National Transportation Safety Board
Aviation Accident Final Report

Location:	Addison, Texas	**Accident Number:**	CEN19MA190
Date & Time:	June 30, 2019, 09:11 Local	**Registration:**	N534FF
Aircraft:	Textron Aviation B-300	**Aircraft Damage:**	Destroyed
Defining Event:	Loss of control in flight	**Injuries:**	10 Fatal
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The pilot, co-pilot, and eight passengers departed on a cross-country flight in the twin-engine airplane. One witness located on the ramp at the airport reported that the airplane sounded underpowered immediately after takeoff "like it was at a reduced power setting." Another witness stated that the airplane sounded like it did not have sufficient power to takeoff. A third witness described the rotation as "steep," and other witnesses reported thinking that the airplane was performing aerobatics.

Digital video from multiple cameras both on and off the airport showed the airplane roll to its left before reaching a maximum altitude of 100 ft above ground level; it then descended and impacted an airport hangar in an inverted attitude about 17 seconds after takeoff and an explosion immediately followed. After breaching a closed roll-up garage door, the airplane came to rest on its right side outside of the hangar and was immediately involved in a postimpact fire.

Sound spectrum analysis of data from the airplane's cockpit voice recorder (CVR) estimated that the propeller speeds were at takeoff power (1,714 to 1,728 rpm) at liftoff. About 7 seconds later, the propeller speeds diverged, with the left propeller speed decreasing to about 1,688 rpm and the right propeller speed decreasing to 1,707 rpm.

Based on the airplane's estimated calibrated airspeed of about 110 knots and the propeller rpm when the speeds diverged, the estimated thrust in the left engine decreased to near 0 while the right engine continued operating at slightly less than maximum takeoff power. Analysis of available data estimated that, 2 seconds after the propeller speed deviation, the airplane's sideslip angle was nearly 20°. During the first 5 seconds after the propeller speed deviation, the airplane's roll rate was about 5° per second to the left; its roll rate then rapidly increased to more than 60° per second before the airplane rolled inverted.

Autofeather not armed, or reduced thrust? This means that the actual Vmca is higher than the published value.

Witness marks on the left engine and propeller, the reduction in propeller speed, and the airplane's roll to the left suggest that the airplane most likely experienced a loss of thrust in the left engine shortly after takeoff. The airplane manufacturer's engine-out procedure during takeoff instructed that the landing gear should be retracted once a positive rate of climb is established, and the propeller of the inoperative engine should be feathered. Right rudder should also be applied to balance the yawing moment imparted by a thrust reduction in the left engine. Examination of the wreckage found both main landing gear in a position consistent with being extended and the left propeller was unfeathered. The condition of the wreckage precluded determining whether the autofeather system was armed or activated during the accident flight. Thus, the pilot failed to properly configure the airplane once the left engine thrust was reduced.

These calculations were not correct; only one of 3 simultaneous lateral-directional equations of motion was solved. See pdf page 38 below.

Calculations based on the airplane's sideslip angle shortly after the propeller speed deviation determined that the thrust asymmetry alone was insufficient to produce the sideslip angle. Based on an evaluation of thrust estimates provided by the propeller manufacturer and performance data provided by the airplane manufacturer, it is likely that the pilot applied left rudder, the opposite input needed to maintain lateral control, before applying right rudder seconds later. However, by then, the airplane's roll rate was increasing too rapidly, and its altitude was too low to recover.

likely? Hard to believe, left rudder... The performance study was not made by a competent person, not to academic standards. Bank angle and aileron inputs both cause sideslip as well.

The data support that it would have been possible to maintain directional and lateral control of the airplane after the thrust reduction in the left engine if the pilot had commanded right rudder initially rather than left rudder. The pilot's confused reaction to the airplane's performance shortly after takeoff supports the possibility that he was startled by the stall warning that followed the propeller speed divergence, which may have prompted his initial, improper rudder input.

In addition, the NTSB's investigation estimated that rotation occurred before the airplane had attained Vr (rotation speed), which decreased the margin to the minimum controllable airspeed and likely lessened the amount of time available for the pilot to properly react to the reduction in thrust and maintain airplane control. Although the airplane was slightly over its maximum takeoff weight at departure, its rate of climb was near what would be expected at maximum weight in the weather conditions on the day of the accident (even with the extended landing gear adding drag); therefore, the weight exceedance likely was not a factor in the accident.

(except for the increase of side force $W \cdot \sin \phi$ (in body-fixed axis system) and hence the large increase of V_{MCA} as the airplane started to bank into the failing engine).

Engine and propeller examinations and functional evaluations of the engine and propeller controls found no condition that would have prevented normal operation; evidence of operation in both engines at impact was found. Absent evidence of an engine malfunction, the investigation considered whether the left engine's thrust reduction was caused by other means, such as uncommanded throttle movement due to an insufficient friction setting of the airplane's power lever friction locks.

Given the lack of callouts for checklists on the CVR and the pilot's consistently reported history of not using checklists, it is possible that he did not check or adjust the setting of the power lever friction locks before the accident flight, which led to uncommanded movement of the throttle. Although the co-pilot reportedly had flown with the pilot many times previously and was familiar with the B-300, he was not type rated in the airplane and was not allowed by the pilot to operate the flight controls when passengers were on board. Therefore, the co-pilot may not have checked or adjusted the friction setting before the flight's departure.

Although the investigation considered inadequate friction setting the most likely cause of the thrust reduction in the left engine, other circumstances, such as a malfunction within the throttle control system, could also result in loss of engine thrust. However, heavy fire and impact damage to the throttle control system components, including the power quadrant and cockpit control lever friction components, precluded determining the position of the throttle levers at the time of the loss of thrust or the friction setting during the accident flight. Thus, the reason for the reduction in thrust could not be determined definitively.

In addition to a lack of callouts for checklists on the CVR, the pilots did not discuss any emergency procedures. As a result, they did not have a shared understanding of how to respond to the emergency of losing thrust in an engine during takeoff. Although the co-pilot verbally identified the loss of the left engine in response to the pilot's confused reaction to the airplane's performance shortly after takeoff, it is likely the co-pilot did not initiate any corrective flight control inputs, possibly due to the pilot's established practice of being the sole operator of flight controls when passengers were on board.

The investigation considered whether fatigue from inadequately treated obstructive sleep apnea contributed to the pilot's response to the emergency; however, the extent of any fatigue could not be determined from the available evidence. In addition, no evidence indicates that the pilot's medical conditions or their treatment were factors in the accident.

In summary, the available evidence indicates that the pilot improperly responded to the loss of thrust in the left engine by initially commanding a ~~left rudder input~~ and did not retract the landing gear or feather the left propeller, which was not consistent with the airplane manufacturer's engine out procedure during takeoff. It would have been possible to maintain directional and lateral control of the airplane after the thrust reduction in the left engine if right rudder had been commanded initially rather than left rudder. It is possible that the pilot's reported habit of not using checklists resulted in his not checking or adjusting the power lever friction locks as specified in the airplane manufacturer's checklists. However, fire and impact damage precluded determining the position of the power levers or friction setting during the flight.

Not evidence, inappropriate use of Lat-Dir equations of motion.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

The pilot's failure to maintain airplane control following a reduction of thrust in the left engine during takeoff. The reason for the reduction in thrust could not be determined. Contributing to the accident was the pilot's failure to conduct the airplane manufacturer's emergency procedure following a loss of power in one engine and to follow the manufacturer's checklists during all phases of operation.

The reason for the loss of control was that the POH does not give guidance to keep Vmca low. Vmca was higher than the published Vmca because straight flight (runway heading) was not maintained using up to max. rudder, a bank angle of 5° into the good engine was not attained and the propeller was not feathered. The large sideslip (drag) also prevented the airplane from accelerating to V2.

Findings

Not determined	(general) - Unknown/Not determined
Personnel issues	Aircraft control - Pilot
Aircraft	(general) - Not attained/maintained
Personnel issues	Lack of action - Pilot

Factual Information

History of Flight

Initial climb	Unknown or undetermined
Initial climb	Loss of control in flight (Defining event)
Post-impact	Fire/smoke (post-impact)
Post-impact	Explosion (post-impact)

On June 30, 2019, about 0911 central daylight time (CDT), a Textron Aviation B-300 (marketed as King Air 350), N534FF, was destroyed when it impacted a hangar shortly after takeoff from runway 15 at Addison Airport (ADS), Addison, Texas. A postimpact fire ensued. The airline transport pilot, the commercial co-pilot, and eight passengers sustained fatal injuries. Visual meteorological conditions prevailed for the flight. The airplane was owned by EE Operation LLC and operated as a Title 14 *Code of Federal Regulations* Part 91 personal flight en route to Albert Whitted Airport (SPG), St. Petersburg, Florida.

During postaccident interviews, personnel from Flyte Aero (an aviation service provider at ADS) reported that they arrived at the owner's hangar between 0700 and 0730 on the morning of the accident to prepare the airplane for the flight; they did not perform any maintenance. According to fueling records, all four of the airplane's tanks were filled with a total of 329 gallons of fuel.

According to Flyte Aero personnel, the pilots and passengers arrived about 90 minutes before the flight. The co-pilot greeted the passengers at the hangar and loaded their bags into the baggage compartment. No scale was present, and none of the bags were weighed. Flyte Aero personnel observed both pilots walk around the airplane before the flight but did not see the airplane taxi out.

The airplane was equipped with a cockpit voice recorder (CVR)—but was not required to be—that recorded the taxi and accident flight (it was not equipped with a flight data recorder nor was it required to be). It was also equipped with automatic dependent surveillance-broadcast (ADS-B) and a terrain awareness and warning system (TAWS). ADS-B recorded the time, the airplane's latitude and longitude, altitude, inertial speed, pressure altitude, geometric altitude, and other parameters, and TAWS recorded radio altitude, latitude, longitude, and airplane roll angle.

The CVR started recording at 0706:54. At 0749:51, an unidentified person began discussing an oil consumption issue concerning the left engine with the pilot and stated that the issue needed to be monitored. The unidentified person concluded by saying the pilots needed to "keep a log" on the issue and "keep notes." Flyte Aero personnel reported during postaccident interviews that they did not have this conversation with the pilot; the identity of the person was not determined.

About 0826, the flight crew obtained local weather information via the automatic terminal information service. At 0830:11, the flight crew received clearance to SPG on the ground control frequency. At 0902:59, the CVR recorded a noise similar to an engine starting. At 0903:15, another sound was recorded similar to the second engine starting. The pilots did not call for the airplane's Before Engine Starting, Engine Starting, Before Taxi, or Before Takeoff (Runup) checklists nor did they discuss any emergency procedures.

According to CVR data, the pilot contacted ground control about 0905 stating he was ready to taxi and was provided taxi instructions to runway 15. At 0909:41, the local controller gave the pilot departure instructions to turn left to heading 050 and cleared the flight for takeoff from runway 15. A sound similar to an increase in propeller rpm was recorded about 0910:11, and the co-pilot called "airspeed's alive" at 0910:25. The National Transportation Safety Board's (NTSB) sound spectrum study of the CVR recording and performance study estimated that rotation occurred about 0910:32 at a groundspeed of about 101 knots (102 knots calibrated airspeed).

A reduction in broadband noise recorded at 0910:34 was consistent with the airplane lifting off from the runway. Using available data, the NTSB's performance study calculated that the airplane fully lifted off the ground about 1,900 ft from the beginning of the takeoff roll at a groundspeed of about 105 knots (106 knots calibrated airspeed). The propeller speeds at the time of liftoff were estimated to be consistent with takeoff power, and the two propellers were operating about the same speed (1,714 to 1,728 rpm).

control. Airspeed not controllable, but airplane.

The pilots did not verbalize any V speeds before or during the takeoff roll. With the reported weather conditions (wind at 6 knots from 100° and temperature at 26°C) and at maximum takeoff weight, the takeoff decision speed (V1) for the flight would have been 106 knots, Vr (rotation speed) would have been 110 knots, V2 (takeoff safety speed) would have been 117 knots, and Vmc (minimum controllable airspeed) would have been 96 knots (with flaps retracted) or 94 knots (with the flaps at the approach setting of about 14°).

Vmc is determined with a feathered propeller, if automatic. When not armed, not feathered, Vmc is higher (refer to POH/AFM).

