Aviation Investigation Final Report

Location:	Provo, Utah	**Accident Number:**	WPR23FA080
Date & Time:	January 2, 2023, 11:35 Local	**Registration:**	N555NR
Aircraft:	EMBRAER EXECUTIVE AIRCRAFT INC EMB-505	**Aircraft Damage:**	Substantial
Defining Event:	Structural icing	**Injuries:**	1 Fatal, 2 Serious, 1 Minor
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The airplane was removed from a heated hangar and refueled, at which time water droplets were visible on both wings. The airplane remained outside for about 40 minutes, with no deice or anti-ice treatment, until takeoff was initiated. Multiple witnesses near the accident site reported observing the airplane take off and enter a nose-high attitude, after which it immediately rolled left and impacted the terrain. Wreckage and impact signatures at the accident site were consistent with the left wing impacting the runway surface before the nose of the airplane impacted terrain just to the left of the runway. Witnesses characterized the precipitation at the time of the accident as snow and misty rain, varying in intensity between light and medium.

The airplane was equipped with a Wing and Horizontal Stabilizer Anti-Icing System to prevent and remove any ice formation on the leading edges of the wing and the horizontal stabilizer; the system is activated by a “Wing Stab” switch. Based upon both witness statements and flight data from the Cockpit Voice Data Recorder (CVDR) and Flight Data Recorder (FDR), the Wing Stab ice switch was turned on about 9 minutes after engine start, while the pilot was performing his checklist; however, it was turned off shortly thereafter. The recorded position of the Wing Stab system switch remained off through the remainder of the recorded data.

The airplane pilot’s operating handbook (POH) stated that airplane surfaces contaminated by ice, frozen precipitation, or frost must be deiced before departure. The POH also stated that the airplane must be anti-iced when the risk of freezing precipitation exists or is actually taking place. While deicing removes ice, anti-icing protects against additional icing for a certain period of time.

The POH further states that the entire wing should be inspected during the pre-takeoff contamination check, not just the leading edge of the wing or wingtips, and that "when inspecting the wing, during the pre-takeoff contamination check, look at the entire upper surface and not only at the leading edge or wing tip. Although the wing tips can be seen from the cockpit, almost the entire wing is visible from a cabin window. Therefore, it is strongly advised that the visual inspection be done by a crew member from the cabin. Additionally, the crew should ask for the assistance of trained and qualified personnel outside the airplane to assist in the pre-takeoff and check to make sure that the tail and fuselage, which are not visible from the cockpit or cabin, are free of any ice contamination."

Furthermore, the before-takeoff checklist included an ice accumulation check, and included guidance that, "aerodynamic surfaces must be confirmed free of all forms of frost, ice, snow and slush prior to entering the takeoff runway or initiating takeoff." No evidence of the pilot requesting a passenger or vocalizing that he was checking the wings for ice accumulation was heard on the CVR audio.

A postaccident examination of the airframe and engine revealed no evidence of mechanical malfunctions or failures that would have precluded normal operation. Although the Wing Stab ice protection switch was found in the on position, recorded data indicated that, after the initial system check, the wing stab ice protection system remained off through the remainder of the recorded data. The panel the switch was mounted to had separated from the instrument panel and had an area of dirt/mud directly below the switch itself. The anti-ice system valves and controller were tested at the respective manufacturers and functioned normally. Accordingly, based on the evidence, the switch was likely moved to the on position during the accident sequence. It could not be determined why the Wing Stab ice protection switch was turned off.

At the accident time, and in the 3 hours before the accident, light snow, mist, IFR ceilings, and a temperature of -1°C were reported at the departure airport. Witnesses reported that around the time of the accident light snowfall with freezing mist existed, which would have allowed for accumulation of ice to form on the upper surfaces of the wings, fuselage, and tail surfaces in the 40 minutes between when the airplane exited the hangar and when it took off. Given that the pilot did not obtain any deice or anti-ice services before departure, and the immediate roll to the left as the weight on wheels transitioned from ground to air, the airplane likely had some degree of ice contamination on the upper surfaces of the wings, fuselage, and tail that affected the flight characteristics of the airplane.

