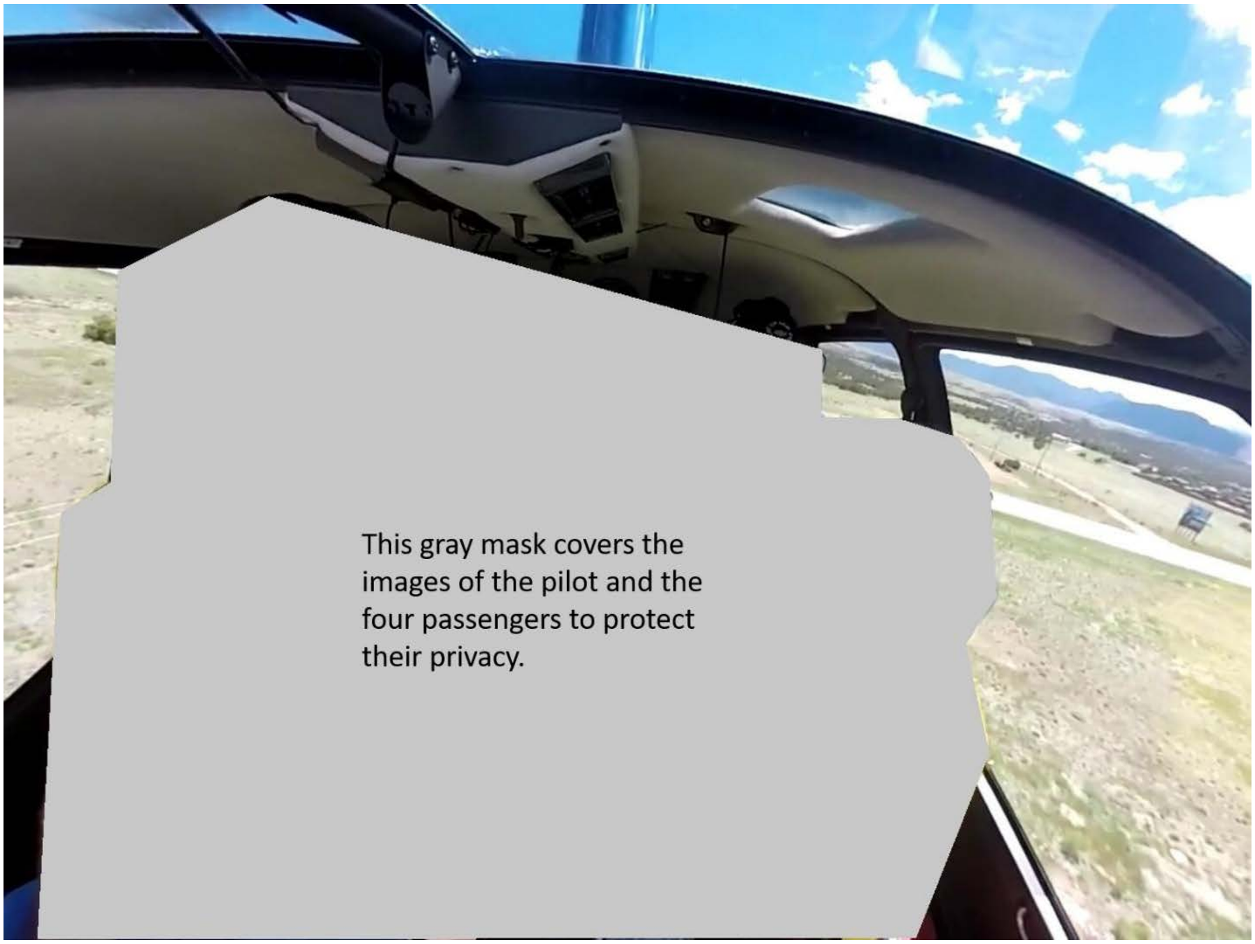

Figure 1. Typical Frame from the Video

<u>Camera Calibration</u>

The analysis of the video was based on a mathematical model of the camera. The model required four parameters. They were the yaw, pitch and roll angles of the camera with respect to the helicopter and the camera horizontal field of view (HFOV) angle. These four parameters were estimated from video frames recorded before takeoff, when the helicopter was still on the helipad.