Six seconds after liftoff (0910:40.1), the pilot stated, "what in the world?" The CVR recorded the sounds of the engines' propeller rpm diverging about the same time; the airplane's groundspeed was about 109 knots (110 knots calibrated airspeed). The NTSB's sound spectrum study determined that the left engine's propeller speed decreased to about 1,688 rpm, and the right engine's propeller speed decreased to 1,707 rpm about this time. A click sound was also recorded about 0910:41 followed by a sound similar to a stall warning horn less than 1 second later. The stall warning horn ended at 0910:43; the left engine's propeller speed was 1,545 rpm about this time. At 0910:43.6, the co-pilot stated, "you just lost your left engine." The NTSB's performance study determined that the airplane had passed over the left edge of runway 15 at this time and continued to climb while turning left.

Stall speed data not found. Was this really a stall warning?

At 0910:44, the sound of a chime was recorded followed by the sound of another click. About this time, the left engine's propeller speed increased to 1,632 rpm but began to decrease again. The NTSB's performance study calculated that the airplane began to roll left about 0910:45. At 0910:45.2, the stall warning horn sounded again and continued until the end of the recording. About 0910:47, the airplane reached a maximum altitude of 100 ft agl. At 0910:48.8, the "bank angle" annunciator sounded; the airplane had rolled to 10.6° left-wing down about this time. At 0910:49.5, an expletive from the co-pilot was recorded along with two more "bank angle" annunciations at 1-second intervals. The airplane's altitude was about 70 ft agl and its groundspeed was about 85 knots about this time.

At 0910:51.1, the sound of the airplane's impact with the hangar was recorded. About this time, the estimated speed of the left engine's propeller was 1,403 rpm, and the estimated speed of the right engine's propeller was above 1,700 rpm. Digital video obtained from multiple cameras both on and off the airport showed that the airplane rolled to its left and impacted the hangar in an inverted attitude and that an explosion immediately followed. The airplane then impacted the hangar floor, breached a closed roll-up garage door, came to rest on its right side outside of the hangar, and was consumed by fire.

Multiple witnesses observed the brief flight. One witness standing on the ramp at the airport reported that the airplane sounded underpowered immediately after takeoff "like it was at a reduced power setting." A second witness standing on the ramp reported that the airplane sounded like it did not have sufficient power to takeoff. A third witness described the rotation as "steep"; the same witness along with two others witnesses reported thinking that the airplane was "showboating" or performing aerobatics.

Pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	71,Male
Airplane Rating(s):	Single-engine land; Single-engine sea; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	Unknown
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	December 21, 2018
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	March 23, 2019
Flight Time:	16450 hours (Total, all aircraft), 1100 hours (Total, this make and model), 45 hours (Last 90 days, all aircraft)		

Co-pilot Information

Certificate:	Commercial; Flight instructor	**Age:**	28,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	Unknown
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 None	**Last FAA Medical Exam:**	April 3, 2018
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	May 14, 2019
Flight Time:	2357 hours (Total, all aircraft), 189 hours (Last 90 days, all aircraft)		

According to people who knew both pilots, they had flown together many times before the accident flight. Although the B-300 is certificated for single-pilot operation, an acquaintance of the pilot reported that he was not comfortable flying the B-300 as a single pilot and that he always had a co-pilot for his flights.

The Pilot

The accident pilot completed recurrent training in the accident airplane (N534FF) on March 23, 2019, at Rich Aviation Services, Fort Worth, Texas. The training consisted of 2.7 hours in the airplane, including abnormal and emergency procedures, and ground training on the airplane's systems, which included—but was not limited to—engine/propellers, performance, and weight and balance.

During a postaccident interview, the flight instructor for the accident pilot's most recent recurrent training stated that it was the only time he had flown with the pilot. They briefed the entire profile before the flight; it was a good briefing of everything they planned to accomplish on the flight. The accident pilot performed well on the simulated single-engine failure on takeoff. Because they were training in the airplane rather than a simulator, the instructor did not reduce power on one of the engines on the runway for safety reasons. The instructor waited to reduce engine power until the airplane had a positive rate of climb, had reached about 200 to 300 ft agl, and the landing gear were coming up. This maneuver, like all the others, was pre-briefed.

The instructor stated that the accident pilot was "super strong" on knowledge about the airplane and nothing about his performance during the training stood out. If the instructor had to point out an area where the accident pilot was weak, it was on the airplane's avionics. They spent extra time with the external power connected to go over the avionics in the airplane. The accident pilot demonstrated a good attitude during the training and accepted advice and coaching well. The recurrent training also accomplished a flight review and instrument proficiency check. The instructor stated that it was obvious to him that the pilot was a career professional pilot and had gone through professional training before.

Several pilots who knew the accident pilot and flew with him in the past were interviewed. Regarding the accident pilot's takeoff rotation technique, two pilots reported that he used two hands during the rotation. None of the pilots interviewed reported that the accident pilot asked them to back him up on or guard the power levers during the takeoff or rotation. One pilot reported that the accident pilot had an aggressive rotation technique and that he would "pull up abruptly" at rotation.

Another pilot reported that the accident pilot "was not strong on using checklists." Another mutual acquaintance of the accident pilot and co-pilot stated that the accident pilot did not like to use a checklist and "just jumped in the airplane and went." The business partner of the accident pilot reported that he was "bad about using checklists" and that he would not use checklists as much if he was familiar with the airplane. His business partner also reported that the accident pilot generally would not do a weight and balance calculation if he was familiar with the airplane and usually verbalized V speeds.

Information to develop a 72-hour history for the pilot was not available.

The Co-pilot

The co-pilot was not type rated in the B-300. He completed recurrent training in the B-200 simulator on May 14, 2019, at Rich Aviation Services, Fort Worth, Texas. The training consisted of 2 hours in the simulator, including abnormal and emergency procedures, and ground training on airplane systems, which included—but was not limited to—engine/propellers, performance, and weight and balance. The systems training also included Beech F90 and Beech C90/B-200 differences training.

During a postaccident interview, the flight instructor for the copilot's most recent recurrent training recalled that the co-pilot was "low time" but was building experience and did a "fine job." He performed well with radio communications, use of checklists, and understanding procedures. The flight instructor stated that he typically emphasized V1 cuts (that is, simulated engine failure at takeoff) in recurrent training and that this material was emphasized during the co-pilot's simulator training.

The co-pilot was described as "very, very particular" and "by the book" during postaccident interviews with pilots who knew him. A mutual acquaintance of the accident pilot and co-pilot stated that the co-pilot did "a great job in the right seat" and was "like a sponge" with "great flying habits."

According to the co-pilot's wife, the co-pilot flew with the accident pilot most of the time and reportedly enjoyed flying with him. The pilot never allowed the co-pilot to manipulate the flight controls in flight if passengers were on board. The co-pilot's wife stated that he did not express any concerns with the pilot's flying abilities and did not discuss any aircraft systems issues with her.

Aircraft and Owner/Operator Information

Aircraft Make:	Textron Aviation	**Registration:**	N534FF
Model/Series:	B-300	**Aircraft Category:**	Airplane
Year of Manufacture:	2017	**Amateur Built:**	No
Airworthiness Certificate:	Normal	**Serial Number:**	FL-1091
Landing Gear Type:	Retractable - Tricycle	**Seats:**	11
Date/Type of Last Inspection:	March 22, 2019 Continuous airworthiness	**Certified Max Gross Wt.:**	15000 lbs
Time Since Last Inspection:	67.03 Hrs	**Engines:**	2 Turbo prop
Airframe Total Time:	691.23 Hrs at time of accident	**Engine Manufacturer:**	Pratt & Whitney Canada
ELT:	Installed	**Engine Model/Series:**	PT6A-60A
Registered Owner:		**Rated Power:**	1050 Horsepower
Operator:		**Operating Certificate(s) Held:**	None

EE Operations LLC, a subsidiary of a family-owned business, purchased the accident airplane on March 21, 2019. According to the chief financial officer (CFO) of EE Operations LLC, the airplane was primarily used for family business and personal travel and was exclusively operated under 14 *CFR* Part 91. No evidence was found indicating that the airplane was operated for compensation or hire.

EE Operations LLC had an aircraft management agreement with the accident pilot's company, S&H Aircraft LLC, to manage all maintenance and flight scheduling, maintain the airplane's records, and provide pilot services. According to the CFO of EE Operations LLC, the accident pilot managed the day-to-day operation of the airplane through his company. EE Operations LLC compensated the accident pilot for his management and pilot services, and S&H Aircraft LLC hired and compensated the co-pilots used in the airplane's operation. Since the airplane was operated exclusively under Part 91, oversight by a Federal Aviation Administration principal operations inspector was not required.

Before its sale to EE Operations LLC, the airplane underwent phase 1 through 4 inspections, special inspections, service bulletin and airworthiness directive compliance, and engine and propeller maintenance at Textron Aviation Services in Wichita, Kansas. Maintenance records showed that the work on the airplane was completed on March 22, 2019. The airplane had 624.2 hours and 423 cycles at the time of the sale and accumulated about 67.03 hours and 31 cycles from that time to the day of the accident.

The accident airplane was equipped with two pilot seats and a nine-passenger-seat cabin (including the aft, belted lavatory seat). It had left and right overwing exits at row 2 and an aft overwing exit across from the lavatory seat.

Engines

Both turning clockwise?

The accident airplane was powered by two Pratt & Whitney Canada PT6A-60A gas turbine engines driving Hartzell HC-B4MP-3C propellers. The Hartzell HC-B4MP-3C propellers on the airplane were four-bladed, hydraulically operated, steel hub, constant-speed propellers with full feathering and reversing capabilities and a normal in-flight operating range of 1,450 to 1,700 rpm. Oil pressure from a propeller governor was used to move the blades toward low pitch (reduced blade angle). Blade-mounted counterweights and a feathering spring moved the blades toward high pitch/feather in the absence of governor oil pressure. The propeller incorporated a beta mechanism that actuated when blade angles were lower than the flight idle position.

As installed on the B-300, selected propeller positions will result in the following blade angle settings:

Reverse	-14.0° (+/- 0.5°)
Beta actuation/low pitch	15.4° (+/- 0.1°)
Flight idle	12.9° to 11.8°
Ground idle	˜ 2°
Feather	80.0° (+/- 0.5°)

Review of the operator's airplane service records found that the engines and propellers were original to the airplane and had never been removed. Work performed on the engines during the last maintenance completed on March 22, 2019, included control linkage inspections, engine oil filter and secondary screen checks, hot section borescope inspections of both engines, and general visual inspection of both propellers.

Engine and Propeller Controls

The engine and propeller control levers on the accident airplane model are located between the two cockpit seats. The power quadrant includes two power levers (which controls engine power from idle through takeoff) and two propeller levers (which control propeller speed and feathering) to the right of the power levers. Two engine condition levers are to the right of the propeller levers and have three positions: FUEL CUTOFF, LOW IDLE, and HIGH IDLE; the idle settings limit idle speed at 62% N1 (39,000 gas generator rpm) minimum for low idle and 70% N1 minimum for high idle. The left condition lever controls the left engine, and the right condition lever controls the right engine (see figure 1).

Friction lock control knobs are located on the power quadrant. Each power lever has its own friction lock control knob at the base of the quadrant to adjust the power levers' tension. One friction knob controls the tension of both propeller levers. Turning the knobs counterclockwise increases tension and turning them clockwise reduces tension (see Additional Information for more information on friction adjustment). The force required to move the power lever or the propeller control lever aft with the friction setting fully disengaged is 0.6 lbs and 2 lbs, respectively.

