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

July 29, 2020

Video Study

NTSB Case Number:
CEN19MA190

A. ACCIDENT

Location:	Addison Airport (KADS), Addison, Texas
Date:	June 30, 2019
Time:	0911 central daylight time (CDT)
Aircraft:	Textron Aviation B300

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

On June 30, 2019, about 0911 central daylight time, a Textron Aviation B300, N534FF, was destroyed when it was involved in an accident near Addison, Texas. The airline transport pilot, the commercial co-pilot, and eight passengers sustained fatal injuries. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 personal flight.

D. DETAILS OF INVESTIGATION

The goal of this investigation was estimating the ground track, altitude, speed, roll angle, pitch angle, angle of attack and sideslip angle of the airplane during its short flight that ended in ground impact. Analysis was based primarily on a video recorded by a camera installed south of the Engineered Material Arresting System (EMAS) section at the southern end of the runway, on the west side of the runway (EMAS camera). The EMAS camera video had 2592x1944 resolution and frame rate of 13.33 fps. A video recorded by a camera installed on the Atlantic Aviation building at the airport provided supporting information. Figure 1 displays an aerial image of the airport with labeled locations that were relevant to the analysis of the EMAS video.

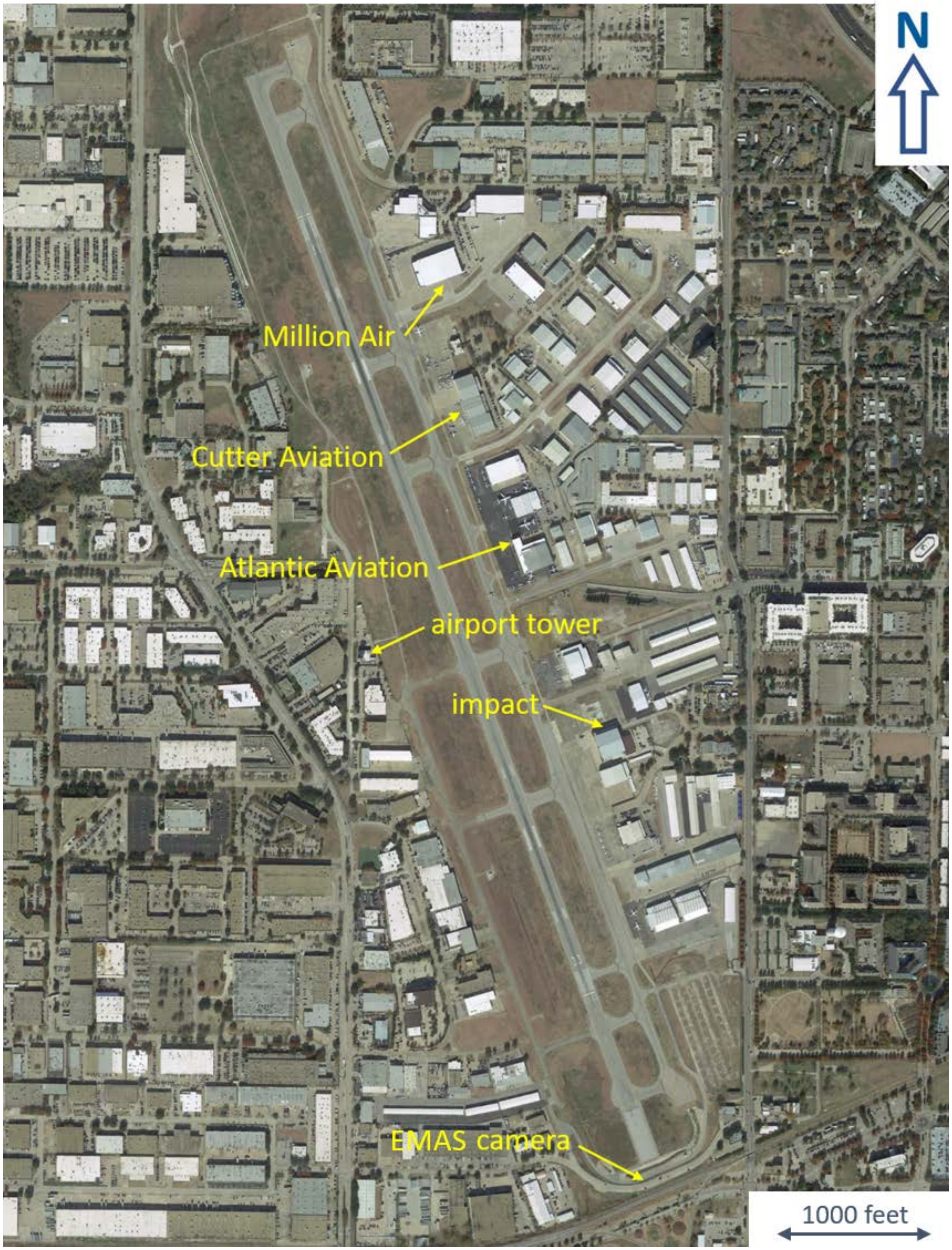

Figure 1. Aerial Image of the Airport

Figure 2 displays a frame from the EMAS video that shows the airborne airplane about six seconds before it crashed into the northern wall of the hangar marked in the figure.

Figure 2. Frame from the Analyzed EMAS Video

<u>Camera Calibration</u>

The analysis of this accident required a calibrated mathematical model of the 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 X and Y coordinates of the camera could be estimated from Google Earth aerial images. The other five parameters had to be estimated as explained next.

The estimation was based on references that were visible both in aerial images and in video frames. The references used for calibration included the runway, the EMAS section, the airport tower and airport buildings located east and west of the runway. These references are visible in the aerial image in Figure 1 and in the video frame in Figure 2.

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

Airplane Trajectory and Speed Estimation

