National Transportation Safety Board
Office of Research and Engineering
Washington, D.C. 20594

Performance Study

Specialist Report
Marie Moler

A. ACCIDENT

Location:	Addison, Texas
Date:	June 30, 2019
Time:	0911 central daylight time (CDT)
Aircraft:	Textron Aviation B300, N534FF
NTSB Number:	CEN19MA190

B. 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.

C. PERFORMANCE STUDY

A variety of data sources recorded the flight. The airplane did not have a flight data recorder, but was equipped with ADS-B (automatic dependent surveillance – broadcast), which recorded the time, the airplane's latitude and longitude, altitude, inertial speed, and other parameters. The ADS-B sampling was at irregular intervals, but position was sampled about once a second. ADS-B recorded pressure altitude, the barometric correction, and geometric altitude. The airplane also had a terrain awareness and warning system (TAWS) that recorded radio altitude, latitude, longitude, and airplane roll angle. The airplane's cockpit voice recorder (CVR) recorded the taxi and the accident flight, and a sound spectrum analysis was conducted to analyze propeller and runway sounds recorded [1, 2]. Additionally, portions of the accident flight were recorded by security cameras at different points around the airfield, and the recorded videos were used to calculate aircraft position, speed, and attitude [3].

Weather Observations

Weather conditions at 0847 CDT (24 minutes before the accident) at the airport were winds at 6 kts from 100°, temperature 79°F (26°C), dewpoint 70°F (21°C), and the altimeter setting was 30.06 inHg. Visibility was 10 miles with scattered clouds at 1,700 ft above ground level (AGL). Visual meteorological conditions prevailed.

Aircraft Flightpath

While many data sources were available, they were not all in agreement. The following discussion describes the creation of a composite data set of time, latitude, longitude, altitude, and speed of the airplane for the take-off roll and accident flight.

The airplane was taking off from runway 15 at Addison Airport at the time of the accident. Runway 15 is 7,203 ft long and 100 ft wide and it has a 979 ft long displaced threshold. Its elevation is 636 ft. Figure 1 shows the airplane taxiing from the west side of the airport, across taxiway E, and then north to the displaced threshold of runway 15. The total time from the start of the ADS-B data to runway 15 was less than four minutes.

Figure 1. Accident airplane's taxi path from ADS-B.

Figure 2 shows a both the ADS-B (orange) and TAWS (green) data of the take-off roll and accident flight. The ADS-B data was sparse during the take-off roll, only recording five data points between 09:10:27 and 09:10:44. The ADS-B path tracked the centerline of the runway until sometime between 09:10:39 and 09:10:44 when it began to track left. The TAWS data was recorded once a second, but the position data was noisy and showed the airplane path along the right edge of the runway, which was not consistent with the ADS-B data and other accident accounts. However, the TAWS path did track left in a similar manner to the ADS-B data, beginning just after 09:10:40. Additionally, the TAWS recorded roll angles (which will be discussed further in *Reduction in left engine propeller speed*), and it recorded a left roll beginning about the same time. Note the recorded altitudes between the two data sources also disagreed throughout the flight.

Figure 2. Accident flight with ADS-B data in orange and TAWS data in green.

In addition to ADS-B and TAWS data, the end of the flight was recorded by a camera on the engineered materials arrestor system (EMAS) at the departure end of runway 15 and security cameras on airport buildings. From the videos, the airplane's altitude, groundspeed, pitch, roll, angle of attack, and sideslip angle were estimated from 09:10:41 until impact with the hanger. Control surface deflections could not be determined from the videos.

Finally, the CVR and sound spectrum analysis were used to determine the approximate time and groundspeed when the propellers reached take off RPM, rotation, liftoff, when the propeller RPM for the two engines began to diverge and their approximate speeds, and the times of stall warnings. The CVR data determined that the engines were at take-off power at 09:10:16, that rotation occurred at 09:10:32.8 and liftoff at 09:10:34. The sound of the propeller RPMs diverged at 09:10:40.5.

Figure 3 shows TAWS and ADS-B data before the runway threshold. The engines were at take-off power at 09:10:16. There was no ADS-B data between 09:10:10 and 09:10:22, and so ADS-B could not be used to determine the location of the beginning of the ground roll. TAWS data was recorded during this time, but the latitude and longitude were irregular. Therefore, the TAWS data was shifted to align with the runway centerline to be consistent with the ADS-B data and the beginning of the ground roll was determined to be at 09:10:16, about 700 ft before the threshold of runway 15. The composite path, shown in purple, is a combination of the ADS-B and TAWS data.

Figure 3. TAWS (green) and ADS-B (orange) at beginning of take-off roll.

