National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594

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VIDEO STUDY

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A. ACCIDENT

Location: Dallas, Texas
Date: November 12, 2022
Time: 1322 central standard time
Aircraft No. 1: Boeing B-17G, N7227C
Aircraft No. 2: Bell P-63F, N6763

B. SUMMARY

B.1. The accident

On November 12, 2022, about 1322 central standard time, a Boeing B-17G airplane, N7227C, and a Bell P-63F airplane, N6763, collided in midair at the Dallas Executive Airport (RBD), Dallas, Texas. A post impact fire ensued. The pilot, co-pilot, and three crewmembers onboard the B-17G and the pilot of the P-63F were all fatally injured. There were no ground injuries reported. Both airplanes were operated under the provisions of Title 14 *Code of Federal Regulations* Part 91 in the Wings Over Dallas Airshow.

B.2. Objective and Scope of the *Video Study*

The objective of this Video Study was estimating the orientation angles and the altitudes above ground level (AGL) of the two aircraft. Analysis was based on a video recorded with a hand-held camera.

C. DETAILS OF THE INVESTIGATION

The analysis was based on a video that was recorded with a hand-held camera. The video had 1280x720 resolution and frame rate of 30 frames per second (fps). The video lasted 47.6 seconds. The two aircraft collided at video time 4.5 seconds.

ADS-B recorded accurate ground track data of both aircraft up to about 0.6 seconds before collision time. The recorded altitude data was less accurate. ADS-B data did not include the heading, pitch and roll orientation angles of the aircraft. The video analysis described below estimated data that were necessary for evaluating the visibility of the B-17 from the cockpit of the P-63, specifically the roll angle of the P-63F and the AGL altitudes of both aircraft. The video analysis provided data up to the time of collision, about 0.6 seconds past the time when ADS-B data ended.

C.1. Camera calibration

The analysis of the video was based on a mathematical model of the optics of the camera that recorded the video. 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 X and Y coordinates of the camera were approximately known because the camera recorded its GPS coordinates. The Z coordinate (elevation) of the camera was also recorded, but the required accuracy of Z if it is to be used for camera calibration using calibration references on the ground in front of the camera is several inches. Since the accuracy of GPS is several feet at best, Z was considered unknown.

The yaw, pitch and roll camera orientation angles and the HFOV were unknown. Consequently, the camera Z, yaw, pitch, roll and HFOV parameters were unknown and had to be estimated. Additionally, the GPS coordinates provided good approximate values of camera X and Y but the accurate values were required and had to be estimated.

The estimation of camera model parameters is based on references that are visible both in aerial images such as the one in Figure 1 and in video frames such as the one in Figure 2. The references used for camera model calibration were markings on the ground at the airport, outlines of grassy areas, US-67 seen in Figure 1 and the buildings located across US-67.

A computer program that simulates camera optics was used to project the calibration references onto a frame from the video in an iterative process in which the seven unknown camera model 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 camera model parameters were their optimal estimates. At that point, the model of the camera optics was calibrated.

The analysis described below estimated the locations and orientations of the airplanes at eight locations, corresponding to eight video frames. Since the camera was hand-held and the camera holder was tracking the airplanes, the camera yaw, pitch and roll angles were not constant. Consequently, camera calibration based on the first video frame estimated camera X, Y, Z and HFOV that were constant, but only the camera yaw, pitch and roll angles for the first video frame. Therefore, the estimation of the camera yaw, pitch and roll angles had to be repeated seven more times.

C.2. Estimation of aircraft ground tracks, altitudes and orientation angles

The calibrated camera optics model was then used to estimate the locations of the airplanes at times corresponding to eight video frames that were analyzed. Wireframe models of the B-17 and the P-63 were constructed, consisting of points on their fuselages, wings and rudders. An analysis program that used the calibrated camera model was then used to project one wireframe model at a time onto a video frame. The wireframe model was moved and rotated until it matched optimally the image of the aircraft in the video frame. When optimal match was reached, the location coordinates (X, Y and Z) of the wireframe model and its orientation angles (heading, pitch and roll) were the optimal estimates of the location and orientation of the aircraft at the time when the analyzed video frame was recorded.

