Aviation Investigation Final Report

Location:	Snohomish, Washington	**Accident Number:**	WPR23FA034
Date & Time:	November 18, 2022, 10:19 Local	**Registration:**	N2069B
Aircraft:	TEXTRON AVIATION INC 208B	**Aircraft Damage:**	Substantial
Defining Event:	Aircraft structural failure	**Injuries:**	4 Fatal
Flight Conducted Under:	Part 91: General aviation - Flight test		

Analysis

The pilot and three other crew members were performing flight testing for a new Supplemental Type Certificate (STC) for the single-engine turboprop-powered airplane. After departure, the pilot performed several maneuvers from the test card, then configured the airplane with the flaps extended for an intentional accelerated stall in a 30° left bank with the engine torque set to 930 ft-lb.

Analysis of ADS-B data combined with a simulation matching the recorded trajectory of the accident maneuver revealed that, after the stall, the airplane rapidly rolled to the left, reaching a roll angle of 120° while the pitch angle decreased to 60° nose down. The airspeed rapidly increased, exceeding both the maximum flaps-extended speed (Vfe) and the airplane's maximum operating speed (Vmo). Recorded engine data indicated that, after the stall, the engine torque increased. ADS-B data was lost at an altitude about 7,000 ft above ground level; the final track data indicated an approximate 8,700 ft/min rate of descent. Witnesses observed the airplane break up in flight and subsequently spiral to the ground. The wreckage was found in a rural field distributed over a distance of about 1,800 ft.

Analysis of the aerodynamic loads in an overspeed condition showed that the wing design stress limit loads would be exceeded at high speeds with full flaps. The simulation of the stall maneuver indicated that reducing engine power to idle after the nose dropped could have reduced the rate at which the airspeed and associated aerodynamic loads increased, and would have likely given the pilot more time to recover.

The airplane was equipped with an Electronic Stability and Protection (ESP) system, which was designed to deter attitude and airspeed exceedances during hand-flying and maintain stable flight by applying an opposite force to the direction of predetermined travel. It was designed to provide a light force that can be overcome by the pilot. To deactivate the ESP, the pilot needed to navigate to a specific page in the primary function display (PFD). Although the accident pilot was an experienced test pilot and qualified to operate the airplane, his experience with the accident airplane's avionics system could not be determined. Videos of his previous flights in the airplane suggested that he was unfamiliar with the ESP system, as he did not deactivate it before the flight nor discuss the forces it was applying during the flight.

Onboard video recording from a test flight the day before the accident indicated that, while performing a turning stall at idle power and 30° of left bank with the wing flaps extended, the airplane rapidly entered a left roll to a maximum of 83° before the pilot recovered to a wings-level attitude. After recovery, the pilot pitched the airplane's nose down about 25° in order to "get some airspeed back," during which the ESP activated the autopilot to effect recovery to a level attitude. The airplane continued to gain airspeed, exceeding the Vmo of 175 knots and reaching 183 knots indicated airspeed, before pilot arrested the airplane's acceleration and disconnected the autopilot.

These two exceedances illustrated shortcomings in the test execution. First, although the 83° roll exceeded the allowable roll limit during this maneuver, the crew failed to identify this exceedance even though they discussed what angle had been reached and had a data acquisition system on board, which they could have consulted to determine the maximum roll angle reached during the maneuver. Correctly identifying the roll exceedance would have resulted in a "failed" test. In accordance with risk mitigation procedures for the test plan, the test buildup should have been stopped after roll limits were exceeded in order to determine the reasons for the exceedance and to implement corrective actions before proceeding with higher-risk conditions in the test plan. Secondly, after exceeding Vmo, the crew did not remark upon the exceedance, and even though the exceedance met the requirements for an overspeed inspection as described in the airplane's maintenance manual, there was no indication that this inspection was completed.

The accident flight simulation indicated that, during the stall immediately preceding the accident, it is likely that the ESP activated as the airplane pitched in excess of 19° nose-up. This would have required the pilot to apply more aft force on the control column in order to induce the stall. After the stall, the ESP would have activated at 45° bank, then deactivated as the airplane quickly exceeded 75°. The extent to which the control forces from the ESP, or the potential distraction due to the system's engagement and disengagement, may have contributed to the pilot's failure to recover from the nose-low attitude following the stall could not be determined.

FAA guidance warns of the risks associated with upset events during stall maneuvers and advises against performing accelerated stalls with flaps deployed due to the increased risk of exceeding the airplane's limitations in this configuration. Following a nose-low departure from controlled flight, reducing the power to idle immediately is crucial to avoid exceeding airspeed limitations and overstressing the airplane.

The circumstances of the accident flight are consistent with the pilot's improper recovery from a nose-low attitude following an intentional aerodynamic stall. Whether the increase in torque following the stall was the result of intentional application of power by the pilot could not be determined; however, the pilot's failure to reduce engine power to idle following the airplane's departure from controlled flight was contrary to published guidance as well as test flight hazard mitigation procedures. It is likely that this resulted in the airplane's rapid exceedance of its airspeed limitations, and subsequently, a structural failure and inflight breakup.

Probable Cause and Findings

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

The pilot's improper recovery following a departure from controlled flight after an intentional aerodynamic stall, which resulted in an exceedance of airspeed limitations, airframe overstress, and a subsequent inflight breakup.

Findings

Personnel issues	Lack of action - Pilot
Personnel issues	Aircraft control - Pilot
Aircraft	Airspeed - Capability exceeded

Factual Information

History of Flight

Maneuvering	Aircraft structural failure (Defining event)

On November 18, 2022, at 1019 Pacific standard time, a Textron Aviation 208B, N2069B, was substantially damaged when it was involved in an accident near Snohomish, Washington. The two airline transport pilots and two flight test crewmembers were fatally injured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 test flight.

The operator, Raisbeck Engineering, held the STC for an aerodynamic drag reduction system (DRS) on the Cessna 208B. The accident flight was part of the testing for Raisbeck to expand the applicability of that DRS to the Cessna 208B EX model modified with the Aircraft Payload Extender (APE III) STC, developed by AeroAcoustics Aircraft Systems Inc. QuickSilver Aero was contracted to provide instrumentation support for Raisbeck's flight test program. At the time of the accident, the Raisbeck DRS STC was not installed.

The airplane began flights to support the flight test three days before the accident. The three flights on the first day comprised a total of 1.1 hours and included a pilot familiarity flight and a ferry flight to have the airplane's weight and balance measured. Two days before the accident, the flight test data collection flights began. Those included two flights, totaling 4.6 hours, to gather baseline data for both mid center-of-gravity (CG) cruise flight and forward CG stall speeds. The day before the accident, two test flights were performed with the accident test pilot and the accident aft-seated testing personnel. The purpose of the first flight, totaling 1.2 hours, was to test aft CG static stability. The last flight that day, totaling 1.4 hours, was terminated prematurely with only about half of the test plan (card) completed, because an aft crewmember was feeling airsick.

The purpose of the accident flight was to complete the test card from the previous day, which consisted of baseline testing of the aft CG stall characteristics of the airplane modified with the APE III STC. A review of ADS-B and radar track data revealed that the airplane departed Renton, Washington, around 0925, and continued to the north in a gradual climb to about 9,500 ft mean sea level (msl) and began a series of turns/maneuvers. The airplane proceeded for about 45 minutes, its altitude varying between about 6,500 ft to 10,275 ft msl.