Figure 4 shows the composite path of the airplane with CVR annotation. The airplane followed a straight path along the runway until, at 09:10:40.5 on the CVR, the propeller sounds diverged, and the airplane's stall warning annunciated. At this point, the airplane began to track left. The greatest recorded difference in propeller sound was noted at 09:10:42.7 and the stall warning continued until 09:10:43. The stall warning began again at 09:10:45 and continued until the end of flight.

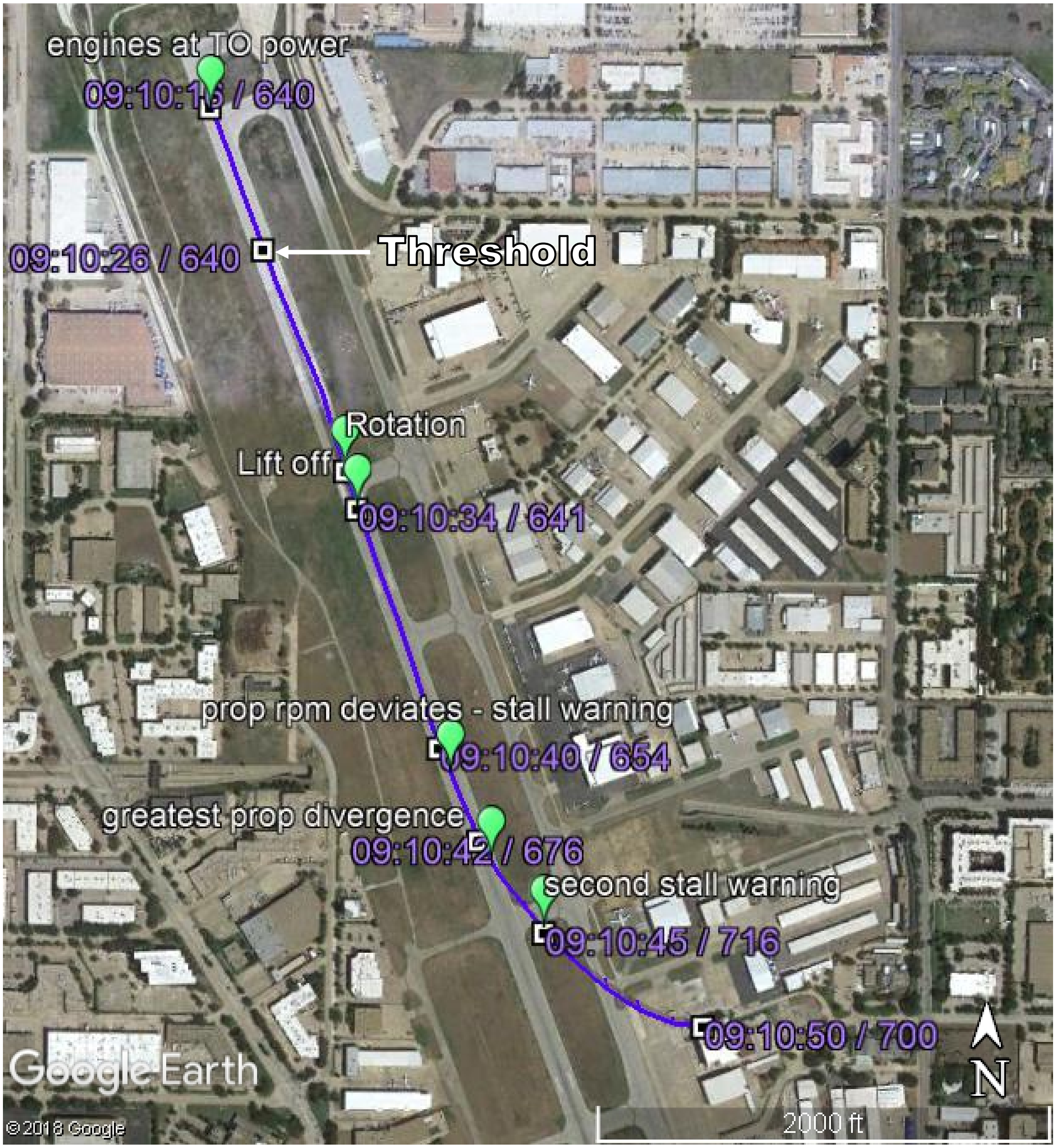

Figure 4. Composite flight path with CVR events.

The altitude for the composite path is shown in Figure 5 with the recorded altitude from ADS-B, TAWS, and the video analysis (height above ground plus a ground elevation of 640 ft). Also included is the calculated groundspeed from ADS-B, a smoothed TAWS track, the video analysis, and the CVR groundspeed estimate at rotation and lift-off. The composite flight path altitude and groundspeed derived from the recorded data are labeled as "combined" in the figure. Data from the CVR and video analysis were weighted heavily, but ADS-B and TAWS data were also incorporated.