The collision occurred at video time 4.5 seconds. The visibility of the P-63 in the video up to video time 1.4 seconds was poor. Therefore, video analysis was performed from video time 1.4 seconds to video time 4.5 seconds, for a total of 3.1 seconds. Analysis time was set to zero at video time 1.4 seconds. The first analyzed video frame was at time zero and the eighth analyzed video frame, the last one, was at time 3.1 seconds. The times when the analyzed video frames were recorded were known because the video frame rate was constant at 30 frames/second.

The accurate ADS-B ground track locations were used to verify that the video-based estimates were accurate. Figure 3 shows the ADS-B ground track and the video-based ground track locations of the two aircraft. The video-based location of an aircraft was defined as the location of its nose. The figure also shows the camera that was placed at location (0,0). Figure 4 is a zoomed segment of Figure 3 that shows the eight video-based ground track locations and the last three ADS-B ground track points of both aircraft. The numbers to the left of the eight P-63 video-based locations are the analysis times when the aircraft was at that location. The times when the B-17 was at its eight marked locations are the same as those of the P-63. The differences between the video-based locations and the ADS-B ground track locations are 80 feet or less.

Since the distance from the camera to the aircraft was 2800 feet or more, the agreement between the ADS-B ground tracks and the video-based ground tracks is considered very good. The accurate agreement of the ground tracks is considered evidence that the video-based estimates of the aircraft AGL altitudes and roll angles, that ADS-B did not provide, will be accurate.

Both aircraft were flying approximately toward the camera, as can be seen in Figure 3. This made estimation of their heading and pitch orientation angles based on the video relatively less accurate. However, the main objective of the analysis was estimating the roll angle of the P-63 and that angle could be estimated accurately.

Figure 5 shows the estimated AGL altitude of the P-63 aircraft. The AGL altitude in the figure is relative to the elevation of the threshold of runway 31. The accuracy of the estimate is ±10 feet. The plotted altitude is that of the nose of the aircraft.

Figure 6 shows the estimated AGL altitude of the B-17 aircraft. The AGL altitude in the figure is relative to the elevation of the threshold of runway 31. The accuracy of the estimate is ±10 feet. The plotted altitude is that of the nose of the aircraft.

Figure 7 shows the estimated roll angle of the P-63 aircraft. The accuracy of the estimate is ±5°. Figure 8 shows the estimated roll angle of the B-17 aircraft. The accuracy of the estimate is ±3°.

The pitch angles of the two aircraft could not be estimated accurately because both were flying approximately toward the camera. Low-accuracy estimates are that fuselage pitch angles of both aircraft were in the 0° to 5° nose-down direction.

Heading angles of both airplanes could not be estimated accurately bases on the orientation of the aircraft images in the video. However, if it is assumed that the longitudinal axes of the aircraft were parallel to the ground tracks, the data in Figure 3 can be used to estimate the heading angles. Using the video-based locations of the P-63, its heading angle was about 357° at time zero seconds and 339° at time 3.1 seconds, where heading is defined as zero when aircraft nose is pointing north and heading increases clockwise in top view. Similarly, the heading of the B-17 can be estimated as 329° at time zero seconds and 339° at time 3.1 seconds.

D. CONCLUSIONS

A video that recorded a B-17 and a P-63 that collided was analyzed. The analysis estimated the orientation angles and the AGL altitudes of the two aircraft up to the time of collision.

