

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, D.C. 20594

May 10, 2021

Video Study

**NTSB Case Number:
ERA21FA130**

A. ACCIDENT

Location: St. Thomas, U.S. Virgin Islands
Date: February 15, 2021
Time: 1514 Atlantic Standard Time
Aircraft: Bell 206B-III helicopter

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

On February 15, 2021, about 1514 Atlantic Standard Time, a Bell 206B-III, N13AT, was destroyed when it was involved in an accident near St. Thomas, U.S. Virgin Islands. The pilot and three passengers were fatally injured. The helicopter was operated as a Title 14 Code of Federal Regulations Part 91 sightseeing flight.

D. DETAILS OF INVESTIGATION

The goal of this investigation was estimating the ground track, ground speed, altitude, orientation angles and main rotor speed of the helicopter based on a video recorded by a viewer on the ground. The iPhone 11 Pro video was about 24 seconds long, it had 3840x2160 resolution and frame rate of 60 fps. The helicopter was visible in the video during the first 14 seconds. After 14 seconds, it was obscured by vegetation. Based on the helicopter altitude at time 14 seconds, its descent rate, and the elevation at the crash location, it is estimated that it impacted terrain before time 16 seconds. The location of the camera is shown in Figure 1 that displays an aerial view of the accident area. The figure also shows the estimated ground track of the helicopter and the crash location.