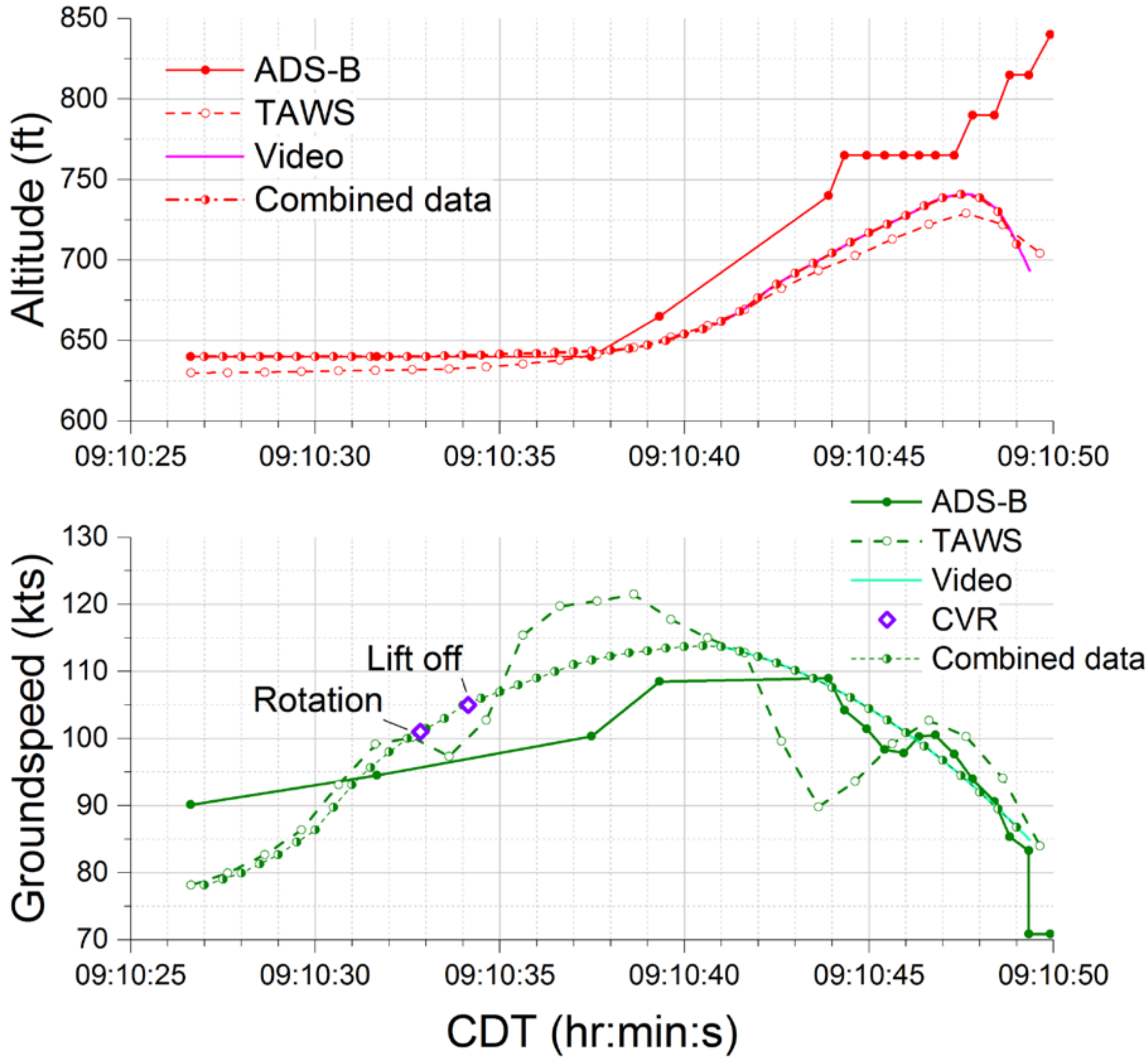

Figure 5. Accident flight altitude and groundspeed from multiple sources.

Figure 6 shows the height above ground and groundspeed of the accident flight with selected CVR events. Engines were stable at take-off power at 09:10:16, which was selected to be the start of the take-off roll and the beginning of distance traveled down the runway. Rotation occurred at 09:10:32.8 according to the CVR, when the groundspeed was estimated to be 101 kts (102 kts calibrated airspeed), 1,720 ft down the runway. The airplane lifted off at 09:10:34, at a groundspeed of 105 kts (106 kts calibrated airspeed) and 1,900 ft from the beginning of the take-off roll. At 09:10:40.5, at 109 kts (calibrated airspeed 110 kts) and 17 ft above the runway, the CVR recorded the sound of the left and right propeller speeds diverging and a stall warning alarmed in the cockpit. The initial stall warning ended at 09:10:43, then a second began at 09:10:45.