FIGURES

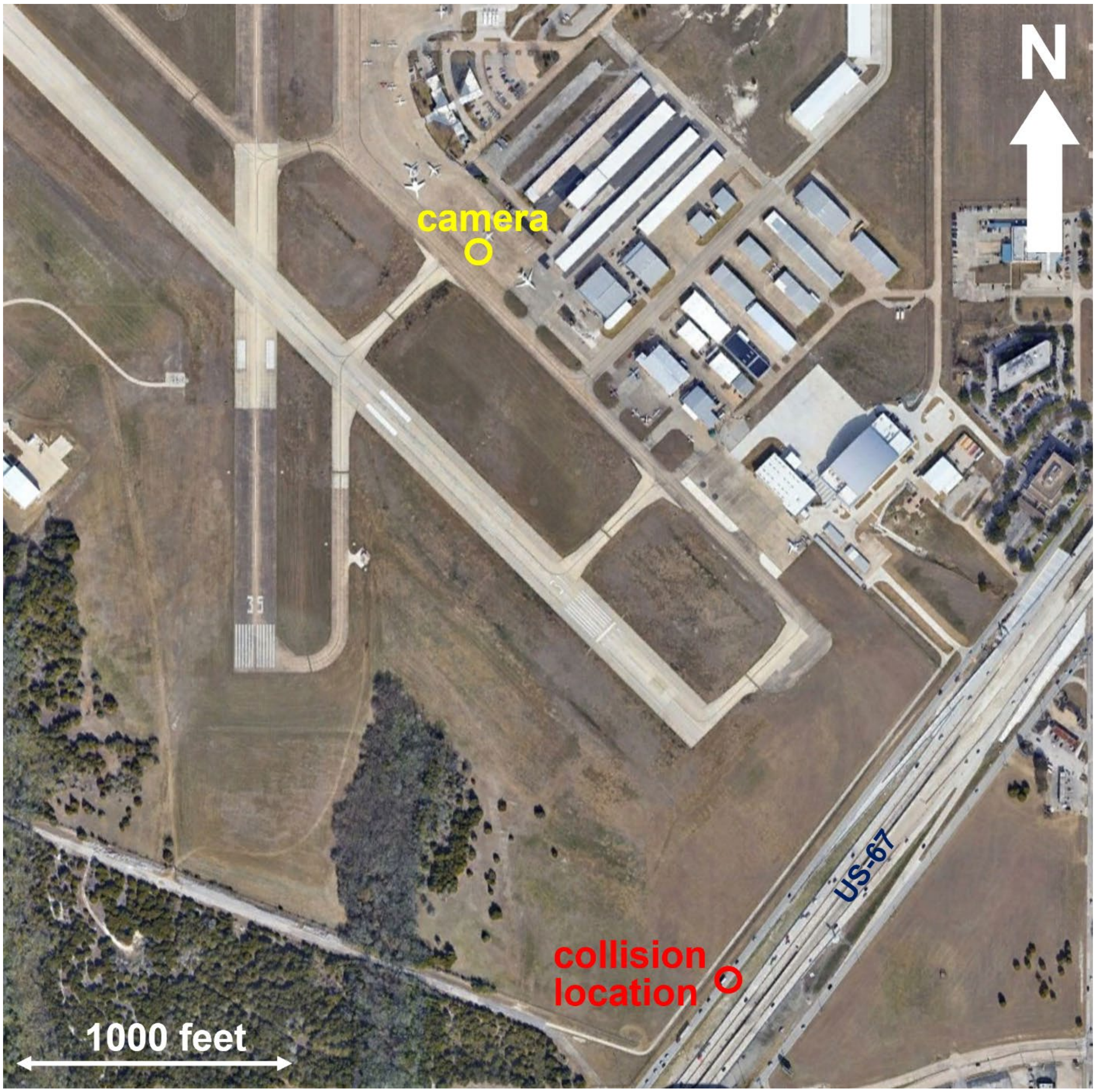

Figure 1. Aerial view of the accident area