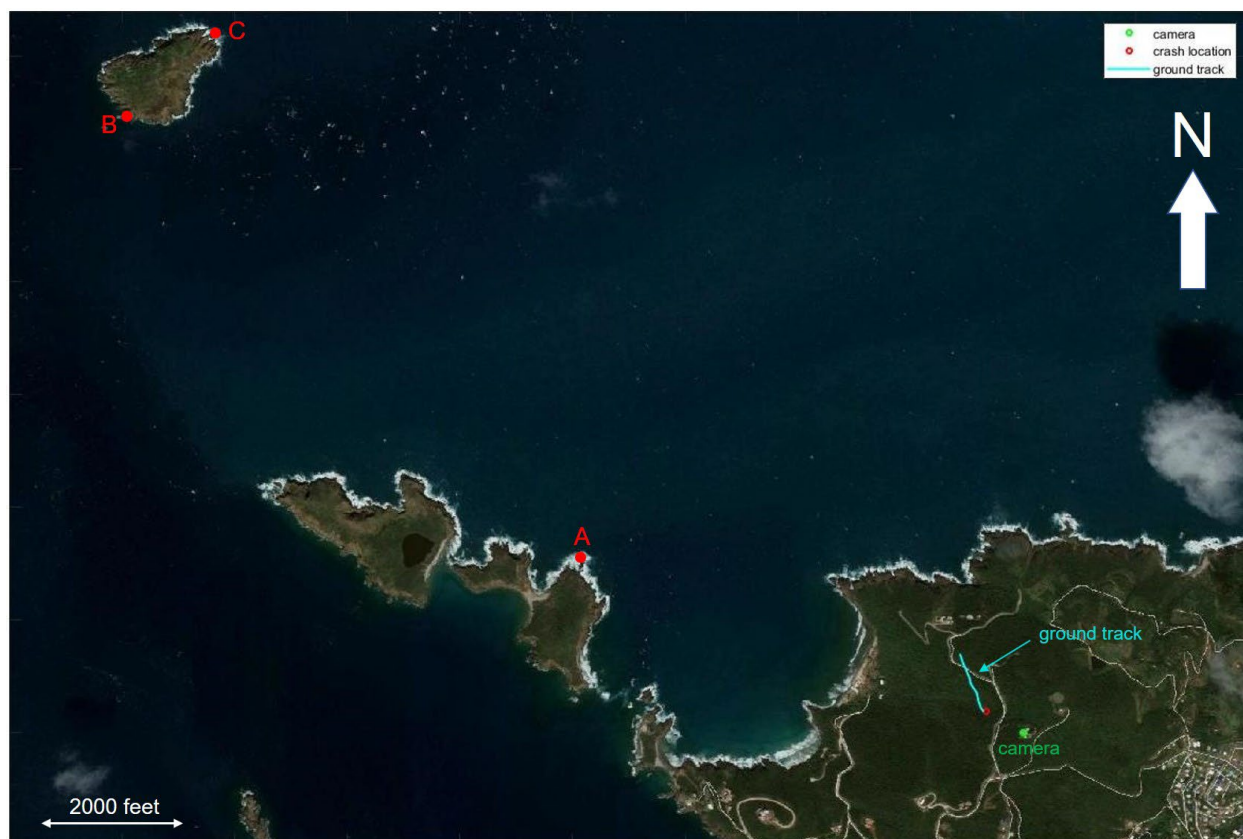


Figure 1. Aerial Image of the Accident Area

Camera Calibration

The estimation of the ground track, ground speed, altitude, and orientation angles of the helicopter based on the video required a calibrated model of the optics of the camera that recorded the video. Such a model must be calibrated against references on the ground.

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 angle (HFOV). The three location coordinates of the camera were known. The four angles had to be estimated as described next.

The estimation was based on references that were visible both in aerial images such as Figure 1 and in video frames such as the one in Figure 2. The only references available for camera calibration were islands located northwest of the camera. Three reference points, A, B and C, are marked in Figure 1. Reference points A and B are also visible and marked in the video frame in Figure 2.



Figure 2. Segment from a Frame at Video Time 13.3 seconds

There were also two islands located about four miles northwest of the camera, beyond the area shown in Figure 1. Two reference points were located on each of these two islands. Therefore, the total number of reference points was seven. None of the video frames showed all seven. During the 14 seconds when the helicopter was visible in the video, the number of visible reference points varied between one and six.

A computer program that simulates camera optics was used to project the references onto frames from the video in an iterative process in which the four unknown camera angles, yaw, pitch, roll and HFOV, 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 four angles were the optimal estimates of these parameters. At that point, the model of the camera optics was calibrated.

The camera yaw, pitch and roll angles were different for each of the fifteen analyzed video frames because orientation of the hand-held camera was changing as it was following the helicopter. Therefore, the camera had to be calibrated fifteen times. The camera user changed the zoom three times during the 14 analyzed seconds. Consequently, the HFOV angle had to be estimated three times.

Estimation of Helicopter Locations, Orientation Angles and Speed

The calibrated camera optics model was then used to estimate the locations of the helicopter at times corresponding to the fifteen analyzed video frames. A wireframe model of the Bell 206B-III helicopter was constructed, consisting of points on its nose, tail, fuselage, horizontal stabilizers, rudder, landing skids, and main rotor. An analysis program that used the calibrated camera model was then used to project the wireframe model onto a video frame. The wireframe model was moved and rotated until it matched optimally the image of the helicopter in the video frame. When optimal match was reached, the location (X, Y and Z) and the orientation angles (yaw, pitch and roll) of the wireframe model were the optimal estimates of the location and the orientation angles of the accident helicopter at the time when the analyzed video frame was recorded.

The estimated ground track of the helicopter is shown in Figure 1. Figure 3 shows a more detailed view of the ground track. It also shows the camera location and the crash location. The camera was placed at location (0,0). The ground track starts at video time 1.8 seconds and ends at time 14 seconds. After 14 seconds, the helicopter was no longer visible.

At video time 6.2 seconds, a puff of smoke is seen originating from the helicopter. The smoke then moved down relative to the helicopter and dissipated during the next three seconds. Video time 6.2 seconds is when the smoke became visible in the video. Therefore, it is estimated that the smoke-generating event occurred shortly before that. It was a short smoke-generating event rather than one that causes continuous generation of smoke.