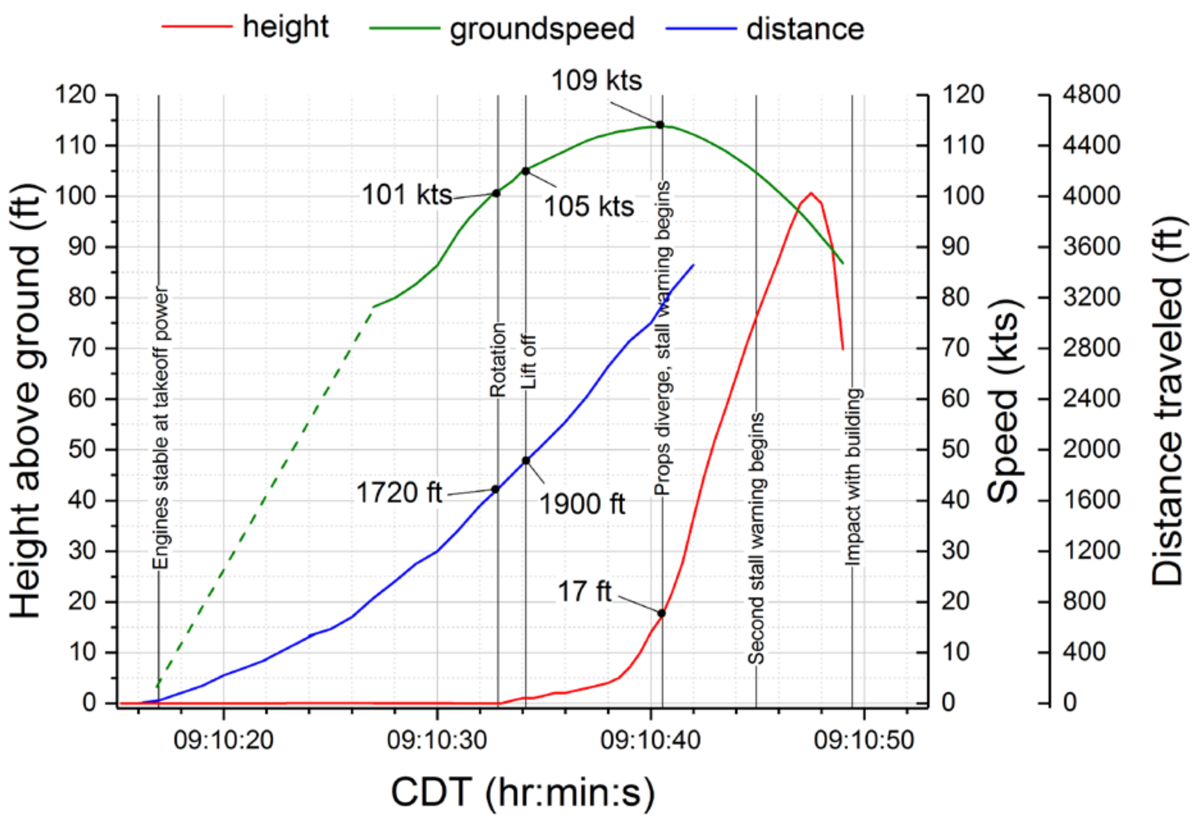

Figure 6. Height above ground, groundspeed, distance traveled, and selected CVR events.

By 09:10:43, the airplane passed over the left edge of runway 15. It continued to climb while turning to the left, reaching a maximum altitude of 100 ft above the ground just before 09:10:48, shortly before impacting the hangar.

Reduction in Left Engine Propeller Speed

Figure 7 shows the propeller speeds as determined from the CVR. Propeller speeds at the time of lift-off were estimated to be 1,714 RPM to 1,748 RPM. The CVR report found that the propeller sound was consistent between engines until 09:10:40.5 when the left engine's propeller speed (1,688 RPM) slowed in comparison to the right (1,707 RPM). By 09:10:42.7, the left engine propeller speed was 1,545 RPM. It rebounded to 1,632 RPM by 09:10:44.9 before further falling. By the end of the recording, the left engine was at 1,403 RPM, while the right was above 1,700 RPM. The propeller speed deviation corresponded with the airplane's left roll. The figure shows the roll from the video and the roll recorded by the TAWS. The airplane rolls from a wings level attitude to -10.6° in the two seconds after the beginning of the propeller speed deviation. This initial roll rate for the first five seconds after the event was about -5°/s. Then, the roll rate rapidly increased to over -60°/s by 09:10:49 and the airplane rolled inverted.