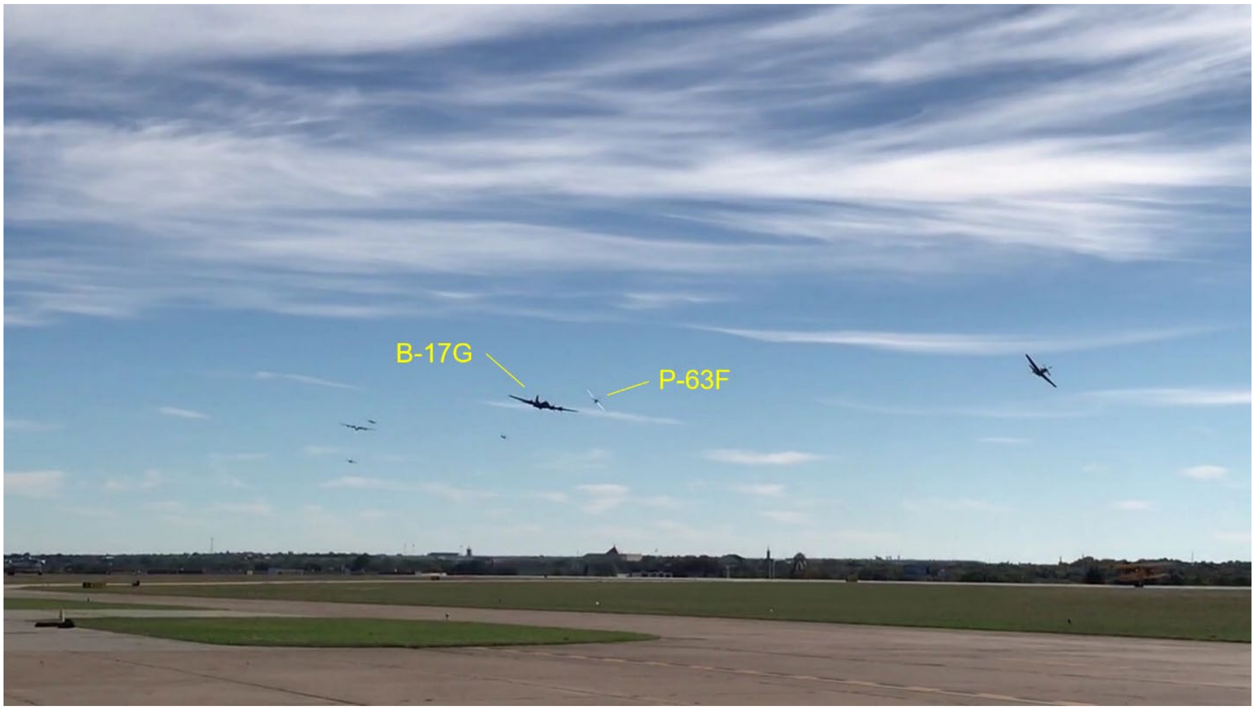

Figure 2. Video frame recorded at video time 3.87 seconds (analysis time 2.47 s)