Probable Cause and Findings

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

The pilot’s failure to deice the airplane before takeoff in weather conditions conducive to ice accumulation, which resulted in an ice-contaminated wing and subsequent stall during takeoff.

Findings

Environmental issues	Drizzle/mist - Effect on operation
Environmental issues	Snow - Effect on operation
Aircraft	Airfoil anti-ice, deice - Not used/operated
Aircraft	(general) - Not inspected
Aircraft	Angle of attack - Capability exceeded
Personnel issues	Use of equip/system - Pilot
Personnel issues	Use of available resources - Pilot
Personnel issues	Decision making/judgment - Pilot

Factual Information

History of Flight

Takeoff	Structural icing (Defining event)
Takeoff	Loss of control in flight
Takeoff	Collision with terr/obj (non-CFIT)

On January 2, 2023, about 1135 mountain standard time, an Embraer EMB-505, N555NR, was substantially damaged when it was involved in an accident at the Provo Municipal Airport (PVU), Provo, Utah. The pilot sustained fatal injuries, two passengers sustained serious injuries, and one passenger sustained minor injuries. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 personal flight.

The airplane's manager reported that the airplane was in a heated hangar, where the temperature was about 60°, and the ramp area in front of the hangar was heated with radiant heat. He stated that they would typically preflight the airplane inside the hangar, so that the only thing left to do before boarding the airplane was refueling. He spoke with the pilot about 30 minutes before the accident, and they discussed the planned flight to Chino, California, along with the weather and braking action. He recalled that the pilot did ask him about deicing, and he told the pilot that if he needed to deice the airplane, to call the fixed-base operator (FBO). However, their truck was out of service, so he told the pilot to call another FBO if he needed to deice. Personnel from the other FBO reported that while their deice truck was operational, the accident pilot did not contact them on the day of the accident. The airplane manager stated that they only had to deice twice in the previous 8 years.

A witness who was removing snow from the ramp area reported that the airplane was in a hangar near his location and remained there until 1055. The witness stated that he watched the airplane be refueled and estimated that the pilot started the engines around 1110 or 1115, around the same time light snow began to fall, and within a few minutes the snow had covered the areas he plowed.

The fueler stated the airplane was parked in the hangar when he arrived to fuel the aircraft. About 5-10 minutes later, the pilot pulled the airplane out onto the ramp and the fueler repositioned his truck to service the airplane with 350 gallons of Jet-A fuel. The fueler stated while he was completing refueling the airplane, the pilot mentioned that they were trying to get out before the weather. The fueler added that he observed what appeared to be unfrozen water droplets on the wings during the refueling, which he estimated took about 5 minutes.

After refueling the airplane, the fueler returned to the FBO. Upon exiting the fuel truck, he observed the airplane taxi past his location. As he walked toward the FBO, he heard the airplane and turned around to watch it. He stated that the airplane was starting its takeoff roll on runway 13, and appeared to “pull up steep,” roll to the left, and the left wing impacted the ground. The refueler stated that at the time of the accident, the precipitation was snow and a misty rain, with light to medium intensity, along with a light breeze out of the north.

Additional witnesses at the airport observed the airplane takeoff, ascend to about 20 to 30 ft above ground level (agl), and then both wings wobbled “back and forth.” The airplane then banked to right, and then banked “hard left” as the left wing struck the ground.

Review of FDR and CVDR data revealed that at 1118:24, the cockpit area microphone captured the pilot describing to a passenger how to enter the cockpit and where to sit. At 1120:47, the right engine was started, followed by both engine anti-ice switches being commanded on, and the left engine anti-ice commanded off 4 seconds later. The left engine was then started, and its anti-ice was turned back on seconds later. At 1129:, the wing stab anti-ice system was commanded on, and the pilot made the comments “we’re gonna get wing stab arm” followed by “yep, wing stab arm, we got that” followed by the Wing Stab anti-ice switch being commanded off, along with a recorded “click” sound. The Wing Stab anti-ice switch remained off until the end of the recorded data.