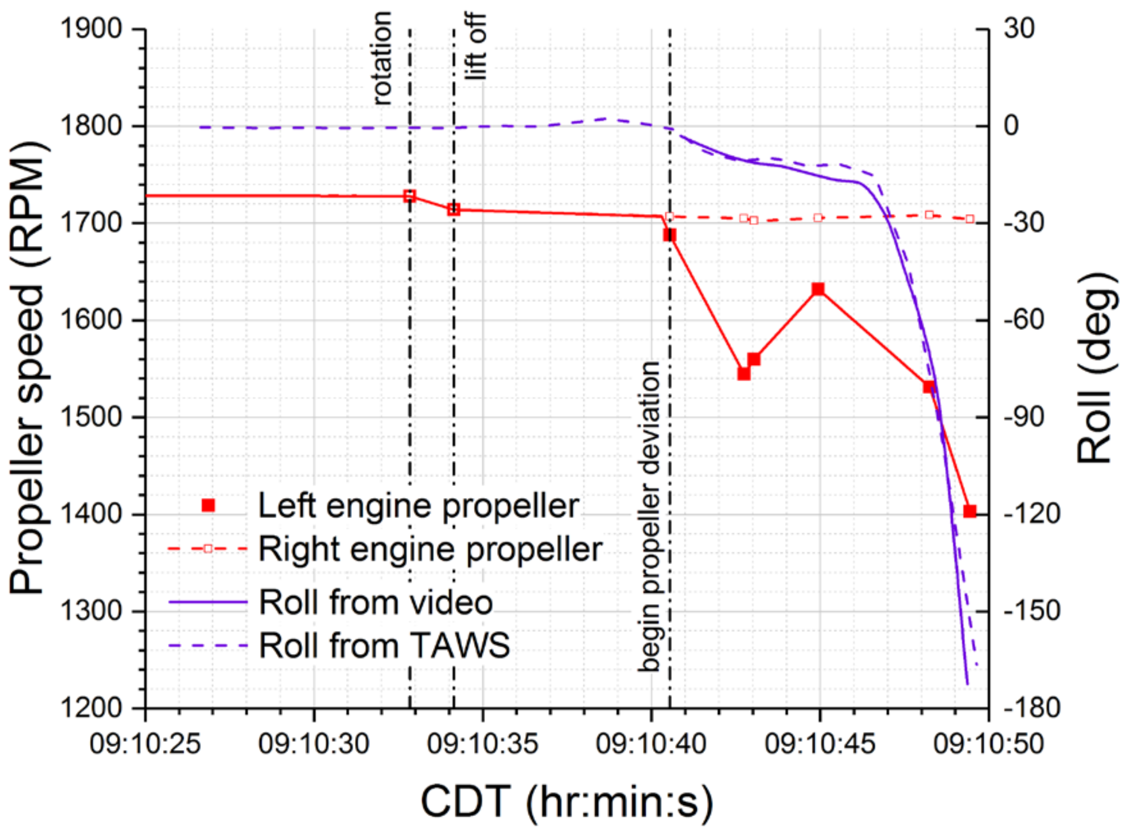

Figure 7. Accident flight propeller speeds and airplane roll angle.

In addition to roll, the video analysis estimated the airplane's pitch, angle of attack (AoA), and sideslip angle. In Figure 8, the roll angle is truncated to more clearly show the changes in pitch, AoA (α), and sideslip (β). Sideslip was greater than 16° nose left one second after the first record of propeller speed deviation but decreased as the airplane continued to roll to the left. By 09:10:42, the airplane's flight path was tracking to the left (Figure 4). Pitch and angle of attack increased together to about 13°, when the roll rate drastically increased. AoA increased to nearly 30° while the airplane rapidly pitched down. After the propeller speed deviation, the airplane was slowing and experiencing large changes in attitude, which is consistent with the stall warnings heard in the cockpit.