Parameter estimation was based on reference points visible both through the helicopter windows and in aerial images of the accident area. They included points along Route 50, road signs, a fence, and bushes. The camera model was capable of mapping reference points in its 3D field of view onto frames from the video. An iterative process was used where the values of the four parameters were varied until the reference points were optimally mapped on their images in the video frames. At that time, the four parameter values were their optimal estimates.

Helicopter Location Estimation

The calibrated camera, with its four parameter values set to their optimal estimates, was then used for estimating the locations of the helicopter. Since the camera was rigidly mounted on the windshield, estimating the camera locations also estimated the locations of the helicopter. Location estimation was based on an iterative process similar to the camera calibration process. However, now the iterated variables were the x, y and z location coordinates of the helicopter and its yaw, pitch and roll orientation angles. Helicopter yaw, pitch and roll angles were set to zero when the helicopter was on the helipad before takeoff.

Reference points used for helicopter location estimation included points on Route 50, a road sign, a house, points on a dirt road, wood piles, bushes and trees. Helicopter location was estimated at six times corresponding to six video frames. These frames were selected because in them the reference points visible through the helicopter windows were sufficient for accurate location estimation. The six frames spanned 7.8 seconds. The first was recorded 10.1 seconds before ground impact. The sixth was recorded 2.3 seconds before ground impact. Estimation during the 2.3 seconds past the sixth point was not possible because there were not enough visible reference points.

The helicopter was 89 feet north of the northern edge of Route 50 and flying north when its first location was estimated. In the analysis, the time corresponding to this location was set to zero. Also set to zero at the first location were the distance traveled in the north direction, the distance traveled in the west direction, and the altitude. The altitude was determined from reference points far behind the helicopter, so it is not possible to accurately determine the height above ground; it is possible to determine accurately the altitude relative to the distant points and so determine the altitude relative to the first point accurately. Figure 2 shows the distances traveled by the helicopter in the north and west directions vs. time.

Forward speed of the helicopter can be estimated by dividing the total travel during the 7.8 seconds by that time. The estimate is 33.7 knots. The contribution of the speed in west direction to the total speed is small. It is the highest between 2.1 seconds and 4.9 seconds where the speed in the west direction is highest. The total forward speed in that time interval is 34.3 knots. Because the video-based estimation involves unavoidable uncertainties, the estimated forward speed during the analyzed 7.8 seconds is set to 34±3 knots.

Figure 3 shows the estimated altitude of the helicopter measured with respect to the altitude at time zero. Estimated vertical descent speed from time zero to the fifth point at time 6.8 seconds is 439 feet/minute. The highest estimated speed of descent of 571 feet/minute is between 4.8 seconds and 6.8 seconds. A 10% tolerance is assigned to the estimated speeds. Therefore, the highest estimated descent speed is set at 570±60 feet/minute.

High Vibration Intensity Time Interval

The video shows a time interval where the helicopter vibration intensity was significantly higher than during the rest of the flight. This interval lasted about seven seconds and is marked in red in Figure 2.