The FDR and CVDR captured that at 1130:, the pilot performed an ice condition test and confirmed the ice sensor functioned. About 6 seconds later, the pilot commented “wing stabs gonna be on, on, on, probes are on, engines are on, wing stabs on.” The sound similar to the airplane’s wheels moving over a hard surface was captured at 1130:48.

At 1134:28.5, the pilot briefed the takeoff, and said he was going to perform a static takeoff, commenting that he would “run up the engines with the brakes on and release them so that we have less effect of that slush on the runway.” The left and right engine thrust lever angles along with N1 speeds of both engines increased at 1135:25, followed by the ground speed increasing 7 seconds later.

At 1135:48, the indicated airspeed reached recorded V1 and VR values of 103 knots, which coincided with the pilot’s verbal call outs “there’s vee 1 and rotate.”

Between 1135:50 to 1135:55, the recorded pitch angle started to increase. As the gear weight on wheels indication for the left and right mains transitioned from ‘GND’ to ‘AIR,’ the airplane started a roll to the left, progressively increasing over time, and a stall warning activated at 1135:53.7 before the CVDR stopped recording.

At no time throughout the recorded CVDR audio did the pilot ask others to look at the airplane’s wings or audibly announce he was looking at the wings.

Personnel from Duncan Aviation, one of the two fixed-base operators (FBO) located at the airport, reported that their deice truck was out of service. Personnel from the other FBO reported that while their deice truck was operational, the accident pilot did not contact them on the day of the accident.

Pilot Information

Certificate:	Airline transport	**Age:**	62,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:**	No
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 3	**Last FAA Medical Exam:**	October 11, 2021
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	May 1, 2022
Flight Time:	3456 hours (Total, all aircraft), 172 hours (Total, this make and model), 3269 hours (Pilot In Command, all aircraft), 36.9 hours (Last 90 days, all aircraft)		

Passenger Information

Certificate:		**Age:**	
Airplane Rating(s):		**Seat Occupied:**	Right
Other Aircraft Rating(s):		**Restraint Used:**	
Instrument Rating(s):		**Second Pilot Present:**	No
Instructor Rating(s):		**Toxicology Performed:**	
Medical Certification:		**Last FAA Medical Exam:**	
Occupational Pilot:		**Last Flight Review or Equivalent:**	
Flight Time:			

Passenger Information

Certificate:		**Age:**	
Airplane Rating(s):		**Seat Occupied:**	Rear
Other Aircraft Rating(s):		**Restraint Used:**	
Instrument Rating(s):		**Second Pilot Present:**	No
Instructor Rating(s):		**Toxicology Performed:**	
Medical Certification:		**Last FAA Medical Exam:**	
Occupational Pilot:		**Last Flight Review or Equivalent:**	
Flight Time:			

Passenger Information

Certificate:		**Age:**	
Airplane Rating(s):		**Seat Occupied:**	Rear
Other Aircraft Rating(s):		**Restraint Used:**	
Instrument Rating(s):		**Second Pilot Present:**	No
Instructor Rating(s):		**Toxicology Performed:**	
Medical Certification:		**Last FAA Medical Exam:**	
Occupational Pilot:		**Last Flight Review or Equivalent:**	
Flight Time:			

The pilot held type ratings for CE-500, CE-525S, and EMB-505 airplanes. His most recent recurrent training in the accident make/model airplane was in May 2022.

Aircraft and Owner/Operator Information

Aircraft Make:	EMBRAER EXECUTIVE AIRCRAFT INC	**Registration:**	N555NR
Model/Series:	EMB-505	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	50500327
Landing Gear Type:	Retractable - Tricycle	**Seats:**	8
Date/Type of Last Inspection:	December 1, 2022 AAIP	**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:		**Engine Manufacturer:**	Pratt & Whitney
ELT:	Installed	**Engine Model/Series:**	PW535
Registered Owner:	EAGLE JET 300 LLC	**Rated Power:**	
Operator:	On file	**Operating Certificate(s) Held:**	None

The airplane was equipped with a Wing and Horizontal Stabilizer Anti-Icing System (locations depicted in figure 1), which was designed to prevent ice formation and remove any ice formed on the leading edges of the wing and the horizontal stabilizer. The system was activated by a

3-position “Wing Stab” switch on the ice protection panel, which is located just below the lower right corner of the left primary flight display.