The airplane was about 4000 feet from the EMAS camera when it became visible in the video. Since the airplane was flying into the camera and its image was small in the video frames, it was not possible to accurately estimate its location along the runway at that time, and, consequently, it was not possible to accurately estimate its speed at that time. Therefore, videos from cameras installed on the Atlantic Aviation, Cutter Aviation and Million Air buildings were used to estimate the airplane speed at locations in these cameras' fields of view. Each one of these videos could only provide a speed estimate at one time and location when the airplane was still flying above the runway. The trajectory and speed estimates after the airplane started turning left had to be based on the EMAS camera video.

The video recorded by a camera on the Atlantic Aviation building provided the most accurate speed estimate. Figure 3 shows a frame from that video recorded when the airplane was above the runway at a location on the line of sight from the camera to the airport tower. The airplane location and speed estimates based the Atlantic Aviation video provided a reference point from which the analysis proceeded based on the EMAS camera video, as described next.

The calibrated EMAS camera optics model was used to estimate the locations of the airplane from the time it became visible in the EMAS video and up to the crash into the hangar. Twelve video frames spaced by 0.75 seconds were analyzed, the last one just before the crash into the hangar when the full image of the airplane was still visible.

A wireframe model of the Textron Aviation B300 was constructed consisting of points on its nose, tail, wings, fuselage and landing gear. An analysis program that used the 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 airplane 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 airplane.

Figure 4 shows the ground track of the airplane superimposed on an aerial image of the area. The twelve white markers on the red trajectory curve are at the ground locations where the airplane nose was when the twelve analyzed video frames were recorded. The red line interpolates in between the twelve markers. The figure shows that when analysis started, the airplane was already deviating to the left and was approximately above the left edge of the runway at the first analysis point.

Figure 3. Frame from the Atlantic Aviation Video

Figure 5 shows the estimated altitude of the airplane above the north end of the runway at the times when the twelve analyzed frames were recorded. Altitude in Figure 5 was set to zero when the airplane was still on the ground. Once airborne, altitude in the figure is the altitude of the nose of the airplane. The time when the first analyzed frame was recorded was set to zero in the figure. This time corresponds to 09:10:40.762 CDT based on the time stamp on the first analyzed frame.