The combination of ADS-B and winds aloft information indicated that, at 1017:00, the airplane was in a nearly level, 10° left-banked turn at 10,000 ft msl and about 110 knots calibrated airspeed (KCAS). Around 1017:20, the airplane climbed about 100 ft while slowing to between 90 and 105 KCAS. Shortly thereafter, a gradual left roll increased to 30° and the altitude began steadily decreasing at a rate of about 400 ft per minute (fpm), with the airplane descending from 9,700 ft to 9,350 ft msl by 1018:46. The airspeed remained constant at approximately 105 KCAS between 1018:20 and 1018:44. Engine torque was consistent about 930 ft-lb between 1016:50 and 1019:05. At 1018:43, the computed airspeed dropped rapidly, reaching a minimum of 48 KCAS at 1019:01 before sharply increasing. Engine torque also abruptly increased, reaching 2,200 ft-lb at 1019:20.

Indicated airspeed recorded by the Pratt & Whitney engine monitoring system (FAST) measured 35 knots indicated airspeed (KIAS) at 1019:00 and 37 KIAS at 1019:03 before quickly rising to a maximum of 223 KIAS at 1019:21, then dropping to approximately 80 KIAS as the airplane descended. During this period, the altitude increased from 9,320 ft to 9,680 ft msl between 1018:47 and 1018:59 as airspeed decreased. Vertical speed decreased from +2,560 fpm at 1018:54 to -14,000 fpm at 1019:13. Between 1019:25 and the end of the FAST data at 1019:52, the computed average vertical speed reached about -12,000 fpm.

At 1019:05, the ADS-B data indicated a sudden and tight course reversal from east to west, corresponding with the minimum airspeed and a dramatic increase in the descent rate. The computed roll angle stayed consistent at about 30° left until the course reversal. The ADS-B data stopped at 1019:17 about 7,025 ft msl with a recorded descent rate of 8,700 fpm (see Figure 1 below). The location of the wreckage, witness statements, and video footage were all consistent with the airplane breaking apart inflight shortly thereafter. The main wreckage was located about 2,145 ft east of the last recorded return.

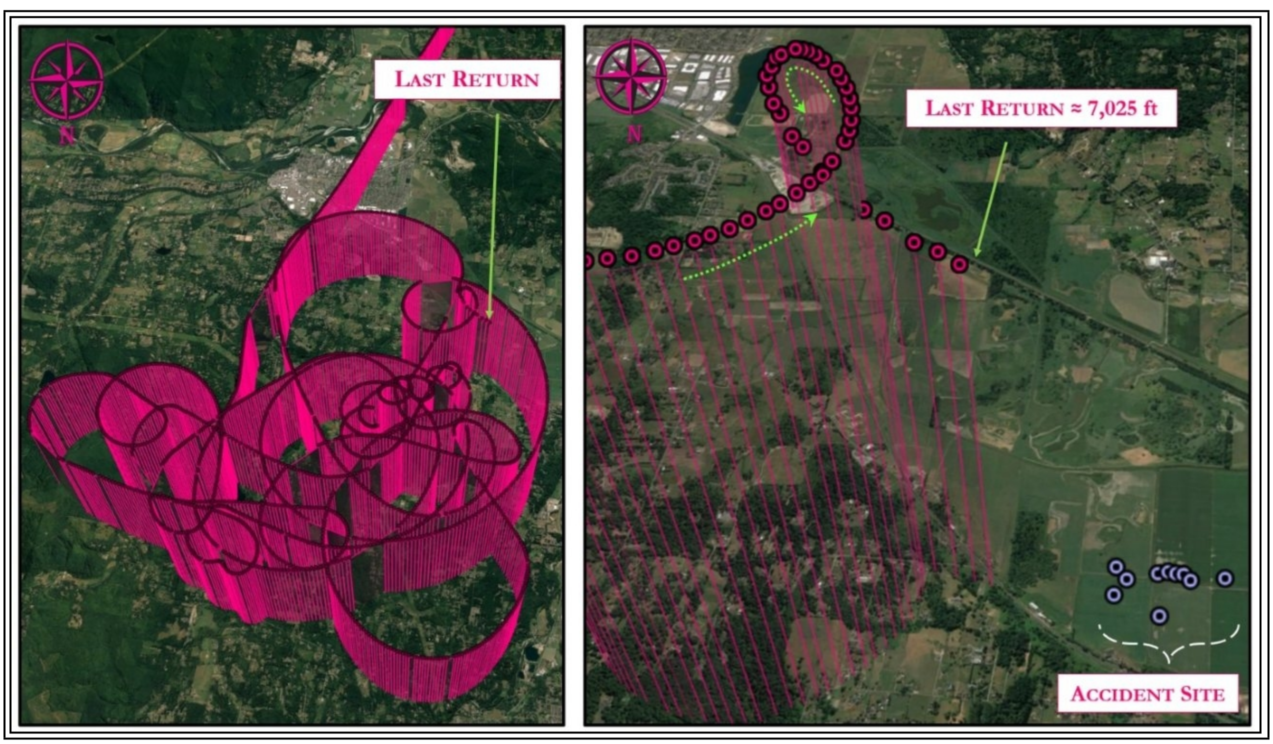

Figure 1: Radar data of maneuvers during flight (left) and last turn (right)

Witnesses reported that they observed the airplane break up in flight and watched pieces floating down. The airplane then descended in a nose-low, near-vertical corkscrew maneuver toward the ground. Several witnesses reported seeing a white plume of smoke when they observed the airplane break into pieces. A security camera recorded a low-quality image of the airplane rotating about its longitudinal axis in nose-low attitude (see figure 2 below).

Figure 2: Picture from witness (left) and excerpts of video still images (right)

The airplane's flight test data acquisition system, used as part of the flight test program, was destroyed in the accident and no flight test data for the accident flight was recovered.

The right seat pilot who flew the test flights the day before the accident reviewed the track data for the accident flight. He believed that just before the accident, the crew were likely performing second-to-last maneuver on the card, which specified: airspeed 96 KIAS; flaps in landing configuration; 930 ft-lbs of torque; propeller rpm fully forward; and accelerated 30° bank to the left.

The airplane's maneuvers and speeds leading up to the minimum airspeed recorded at 1019:01 suggests the performance of an intentional stall in a 30° left roll with the engine power above idle (at about 930 ft-lb of torque), consistent with the stated intent of the flight and the items remaining on the flight test card for that flight (including a power-on stall in a 30° bank).

Co-pilot Information

Certificate:	Airline transport; Flight instructor	**Age:**	52,Male
Airplane Rating(s):	Single-engine land; Single-engine sea; 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):	Airplane multi-engine; Airplane single-engine	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	March 21, 2022
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	May 25, 2022
Flight Time:	(Estimated) 10600 hours (Total, all aircraft), 5000 hours (Total, this make and model)		

Pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	67,Male
Airplane Rating(s):	Single-engine land; 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):	Airplane multi-engine; Airplane single-engine	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	March 3, 2022
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	October 1, 2021
Flight Time:	(Estimated) 11720 hours (Total, all aircraft), 232 hours (Total, this make and model)		

The test pilot was seated in the front left seat. He was contracted by Raisbeck through the company's Organization Designation Authorization program, which allows Raisbeck to perform specific functions on the FAA's behalf. On August 1, 2022, he completed the FAA recurrent training for a Designated Engineering Representative/Flight Test Designee.

The pilot's personal flight records were not recovered, but information provided to the insurance company before the accident indicated 11,720 total hours of flight experience, of which 232 hours were in the accident airplane make and model.

The right seat pilot had accrued 10,900 total hours of flight experience, of which 5,000 hours were in the accident airplane make and model.