The switch could be placed in 3 different positions:

ON (up): activated the wing and the horizontal stabilizer anti-ice systems.

OFF (middle): deactivated the wing and the horizontal stabilizer anti-ice systems.

ICE SPEED RESET (down): reset the Stall Warning and Protection System (SWPS) to non-icing schedule and removed the SWPS ICE SPEED message.

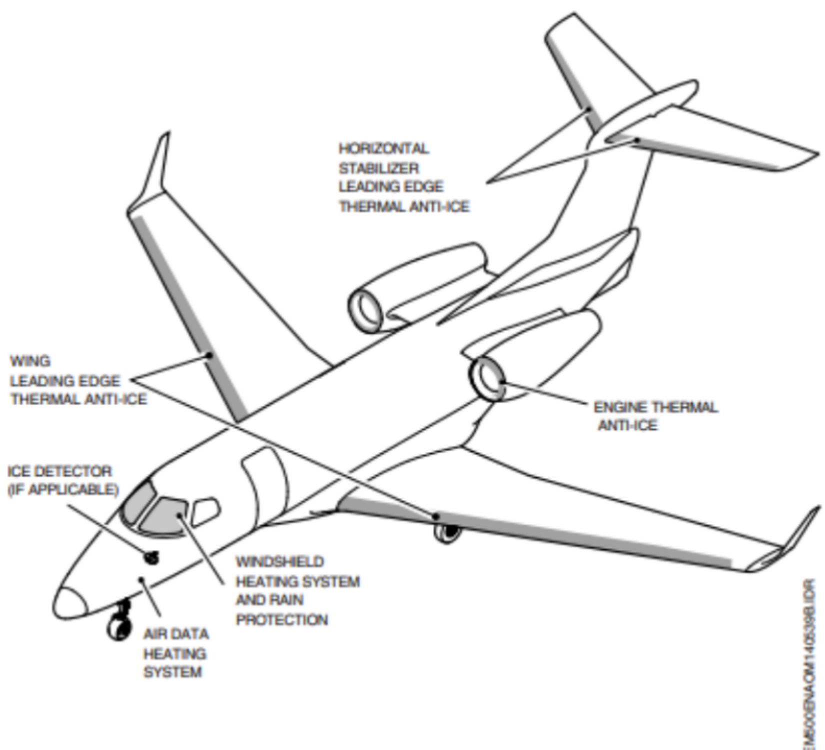

Figure 1: Airframe Ice and Rain Protection System Deice Systems (Source: Phenom 300 Pilot’s Operating Handbook, Volume 1)

The airplane’s Pilot’s Operating Handbook, Section 2-15, Cold Weather Operation, DEICING/ANTI-ICING FLUID APPLICATION, stated in part:

> Airplane surfaces contaminated by ice, frozen precipitation or frost must be deiced before departure. The airplane must be anti-iced when the risk of freezing precipitation exists at dispatch or freezing precipitation is actually taking place.

> While deicing removes ice, anti-icing protects against additional icing for a certain period of time, called holdover time. A combination of both deicing and anti-icing may be performed based on the judgment of the flight crew and procedures developed by the operator. The choice of the correct method and fluid to be applied must be done according to the weather condition, available equipment, available fluids and the holdover time.
>
> Deicing and anti-icing fluids lower the freezing point of frozen precipitation thus delaying the accumulation of contamination on the airplane. When applied to a clean surface, the fluid forms a thin layer that has a lower freezing point than precipitation. The fluid is highly soluble in water, thus the precipitation or ice melts on contact with the fluid. These fluids also delay the onset of frost on airplane surfaces. As the ice melts, the fluid dilutes with the water, thereby causing the mixture to become less effective or to run off. Ice can begin to form again after enough dilution has occurred and the freezing point begins to rise.
>
> Deicing/anti-icing fluids are not intended to provide icing protection during flight. The fluid must flow off the surface during takeoff. Embraer has performed flight tests to investigate the effects of approved fluids on performance and handling characteristics. The flight tests demonstrated these fluids did not have a measurable effect on takeoff and climb performance."