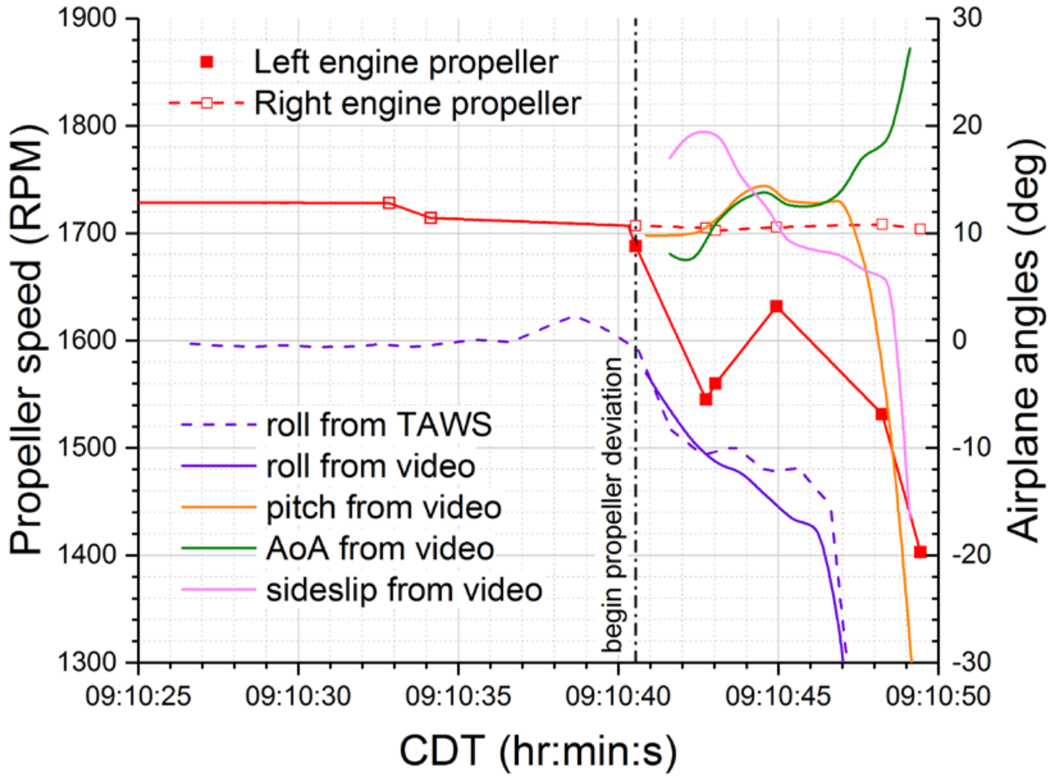

Figure 8. Accident flight propeller speeds and airplane roll, pitch, angle of attack (AoA), and sideslip.

Hartzell Propeller Inc. provide engine power and propeller thrust estimates based on the airplane's speed and propeller RPM from the CVR. Hartzell stated that propeller thrust is relatively insensitive to inflow angles (angle of attack and sideslip) less than 30°. Figure 9 shows that when the left engine propeller speed dropped from 1,700 to 1,550 RPM, the thrust produced by the left engine dropped to near zero. The right engine was still producing over 2,000 lbs of thrust until the end of flight. The thrust disparity was consistent with the left yaw and roll of the airplane.

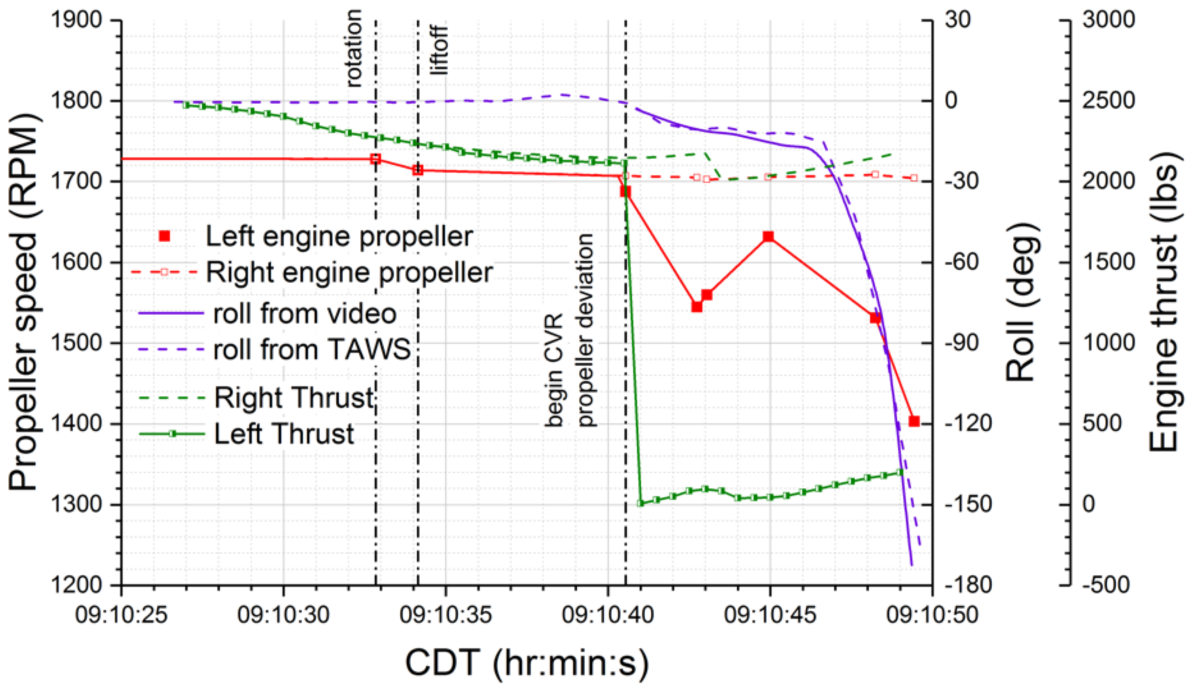

Figure 9. Accident flight propeller speeds, engine thrust, and airplane roll.