Aircraft and Owner/Operator Information

Aircraft Make:	TEXTRON AVIATION INC	**Registration:**	N2069B
Model/Series:	208B EX	**Aircraft Category:**	Airplane
Year of Manufacture:	2021	**Amateur Built:**	
Airworthiness Certificate:	Experimental (Special)	**Serial Number:**	208B5657
Landing Gear Type:	Tricycle	**Seats:**	12
Date/Type of Last Inspection:	Continuous airworthiness	**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	1 Turbo prop
Airframe Total Time:		**Engine Manufacturer:**	P&W CANADA
ELT:	Installed	**Engine Model/Series:**	PT6A-140
Registered Owner:	COPPER MOUNTAIN AVIATION LLC	**Rated Power:**	867 Horsepower
Operator:	Raisbeck Engineering	**Operating Certificate(s) Held:**	None

The Textron Aviation (formerly Cessna) 208B EX Grand Caravan is a single-engine, propeller-driven, single-pilot airplane originally designed as the 208 for the first production model certified in 1984. The 208B incorporates a fuselage extended by 4 feet and was certified as an 11-seat passenger airplane in 1989. The high-wing airplane is equipped with wing struts, a conventional tail, fixed tricycle landing gear, and an underbelly cargo pod. The airplane is powered by a single Pratt & Whitney Canada PT6A-140 turboprop engine driving a McCauley 4-blade, constant speed, full feathering, reversible pitch propeller. The airplane is certificated in the normal category, which includes maneuvers incidental to normal flying such as stalls (except whip stalls), lazy eights, chandelles, and turns with bank angles not more than 60°. Aerobatic maneuvers, including spins, are not approved.

On November 1, 2022, AeroAcoustics Aircraft Systems STC SA01213SE, Aircraft Payload Extender (APE) III, was installed on the airplane. The STC adds wing stall fences to both wings outboard of the landing lights, new main landing gear axles, and 29-inch main landing gear tires to increase the maximum takeoff and landing weights and increases the payload and range.

On November 11, 2022, AeroAcoustics Aircraft Systems STC SA01805SE, Aircraft Payload Extender STOL, was installed on the airplane. The STC installs a scalloped Gurney flap on the trailing edge of each flap to improve the low-speed aerodynamics of the wing.

On November 14, 2022, the FAA issued a Special Airworthiness Certificate in the Experimental category for the purpose of research and development for the airplane. The certificate was requested by Raisbeck Engineering to perform company flight testing for the development of an STC for the airplane.

The installed STCs on the airplane imposed limitations beyond those published in the Pilot's Operating Handbook (POH):

Limit Speeds (IAS):	Maneuvering Speed at 9,062 lbs = 143 kt
Maximum Weights:	Takeoff: 9,062 lbs
Limit Factor:	Flaps up: +3.36, -1.34
Limits (g's):	Flaps down (all settings): +2.00
Max Operating Speed (Vmo):	175 KIAS
Maneuvering Speed (VA):	148 KIAS (at 8,807 lbs)
Max Flap Extended Speed (Vfe):	125 KIAS (Land) ; 150 KIAS (Takeoff)
Flap Operating Range:	50-125 KIAS

The airplane's approximate weight at the time of the accident was 7,965 lbs with the CG at 203.5 inches. The airplane's aft CG limit is 204.35 inches aft of datum at all weights up to 8,807 lbs. The datum is located 100 inches forward of the face of the firewall.

The airplane was equipped with a Garmin G1000NXi integrated glass cockpit. Included is an electronic flight instrument system (EFIS) composed of 2 primary flight displays (PFDs) and a multi-function display (MFD). Incorporated is the GFC 700 Automatic Flight Control System (AFCS), a fully digital, three-axis, dual channel, fail passive autopilot.

The airplane was also equipped with an Electronic Stability and Protection (ESP) system, which operates through the air data computers, the attitude and heading reference system (AHRS), and autopilot servos in the integrated avionic systems independently of the autopilot. According to the Garmin G1000NXi Pilot's Guide for the Cessna Caravan:

Electronic Stability and Protection (ESP™) is an optional feature that is intended to discourage the exceedance of attitude and established airspeed parameters. This feature will only function when the aircraft is above 200 feet AGL and the autopilot is not engaged.

ESP engages when the aircraft exceeds one or more conditions (pitch, roll, and/or Vmo) beyond the normal flight parameters. Enhanced stability for each condition is provided by applying a force to the appropriate control surface to return the aircraft to the normal flight envelope. This is perceived by the pilot as resistance to control movement in the undesired direction when the aircraft approaches a steep attitude or high airspeed.

As the aircraft deviates further from the normal attitude and/or airspeed, the force increases (up to an established maximum) to encourage control movement in the direction necessary to return to the normal attitude and/or airspeed range. For all conditions except for high airspeed, once maximum force is reached, force remains constant up to the maximum engagement limit. Above the maximum engagement limit, forces are no longer applied. There is no maximum engagement associated with high airspeed.

The ESP can be enabled or disabled in a System Setup page within the MFD. It can also be interrupted by the pilot by pushing and holding either Control Wheel Steering (CWS) or Autopilot Disconnect (AP DISC) switch on the control yoke. Upon releasing either switch, ESP will again apply control force, provided aircraft attitude and/or airspeed are within engagement limits.

Roll Limit Indicator bars are displayed on the attitude indicator where the 45° left and right bank hash marks are located. This indicates that the ESP will engage as the roll exceeds 45° and the Roll Limit Indicator bars will move to the 30° and 75° degree positions, which shows where ESP will disengage as roll attitude increases/decreases (i.e., ESP will disengage once roll is returned to 30° or beyond 75°). Once engaged, ESP force varies. The force increases as bank angle increases with maximum servo torque attained at 60°.

For the Cessna Caravan, the ESP system engages at 19° nose up and 20° nose down. Once engaged, it applies opposing force between 17° and 50° nose up and between 18° and 50° nose down. Maximum opposing force is applied between 24° and 50° nose up and between 25° and 50° nose down. The opposing force increases or decreases depending on the pitch angle and the direction of pitch travel. For pitch recovery, ESP applies a maximum force of 15 lbs and is limited to about 1.3G or 1.5G, depending on manufacturer specifications. The system disengages when engagement parameters, such as pitch attitude or airspeed, are no longer met, but leaves the airplane's trim unchanged.

There are no indications marking the pitch ESP engage and disengage limits in these nose-up/nose-down conditions, nor is there an indication when it is activated.

If Vmo (175 kts) is exceeded, the ESP activates and applies force to raise the nose of the aircraft until the overspeed condition is resolved. There is no minimum airspeed protection.

In the roll axis, the only indication of ESP engagement other than the roll indices on the PFD moving to 30° is the additional control wheel force perceived by the pilot. The wheel force applied varies from 0 lbs at 30° bank to a typical maximum of 15 lbs at 60° bank. At 45°, ESP engages at 50% of the maximum force to ensure the pilot notices activation. Even if the pilot applies counteracting force, the system does not disengage.

In the pitch axis, the only indication of ESP engagement is the additional column force perceived by the pilot. The Pilot's Guide states that:

Once ESP is engaged, it will apply opposing force between 17° and 50° nose-up and between 18° and 50° nose-down. … Maximum opposing force is applied between 24° and 50° nose-up and between 25° and 50° nose-down.

The opposing force increases or decreases depending on the pitch angle and the direction of pitch travel. This force is intended to encourage movement in the pitch axis in the direction of the normal pitch attitude range for the aircraft.

According to Garmin, the maximum column force ESP can apply is 15 lbs.

When ESP has been engaged for more than 10 cumulative (not necessarily consecutive) seconds of a 20-second interval, the autopilot is automatically engaged with the flight director in Level Mode, bringing the aircraft into level flight. An aural "Engaging Autopilot" alert is played, and the flight director mode annunciation will indicate LVL for vertical and lateral modes.