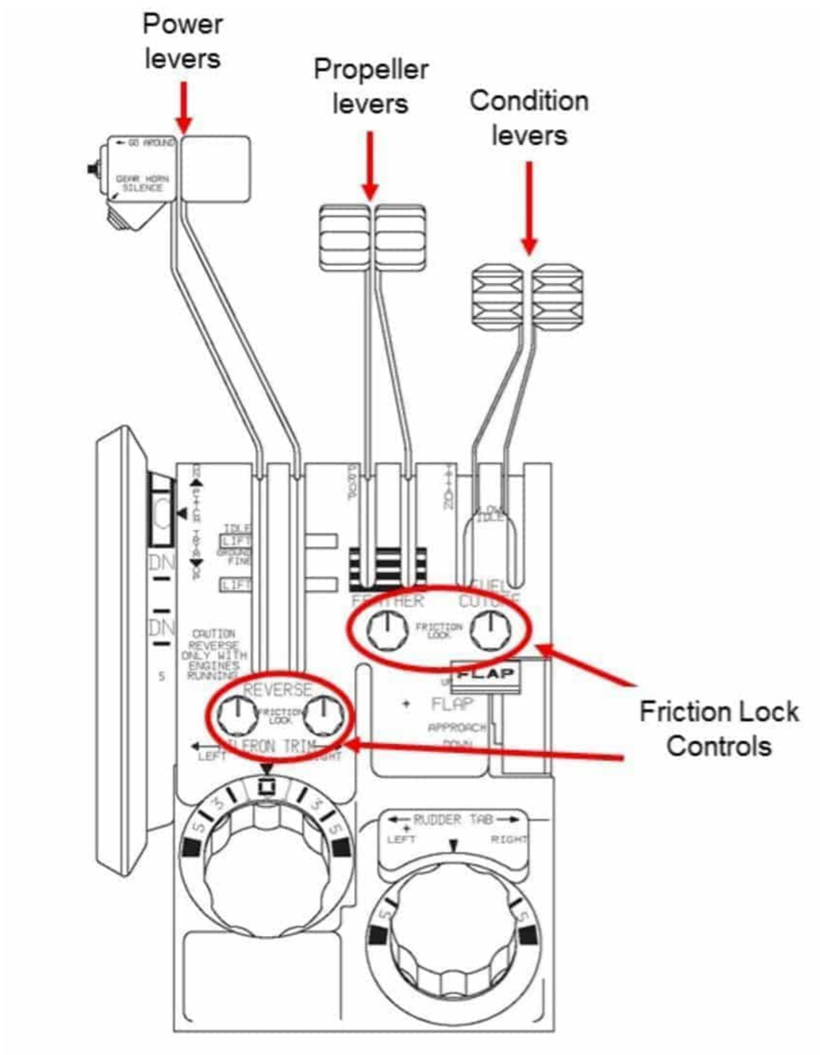

Figure 1. Diagram of B-300 Engine and Propeller Controls

The accident airplane was equipped with an autofeather system that, according to the airplane manufacturer, is intended for use during takeoff and landing if there is a loss of engine power. The system is armed when the autofeather switch is moved to the ARM position, the power levers are advanced to 87% to 89% N1, and both engine torque indications are above 17%. The letters AFX illuminate in green next to the corresponding propeller indication on the multifunction display (MFD). When armed, the system automatically feathers the propeller to reduce drag if the torque on its corresponding engine drops to between 7% to 13%. Aft movement of the power lever for that engine disarms the autofeather system. When the system is not armed, AUTOFEATHER OFF illuminates in amber on the MFD. According to the airplane manufacturer, the AUTOFEATHER OFF caution message would not be inhibited during takeoff.

Rudder Boost System

The accident airplane was equipped with a rudder boost system, which was designed to reduce the required rudder pedal force in the event of an engine failure. Rudder boost is armed by selecting the control switch (mounted on the pedestal) to the RUDDER BOOST position. The system is disarmed by selecting the control switch to the OFF position; the system can also be disarmed by pushing the button on the control wheel that disconnects the trim/autopilot yaw damper (DISC TRIM/AP YD). RUDDER BOOST OFF illuminates in amber on the MFD to indicate that the rudder boost control switch is in a position other than ON. The BEFORE TAKEOFF (RUNUP) checklist in the B-300 pilot operating handbook, Normal Procedures, included procedures for testing the rudder boost system; the system would normally be ON for takeoff. According to the aircraft manufacturer, the RUDDER BOOST OFF caution message is not inhibited during takeoff.

Weight and Balance

The airplane's maximum takeoff and landing weight was 15,000 lbs. Based on the pilots' FAA records, passenger weights provided by family members, baggage and other items recovered from the wreckage, and fuel on board, the airplane's estimated ramp weight before departure was 15,660 lbs. The airplane's computed center of gravity at departure was 206.71 inches aft of datum. The aft limit was 208.0 inches aft of datum.

Hence cg is near aft, rudder power lowest (for Vmca)

Airplane Performance

According to the airplane manufacturer, the left engine is the critical engine on the B-300; if it loses power, there will be a greater yaw and rolling moment on the airplane (due to asymmetrical thrust) than if right engine power is lost. The appropriate response to a reduction in left engine thrust is to apply right rudder to balance the imparted yawing moment.

and attain 5° bank to the same side as rudder.

The B-300 engine-out procedure during takeoff (at or above V1) directed a pitch attitude of 10°, retracted landing gear when positive climb is established, takeoff safety speed (V2) to be maintained to 400 ft above ground level (agl), and the propeller of the inoperative engine to be feathered. Once an altitude of 400 ft agl is reached, flaps should be retracted at an airspeed of V2 plus 9 knots then airspeed should be increased to 125 knots. The airplane's performance charts indicated a one-engine-inoperative climb capability of about 700 fpm with landing gear and flaps up, the inoperative engine's propeller feathered and at maximum takeoff weight, and a climb speed of 125 knots.

No bank requirement? (for min. drag, max ROC)

Only little greater moments. Is accounted for in V_{MCA}, which is the worst case, the highest V_{MCA} after failure of either engine.
V_{MCA} is the lowest speed at which the pilot can maintain straight flight after either engine failure, provided a small bank angle (<=5°) is being maintained away from the inoperative engine. The manufacturer should publish this bank angle in the POH with V_{MCA}, in engine emergency procedures and engine-out performance data (some manufacturers do).
Pilots and investigators should not talk about critical engine, is for airplane design engineers during sizing the vertical tail.
For pilots: V_{MCA} and engine emergency procedures apply after failure of either engine (not only after failure of the critical engine).
Bank angle has a much larger influence on V_{MCA} and performance, but is not mentioned.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KADS,643 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	08:47 Local	**Direction from Accident Site:**	360°
Lowest Cloud Condition:	Scattered / 1400 ft AGL	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	6 knots /	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:	100°	**Turbulence Severity Forecast/Actual:**	N/A / N/A
Altimeter Setting:	30.06 inches Hg	**Temperature/Dew Point:**	24°C / 20°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Addison, TX (ADS)	**Type of Flight Plan Filed:**	IFR
Destination:	St. Petersburg, FL (KSPG)	**Type of Clearance:**	IFR
Departure Time:	09:05 Local	**Type of Airspace:**	Class D

Airport Information

Airport:	Addison Airport ADS	**Runway Surface Type:**	Asphalt
Airport Elevation:	644 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	15	**IFR Approach:**	None
Runway Length/Width:	7203 ft / 100 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	2 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:	8 Fatal	**Aircraft Fire:**	On-ground
Ground Injuries:		**Aircraft Explosion:**	On-ground
Total Injuries:	10 Fatal	**Latitude, Longitude:**	32.96611,-96.832778

Witness marks and wreckage distribution were consistent with the airplane impacting the top of the hangar in a right-wing-low, nose-down, and inverted attitude. The airplane was destroyed by the impact forces and postimpact fire. Fragmented pieces of both wings were located on top and inside of the hangar and immediately to the north of the hangar. The main wreckage, which included the right engine and the fuselage, was located outside of the hangar and came to rest on its right side adjacent to a brick wall. Portions of all the crew and cabin seats were identified, and all showed evidence of various degrees of fire consumption. Some seats exhibited deformation consistent with impact damage. Wreckage examination found no evidence of an in-flight fire before the impact with the hangar.

The left propeller and left engine were found on the hangar floor beneath the roof entry hole. The left engine case and external components were deformed and fractured consistent with impact. There was no evidence of catastrophic mechanical failure. One blade was missing from the left propeller hub. The liberated blade was found on the tarmac in the ramp area outside of the hangar with about 5 inches of its tip missing. There were chordwise white scrape marks on its leading edge. The missing propeller blade tip was found inside the hangar.

Propeller blade strikes (see figures 2 and 3) were observed at the airplane's initial point of impact including a strike to a hangar roof truss, which was coated white. Evidence indicates that the strikes were made by the left propeller. The distances between the propeller blade strikes were measured to determine propeller speed at impact (see figure 3). The left propeller's speed at impact was estimated at 1,259 to 1,300 rpm.

Figure 2. Photograph of an aerial view of the accident site

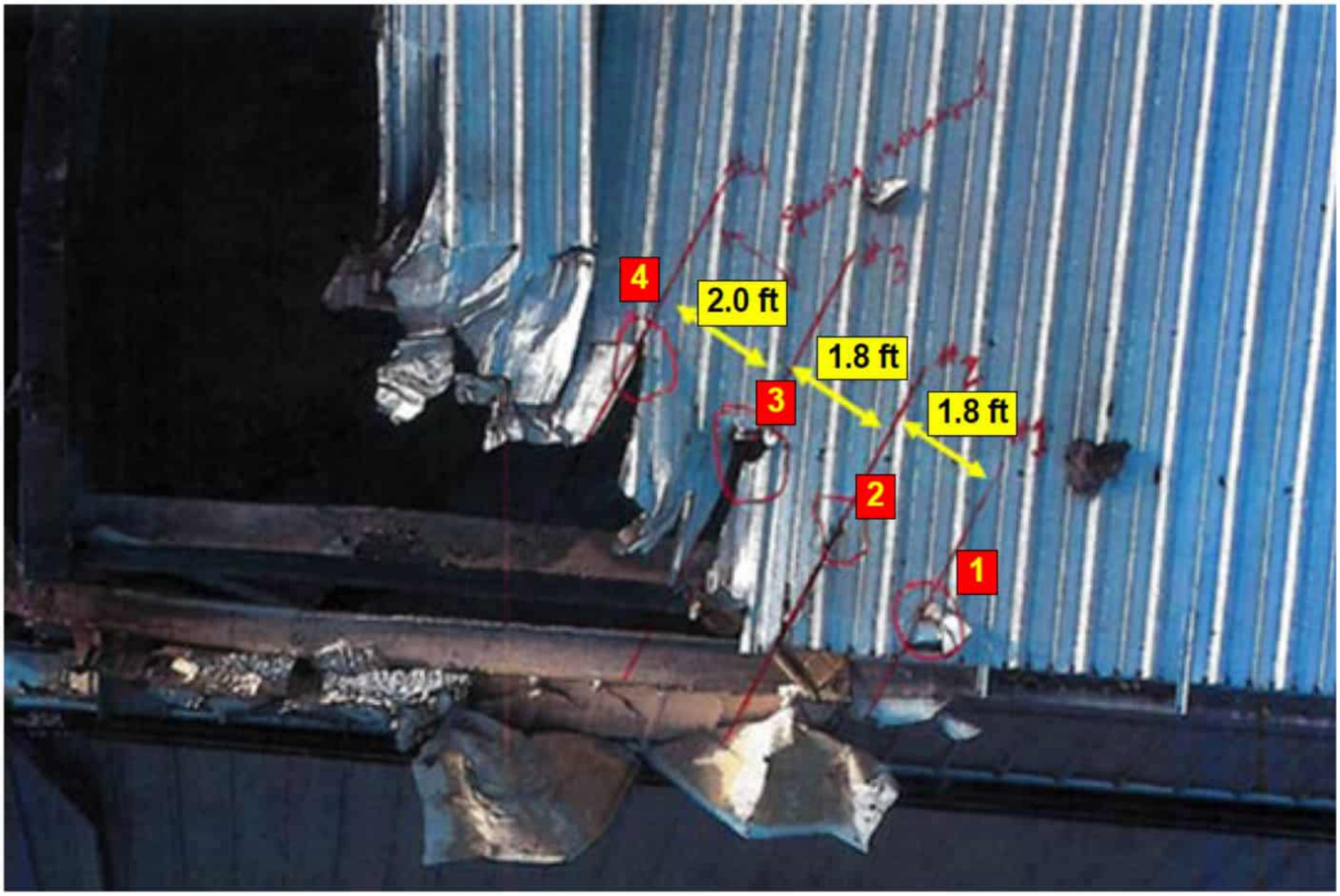

Figure 3. Photograph of propeller blade strikes in hangar roof

The left engine was found about 50 ft southeast of the left propeller. The engine case and external components were deformed and fractured. The first-stage compressor rotor was intact as viewed through the inlet case. The second-stage power-turbine blades were intact as viewed through the exhaust ducts. Both engine rotors were seized. Liberated components, including the compressor discharge pressure filter, propeller governor flyweights, and the fuel heater, were recovered near the engine.

The right propeller was found charred and sooted lying near the east wall of the hangar. The spinner was in place but crushed. Two blades exhibited forward bending and two exhibited aft bending. The front case of the engine reduction gearbox was attached.