Lateral Control Data from Flight Test

Performance data was provided by Textron for the B300 including test data related to the airplane's lateral and directional control and included take-offs when the left engine was inoperative. On the B300, the left engine is the critical engine; if it loses power, it will impart a greater yaw and rolling moment to the airplane than if the right engine is lost. While a test scenario exactly matching the accident flight was not performed in flight test or for certification, the data supports that directional and lateral control could have been maintained during the initial loss of the left engine. During the first five seconds after the loss of left thrust, the roll, roll rate, and sideslip were within the tested bounds of controllability.

Lateral Control Data from Wind Tunnel Testing

Wind tunnel testing data provided by Textron Aviation resulted in airplane yawing moment coefficients for sideslip and rudder input. The following yawing moment equation was used

$$C_n = \frac{N}{qSb} = C_{n_0} + C_{n_\beta}\beta + C_{n_{\delta r}}\delta r$$

Where N is the torque on the aircraft from the asymmetric engine thrust, q the dynamic pressure, S the wing area, and b the wingspan. ß is sideslip and δr is rudder deflection. The coefficients Cn_0, $Cn_ß$, and $Cn_{\delta r}$ were from wind tunnel data. Within the normal flight regime, the yawing moment coefficients can be considered accurate. At larger sideslip angles, the coefficients should be considered approximate. Full rudder travel is 25° left or right. The appropriate response to a reduction in left engine thrust is to apply right rudder to balance the imparted yawing moment.

Figure 10 shows the resultant calculated sideslip from no rudder, 10° nose left rudder, and 10° nose right rudder versus the accident sideslip from the video analysis. The shaded region is a region of lower calculation confidence as the airplane roll angle rapidly increased. The initial accident sideslip angle is consistent with nose left rudder before moving towards nose right rudder. Figure 11 shows only the calculated rudder to result in the accident sideslip. Two seconds after the divergence in engine thrust, calculated rudder is about 11° nose left. Two seconds later, left rudder has decreased, passing through zero rudder to right rudder input.

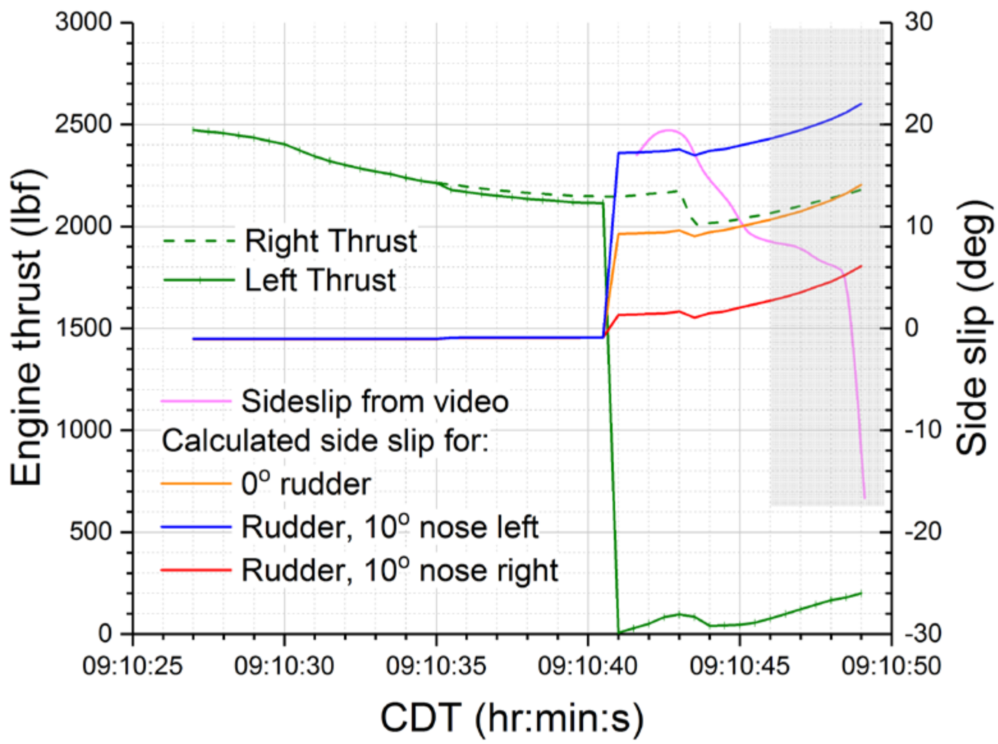

Figure 10. Calculated sideslip for 10° nose left rudder, no rudder, and 10° nose right rudder versus accident sideslip from the video analysis.