The airplane was equipped with a Garmin GFC700 autopilot. According to the Garmin Manual:

When the autopilot is engaged, a small amount of pressure or force on the pitch controls can cause the autopilot's automatic trim to run to an out-of-trim condition. Therefore, any application of pressure or force on the controls should be avoided when the autopilot is engaged. Overpowering the autopilot during flight will cause the autopilot's automatic trim to run, resulting in an out-of-trim condition or causing the trim to hit the stop if the action is prolonged. Unanticipated control forces are required after the autopilot is disengaged.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KPAE,548 ft msl	**Distance from Accident Site:**	9 Nautical Miles
Observation Time:	18:53 Local	**Direction from Accident Site:**	276°
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	3 knots / None	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:	20°	**Turbulence Severity Forecast/Actual:**	N/A / N/A
Altimeter Setting:	30.5 inches Hg	**Temperature/Dew Point:**	7°C / -9°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Renton, WA (RNT)	**Type of Flight Plan Filed:**	None
Destination:	Renton, WA (RNT)	**Type of Clearance:**	None
Departure Time:	09:25 Local	**Type of Airspace:**	

Wreckage and Impact Information

Crew Injuries:	2 Fatal	**Aircraft Damage:**	Substantial
Passenger Injuries:	2 Fatal	**Aircraft Fire:**	On-ground
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	4 Fatal	**Latitude, Longitude:**	47.905952,-122.04892(est)

The accident site was located in a grass field in rural farmland at an elevation about sea level.

The wreckage was distributed over about 1,830 ft on a median magnetic heading of about 270°. The main wreckage and right wing were located at the beginning of the debris field and about 580 ft apart (see Figure 3 below). The main wreckage, consisting of the engine, cockpit (and cargo pod), cabin, vertical stabilizer, and rudder, was partially consumed by fire. The right wing strut separated from the fuselage attachment point, but remained attached to the wing; the right flap was separated into numerous pieces and scattered among the debris field. The left wing separated from the fuselage and was located adjacent to the main wreckage; the flap remained attached and was found in the retracted position.

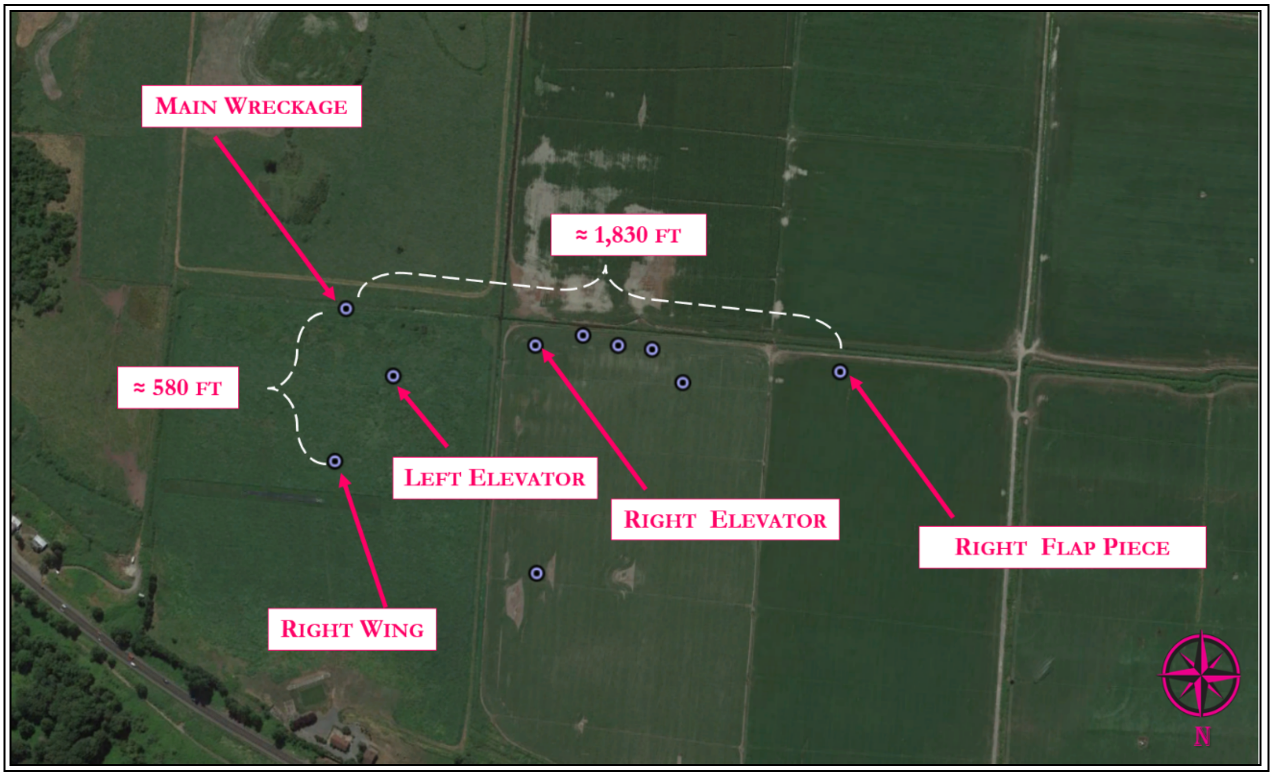

Figure 3: Wreckage debris field

The left control column had separated consistent with thermal damage, though the bolts at the base remained intact. The control column held trapped swaged ends, and the control wheel tube had melted free from its rotating mount. Upon alignment of the melted surface fractures, investigators found the control yoke frozen in a near-vertical alignment, consistent with full left aileron deflection; there was a bend in the control column consistent with the control being nearly fully aft during impact. The left fuselage pulley, attached to a melted piece of the airframe, suffered thermal damage, with no aileron cable present.

Empennage

The empennage was cut from the main wreckage near the fuselage. The vertical stabilizer and rudder, which remained attached to the empennage, showed deformation and crushing damage. The aft fuselage was crushed laterally. The elevator bellcrank, control tube, and control horn remained attached, although the control tube was fractured between the bellcrank and the control horn. The elevator torque tubes displayed shear failure signatures.

The forward horizontal stabilizer attach points were intact with bolts installed, and the forward spar sections on both sides were rotated down about 45 degrees. The rear spar attach points of the horizontal stabilizer exhibited fractures. The right horizontal stabilizer showed minimal damage, with a downward separation consistent with deformation. The right stabilizer displayed a cable tear in the lower skin, and the forward and rear spars exhibited downward separation. Only the inboard 1.5 ft of the right elevator was located. The trim cables were separated from the chain and displayed broomstrawing at the sprockets, which showed evidence of crush deformation. The control cable had sawed through the bottom of the right horizontal stabilizer to approximately 30 inches outboard.

The left horizontal stabilizer fractured near the fuselage and showed downward bending and buckling between specific points. All vortex generators remained installed. The left elevator was recovered intact but showed deformed and fractured upper skin at hinge locations, consistent with over-travel trailing edge up. There was also buckling damage to the left elevator skins in line with the left horizontal stabilizer damage. The inboard webbing and spars exhibited downward bending consistent with a negative load.

The left elevator trim actuator extension was measured at approximately 1 1/2 inches, which, according to a Cessna representative, corresponded to approximately 17° of trim tab trailing edge down (full travel). The right elevator trim actuator extension was measured at approximately 2 5/8 inches, which corresponded to approximately 17° of trim tab trailing edge up (full travel).