The right engine was found in the main wreckage area. Several external components exhibited extensive thermal damage. The forward section of the right engine's reduction gearbox separated at the second stage planet gear carrier web. The second stage planet gear was liberated. The forward section of the reduction gearbox and the planet gear were both found nearby. The first-stage compressor rotor was intact as viewed through the inlet case. The second-stage power-turbine blades were intact as viewed through the exhaust exit ducts. Both engine rotors were seized. The power control and reversing linkage was fractured. The compressor discharge pressure line was damaged but continuous. Liberated components, including the second-stage reduction gearbox planet gear and the propeller governor speed lever, were found nearby.

During teardown examinations, positive evidence of operation at impact was found inside both engines. Among other indicators, rotational scoring noted on the stator structure adjacent to gas generator and power turbine rotating components showed that both engines were operating when impact occurred. In addition, the second-stage planet gear carriers of both engines were separated at their webs and the separated material was plastically deformed in the direction opposite of propeller rotation, indicating that the propellers were being driven when rotation stopped. Detailed engine and propeller disassembly examinations and functional evaluations of engine and propeller controls found no condition that would have prevented normal operation.

Both propeller assemblies displayed internal damage that could provide information about propeller blade position at the time of impact. The estimated preimpact blade angles for the left propeller was 11° to 15°, that is, near low pitch (with a bias toward the low end of the range) and 15° to 24° for the right propeller (with a bias toward the high end of the range).

No evidence was found in the wreckage indicating whether the autofeather system on the airplane was armed or activated during the accident flight.

Hence, the actual V_{MCA} was higher than the AFM published V_{MCA}.

The horizontal and vertical stabilizers were found attached to each other beneath the initial impact point; the rudder control surface and rudder trim tab were found attached to the vertical stabilizer. Control continuity could not be established due to significant impact and fire damage. The condition of the wreckage precluded determining whether the rudder boost system was active during the accident flight.

Several sections of flaps were found, most with heavy burn damage. The right outboard flap and jackscrew were present. The jackscrew actuator position was about 1 3/4 inches from the actuator housing to the middle of the attachment bolt. The right inboard flap and jackscrew were not present. The jackscrew for the left inboard flap was in the wing, but the flap was not found. The jackscrew actuator position was about 3 3/16 inches from the actuator housing to the middle of the attachment bolt. The left outboard jackscrew was attached to flap structure, but the flap was extensively burned. The jackscrew actuator position was about 1 3/4 inches from the actuator housing to the middle of the attachment bolt. According to the aircraft manufacturer, these flap jackscrew measurements are consistent with a flap position between 0° and 10°.

Both main landing gear were found in a position consistent with being extended. The nose gear upper strut was found in the extended and locked position.

The cockpit area wreckage was extensively burned. The control wheels, power quadrant, rudder pedals, and instrument panel all sustained significant fire damage. All three primary adaptive flight displays were cracked, burned, and sooted. It was possible to determine the following lever-locked switch positions on the fuel system control panel:

- left standby pump switch—ON
- left auxiliary transfer switch—OVERRIDE
- right auxiliary transfer switch—OVERRIDE
- fuel quantity test switch—MAIN
- right standby pump switch—ON

The aileron trim knob was found attached to the power quadrant, and the rudder trim knob and a section of connecting rod were found in the wreckage. No trim position indications could be determined for either knob. Damage to the control lever friction components precluded determining the friction setting during the accident flight.

Additional Information

Emergency Response

Addison Fire Department Fire Station 1 was located about 600 ft from the accident site. The battalion chief reported that he was inside the station at the time and heard an explosion but did not know what it was. The station was equipped with a direct line ringdown service from the airport control tower (ATCT), which activated almost immediately to report an accident at the airport. The battalion chief and nine other firefighters in the station responded to the accident site in five vehicles. The emergency personnel reported observing heavy smoke as soon as they left the station. The hangar was completely engulfed in fire and smoke upon their arrival. Emergency personnel reported that the fires (one in the hangar and a second outside to the left of the hangar, which was the airplane wreckage) were knocked down within 14 to 15 minutes.

ATCT personnel initially reported to the battalion chief that at least two people were on board, but they were uncertain about the number of occupants. The battalion chief did not learn until several hours later that 10 people were on board; he reported, however, that the information would not have changed his tactics because he did not recognize that the location of the secondary fire was the airplane wreckage. He further stated that he may have concentrated more on the second fire upon arrival had he known that it was the accident airplane but, until the fire was extinguished, there was no way to know that it was an airplane.

Friction Lock Checklist Procedures and Reports of Uncommanded Power Lever Movement

FlightSafety Textron Aviation Training, which emphasizes the risk of an unintended power lever migration and potential loss of control if the friction lock setting is adjusted incorrectly, also provides the manufacturer's checklist procedures. The following procedures are listed as part of the 'BEFORE ENGINE START' checklist:

a. Power Levers................................ IDLE, FRICTION SET

b. Prop Levers................ FULL FORWARD, FRICTION SET

c. Condition Levers.............. FUEL CUT OFF, FRICTION SET

In addition, item 7 in the B-300 Before Takeoff (Runup) checklist states that the engine control friction locks should be "set." The Before Engine Starting checklist in the B-300 quick reference handbook also contains an item to check that friction is set on the power, propeller, and condition levers.

According to Textron, the B-300 friction control is the same as that used on all Beechcraft brand twin-engine airplanes since the Queen Air model 88 (introduced in 1965). A search of the Aviation Safety Reporting System found three customer service reports of an insufficient friction setting on the power lever friction locks that led to uncommanded throttle movement in various King Air model aircraft during takeoff.

Flight recorders

The airplane's CVR, model L-3/Fairchild FA2100-1020, recorded (via four channels) 2 hours of high-quality audio, including the accident flight. The outer case of the CVR sustained significant heat and structural damage, but the memory board was undamaged. Excellent quality audio was downloaded from all four channels at the NTSB's recorders laboratory and a transcript was prepared.

Medical and Pathological Information

The two pilots and eight passengers all sustained fatal injuries in the accident. Autopsy reports obtained from the Southwestern Institute of Forensics Sciences at Dallas, Office of the Medical Examiner indicated that all occupants experienced thermal and or smoke inhalation injuries that contributed to their deaths. Six of the 10 occupants also had blunt force traumatic injuries that contributed to their deaths, while 4 occupants died solely from thermal and/or smoke inhalation injuries.

Tests and Research

Video Study

Security cameras located at different points around the airfield recorded portions of the accident flight. The NTSB performed a video study of the flight (from the time the first stall warning sounded about 0910:41 to the airplane's impact with the hangar) to estimate the airplane's groundspeed, altitude, roll angle, pitch angle, angle of attack (AoA), and sideslip angle. The NTSB's video study was primarily based on a video recorded by a camera installed beyond the southern end of the departure runway. Supporting information for the study was obtained from video cameras installed on three buildings near the crash site.

The video study determined that the airplane reached a maximum altitude about 100 ft above the runway. Sideslip was near 20° nose left about 2 seconds after the propeller speed deviation; AoA and pitch were 10° about this time. The airplane's pitch and AoA reached a maximum of 13° before rapidly diverging as the airplane rolled, with AoA increasing to nearly 30° and pitch decreasing to 30° nose-down before impact with the hangar. The study estimated a decrease in the airplane's groundspeed from 114 knots (at the start of the analyzed time) to 85 knots shortly before the airplane crashed into the hangar.

Sound Spectrum Study

A sound spectrum study was completed on a portion of the cockpit area microphone channel of the CVR recording to attempt to determine the airplane's groundspeed and propeller speeds during the takeoff roll and accident sequence, the characteristics of the click sounds recorded shortly after takeoff, and the condition of each engine's operation. Concurrent with the sound of the engines advancing in power, the study identified the presence of a signal in the sound spectrum that was determined to be the blade pass frequency of the propellers. After takeoff, this signal was one tone, consistent with both propellers turning at about the same speed. About 7 seconds later, at 0910:41, about the same time as the sound of a click was recorded, the tone diverged into two tones, consistent with one propeller turning slower than the other.

The CVR recording was also analyzed to identify other data pertinent to the engines' operation. A comparison of the CVR recording with shaft speed and gearbox ratio data provided by the engine manufacturer found that the sound frequencies corresponding to these data were likely masked by other sounds in the cockpit or exceeded the upper frequencies recorded by the CVR. No other engine information could be determined based on this analysis.

Using an exemplar B-300 cockpit, a ground test was conducted (with avionics on and engines not running) to determine if throttle movement (with idle detent contact) and the actuation of an unidentified flight deck switch would produce sounds similar to the two clicks recorded on the CVR (at 0910:41 and 0910:44). After adjusting energy levels in the accident recording (background noise on the accident flight may have masked frequencies of the click sounds), the energy levels from the first recorded click exhibited characteristics similar to the sound recorded during the test when the throttle contacted the idle stop. Similarly, the adjusted energy levels from the second click recorded during the accident flight exhibited characteristics similar to the sound recorded during the test when a flight deck switch was actuated. However, this comparison contains a high degree of uncertainty because of the differences in background noise levels.

Aircraft Performance Study

What do you mean? With opposite rudder you would expect zero sideslip angle, which is subject to engine-out flight-testing, including determination of V_{MCA}.

Based on analysis of the video study and data provided by Textron, the performance study found the airplane's initial sideslip angle (near 20° nose left) is consistent with the opposite rudder input needed to balance the yawing moment imparted by the thrust reduction in the left engine. Based on the airplane's estimated speed and propeller rpm when the propeller speeds diverged, the propeller manufacturer estimated that the thrust produced by the left engine dropped to near 0 while the right engine was likely operating at slightly less than maximum takeoff power.

Study was not good, see comments in the study, pdf page 40 below. Large effects of W·sin ϕ and δa on sideslip were not included.

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The performance study calculated that the thrust asymmetry alone was unable to produce the sideslip seen in the video. Yawing calculations estimated the airplane's rudder position to be 11° nose left 2 seconds after the loss of thrust in the left engine then, 2 seconds later, the left rudder decreased to 0°, and the rudder moved to exceed 20° nose right as the airplane's sideslip angle ultimately reached 16° nose right. The airplane's initial roll rate (the first 5 seconds after the propeller speed deviation) was about 5° left per second. Its left roll rate rapidly increased to more than 60° per second before rolling inverted.

were inappropriate

The performance study determined that, based on performance data provided by Textron, the airplane was within the tested bounds of controllability during the first 5 seconds after the thrust reduction while the roll rate was still relatively low. The data support that it would have been possible to maintain directional and lateral control of the airplane after the thrust reduction in the left engine if right rudder had been commanded ~~initially rather than left rudder~~.

+ small bank angle into good engine.

The performance study is not appropriate, was conducted by an incompetent specialist. Very disappointing. Was there nobody in the team who raised the red flag? I wrote the IIC quite a few notes on this, written using my flight-test knowledge gained at the USAF Test Pilot School, but she regrettably neglected these.

Not given thought to minimum control speed V_{MCA}? The left propeller was obviously not feathered, resulting in a higher actual V_{MCA} than the one published in the AFM/POH. A bank angle into the failed engine also increases the actual V_{MCA} considerable. V2 was not reached due to the drag caused by the large sideslip. Control was lost because the actual V_{MCA} increased above the airspeed of the airplane, despite the right thrust not being maximal.

Administrative Information

Investigator In Charge (IIC):	Rodi, Jennifer
Additional Participating Persons:	Matthew Rigsby; Federal Aviation Administration AVP; Fort Worth, TX Jennifer Barclay; Textron Aviation; Wichita, KS Marc Hamilton; Transportation Safety Board of Canada; Ottawa Les Doud; Hartzell Propeller; Piqua, OH Brandon Johnson; National Air Traffic Controllers Association; Salt Lake City, UT Marc Gratton; Pratt & Whitney Canada; Longueuil
Original Publish Date:	May 18, 2021 **Investigation Class:** 2
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=99731

Investigators should read paper *Airplane Control and Analysis of Accidents after Engine Failure* (#3) that can be downloaded for free from the Downloads page of the website of AvioConsult.

The National Transportation Safety Board (NTSB), established in 1967, is an independent federal agency mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

The Independent Safety Board Act, as codified at 49 U.S.C. Section 1154(b), precludes the admission into evidence or use of any part of an NTSB report related to an incident or accident in a civil action for damages resulting from a matter mentioned in the report. A factual report that may be admissible under 49 U.S.C. § 1154(b) is available here.