Figure 6 shows the estimated ground speed of the airplane. The speed was estimated in segments between pairs of adjacent trajectory points. The eleven numbered markers in the figure are at the estimated speeds in segments ending at that trajectory point. The speed fluctuations indicated by the raw data points are due to the unavoidable high sensitivity of the estimated speed to the accuracy of the segment lengths. The segments are 150 feet long or shorter and a 5-foot segment length error causes a 3-knot speed estimation error. To provide a more reliable speed estimate, a polynomial curve was fitted to the raw data points and is shown in the figure.

Figure 4. Estimated Ground Track of the Airplane

Figure 7 shows the estimated roll angle of the airplane at the twelve analyzed times. The blue line interpolates in between the markers. Positive roll angle corresponds to right wing down. The roll angle was negative during the entire flight as could be expected from the shape of the ground track in Figure 4.

Figure 8 shows the estimated pitch angle of the airplane at the twelve analyzed times. Positive pitch angle corresponds to nose up. The blue line interpolates in between the markers.

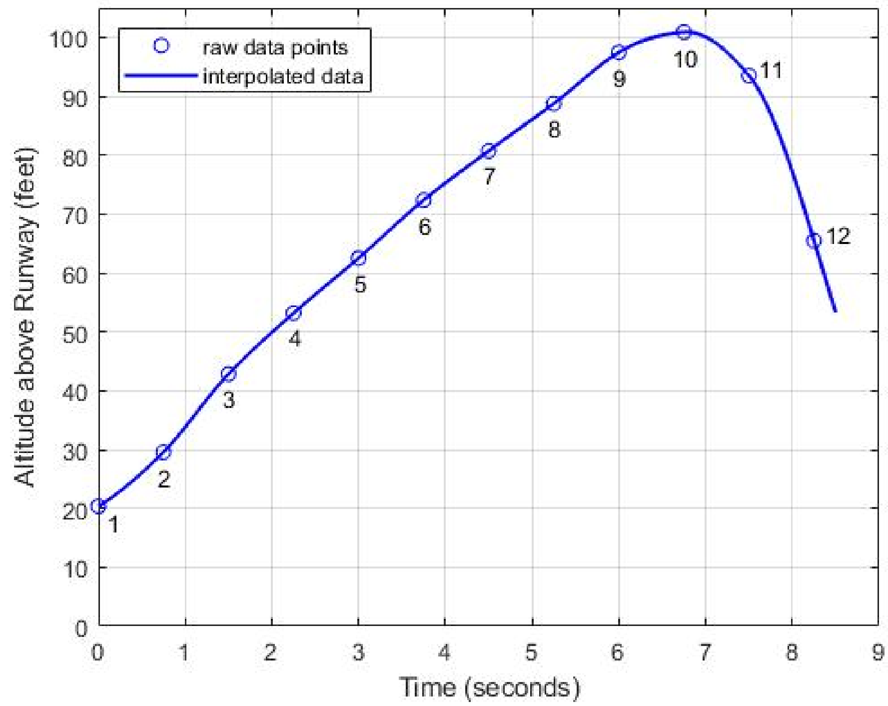

Figure 5. Estimated Altitude of the Airplane

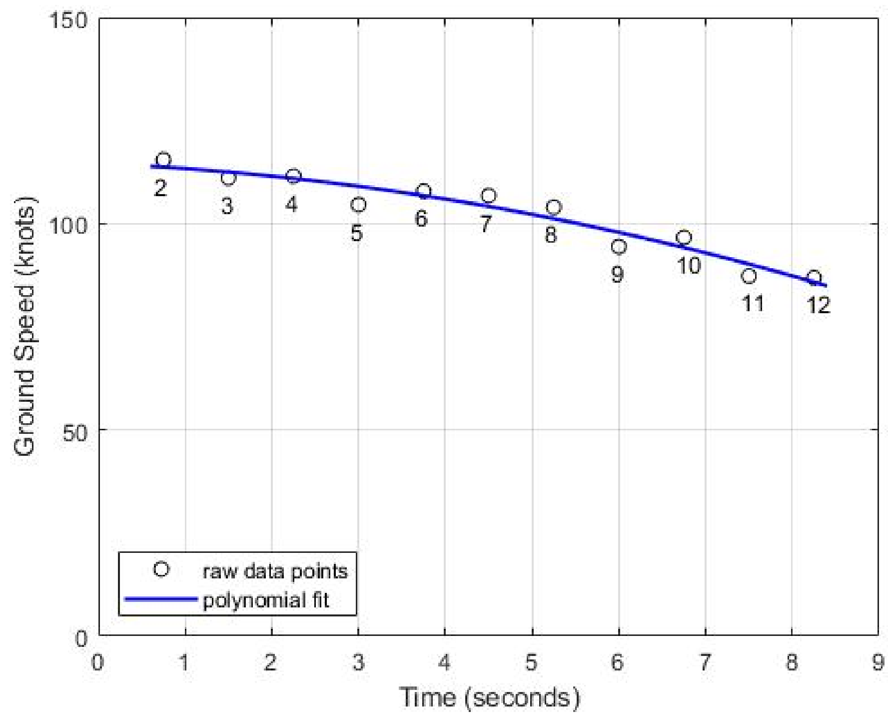

Figure 6. Estimated Ground Speed of the Airplane

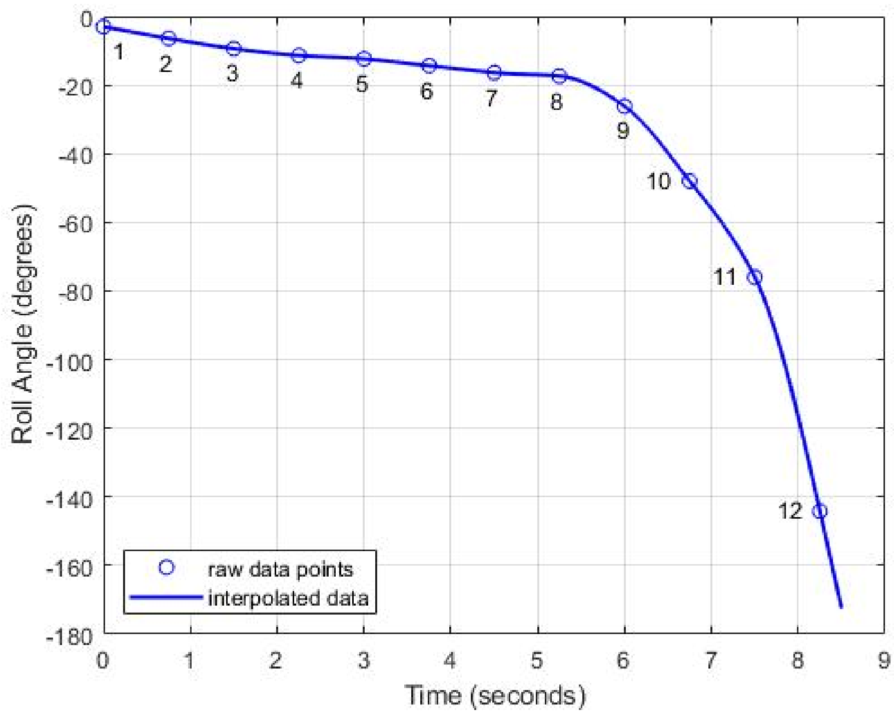

Figure 7. Estimated Roll Angle of the Airplane

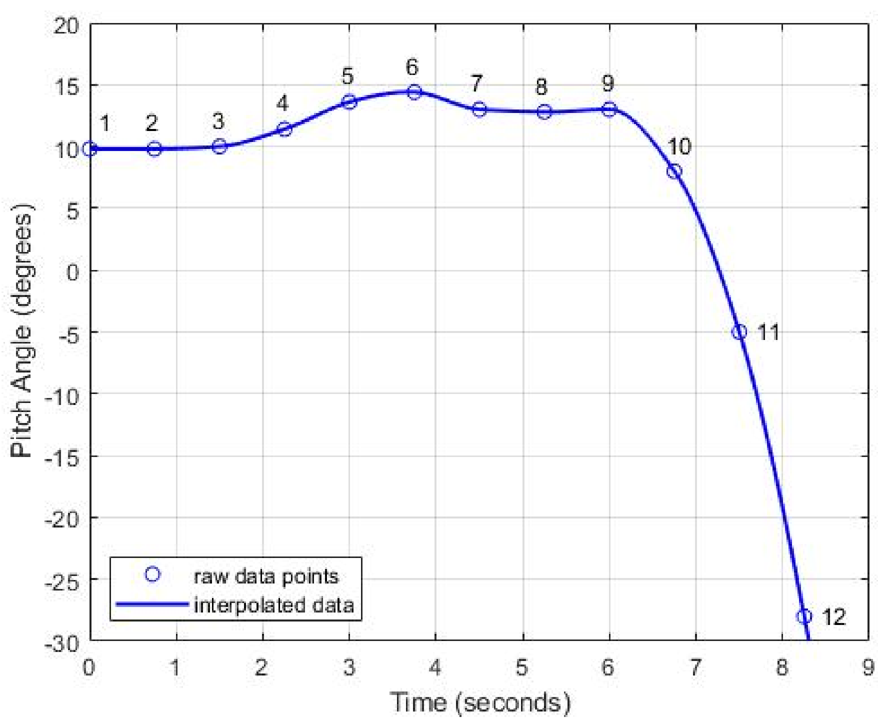

Figure 8. Estimated Pitch Angle of the Airplane

Estimation of the angle of attack and sideslip angle of the airplane involved transformation of coordinates between the body axes and the stability and