Wings

The right wing was recovered mostly intact from root to tip, with the right aileron and trim tab intact. The upper wing skin exhibited diagonal buckling, and the right flap was found in several pieces, with the largest section being mostly undamaged. The outboard flap section was mechanically cut and exhibited upward-curled edges. Significant crushing and mechanical cuts were noted on the flap and wing, with evidence of black paint transfer on the cut edges consistent with contacting the propeller (see Figure 4 below).

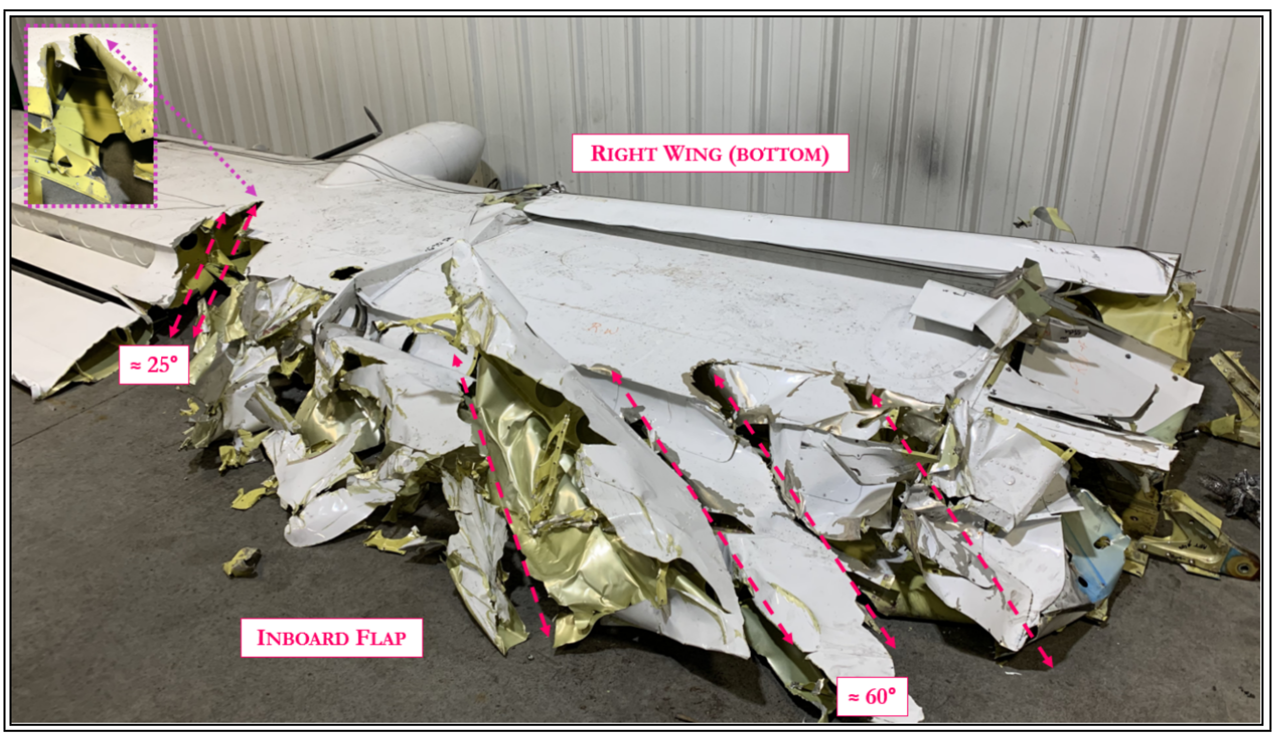

Figure 4: Bottom of the right wing showing cuts

The right-wing strut remained attached to the wing but displayed trailing edge buckling and deformation. The forward and rear spars were deformed, with the lower strut attach fittings fractured. The upper strut attach bolt was intact. The forward spar wing attach fittings and fuselage lugs were deformed forward, with the right wing's aft spar upper cap twisted and the lower spar cap showing s-bending deformation. The forward and aft wing attach bolts were intact and installed. The forward wing attach fitting was jammed upward, while the aft wing attach fitting was slightly jammed. The fittings and bolts from the wing attach points and strut were disassembled and inspected, revealing no obvious deformation, although the right lower aft strut fitting hole was significantly larger than the original size, consistent with overstress separation.

The inboard section of the left wing was consumed by fire and the remainder of the wing came to rest adjacent to the fuselage. The left wing's attach points and root area were thermally damaged, and only melted pieces remained as identified by the fittings (e.g., bolt, nut, and cotter pin, etc.). The aft wing strut attach point was almost completely thermally consumed, with melted metal surrounding the bolt.

The flap motor jackscrew, located in the upper cabin, was found flush, consistent with the flaps being fully down.

Medical and Pathological Information

The Snohomish County Medical Examiner, Everett, Washington, conducted an autopsy of the pilot. The cause of death was determined to be multiple blunt force injuries. No significant natural disease was identified.

The FAA's Forensic Sciences Laboratory performed toxicology testing on the pilot's tissue samples, identifying the antihistamine brompheniramine. The non-steroidal pain medication ibuprofen and the cough suppressant dextromethorphan and its metabolite, dextrorphan, were detected in the test pilot's cavity blood and liver tissue; these three compounds are generally considered non-impairing.

Tests and Research

The NTSB Vehicle Performance division performed a study to determine and analyze the motion of the airplane and the physical forces that produced that motion. A simulation of the Cessna 208B was conducted to determine flight control and throttle inputs that result in an approximate match of recorded ADS-B, winds aloft, and FAST torque data. The goal was to achieve reasonable alignment between the simulated airplane's trajectory (position, speed, and attitude) and the recorded data defined by engineering judgment rather than precisely defined tolerances. Flaps were progressively lowered during the simulation, and maximum lift coefficients achieved in the simulation indicated that a stall likely occurred with the flaps fully down, consistent with the airplane's flap motor being found in the full-down position.

The simulation revealed that, to match the sudden course reversal indicated in the ADS-B data at 1019:05 (4 seconds after the lowest airspeed was achieved), a further roll to the left from the initial -30° was required. In the simulated maneuver, the roll angle reached -120° and the pitch angle decreased to between -53° and -62°. The FAST data indicated that, following the stall, the engine torque increased from about 930 ft-lb to over 2,200 ft-lb. The FAST airspeed peaked at 223 KIAS at 1019:21, about 3 seconds after the end of the ADS-B data, before dropping precipitously, suggesting that the airplane broke apart at or shortly before this time.

In the simulation, the pitch trim was adjusted during flap transitions to maintain an approximate zero control column force, and was not adjusted further after the final, landing flaps setting was reached. During the approach to the stall, about 20 lbs of control column force was required, increasing to up to 40 lbs following the stall as the ailerons were used to induce rapid left roll. The simulation column forces do not account for any force contributions from the ESP system; these might have been present (and increased the required column force) once the pitch angle increased above 19° at 1018:51 in the simulation. Since the actual roll likely resulted from flow separation asymmetries on the wings during the stall, the pitch and roll control simulation inputs during this phase were primarily used to replicate airplane attitudes matching the trajectory recorded by ADS-B data. The simulation did not implement lateral and directional flight control system models; instead, the control surfaces (ailerons and rudder) were directly manipulated by the simulation. However, the pitch control system model was included, allowing simulation of column, column force, and elevator parameters (with the exception of the effects of the ESP system).

According to the Cessna 208B Grand Caravan EX Pilot’s Operating Handbook (POH), the airplane’s maximum operating speed (Vmo) is 175 KIAS, and the maximum flaps-extended speed with landing flaps (Vfe) is 125 KIAS. The FAST recorded airspeed of 223 KIAS at 1019:21 was 98 KIAS above Vfe and 48 KIAS above Vmo. The structural failure likely occurred around this time and is consistent with these speed exceedances.