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March 2, 2021

NOTES

Beech 350 KADS accident docs, docket CEN19MA190, Date of Accident: 06/30/2019

Dear Dr. Rodi,

In July 2019, I was invited to write a post on the BeechTalk forum in the thread of this accident (page 77) because I wrote and presented many papers on maintaining control after engine failure using knowledge gained at the USAF Test Pilot School (TPS) of which I am a graduate Flight Test Engineer (1985). As expected, another invitation will follow to review the final NTSB report once it is released, which is the reason that I already reviewed the available studies in the docket of this accident.
I regret to have to let you know that a few of the reviewed studies and the excerpt of the POH Beech 300 are neither in agreement with airplane design methods as taught at aeronautical universities, nor with flight test techniques as defined by the FAA in Advisory Circulars which are taught at US Test Pilot Schools.
I believe it is fair to inform you, as the lead investigator, of my review, before again writing a right and proper post on the forum. My notes below might serve to assist you and your team in improving the final report of this accident, and in improving investigations of engine failure related accidents in the future.

During the past 25 years, more than 460 accidents after engine failure happened in countries that report on the Internet during which over 3200 people lost their life. Airplanes are designed and flight-tested to continue to fly safely while an engine fails or is inoperative. At the TPS, I learned flight-testing an engine-out airplane to determine its minimum control speeds and its handling qualities, and did not crash. I wondered why such accidents continue to happen. After reviewing more than 400 accident investigation reports, it became clear that (airline) pilots (and accident investigators) do not learn and know anymore what the limitations of an airplane are when an engine is inoperative, and how to prevent the loss of control. Most of these accidents happened because of Inappropriate Crew Response to Propulsion System Malfunction. Airplane Flight Manuals, POH's and training manuals do not present the flight restrictions after engine failure that apply as consequence of the design methods that airplane design engineers are allowed to use.
Loss of control was also number one on the Top 10 causes of General Aviation accidents of the NTSB. Obviously there is a knowledge gap to be bridged, which was the reason why I started writing and presenting papers on the subject of controllability after engine failure already 20 years ago.
I did not develop anything new on the subject, but merely try to write and explain how to prevent the loss of control after engine failure in a language that pilots and investigators might understand, rather than in academic terminology.

I wrote letters to the NTSB Office of Aviation Safety (10-23-2008) and to Board Member Dr. Earl F. Weener (03-27-2018), and to the industry in an attempt to contribute to deleting the loss of control from the NTSB Top 10 list, but received no adequate response. My letters must have fallen into the hands of ignorant people before they reached their addressee. This is why I write you now directly, because you are the lead investigator of the KADS accident and hold a PhD degree. I would like to recommend you to either download and read my paper for investigators (#3) from the Downloads page of my website, or – if you don't believe me – review FAA Flight Test Guides (FAA Advisory Circulars 23-8C: Section 4.4 § 23.149 and/ or 25-7C: § 5.4), textbooks of US Test Pilot Schools or college books of Dr. Jan Roskam (KU, ret.) before allowing your investigators to draw conclusions that are not in agreement with airplane design and flight-test, as already happened so often. If you will not review these publications yourself, please find a TPS graduate or an investigator within your organization who holds an aeronautical engineering degree. I don't blame anybody, but only knowledge can improve investigations. Pilots believe they know it all, which of course is not the case;

they didn't need an engineering degree to get a pilot license or become CFI, but such a degree is needed to enter a TPS and also to explain airplane control after engine failure. Links to the above mentioned documents are provided for your convenience on the Links page of my website.

I am on your side, I also want to prevent unnecessary accidents, like this one at KADS, to prevent people from dying. My 15 years long experimental flight-test career was devoted to accident prevention and developing meticulous flight procedures. Regrettably, people continue to die because the flight techniques to prevent the loss of control after engine failure were obviously not forwarded anymore to the mishap pilots in a comprehendible and appropriate way. A good accident investigation report with the right conclusions and recommendations could change that. After reading the referenced formal documents, my papers, or viewing the video on my YouTube Channel, you and your team will be able to write conclusions and recommendations that will indeed prevent similar future accidents.

Below are my unsolicited notes and observations of 5 documents in the above mentioned docket, accompanied by some clarification. Please take a close look at them, and use them to improve the final report.

1. Performance study

On page 12, the yawing moment equation is presented. This equation is incomplete; the yawing due to aileron coefficient is missing, while the aileron deflection, that was required to counteract the asymmetrical thrust rolling moment, contributed to the total yawing moment as well. This equation however, is only one of three simultaneous linear lateral-directional equations of motion. The other two, the lateral (rolling) moment and side force equations, cannot be left out when solving for the total sideslip. There are more side forces in the three equations that contribute to the sideslip. Rudder deflection generates an aerodynamic side force, which also creates the yawing moment that counteracts the asymmetrical thrust yawing moments. Airflow bending by the propeller of the good engine during a sideslip causes the destabilizing thrust bending side force ($T \cdot \sin \beta$). During banking, a side force due to weight and bank angle (through the term $W \cdot \sin \phi$ (or $mg\phi$) in the side force equation) acts in the center of gravity and adds to the other side forces acting on the airplane (in the body axis system), hence also on the side slip. Neither the calculated sideslip presented in Figures 8 and 10, nor the calculated rudder in Figure 11 can therefore be correct.

In this performance study, the minimum control speed $V_{MC(A)}$ is regrettably not mentioned. V_{MCA} is not correctly explained by most pilots and investigators. V_{MCA} is the lowest airspeed at which *straight flight* can be maintained and at which the drag is minimal, provided a small bank angle, that was also used for sizing the vertical tail with rudder (usually 5° into the good engine), is being maintained. The vertical tail is not designed large enough for maintaining control during banking / turning, but is as small as approved by FAR 23/25.149 for saving airplane weight and cost [Airplane Design Part II, Dr. Jan Roskam, KU]. Not maintaining the small favorable bank angle not only increases sideslip, hence drag decreasing the performance, but also increases V_{MCA} to a higher *actual* value, leading to the loss of control if the IAS is not increased first. When a large sideslip is allowed by deviating from the favorable 5° bank, the drag is large as well and the Rate of Climb reverts into a large Rate of Descent. Dr. Jan Roskam (KU) wrote in one of his college books for designing multi-engine airplanes: "*The $V_{MC(A)}$ value ultimately used ties takeoff performance to engine-out controllability*". The design engineer already 'chooses' the V_{MCA} and sizes the fin with rudder accordingly. More in § 2 below.

Not mentioned either is propeller feathering and its consequence on performance. Not feathering the propeller of a failed engine increases the thrust yawing moment, hence the sideslip and drag, decreasing performance.

The flight limitations that airplane design engineers are allowed to use and apply for engine-out flight, are regrettably not communicated anymore to pilots, are not mentioned anymore in Airplane Flight and Training Manuals and during multi-engine training, because manual writers and flight instructors are not made aware either anymore, which is the main cause of the many engine failure related accidents and casualties during the past 25 years – accidents due to forgotten knowledge. Performance at airspeeds as low as V_{MCA} is only maximal if straight flight is being maintained, while banking 5° into the good engine. At the airspeed for max. ROC, the small bank angle still needs to be 3°, or as determined by the manufacturer (and published with the OEI Performance data) for maximum performance.

The writer of this study is regrettably not aware of the controllability of multi-engine airplanes when an engine is inoperative, of the consequences of banking on performance and of the real value of V_{MCA}. The writer does not tie V_{MCA} and performance (sideslip – drag) together, as airplane design engineers do. Some homework is recommended: the papers on the Downloads page of my website (#1 and #2 are for pilots, #3 is intended for investigators), FAA Advisory Circulars 23-8C or 25-7C for engine-out testing and TPS textbooks for asymmetrical powered flight. Download links to these documents are presented on the Links Page of my website, including to the Airplane Design Series of books by Dr. Jan Roskam (KU), if still required.

2. Sideslip Thrust and Rudder Study (CEN15FA034, 2014)

In this study, conducted after a similar accident with a Beech 200, the sideslip was developed from a video study. On the video though, the full sideslip is shown, not the individual components / sources that add up to the full sideslip. As already mentioned in § 1 above, sideslip is not only resulting from yawing moments due to sideslip and rudder input, but also from yawing moments due to aileron deflection, the drag of a non-feathered propeller and the side forces that act on the airplane due to rudder deflection and the weight and bank angle.

In this sideslip study, the side forces due to rudder deflection and due to banking the airplane ($W \cdot \sin \phi$) are not included, while these side forces (in the body fixed axes system) were used to calculate the required size of the vertical tail for maintaining control after engine failure and during flight-testing to measure the V_{MCA} of the airplane. An equilibrium – whether all engines are operating or one engine is inoperative – can only be established if the sum of all of the moments and the sum of all of the forces that act on an airplane are both zero.

On page 4 is written: *"The results show that with full right rudder deflection, the airplane sideslip angle should have been near zero. A zero rudder deflection would result in an airplane sideslip angle between 14 – 19 degrees. A full left rudder deflection would result in an approximate airplane sideslip angle between 28 and 35 degrees ANL".*
When not only yawing moment coefficients would have been provided by Textron, but also the others, and all three simultaneous lat-dir equations would have been solved (see § 1 above), the sideslip calculations would have a different, more realistic outcome. Recommended is not to publish these results; they are definitely not right.

The POH-published V_{MCA} (page 5) is only valid, and control of the airplane at V_{MCA} can only be maintained, during straight (constant heading) flight while banking 5° away from the inoperative engine. This is a consequence of the tail design method and conditions that are approved by the authorities and published in FAR 23/25.149 (see § 1 above). The error made by the writer of this study and by other manual and textbook writers is that they copy or use a paragraph out of FAR 23/25.149, which allows the design engineer to use a bank angle of *maximum 5 degrees* for sizing the vertical tail. But once the tail is designed and installed on the airplane, the bank angle to be maintained for maintaining control should not be maximum 5 degrees, but the exact number of degrees that the manufacturer indeed used to size the vertical tail, while maintaining straight flight. The required bank angle for maintaining control is a fixed number, a constant value of usually 5 degrees, rather than a *'maximum of 5 degrees'*. Most pilots interpret this condition inappropriately or forgot about it because the bank limit is not understood or was never explained because CFI's don't know this anymore either, which might very well be one of the causes of loss of control accidents. This fixed bank angle was also used to measure V_{MCA} during flight-test. When this bank angle is not being maintained, the actual V_{MCA}, that is the V_{MCA} that the pilot experiences in-flight, will be higher. Wings-level V_{MCA} of the King Air might be at least 8 kt higher than the published and red-lined or placarded V_{MCA} and increases even higher when the bank angle increases into the dead engine. My study Effect of Bank Angle and Weight on V_{MCA} can be downloaded from the Downloads page of my website (#6).

The quoted definition of V_{MCA} out of the King Air 200 POH is therefore not quite correct. V_{MCA} is not determined during straight flight "with no more than 5 degrees of bank", but with exactly 5 degrees of bank or with a smaller bank angle as determined by the manufacturer, into the good engine. FAR 23.149, that is for design and certification, is inappropriately copied into the referenced POH, that is for flight operations. Although the quote includes that it is not advisable to fly at speeds approaching V_{MCA}, V_{MCA} is determined to be a safe minimum speed for maintaining straight flight. To ensure that control can be maintained, a pilot must maintain straight flight (using rudder) and a small bank angle of 5 degrees, or a little smaller as determined by the manufacturer, into the good engine to keep both V_{MCA} and the drag as low as possible, the performance as high as possible. The published V_{MCA} is not valid during turns; the actual V_{MCA} during banking will be a lot higher, for a twin even 30 kt or more higher at moderate bank angles! The manufacturer should publish this higher, safe turning speed in the AFM or POH.
Neither the quote of V_{MCA} nor this study mentions the loss of performance when the small favorable bank angle is not maintained. The sideslip, hence drag will not be minimal, the ROC might then be negative. In the legend of the OEI performance data the required bank angle should also be mentioned.

3. Video Study

As already mentioned above, in this study, although the body axes are mentioned, the side force component of the weight ($W \cdot \sin \phi$) and the side force due to rudder deflection ($Y_{\delta r}$) as important contributors to the sideslip are not mentioned. Pilots consider a bank angle to provide for a centripetal force for turning, but in the body axes system the lift vector has no contribution to side forces and sideslip. A knife edge maneuver, at airshows sometimes performed by fighter aircraft, can only be explained in the body axes system, because the bank angle is 90 degrees, while the airplane flies straight ahead.