wind axes. Figure 9 shows the relationships between these coordinate systems. The equations in [1], pages 9-11, were used for the transformations. In the figure, α is the angle of attack and β is the sideslip angle.

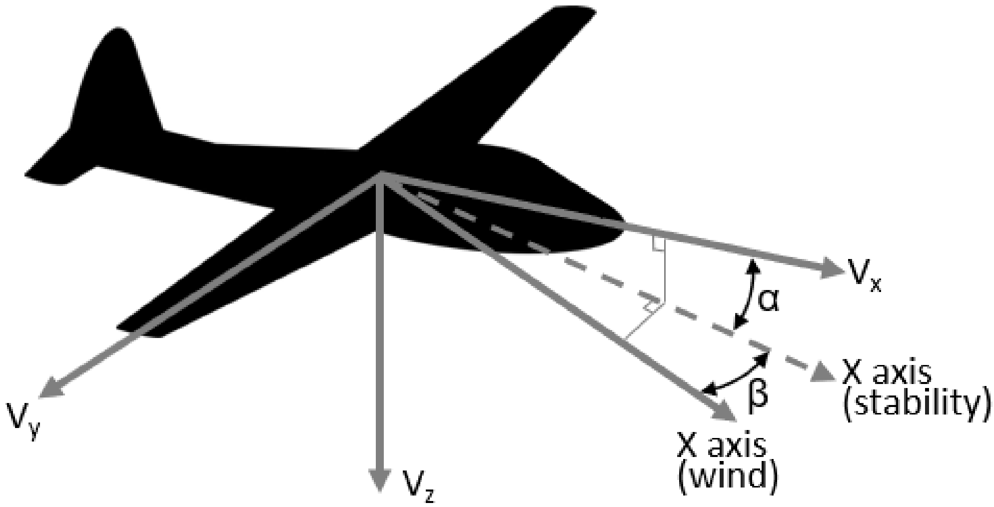

Figure 9. Illustration of the Stability and Wind Coordinate Systems

Figure 10 shows the estimated angle of attack and sideslip angle of the airplane. Up to point No. 9 at time 6 seconds, the lines interpolating between the raw data point markers are solid, indicating that the airplane was still mostly in normal controlled flight. Past time 6 seconds, the interpolating lines are shown dotted, indicating that the airplane was no longer in normal controlled flight. Figure 11 shows the airplane at time 7.5 seconds, when its left-wing-down roll angle was approaching 90º and it was losing altitude.