Load Analysis

The NTSB requested Textron Aviation to analyze wing, flap, and horizontal tail loads for full flap overspeed conditions during the accident flight using their existing models. The analysis evaluated external loads using inputs of wing geometry, aerodynamic data, weight distribution, load factor, velocity, and center of gravity (CG). Calculations were performed for specific speeds (Vfe, Vmo, and maximum analysis speed) with full flaps (30°) and compared to the airplane's design limit load (DLL) and ultimate load (UL) envelopes.

Results showed that wing beam shear and bending moment loads remained within DLL limits under all conditions; however, wing chordwise shear loads exceeded the UL envelope by up to 14% between the wing root and strut attach point at higher speeds and load factors. Wing torsion results indicated moments exceeding DLL limits along portions of the wingspan under certain conditions.

Flap loads at 175 KIAS exceeded the UL envelope by about 7% in overspeed conditions, and the forward and rear spar attach point loads at 175 KIAS exceeded the UL envelope by up to 13%. Tail loads, with no elevator deflection, remained within the DLL envelope across all conditions. The findings highlighted significant increases in structural loads at higher speeds and load factors, particularly for wing chordwise shear and flap components.

Additional Information

Previous Flights

A review of the videos for all the previous flights showed no evidence of the pilot turning off the ESP system, nor did he verbally acknowledge when the ESP activated or when the autopilot was activated by the system. The videos showed the pilot engaging and disengaging the autopilot on numerous occasions.

On the day before the accident, the airplane flew Flight 06 and Flight 07. The flight crew was the same as the accident flight, with the exception of the right seat pilot.

Flight 07 was the last flight recorded the day before the accident flight. The purpose of the flight was to evaluate the airplane's aft CG stall characteristics. The flight departed Renton on northbound heading to an uncongested area in Snohomish County to complete the planned series of stalls. During the flight, 10 of 12 stalls on the flight test card were performed. The maneuvers were to be performed between 8,000 and 10,000 ft msl. All 10 maneuvers were executed with the yaw damper (Y/D) and autopilot (AP) off. The first 4 stalls were straightahead, and the remaining 6 stalls were in a 30° banked turn to either the left or right, with the flaps in the “up” and “landing” positions.

Flight 07 was recorded with audio and video. For the 5.7L (left bank) and 5.7R (right bank) stall tests, the maneuver was to begin at 96 KIAS in a 30° bank, power at 930 ft-lbs of torque, and flaps in the up position. For the 5.6L and 5.6R tests, the maneuver was to begin at 96 KIAS in a 30° bank, power at idle, and flaps in the landing (down) position. All these maneuvers were to be “unaccelerated” turning stalls, meaning the target deceleration rate was 1 kt per second until reaching a stall, followed by stall recovery. The pilots and engineers would note the airspeed at the stall warning horn, low-speed stall buffet, and the minimum airspeed where the stall occurred. The maximum bank angle was noted during the stall recovery. The maneuver was considered to “pass” if the bank angle did not exceed 60° in the direction of the turn or 30° in the direction opposite the turn (as per 14 *CFR* 23.203 (b)(4)), and considered to “fail” otherwise. Full aft elevator control pressure was held for two seconds before the pilot initiated recovery if the stall did not break at the minimum airspeed.

The left turning stall designated as 5.7L started at 96 KIAS. The pilot stated, “Stall warning at 78, buffet at 72... pitching out at 64… slight tendency to want to roll out of turn.” No minimum speed was verbalized. The pilot then began the right turning stall designated as 5.7R . The pilot stated, “Warning 85, buffet at 72…full stop, 1 potato 2 potato… slight tendency to want to roll out of turn.” The video showed during the turning stall to the right that the airplane rolled back to the left and the minimum speed was recorded at 69 KIAS.

Maneuver 5.6L began at 96 KIAS and 30° bank to the left. The pilot stated, “Stall warning at 72… buffet at 59…” At a recorded time of 1514:51, when the pilot was performing the stall, the airplane rolled left and passed the 45° threshold, which was seen to activate the ESP (the Roll Limit Indicator bars moving from 45° to 30°). The airplane continued to roll past 75° (at which point the ESP system would have disengaged) and per recorded flight data, reached a maximum roll of about -83° before returning to wings level (see Figure 5 below).

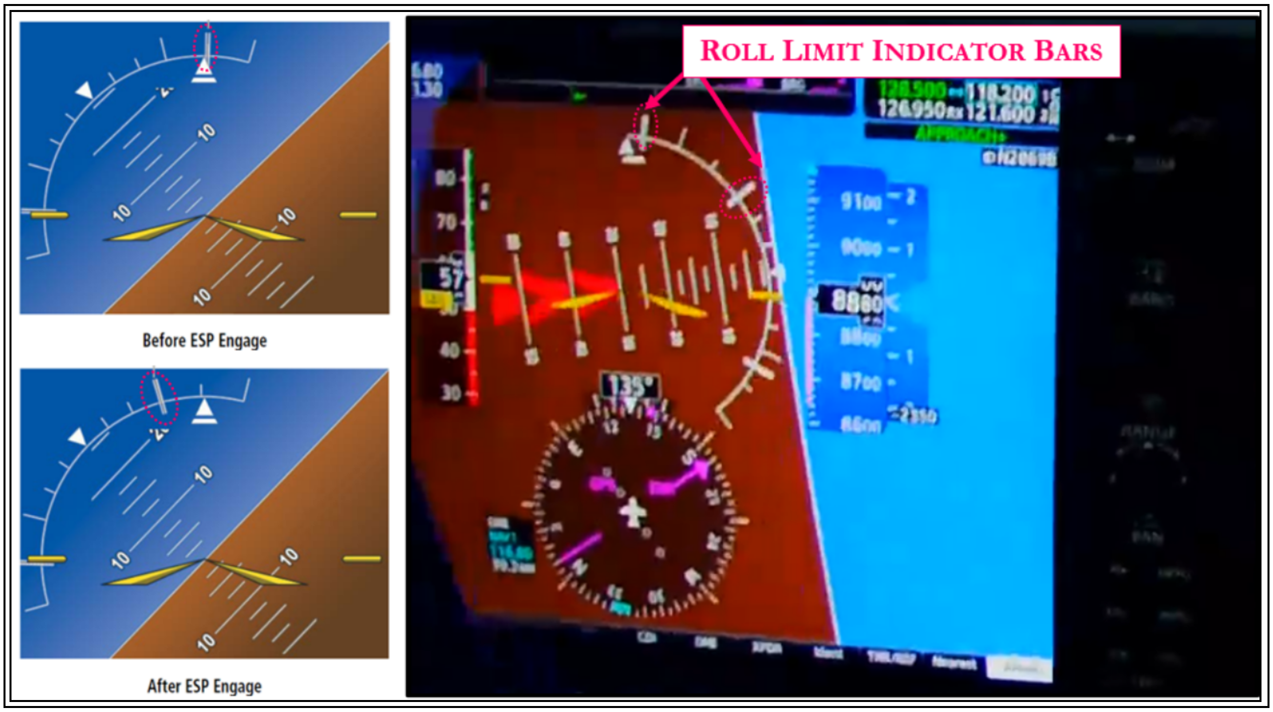

Figure 5: Image of the PFD during the stall

After the recovery was started, while pointing at an instrument above the panel, the pilot stated, "just out of curiosity, this column position, what is it telling me?" There was confusion between the pilot and engineer about elevator control column input and elevator position. The pilot was told full elevator travel would be 100% at full stop. The pilot stated he was only seeing 13-14% at full stop. The pilot was queried if the elevator was at aft full stop, and he said he believed it was, because he was pulling and didn't see any more movement. The following conversation happened after the maneuver was completed:

Time	Speaker	Content
15:16:21	Engineer	And were we more than sixty on that roll-off?
15:16:24	Pilot	Uh … more than sixty … ah let me think …
15:16:35	Pilot	No. We were probably about fifty.
15:16:37	Engineer	'K.
15:16:40	Pilot	So technically I guess that's good.
15:16:42	Engineer	It's a pass.
15:16:42	Pilot	That's a pass.
15:16:45	Pilot	So we're going back up to try one to the right.
15:16:46	Engineer	Correct.
15:16:50	Pilot	Glad you mentioned it I was getting ready to reject it.
15:16:54	Pilot	Just 'cause it, it rolled and I couldn't stop it, but … you know, pushed out … it was … it was still within.