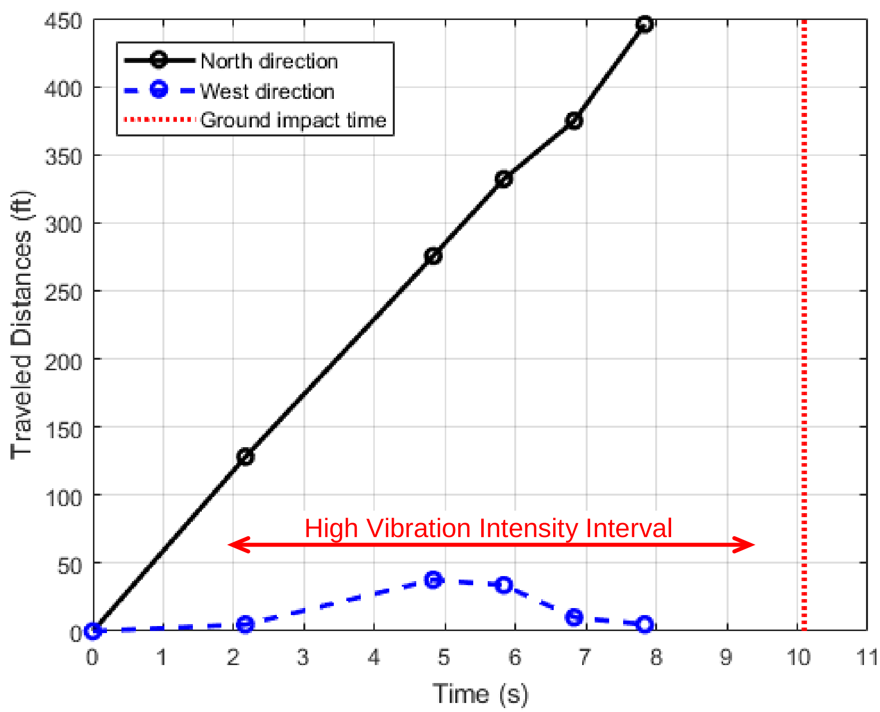

Figure 2. Estimated Distances Traveled by the Helicopter

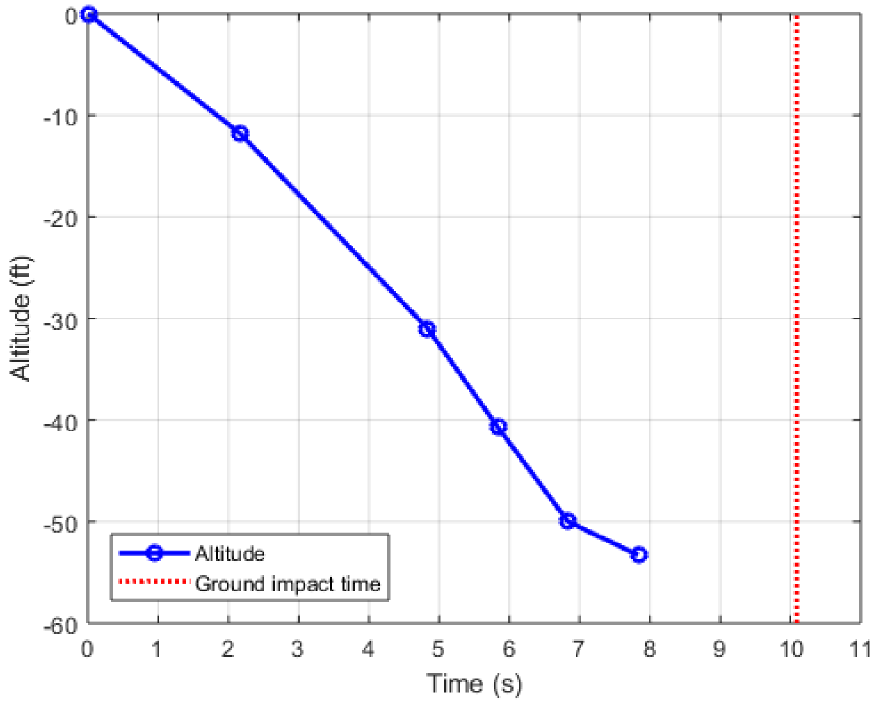

Figure 3. Estimated Altitude of the Helicopter

E. CONCLUSIONS

The forward speed and the vertical speed of a helicopter that made a hard landing were estimated based on a video recorded by a camera installed on the helicopter windshield. The estimated forward speed is 34±3 knots. The highest estimated vertical descent speed is 570±60 feet/second.

The helicopter experienced an elevated level of vibrations during a time interval of approximately seven seconds that ended just before ground impact.