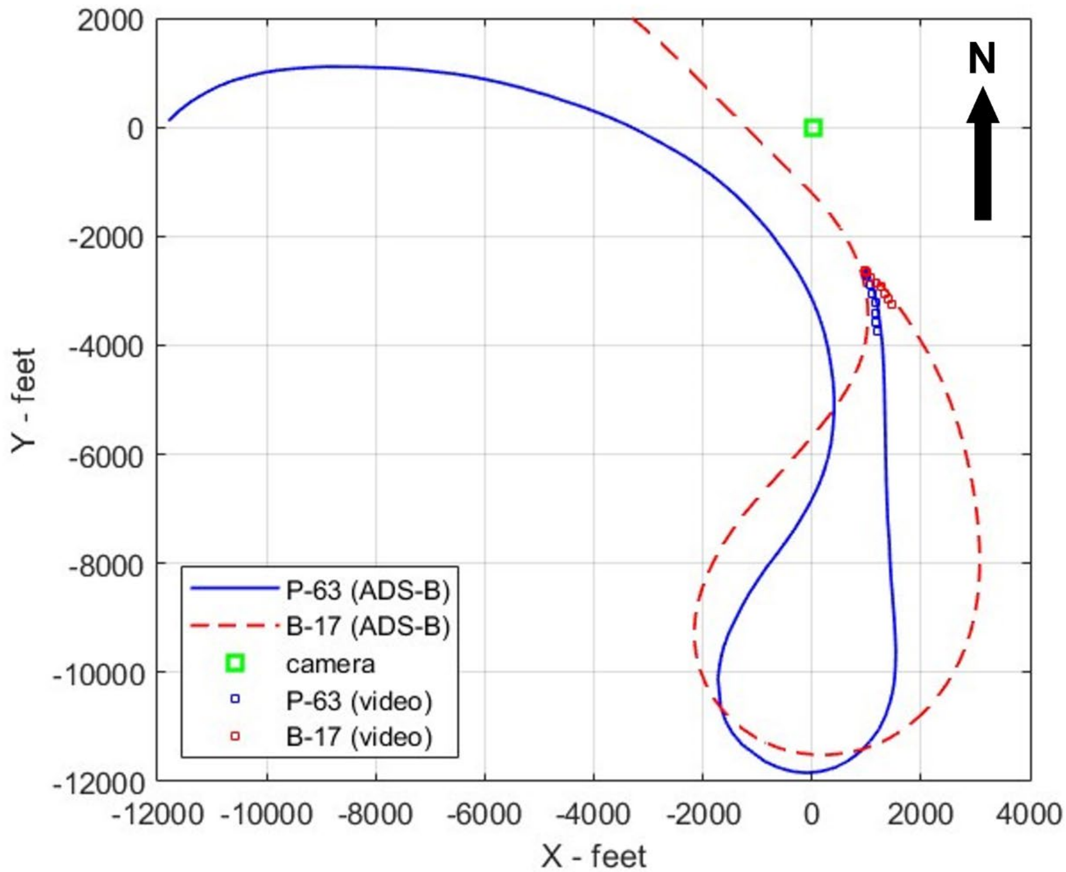

Figure 3. ADS-B ground tracks and video-based ground tracks

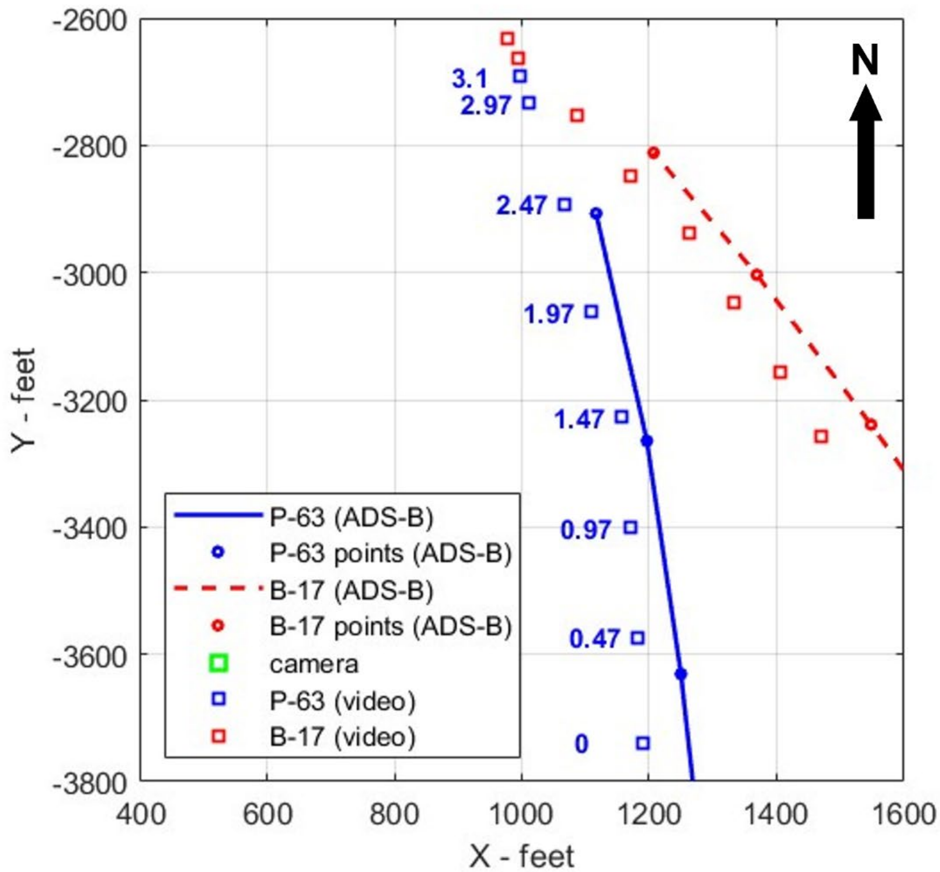