Between 1521:27 and 1521:40, after the airplane had recovered from the stall and returned to level flight, the pilot pitched the airplane nose-down to a little below -25° in order to "get some airspeed back." The attitude indicator displayed red chevrons pointing up, indicating an unusual attitude. The magenta airspeed trend vector line predicted Vmo within 6 seconds and the actual airspeed readout turned yellow.

At 1521:44, the autopilot turned on into LVL mode, indicating that the airplane was below the nose-down attitude of 20° for more than 10 seconds. There was a beeping sound in the cockpit, and at 1521:46, the MAXSPD amber warning illuminated as the airspeed increased through 173 KIAS. The airspeed increased through Vmo (175 KIAS) at 1521:47, after which the PFD displayed the airspeed in white numbers against a red background. The airspeed peaked at 183 KIAS at 1521:50 and then started to decrease, as the airplane pitch increased through 0°. The autopilot disconnected at 1521:52, presumably by the pilot disengaging it on the control wheel.

After the maneuver was complete, there was discussion about completing the last 2 stalls on the card, but the recent Vmo exceedance was not mentioned. Because one of the engineers was feeling airsick, the test team decided they should end the flight testing and finish the remainder of the test card the next day.

The right seat pilot on Flight 07 was provided the video and audio from that flight for review. He stated that during the stall to the left (5.6L), "it was quite a roll off but the recovery was a nonevent and occurred immediately." He added that, "I did mentally question the decision to call it 50 degrees but decided they had their reasons in this test environment," and that, "my mindset in these test flights is to defer to the test pilot who has a much deeper knowledge of the program and the parameters experienced." He stated that at no time was he uncomfortable with the stall or the pilot's handling of the airplane during the recovery. When asked about the Vmo exceedance, he stated that because it was corrected immediately, he did not believe it would pose a problem.

The FAA Airplane Flying Handbook Guidance

The Airplane Flying Handbook section titled "Maintaining Aircraft Control: Upset Prevention and Recovery" references the Airplane Upset Recovery Training Aid in defining an "airplane upset" as follows:

An event that unintentionally exceeds the parameters normally experienced in flight or training. These parameters are:

1. Pitch attitude greater than 25°, nose up
2. Pitch attitude greater than 10°, nose down
3. Bank angle greater than 45°
4. Within the above parameters, but flying at airspeeds inappropriate for the conditions

The Handbook states that "in general, upset recovery procedures are summarized" as follows:

1. Disconnect the wing leveler or autopilot

2. Apply forward column or stick pressure to unload the airplane
3. Aggressively roll the wings to the nearest horizon
4. Adjust power as necessary by monitoring airspeed
5. Return to level flight

The Handbook cites the following “common errors associated with upset recoveries:”

1. Incorrect assessment of what kind of upset the airplane is in
2. Failure to disconnect the wing leveler or autopilot
3. Failure to unload the airplane, if necessary
4. Failure to roll in the correct direction
5. Inappropriate management of the airspeed during the recovery

The “stall recovery template” provided in the Handbook follows the procedures specified for upsets in general:

1. Wing leveler or autopilot: disconnect
2. a) Pitch nose-down: apply until impending stall indications are eliminated
b) Trim nose-down pitch: as needed
3. Bank: wings level
4. Thrust/Power: as needed
5. Speed brakes/spoilers: retract
6. Return to the desired flight path

The “Accelerated Stalls” section of the Handbook describes these stalls, stating that the airplane can stall at a higher indicated airspeed when subject to an acceleration greater than +1G, such as during turns, pull-ups, or other abrupt changes in the flight path. Stalls that occur when the G-load exceeds +1G are called “accelerated maneuver stalls.” These stalls most commonly occur inadvertently during improperly executed turns, stall and spin recoveries, pullouts from steep dives, or overshooting a base-to-final turn. Accelerated stalls are typically demonstrated during steep turns.

The Handbook states that pilots should never practice accelerated stalls with wing flaps in the extended position due to the lower design G-load limitations in that configuration. Accelerated stalls should be performed with a bank of approximately 45° and never at a speed greater than the airplane manufacturer’s recommended airspeed or the specified design maneuvering speed (*Va*) or operating maneuvering speed (*Vo*).

The Handbook states that, "an airplane typically stalls during a level, coordinated turn similar to the way it does in wings-level flight," with the stall buffet being sharper. In a coordinated stall, the nose pitches away from the pilot as both wings stall nearly simultaneously. However, if the airplane is uncoordinated, "the stall behavior may include a change in bank angle until the AOA has been reduced." The Handbook emphasizes the importance of recovering immediately at the first indication of a stall or after the stall has fully developed, by "applying forward elevator pressure as required to reduce the AOA and to eliminate the stall warning, level the wings using ailerons, coordinate with rudder, and adjust power as necessary." Accelerated stalls, which result from abrupt maneuvers, can be more aggressive, occurring at higher-than-normal airspeeds or lower-than-expected pitch attitudes. These stalls may surprise inexperienced pilots and, if not recovered immediately, may result in "a spin or other departure from controlled flight."

The Handbook further states that "cross-control stalls" can result in extreme roll angles. It warns that, "the aerodynamic effects of the uncoordinated, cross-control stall can surprise the unwary pilot because this stall can occur with very little warning …." The airplane may pitch down, change bank angle, or roll into an inverted orientation, leading to the start of a spin. Recovery requires reducing the AOA, leveling the wings with ailerons, and coordinating rudder inputs before the airplane enters a spiral or spin. Thereafter, the pilot should close the throttle. The Handbook advises, "to avoid the possibility of exceeding the airplane's limitations, the pilot should not extend the flaps."

FAA Stall Characteristics Certification Standards and Flight Test Guidance

The Flight Test Plan for Raisbeck (Test Plan) describes that the test procedures must meet or exceed the requirements to show compliance to several 14 *CFR* Part 23 regulations that included §23.203 (at Amendment 23-62):

Turning flight and accelerated turning stalls must be demonstrated in tests as follows:

(a) Establish and maintain a coordinated turn in a 30° bank. Reduce speed by steadily and progressively tightening the turn with the elevator until the airplane is stalled, as defined in §23.201(b). The rate of speed reduction must be constant, and—

> (1) For a turning flight stall, may not exceed one knot per second; and
> (2) For an accelerated turning stall, be 3 to 5 knots per second with steadily increasing normal acceleration.

(b) After the airplane has stalled, as defined in §23.201(b), it must be possible to regain wings level flight by normal use of the flight controls, but without increasing power and without—

> (1) Excessive loss of altitude;
> (2) Undue pitchup;
> (3) Uncontrollable tendency to spin;
> (4) Exceeding a bank angle of 60 degrees in the original direction of the turn or 30 degrees in the opposite direction in the case of turning flight stalls;
> (5) Exceeding a bank angle of 90 degrees in the original direction of the turn or 60 degrees in the opposite direction in the case of accelerated turning stalls; and
> (6) Exceeding the maximum permissible speed or allowable limit load factor.