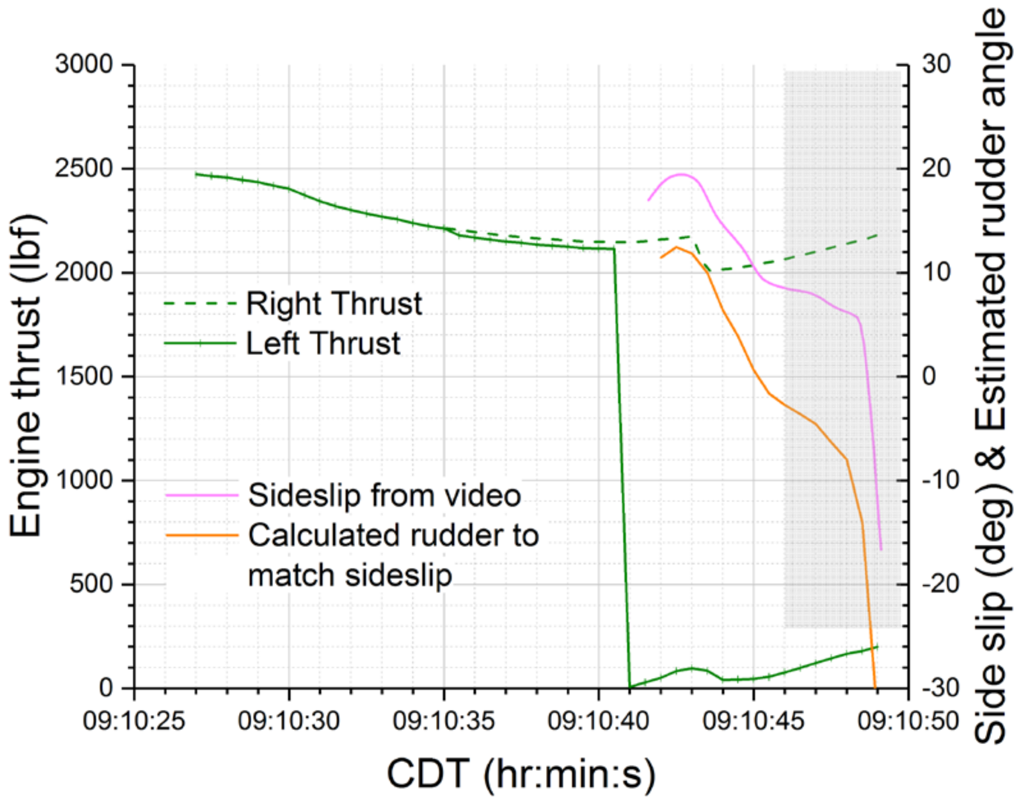

Figure 11. Calculated rudder to match sideslip from video.

This result, that initial rudder input may have been opposite the rudder input needed to balance the yawing moment imparted by the reduction of left engine power, is similar to the result of the Sideslip Thrust and Rudder Study from a similar King Air accident in 2014 [5]. For that accident, the investigation concluded the pilot applied inappropriate rudder pedal at the reduction in left engine power. However, there is uncertainty in the yawing moment imparted by the thrust imbalance, and the yawing coefficients used in these calculations cannot be considered as accurate for the high sideslip values seen and control inputs by the pilot were not recorded for confirmation.

D. CONCLUSIONS

The time from the start of ADS-B data on the west side of the airport until it reached runway 15 was less than four minutes. At 09:10:16, the airplane was 700 ft before the threshold of runway 15 and at take-off power. It rotated at 09:10:32.8, 1,720 ft from the beginning of the take-off roll, and at a speed of 102 kts. It lifted off at 09:10:34 and at 09:10:40.5, the CVR recorded the sound of the slowing of the left engine propeller speed. The propeller manufacturer estimated thrust from the left propeller dropped from 2,100 lbs to less than 200 lbs while the right engine maintained more than 2,000 lbs of thrust. The airplane rolled as the left wing dropped, initially at a rate of about -5°/s. Sideslip increased rapidly to nearly 20° nose left. By 09:10:43, the airplane's flight path was over the edge of the runway and continuing to track left while climbing. Sideslip decreased as the roll rate rapidly increased and the airplane impacted the hangar.

Flight certification data show the loss of left engine power is controllable with appropriate right rudder input. Yawing moment data from wind tunnel testing indicate that initially left rudder may have been incorrectly applied, increasing the sideslip to more than what would be expected from the loss of left engine thrust.

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E. REFERENCES

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2. Sound Spectrum of Cockpit Voice Recorder, CEN19MA190, National Transportation Safety Board, 2020.
3. Video Study, CEN19MA190, National Transportation Safety Board, 2020.
4. Beechcraft Pilot Checklist B300/B300C, April 2018.
5. Sideslip Thrust and Rudder Study, CEN15FA034, National Transportation Safety Board, 2015.