Figure 4. Zoomed view of ADS-B and video-based ground tracks

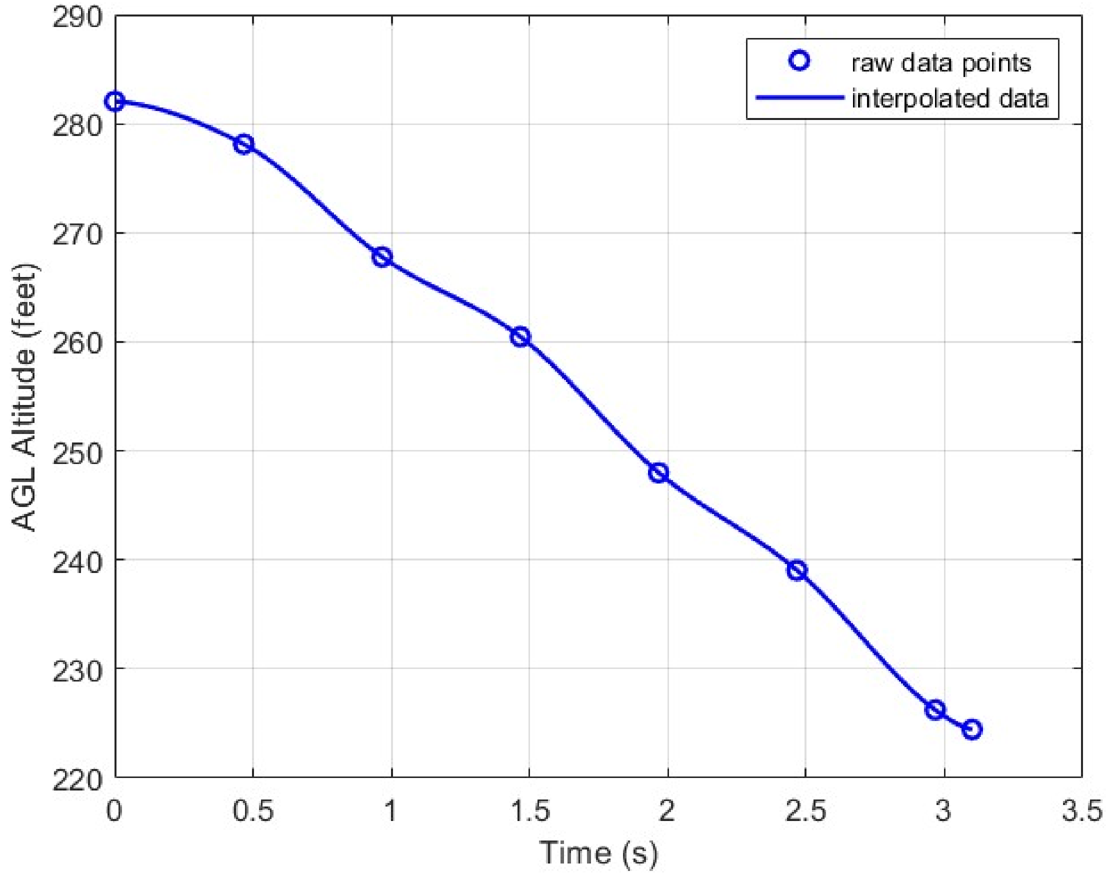

Figure 5. Estimated AGL altitude of the P-63