(c) Compliance with the requirements of this section must be shown under the following conditions:

(1) Wings flaps: Retracted, fully extended, and each intermediate normal operating position as appropriate for the phase of flight.
(2) Landing gear: Retracted and extended as appropriate for the altitude.
(3) Cowl flaps: Appropriate to configuration.
(4) Spoilers/speedbrakes: Retracted and extended unless they have no measurable effect at low speeds.
(5) Power:
(i) Power/Thrust off; and
(ii) For reciprocating engine powered airplanes: 75 percent of maximum continuous power. However, if the power-to-weight ratio at 75 percent of maximum continuous power results in nose-high attitudes exceeding 30 degrees, the test may be carried out with the power required for level flight in the landing configuration at maximum landing weight and a speed of 1.4 VSO, except that the power may not be less than 50 percent of maximum continuous power; or
(iii) For turbine engine powered airplanes: The maximum engine thrust, except that it need not exceed the thrust necessary to maintain level flight at 1.5 VS1 (where VS1corresponds to the stalling speed with flaps in the in the approach position, the landing gear retracted, and maximum landing weight).
(6) Trim: The airplane trimmed at 1.5 VS1.
(7) Propeller: Full increase rpm position for the power off condition.

The Test Plan also specifies the procedures to be used when performing the stalls:

(1) With the engine at specified power setting, trim the airplane for flight at the target trim speed (1.5VS).
(2) Call out trim point.
(3) Establish a 30° banked turn.
(4) Using elevator only (column), steadily decelerate the airplane into the stall with entry rate no greater than -1.0 knot/second.
(5) Call out: initial buffet, stall warning, aft stop, minimum speed.
(6) Recover after the aft elevator stop is reached for approximately 2 seconds.
(i) For Turning stalls: Roll occurring during recovery may not exceed 60° of bank in the original direction of the turn or 30° in opposite direction.
(ii) For Accelerated stalls: Roll occurring during recovery may not exceed 90° of bank in the original direction of the turn or 30° in opposite direction.
(7) Allow airplane to stabilize between stalls.
(8) Evaluate and comment on airplane handling characteristics.

Pilot’s Operating Handbook and Maintenance Manual

Stall guidance in the 208B Pilot's Operating Handbook is contained in the "Normal Procedures" section, and states: "Stall characteristics are conventional and aural warning is provided by a stall warning horn which sounds between 5 and 10 knots above the stall in all configurations."

The POH prohibits intentional spins. In the event of an inadvertent spin, the "Emergency Procedures" section of the POH provides the spin recovery steps, the first of which is "retard the power to idle position."

The Cessna 208 Series Maintenance Manual includes a section titled Unscheduled Maintenance Checks. This section states that when an overspeed (among other events) is reported by the flight crew, "a visual inspection of the airframe and specific inspections of components and areas involved must be accomplished. The inspections are performed to determine and evaluate the extent of damage in local areas of visible damage, and to structure and components adjacent to the area of damage."

The Maintenance Manual defines an "overspeed" as follows:

(1) Any time an airplane has exceeded one or both of the following:
  a. Airplane overspeed exceeding placard speed limits of flaps.
  b. Airplane overspeed exceeding design speeds.

(2) Airplanes equipped with an airspeed exceedance device capable of recording an airspeed exceedance with accompanying time duration:
  a. For a recorded airspeed above 175 knots in smooth air, with duration greater than 5 seconds, or any airspeed above 181 knots, perform the specified overspeed inspection.

Exceedances

The Test Plan includes a table that specifies the "test conditions" for the stalls, which include a "target entry rate" of -3 to -5 knots per second, as noted in the remarks column of the test card. The test conditions also include both idle power and "power on" conditions, with the "power on" condition set at 930 ft.-lb. of torque, which corresponds to the power required for level flight at 1.5 VS with flaps in the takeoff/approach position.

The Test Plan's "Pass/Fail" column provides space to record whether the stall met the characteristics required by §23.203 and the procedures outlined in the plan. Test condition 5.6L during Flight 07 resulted in a recorded maximum roll angle of -83°, with the post-stall roll exceeding the -60° limit in the original direction of the turn. Per the criteria in §23.203 and the Test Plan, condition 5.6L should have been marked as a "fail" because the stall was unaccelerated, but the roll angle exceeded 60°.

The guidance in the FAA *Airplane Flying Handbook* to close the throttle and keep the flaps up during a cross-control stall suggests that the risk of the maneuver increases when power is applied and the flaps are extended, as was the configuration during the accident. A cross-control stall introduces a sideslip angle at the stall break, which can create asymmetry in the stall and lead to extreme roll angles. The sideslip angle at the time of the accident is unknown; however, video from the previous day's flight (Flight 07) during a similar unaccelerated flaps 30° (landing) stall in a -30° left roll with idle thrust, shows the Slip/Skid Indicator bar on the Primary Flight Display (PFD) displaced about one bar's width to the right before the stall. This displacement corresponded to a lateral load factor of approximately -0.07G. Additionally, the PFD depicted a roll angle greater than the specified -60° for the maneuver. After the stall break, the airplane rolled further left to a recorded angle of -83°, and the pitch angle decreased to -45°. During this maneuver, engine power was at idle with 165 ft-lb. of torque at the stall break, the deceleration target was 1 knot per second, and airspeed remained below Vfe during stall recovery.

During Flight 07, the airplane exceeded its maximum operating speed (175 KIAS) for over six seconds, peaking at 183 KIAS during a pitch-over maneuver to recover airspeed. Although this overspeed condition required an inspection per the Maintenance Manual, no record of such an inspection was found, and the condition was not documented in the airplane's logbook, contrary to FAA Order 4040.26C guidance.

The Order's post-flight briefing recommendations emphasize reviewing test conduct, including whether any limits were exceeded, whether inspections were required, and whether there were unusual events. A thorough review after Flight 07 could have identified the overspeed condition as requiring an inspection and highlighted the excessive roll observed during condition 5.6L as an area needing further attention.

Risk Mitigation

Flight testing of new airplane designs inherently carries risks since the purpose of such tests is to determine compliance with certification requirements. However, the Cessna 208B EX modified with the APE III STC was already a certified design, potentially reducing the risks involved in its stall testing compared to testing an entirely new design. Despite this, the Test Plan for the DRS testing applied a conservative approach, adhering to FAA Order 4040.26C, Aircraft Certification Service Flight Test Risk Management Program, which outlines risk management requirements for certification flight tests.

The Test Plan included Test Hazard Analysis (THA) worksheets that identified hazards, their causes and effects, mitigation measures, and emergency procedures. THA 9.5, which focused on aft CG stall characteristics, identified "departure from controlled flight" as a hazard caused by "unpredicted aerodynamic response" or "improper control inputs," with the effect being a significant altitude loss leading to ground impact. The risk for THA 9.5 was assessed as "medium," but it did not mention mitigations for overspeed conditions or the inclusion of some mitigations listed in NASA's Flight Test Safety Database (FTSD) for similar testing, such as terminating tests when roll angle limits are exceeded.

The FTSD assessment for stall characteristics testing, labeled THA 56, assigned a “high” risk level and included mitigations absent in THA 9.5, such as ensuring all stalls are coordinated, retarding throttles to idle during departures from controlled flight, and halting testing if roll angle limits are exceeded.

Administrative Information

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