Figure 4 shows the estimated ground speed of the helicopter. Before the smoke-generating event, the estimated speed was about 39 knots. The speed then decreased to about 30 knots over about 2.5 seconds. Past that time, as the helicopter was descending, the speed was increasing and was about 68 knots when the helicopter became obscured by vegetation. The speed was computed based on 15 estimated locations between video time 1.8 seconds and video time 14 seconds. With the short average time between adjacent locations of only about 0.8 seconds, the raw speed estimate was noisy. Therefore, the estimate shown in Figure 4 is after the estimate based on raw data was low-pass filtered, eliminating the effect of noise.

Figure 5 shows the estimated yaw angle of the helicopter. Yaw angle is zero when the helicopter nose points north and it increases as the helicopter rotates to the right. At about time 4.6 seconds, the helicopter started yawing to the left. It is estimated that it was shortly after the smoke-generating event started. At time 8.3 seconds, the helicopter started yawing to the right.

Figure 6 shows the estimated MSL altitude of the helicopter. It shows that the helicopter was descending during the entire analyzed time period and the descent rate was increasing. The descent rate was about 80 feet/second (4800 feet/minute) when the

helicopter became obscured by vegetation at time 14 seconds. The pitch angle of the helicopter was about zero degrees and the roll angle was about 7° at that time.