The POH continues later in the same section:

> The pre-takeoff contamination check is normally accomplished either from inside or outside the airplane within 5 minutes prior to beginning takeoff.
>
> When inspecting the wing, during the pre-takeoff contamination check, look at the entire upper surface and not only at the leading edge or wing tip. Although the wing tips can be seen from the cockpit, almost the entire wing is visible from a cabin window. Therefore, it is strongly advised that the visual inspection be done by a crew member from the cabin. Additionally, the crew should ask for the assistance of trained and qualified personnel outside the airplane to assist in the pre-takeoff and check to make sure that the tail and fuselage, which are not visible from the cockpit or cabin, are free of any ice contamination.
>
> It is the pilot's responsibility to decide whether or not to accept the airplane for flight. If contamination is suspected, the airplane should return for additional deicing or anti-icing. Takeoff in conditions of moderate and heavy freezing rain is not approved.

The POH further stated that "to prevent frozen contamination on airplane surfaces deice and anti- icing operation requires that fluids be distributed uniformly over surfaces. In order to control uniformity, all horizontal surfaces must be visually checked during fluid application.

The correct amount is indicated by fluid just beginning to drip off the leading edge. Do not use tools to scrape or scratch compacted snow from the airframe surfaces or from the gaps between fixed or movable surfaces. Once the airplane has been fully deiced, it is time to consider the prevention of any further ice contamination prior to takeoff by application of an anti-icing treatment. The following surfaces must be protected:

fuselage;
wing upper surface and leading edge;
horizontal stabilizer upper surface and leading edge;
elevator upper surface;
vertical stabilizer and rudder.

Additionally, the airplane's BEFORE TAKEOFF checklist includes an ice accumulation check and includes the following specific guidance:

> Aerodynamic surfaces must be confirmed free of all forms of frost, ice, snow and slush prior to entering the takeoff runway or initiating takeoff. This check is particularly important when the published holdover times are about to run out. When contamination is in evidence, the de-icing/anti-icing operation must be repeated.
>
> Visually inspect wing surfaces/leading edge and engine by looking through an appropriate window. The pilot-in-command must ask for the assistance of trained and qualified ground personnel to assist in the pre-takeoff check, so that tail surfaces and fuselage are also inspected.

The Phenom 300 stall warning system is designed to provide an aural alert at 15.93° local angle of attack (AOA) with a wing flap setting of 1.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KPVU,4497 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	11:44 Local	**Direction from Accident Site:**	168°
Lowest Cloud Condition:		**Visibility**	3 miles
Lowest Ceiling:	Overcast / 800 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	/ None	**Turbulence Type Forecast/Actual:**	/
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.79 inches Hg	**Temperature/Dew Point:**	-1°C / -1°C
Precipitation and Obscuration:	Moderate - None - Mist		
Departure Point:	Provo, UT	**Type of Flight Plan Filed:**	IFR
Destination:	Chino, CA (CNO)	**Type of Clearance:**	IFR
Departure Time:		**Type of Airspace:**	Class D

Recorded weather data at PVU at 1117 included wind variable at 6 knots, visibility 3 miles, light snow, mist, overcast ceiling at 800 ft, temperature of -1° C (30° F), dew point temperature -1° C (30° F), and an altimeter setting of 29.79 inches of mercury (inHg). Remarks noted the automated station with a precipitation discriminator; that unknown precipitation began at 1103 and ended at 1111; snow ended at 1103 and began again at 1111; the ceiling varied between 600 and 1,100 ft agl; and that a trace of precipitation occurred after 1056.

At 1144, recorded weather included wind variable at 6 knots, visibility 3 miles, light snow, mist, overcast ceiling at 800 ft, temperature of -1° C (30° F), dew point temperature -1° C (30° F), and an altimeter setting of 29.79 inHg. Remarks noted the automated station with a precipitation discriminator; that unknown precipitation began at 1103 and ended at 1111; snow ended at 1103 and began again at 1111; the ceiling varied between 700 and 1,200 ft agl; and that a trace of precipitation occurred after 1056.