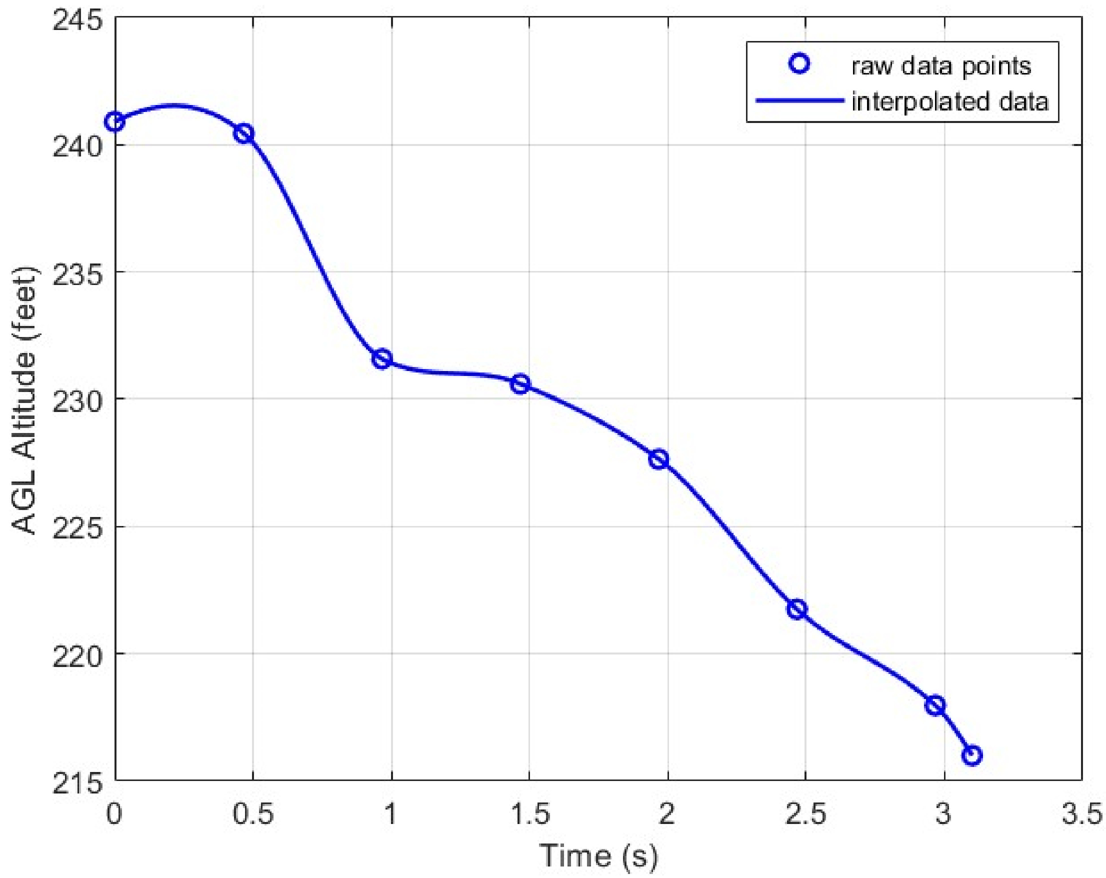

Figure 6. Estimated AGL altitude of the B-17

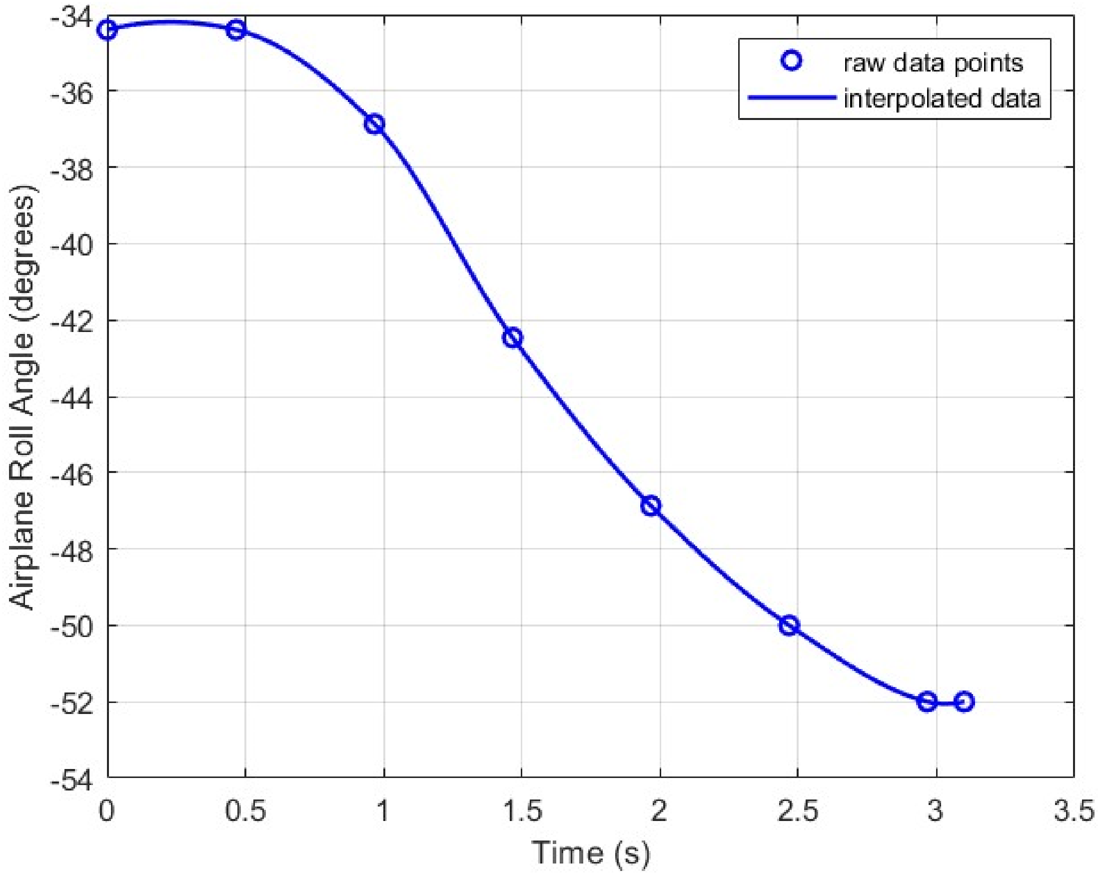