4. Excerpt POH Beech 300

4.1. Page 3-9: Engine failure during takeoff (at or above V_1) – takeoff continued.

THE most important step (as memory item) to prevent the loss of control is missing in this POH procedure:

> **1a. Apply rudder to maintain straight flight, and aileron to maintain 5° into the good engine (same side as rudder)**

Pilots need to be reminded of this life-saving condition/ requirement.

Step 6 requires acceleration to 125 kt, and step 7 Climb to 1500 ft. If straight flight and the small (≈5°) bank angle into the good engine, that both originate from, and are control limitations/restrictions as consequence of airplane design and V_{MCA} flight-testing, are not being maintained, the sideslip angle might be considerable, as is the resulting drag which might not at all allow for the speed increase and climb. Safer would be to require straight (constant heading) flight at the speed for best rate of climb (V_{YSE}) while also maintaining a small 5° bank angle (or a little smaller for this speed – for minimum drag – as determined by the manufacturer) until reaching 1500 ft AGL. Then increase speed and turn, sacrificing altitude because of the increased drag. The actual V_{MCA}, that is the V_{MCA} that the pilot would experience in-flight when banking away from the favorable bank angle of 5° into the good engine, might be 30 kt or more higher during turns.

4.2. Page 3-9: Engine failure in flight below Air Minimum Control speed (V_{MCA})

Step 1 tells the pilot to reduce power as required to maintain control, which in itself is the only option to maintain control – by definition. But attaining a bank angle as small as 5° into the good engine reduces the actual V_{MCA} with 8 – 10 kt and is therefore worth mentioning, as well as maintaining straight flight. Actual V_{MCA} might also be lower than the red-lined or listed V_{MCA} if not all of the factors that have influence on V_{MCA} are at their worst case value.
When the airspeed is just below or decreases below the actual V_{MCA}, then the uncommanded change of heading due to asymmetrical thrust that cannot be counteracted with maximum rudder, and/ or the uncommanded banking that cannot be counteracted with maximum ailerons, are initially very slow. The question is whether pilots recognize a slow heading change as an imminent loss of control that requires immediate action: apply rudder (and/ or aileron) as to maintain heading (and bank angle) and if this is not adequate, reduce asymmetrical thrust (a bit, temporarily) until straight flight with a small 5° bank angle and an airspeed of at least V_{MCA} is attained, because there is nothing else to avoid a collision with the ground when at low altitude.

This POH, and obviously also the training manuals that the pilot of this airplane used for obtaining his multi-engine rating, require attention for preventing accidents in the future. So does also Chapter 12 of Handbook FAA-H-8083 Transition to Multiengine Airplanes.

Safety-critical procedure development requires high level multi-disciplinary knowledge, not only piloting skills. This is also the title of the paper I presented during the Safety and Procedures Forum of Eurocontrol in Brussels, 4 - 5 June 2019, which can be accessed via the Downloads Page of my website (#12).

5. Power Plant Group

No remarks on a feathered left propeller. Was it not or not fully feathered? Would be interesting to know for estimating the increase of V_{MCA} and decrease of performance due to additional propeller drag for improving the performance and sideslip studies.

Please do not hesitate to ask for further expertise in this investigation, for writing conclusions and recommendations that will really prevent similar future accidents, or for just reviewing the draft of the final report.

Yours sincerely,

Harry Horlings
Lt-Col RNLAF ret., Owner Avio*Consult*
Graduate FTE USAF Test Pilot School

Limited review by AvioConsult.com. Comments added in text boxes.

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.

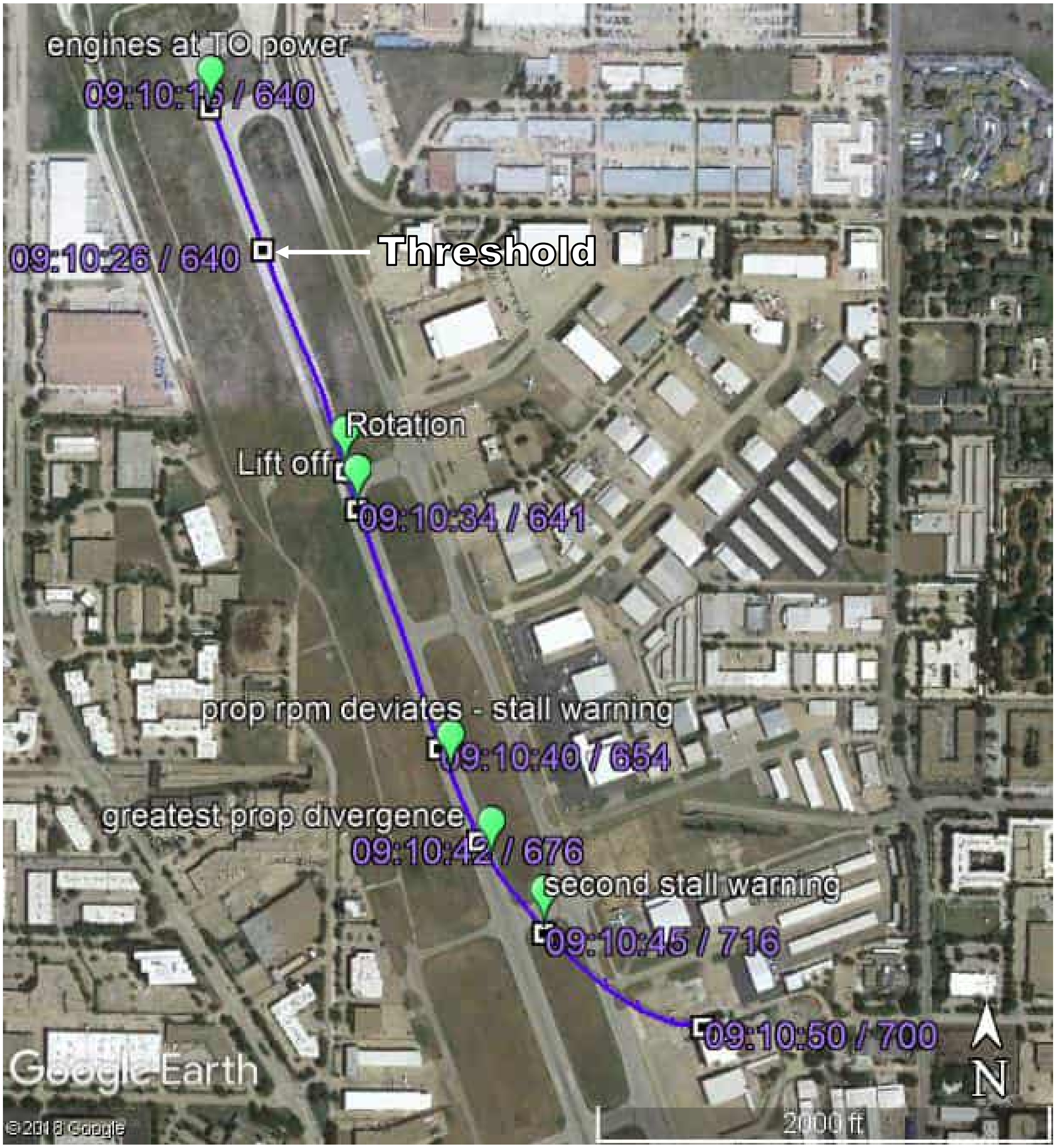

Figure 4. Composite flight path with CVR events.

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.

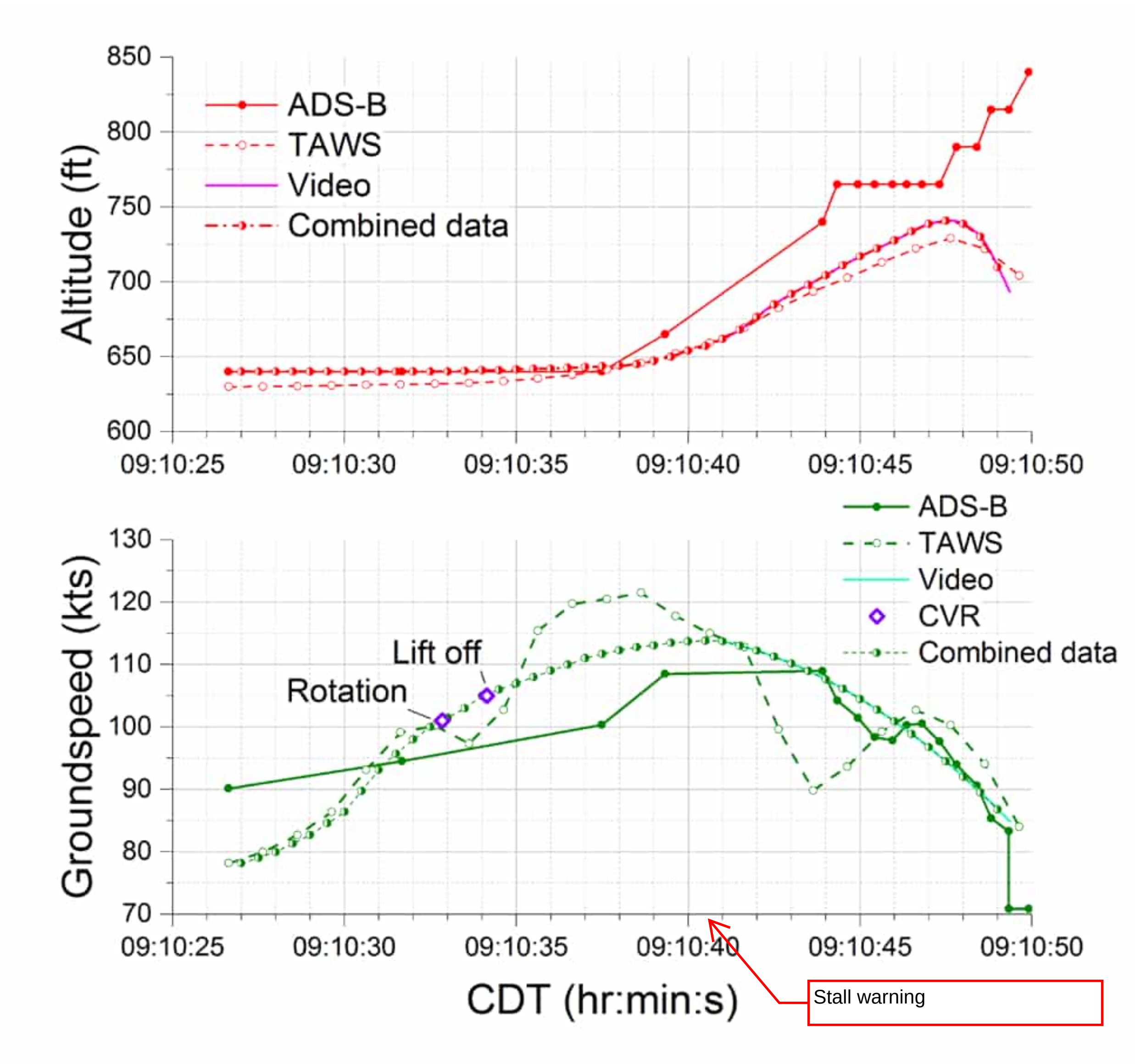

Figure 5. Accident flight altitude and groundspeed from multiple sources.

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.

Too early, given VR. These takeoff speed data should have been included here.

From Final report, POH data:
V1 106 kCAS
VR 110 kCAS
V2 117 kCAS
Vmca 96 kCAS, flaps up
Vmca 94 kCAS, appr. flaps 14°
VS?

Flight data:
VR 102 kCAS
VLOF 106 kCAS
POH VS?
At 110 kCAS a stall warning?
Sure? Bank was only 3° left!

Rotated at too low speed, 8 kt above Vmca, close to wings-level Vmca. VLOF was Vmca + 12? But asym. thrust was not max.