The polarity of the sideslip angle in Figure 10 is positive when the relative wind is coming from the right of the nose of the airplane. The relative wind was mostly due to the forward motion of the airplane and partially due to the wind conditions at the airport at the time of the accident. The wind at the airport at time 0847 CDT was reported as 6 knots from 100º. The sideslip angle was positive up to shortly before the impact into the hangar. It was positive because the airplane was yawed to the left (CCW in top view) more than the slope to the left of the ground track shown in Figure 4.

Note in Figure 10 that during the analyzed time, either the sideslip angle was above 15º or the angle of attack was above 12º. Both high sideslip angle and high angle of attack cause significant decrease in the lift-to-drag ratio (primarily due to increased drag) that could explain the ground speed decreasing from about 114 knots to about 85 knots during the analyzed time, as shown in Figure 6.

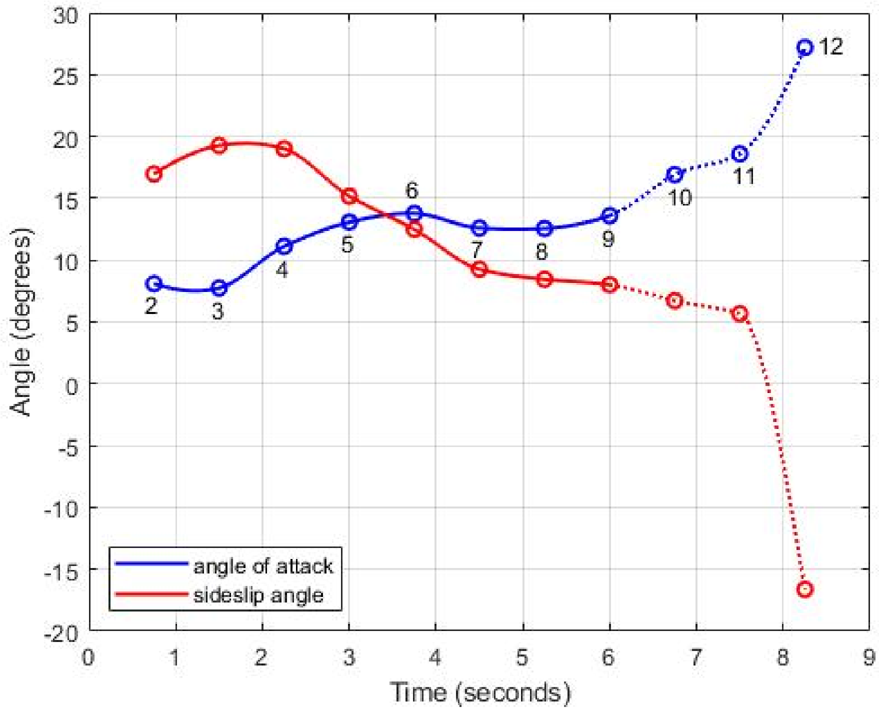

Figure 10. Estimated Angle of Attack and Sideslip Angle

Figure 11. Frame from the Analyzed EMAS Video at Time 7.5 seconds

E. CONCLUSIONS

The ground track, altitude, speed, roll angle, pitch angle, angle of attack and sideslip angle of an airplane that crashed shortly after takeoff were estimated based on videos. The airplane ground speed decreased from 114 knots when analysis started down to 85 knots shortly before the airplane crashed into a hangar. The maximum altitude reached during the short flight was about 100 feet above the runway. The angle of attack and the sideslip angles were high throughout the analyzed 8.25 seconds.

F. REFERENCE

1. Peters, M. and Konyak, M. A., "The Engineering Analysis and Design of the Aircraft Dynamics Model for the FAA Target Generation Facility", Air Traffic Engineering Co.,LLC, Palermo, NJ, 2012.