Figure 7. Estimated roll angle of the P-63

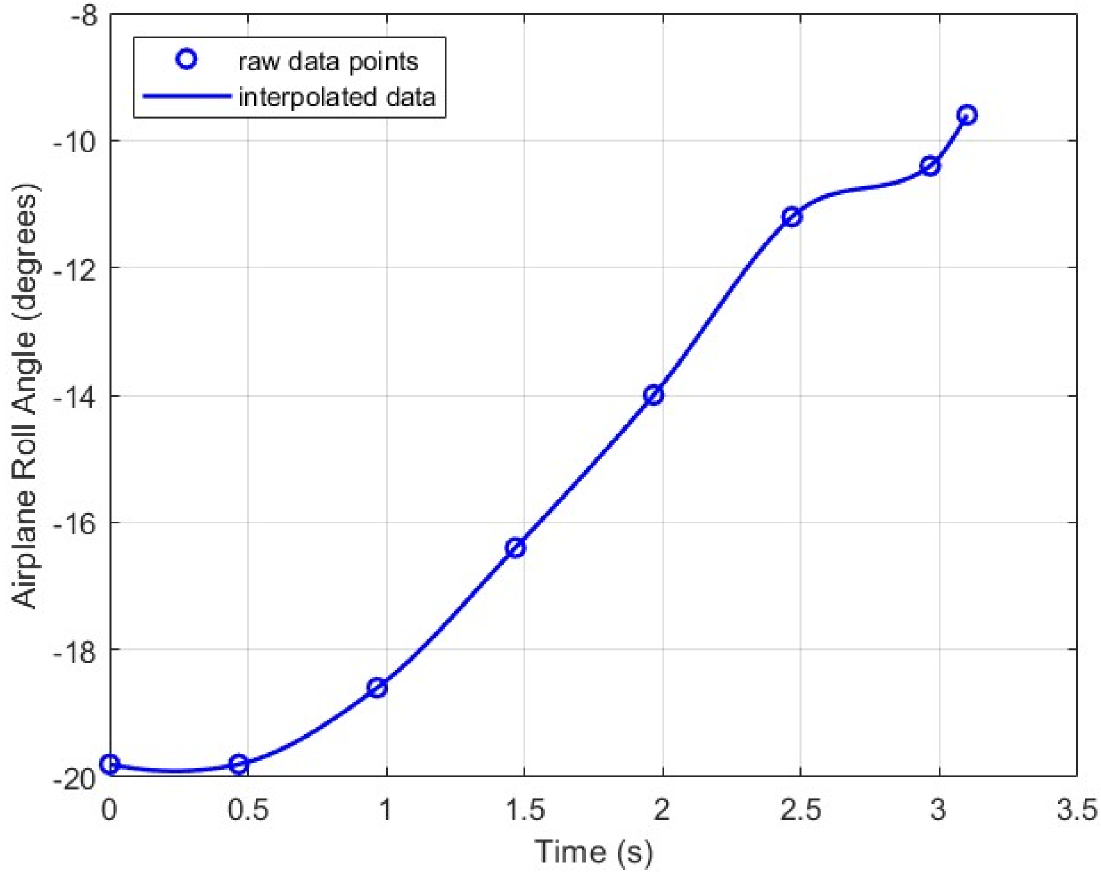

Figure 8. Estimated roll angle of the B-17