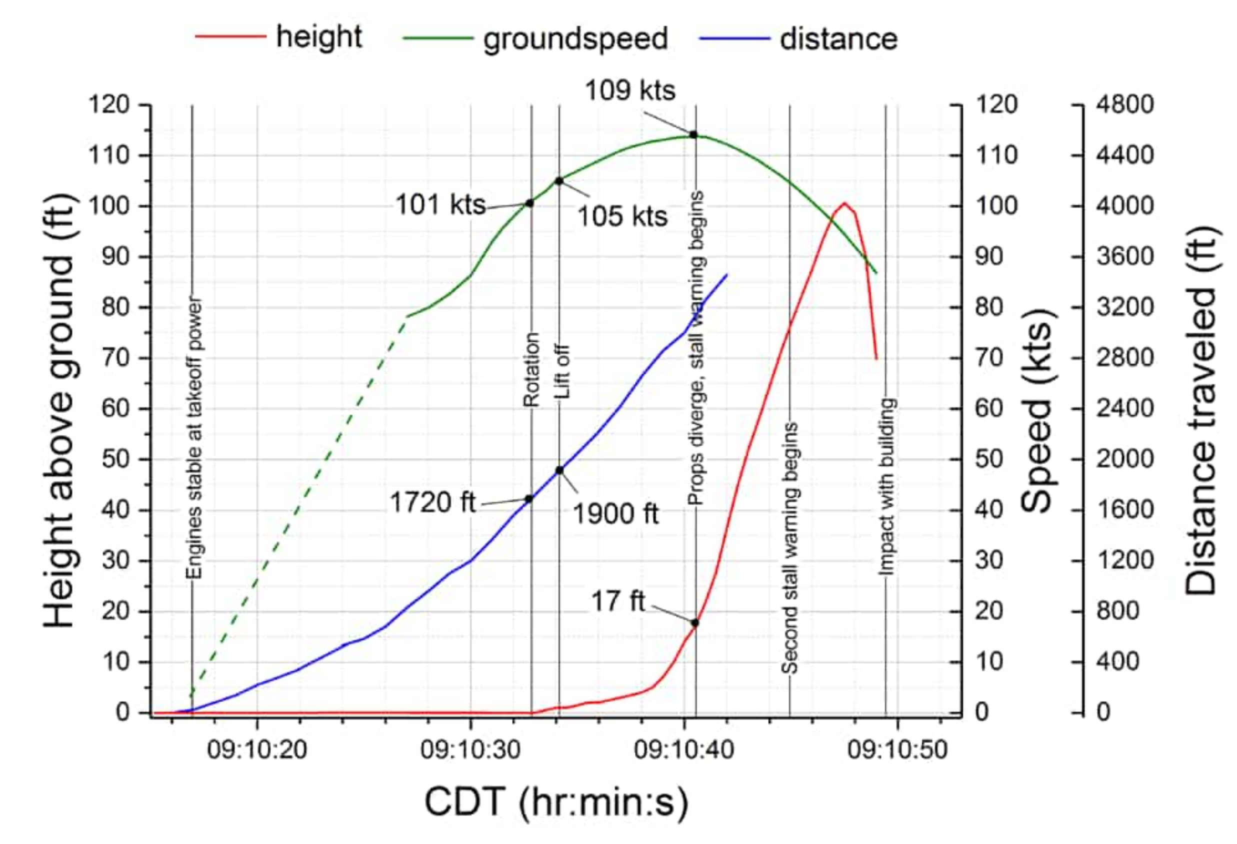

Figure 6. Height above ground, groundspeed, distance traveled, and selected CVR events.

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.

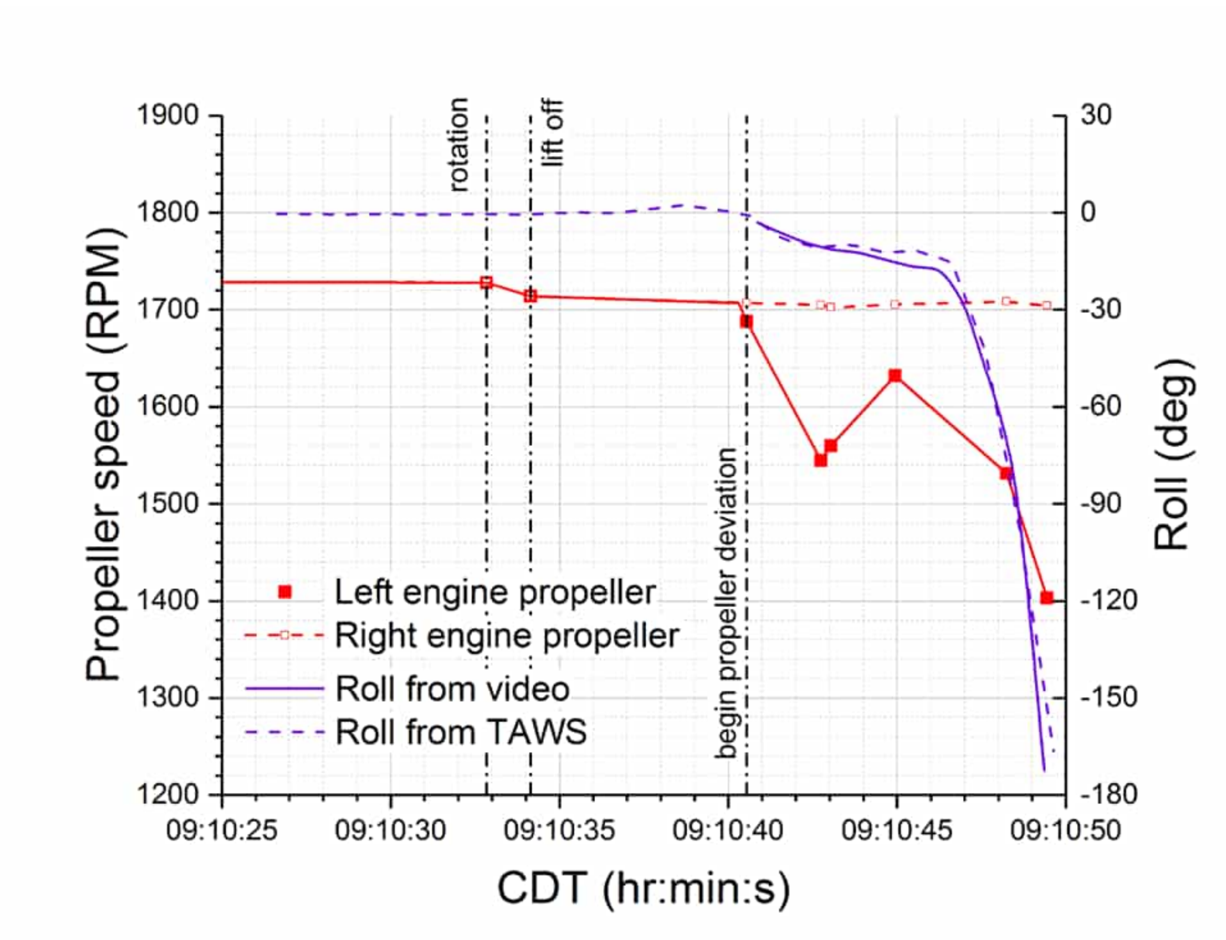

Figure 7. Accident flight propeller speeds and airplane roll angle.

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.

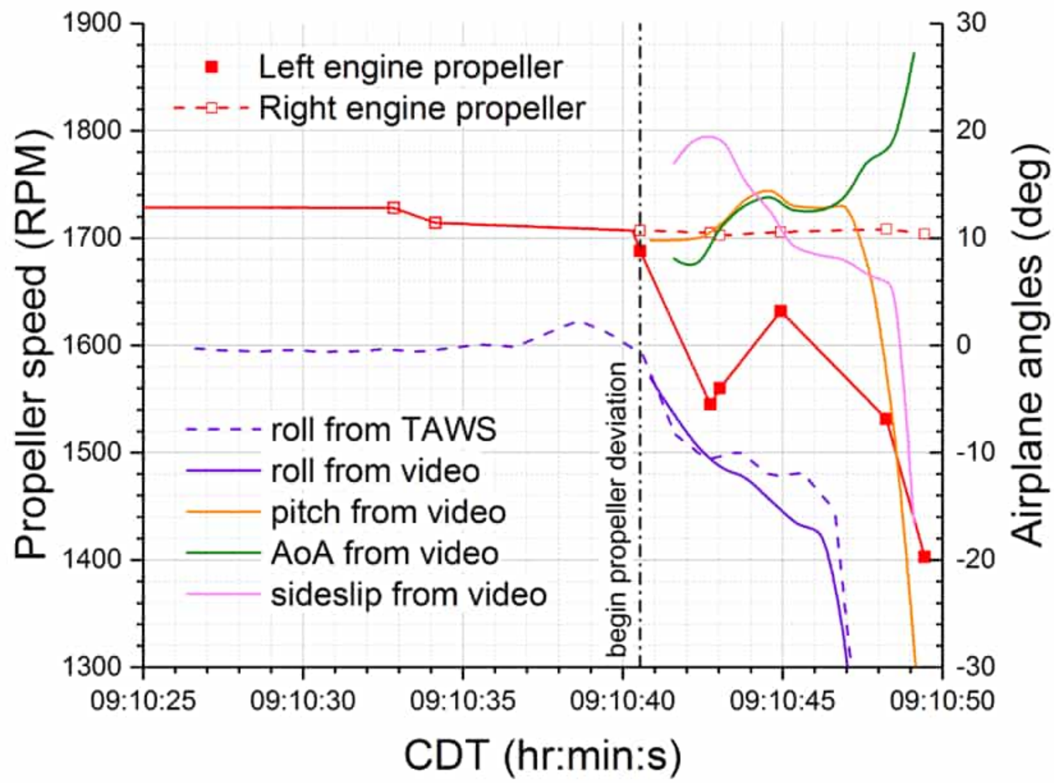

Figure 8. Accident flight propeller speeds and airplane roll, pitch, angle of attack (AoA), and sideslip.

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.

But the thrust vector shifts?
(which determines which engine
is the critical engine)

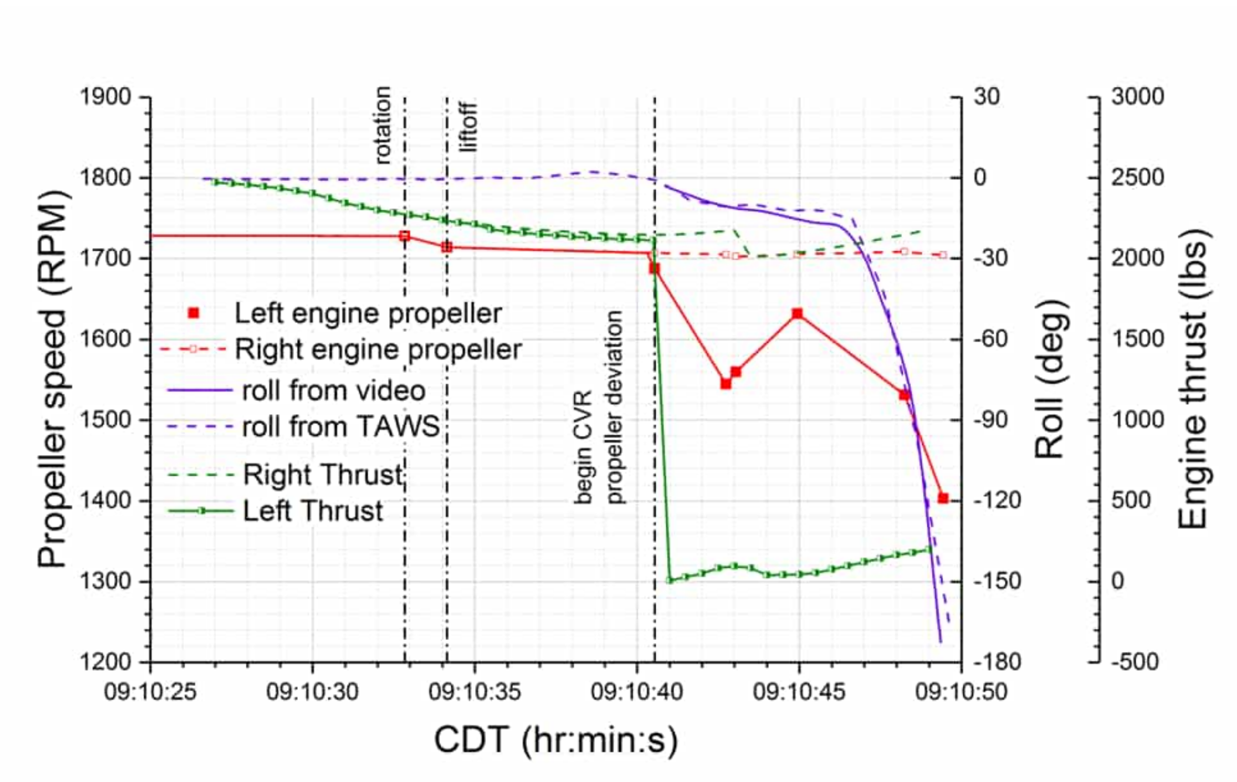

Figure 9. Accident flight propeller speeds, engine thrust, and airplane roll.