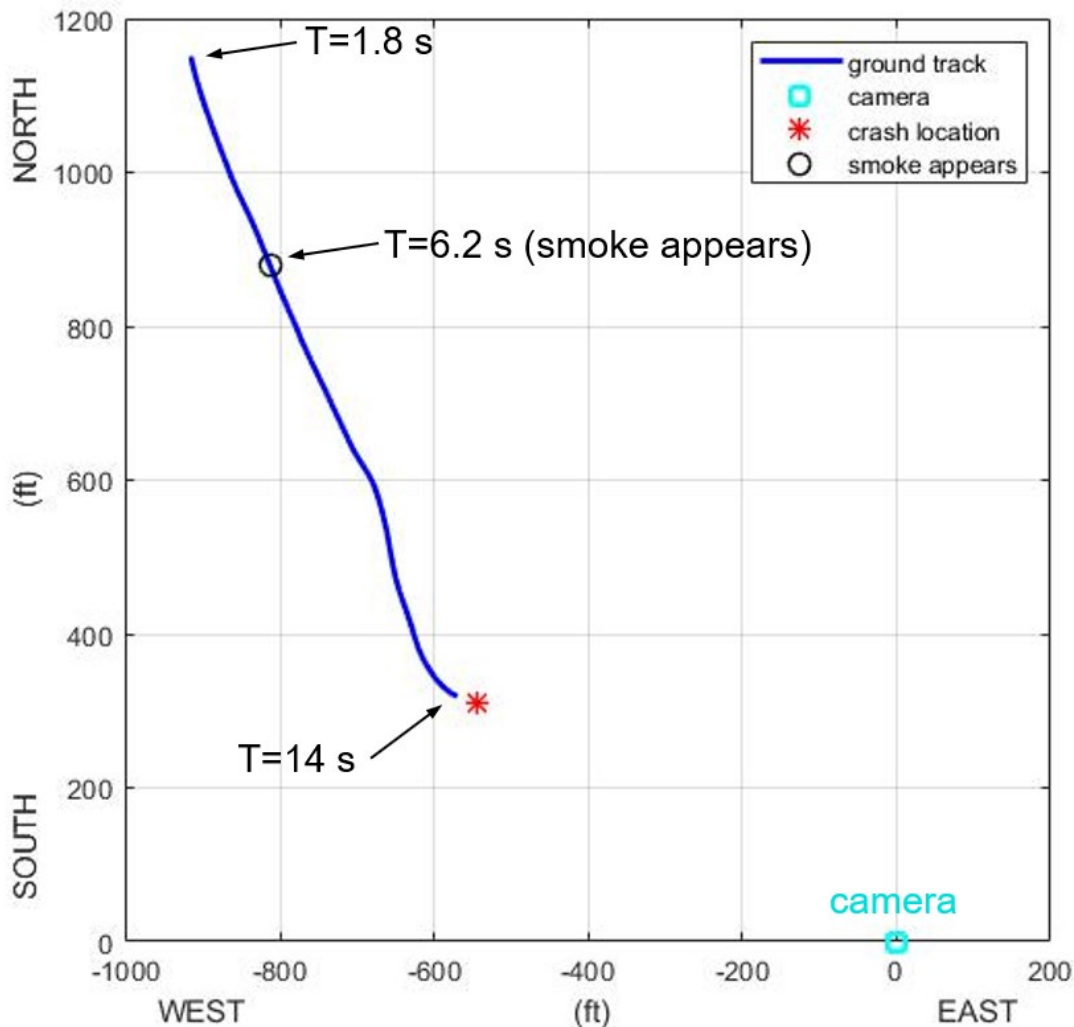


Figure 3. Estimated Ground Track of the Helicopter

Estimation of Helicopter Main Rotor Speed

The high video frame rate of 60 fps and the high 3840x2160 resolution made it possible to estimate the main rotor speed by counting the rotations of the 2-bladed rotor by stepping through the video one frame at a time. Figure 7 shows the estimated main rotor speed. During the first 4.5 seconds, the estimated main rotor speed was 390 rpm, almost exactly at the nominal main rotor speed of 395 rpm of the Bell 206B-III helicopter. Past that time, the main rotor speed was decreasing and was only 74 rpm (19%Nr) at time 14 seconds.