KMTX WSR-88D base reflectivity images for the 0.0° elevation scans initiated at 1136:41 and 1142:18 depicted reflectivity values between 10 and 22 dBZ moving from north to south over PVU at the time of the accident.

The Graphical Forecasts for Aviation (GFA) products issued before the accident flight and valid at 1100 included light snow likely (greater than 60 percent chance). The National Weather Service Terminal Aerodrome Forecast (TAF) at PVU, which was issued at 1038, included light snow showers and overcast cloud layers at 1,000 ft around the time of the accident.

A search of archived information indicated that the pilot did not request weather information from Leidos Flight Service. He did not receive a weather briefing package from ForeFlight;

however, he did view and update several route strings in their ForeFlight application the evening before the accident.

Airport Information

Airport:	PROVO MUNI PVU	**Runway Surface Type:**	Asphalt
Airport Elevation:	4496 ft msl	**Runway Surface Condition:**	Ice;Snow;Wet
Runway Used:	13	**IFR Approach:**	None
Runway Length/Width:	8603 ft / 150 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Substantial
Passenger Injuries:	2 Serious, 1 Minor	**Aircraft Fire:**	None
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	1 Fatal, 2 Serious, 1 Minor	**Latitude, Longitude:**	40.222154,-111.72385

Investigators arrived onsite about 23 hours after the accident, and about 4 to 6 inches of fresh snow had fallen, masking impact marks, ground scars, and debris. Examination of the accident site revealed that the airplane impacted the runway surface about 2,626 ft from the approach end of runway 13 and about 20 ft left of the runway centerline. A scrape mark extended about 91 ft and was parallel to the runway centerline.

A second scrape mark was observed about 2,903 ft from the approach end of runway 13, and arced left to the left edge of the runway surface about 3,126 ft from the approach end of the runway. A swath of displaced snow and dirt extended from the runway's left edge about 100 ft to a large impact crater. The crater contained portions of airframe debris and various airframe components. Wreckage debris extended from the crater about 597 ft to the fuselage. The wings were separated from the airframe and were located about 106 ft beyond the fuselage. Both engines were separated and located adjacent to the fuselage.