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

This is only one of three simultaneous lat-dir linear equations. For calculating β, you also need the lateral moment and side force equations, both have a β coefficient, the latter because of the large influence of weight and bank angle (W·sin ϕ or mgϕ) on the resulting sideslip. See bottom next page.

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

N_T

This equation is incomplete. Yawing due to aileron (Cnδa) coefficient is missing as is the large (W·sin ϕ or mgϕ).
Sideslip is an effect, not a cause.

N_T, usually called the yawing moment (thrust times thrust arm).

Sure? Should have presented these data.

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.

and right aileron to counteract the rolling moment to the left and attain and maintain a 5° bank angle to the good engine to lower Vmca.

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.

Not with Asym. thrust that caused yaw to the left, resulting in right sideslip (wind in right ear)? Is visible on video. The airplane doesn't continue to yaw to the left, can be because of neutral rudder. Roll continues seconds later because IAS < actual Vmca. Then W·sin ϕ causes an additional sideforce to the left. L_T is not mentioned: Roll due to thrust asymmetry (propulsive lift right wing).

Effects of weight and bank angle (W·sin ϕ) and ailerons not included. This figure is definitely wrong. Was left propeller feathered?

Valid for what airspeed?

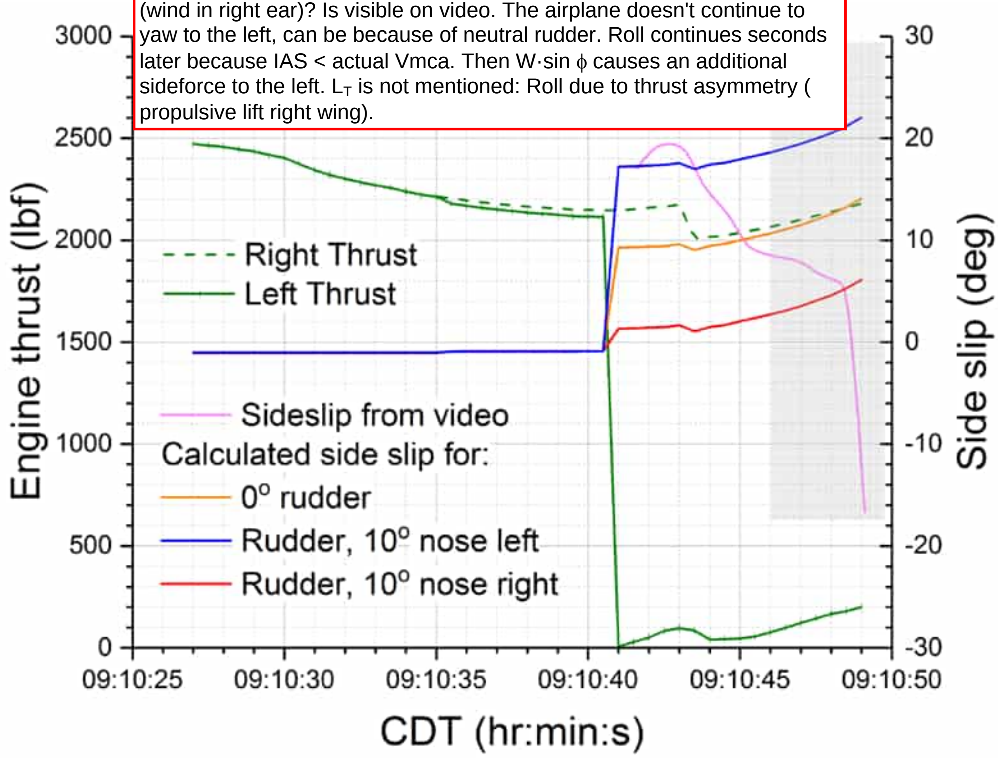

Figure 10. Calculated sideslip for 10° nose left rudder, no rudder, and 10° nose right rudder versus accident sideslip from the video analysis.

These are the 3 Lat-Dir equations of motion that need to be solved simultaneously for obtaining valid (sideslip) data.
Forces, moments and coefficients are (to be) in the body-fixed axes system.

Wing lift does not have a lateral component in this axis system, weight (mg) does.

Refer to papers #6 and #3 on the Downloads page of the website of AvioConsult.

$$C_{y_\beta}\beta_{trim} + C_{y_{\delta_a}}\delta_{a_{trim}} + C_{y_{\delta_r}}\delta_{r_{trim}} = \frac{-F_y}{\bar{q}S} - \frac{mg\Phi}{\bar{q}S} - C_{y_0}$$

$$C_{l_\beta}\beta_{trim} + C_{l_{\delta_a}}\delta_{a_{trim}} + C_{l_{\delta_r}}\delta_{r_{trim}} = \frac{-L_T}{\bar{q}Sb} - C_{l_0}$$

$$C_{n_\beta}\beta_{trim} + C_{n_{\delta_a}}\delta_{a_{trim}} + C_{n_{\delta_r}}\delta_{r_{trim}} = \frac{-N_T}{\bar{q}Sb} - C_{n_0}$$

Effect of side forces due to weight and bank angle and due to aileron deflection are not included, so this calculation cannot be correct.

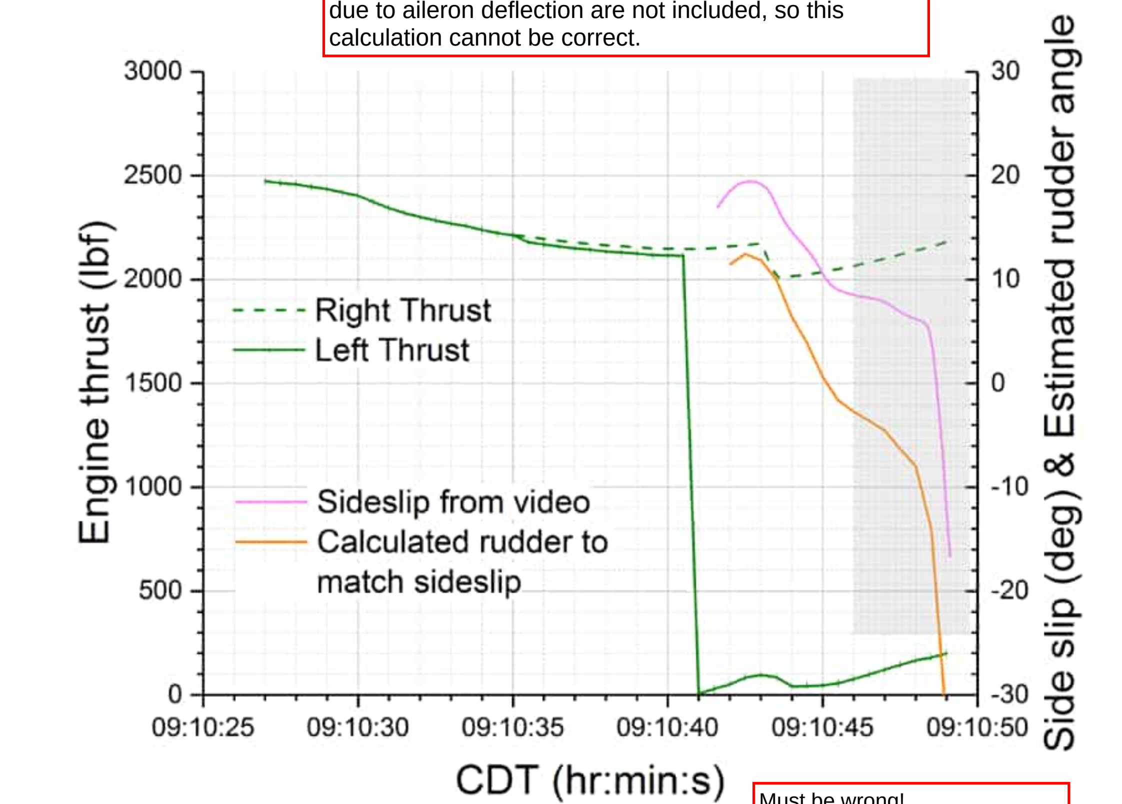

Figure 11. Calculated rudder to match sideslip from video.

Must be wrong!
Other sideslips sources than rudder are not included.

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.

So indeed a training issue? Or also an inappropriate analysis?

Because other sources of yawing moments and sideslip were not included by the specialist: W·sin ϕ (or mgϕ in radians, the effect of weight and bank angle in the body axes system), thrust bending (T·sin β) and ailerons deflection.

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.

That is what airplanes always do: during a roll to the left, the left wing 'drops'. This airplane rolled because the propulsive lift on the right wing was much higher than on the left wing (L_T) and because of the roll due to rudder ($C_{L\delta r}$).These two factors were regrettably not used by the NTSB specialist, rendering the conclusions useless.

First, left yaw due to asym. thrust. Then roll (video).

while maintaining a small bank angle into the good engine.

not really controllable. Only straight flight is required during certification.

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.

V_{MCA} is regrettably not mentioned at all, nor the increase of V_{MCA} and the increase of sideslip/ drag due to bank angle.

Published V_{MCA} was 96 kCAS, when wings kept level, V_{MCA} will be higher, could be 106 kCAS. Since the prop. was not feathered, V_{MCA} increased even more. Allowing a bank angle into the failing engine increases V_{MCA} most. The actual V_{MCA} must have been much higher than the IAS; loss of control could not be avoided.

Marie Moler
Specialist – Aircraft Performance
National Transportation Safety Board

The most important conclusion was not drawn: The pilot did not maintain takeoff/runway heading using up to full rudder and banking 5° towards the operative engine (same side as rudder) when an uncommanded yaw was experienced,

E. REFERENCES

1. Cockpit Voice Recorder Factual Report, CEN19MA190, National Transportation Safety Board, 2020.
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.

https://dms.ntsb.gov/pubdms/search/hitlist.cfm?docketID=58260&CFID=2539025&CFTOKEN=e0e0cab7c701c04f-560EDC0C-A25B-38FC-44D51D227217E066

Limited review by AvioConsult.com. Comments added in text boxes.

ENGINE FAILURE DURING TAKEOFF (AT OR ABOVE V_1) - TAKEOFF CONTINUED

1. V_R Speed . . . . ROTATE TO APPROXIMATELY 10° PITCH ATTITUDE
2. Landing Gear (when positive climb established) . . . . UP
3. Airspeed . . . . MAINTAIN V_2 TO 400 FT AGL
4. Propeller (inoperative engine). . . . . VERIFY FEATHERED

+ Apply rudder to maintain straight flight (runway heading) and bank 5° into good engine for min. drag and lowest V_{MCA}.

WARNING

Do not retard the failed engine power lever until the autofeather system has completely stopped propeller rotation. To do so will deactivate the autofeather circuit and prevent automatic feathering.

5. Flaps (at 400 ft AGL minimum) . . . . UP AT V_2 + 9
6. Airspeed . . . . INCREASE TO 125 KNOTS
7. Climb to 1500 ft AGL, then accomplish the following cleanup procedures on the inoperative engine:

   while maintaining a small bank angle of 3° or as recommended by the manufacturer (to reduce the sideslip, hence drag.

   a. Condition Lever . . . . FUEL CUTOFF
   b. Prop Lever. . . . . FEATHER
   c. Firewall Fuel Valve . . . . CLOSE

   EXTINGUISHER PUSH & CLOSED - ILLUMINATED

   d. Generator . . . . OFF
   e. Engine Auto Ignition . . . . OFF
8. Autofeather. . . . . OFF
9. Brake Deice (if installed) . . . . OFF
10. Electrical Load . . . . MONITOR

ENGINE FAILURE IN FLIGHT BELOW AIR MINIMUM CONTROL SPEED (V_{MCA})

V_{MCA} = 94 KIAS (flaps appr. 14°)

1. Power . . . . REDUCE AS REQUIRED TO MAINTAIN CONTROL
2. Nose . . . . LOWER TO ACCELERATE ABOVE V_{MCA}
3. Power . . . . AS REQUIRED
4. Engine . . . . SECURE

(See ENGINE FIRE OR FAILURE IN FLIGHT procedure.)

No annotations in the remainder of this excerpt.
No Performance data found in this excerpt. Therefore remaining 30 pages not included here. Refer to the docket.

Good point, but power can be increased to max. when a bank angle of 5° into the good engine is attained and rudder is increased to max. simultaneously with the power increase.