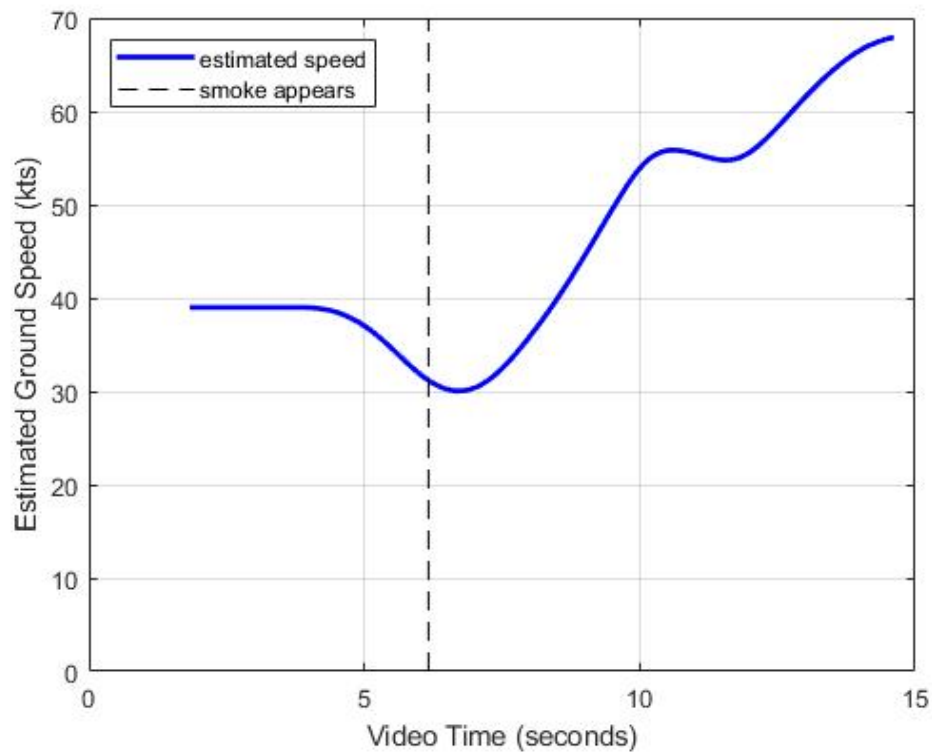


Figure 4. Estimated Ground Speed of the Helicopter

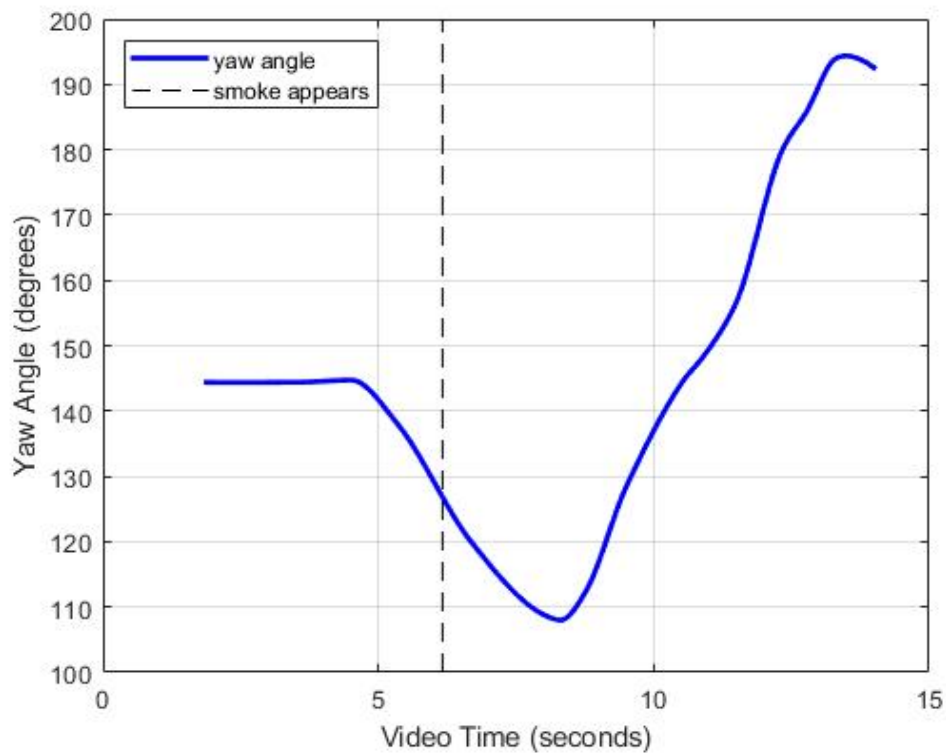


Figure 5. Estimated Yaw Angle of the Helicopter

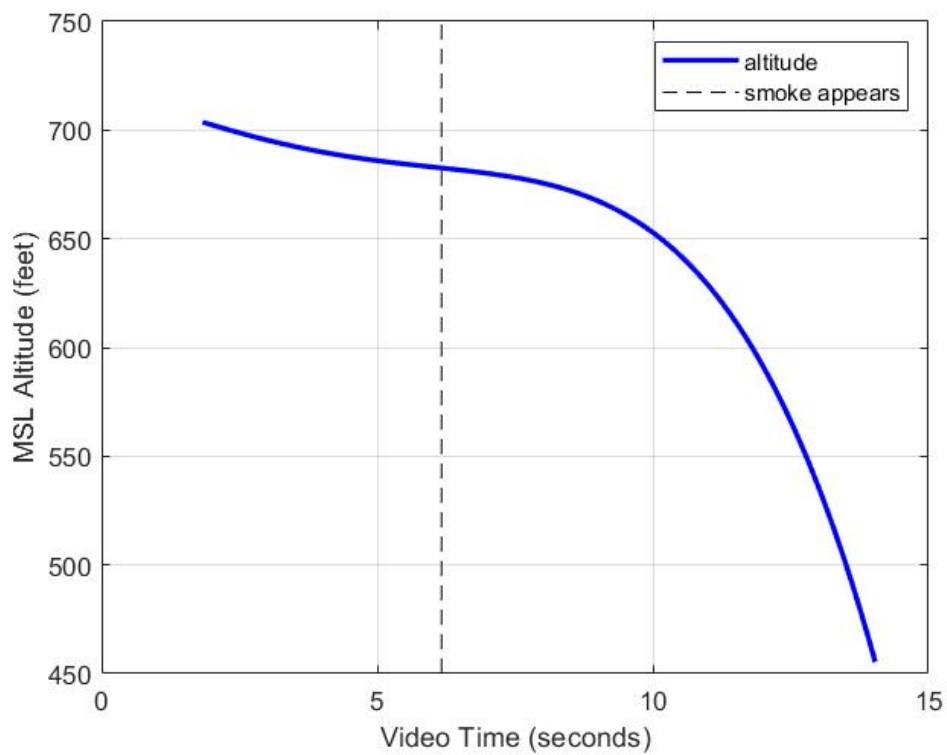


Figure 6. Estimated MSL Altitude of the Helicopter

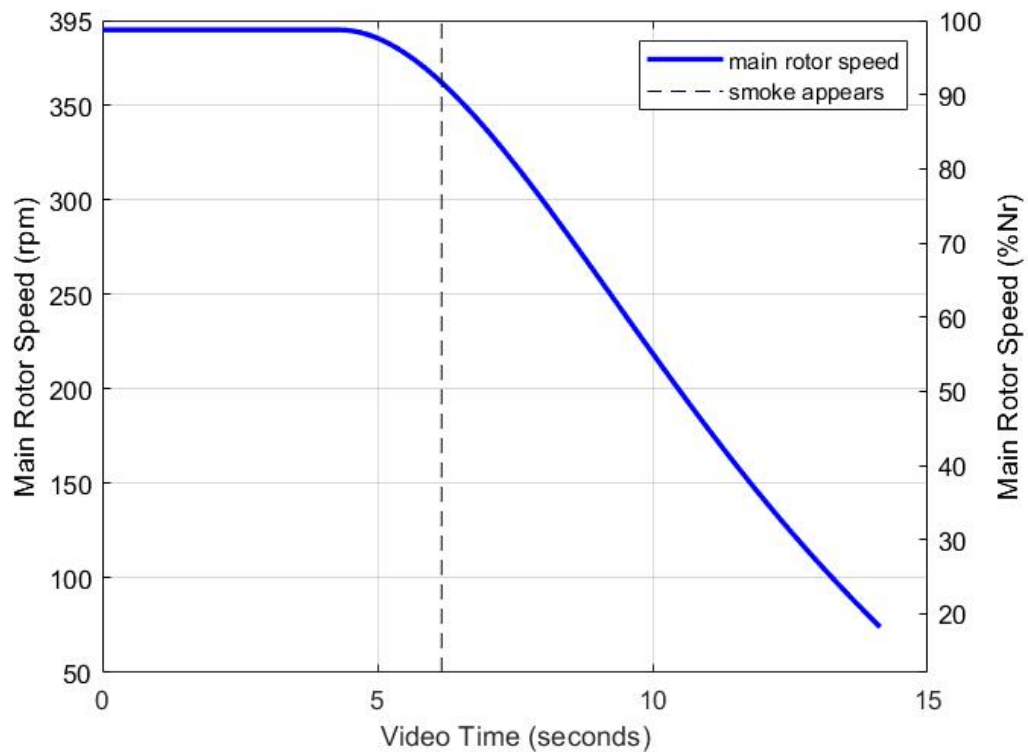


Figure 7. Estimated Main Rotor Speed

E. CONCLUSIONS

The ground track, ground speed, altitude, orientation angles and main rotor speed of a helicopter that crashed were estimated based on a video recorded by a viewer on the ground. The analysis showed that after a puff of smoke that originated from the helicopter was seen in the video, the main rotor speed and the altitude of the helicopter were decreasing for as long as the helicopter was visible in the video. The helicopter impacted terrain less than two seconds after it became obscured from view by vegetation.