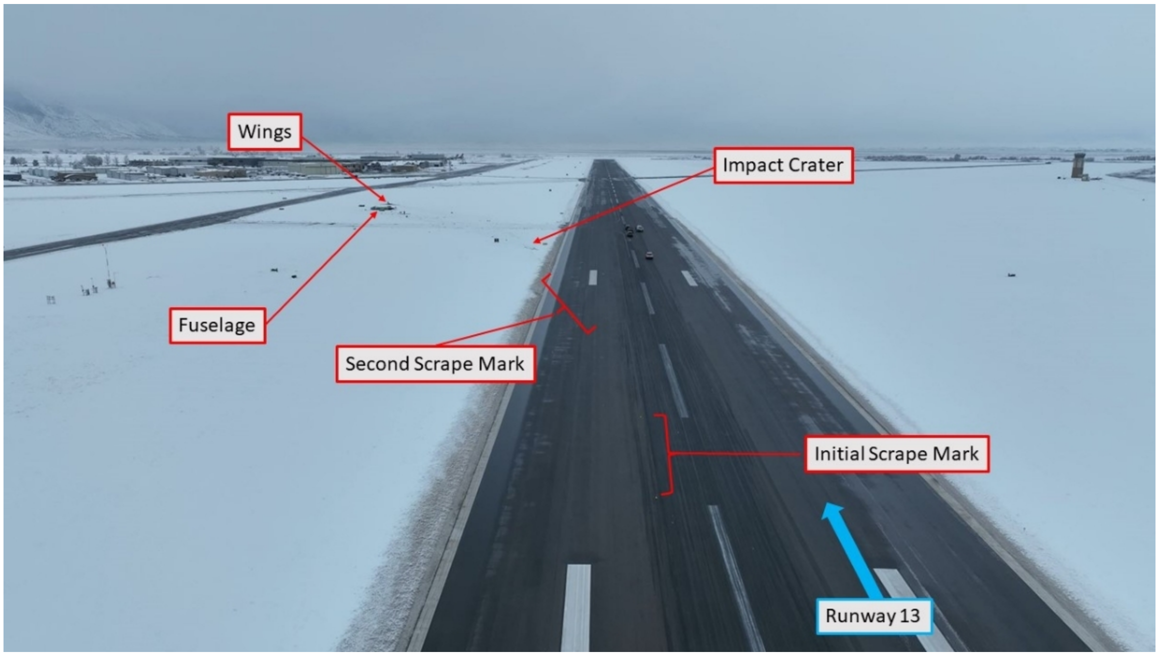

Figure 2: Aerial overview of the accident site. Image courtesy of Provo Police Department with NTSB annotations.

The fuselage was mostly intact. The forward left side of the cockpit was compromised and torn open, with varying degrees of impact damage. The fuselage structure immediately aft of the pilot and co-pilot seats was intact, aft to the empennage and engine mount pylons. Both the left and right engines were separated and located throughout the debris path within the vicinity of the fuselage. Both engines exhibited varying degrees of rotational scoring throughout the inlet compressor area.

Both wings exhibited damage to their wing tips and their winglets were separated. The flaps and ailerons remained attached to each wing via their mounts.

The empennage was impact damaged. The upper half of the rudder and vertical stabilizer were separated along with the horizontal stabilizers and elevators, and the lower half of the rudder and vertical stabilizer remained attached to the airframe.

The ice protection panel was separated from the instrument panel and all of the respective wiring bundles remained attached. The Eng 1 and Eng 2 ice protection switches were in the ON position and the Wing Stab switch was found in the ON (up) position. An area of dried dirt/mud was observed directly under the Wing Stab switch.

When moved by hand, the switch was verified up, consistent with the ON position. The switch could be moved to the OFF and RESET positions normally. When the switch was in the OFF position, minimal upward pressure was applied to move the switch to the ON position. The switch was removed, and electrical continuity was established throughout the switch positions.

Electrical continuity was established from the stab ice switch connector to the air management system (AMS) controller. A cut in the wire was observed at the cannon plug connector, consistent with impact damage. Continuity was established from the engine 1 anti-ice circuit breaker to the left anti-ice auxiliary relay, with a break in the wire about 4 inches from the cannon plug, consistent with impact damage. Continuity was established on all connections from the AMS controller to both anti-ice valves.

Both anti-ice valves and the AMS controller were removed for testing. The anti-ice valves and AMS controller were tested at the respective manufacturers and functioned normally.

No mechanical anomalies were noted with the airplane’s flight control system.

Medical and Pathological Information

An autopsy of the pilot was performed by the Utah State Medical Examiner. The cause of death was extensive blunt force injuries, and the manner of death was accident.

Toxicology testing performed at the FAA Forensic Sciences Laboratory found no drugs of abuse.

Tests and Research

A performance study was performed using data extracted from the FDR and CVR. It revealed that the airplane ultimately reached a maximum speed of 123 knots and a maximum radio altitude of 14 ft before the data ended. The study showed that the airplane immediately rolled left after rotation and continued to roll to a maximum bank angle of 60° left-wing-down before the FDR stopped recording. At 1135:53.9, the stall warning activated about the same time the airplane reached a local angle of attack of about 16° and a vertical load factor of 1.1g’s. The study noted that, based on runway scrapes, an impact crater on the left side of runway 13, and the bank angle recorded on the FDR, the left wing climbed little, if at all. It also noted that deicing before takeoff is critical “because the airplane is airborne, close to the ground, and near the wing’s critical angle-of-attack. The stall margin is only further reduced by wing contamination.”

Administrative Information

Investigator In Charge (IIC):	Cawthra, Joshua
Additional Participating Persons:	Lyndsay Carlson; Federal Aviation Administration; Salt Lake City, UT Daniel S Marimoto; Embraer; Ft. Lauderdale, FL Diego Bandeira da COSTA; CENIPA Jennifer Braaten; GE Aerospace; Grand Rapids, MI
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