Aviation Investigation Final Report

Location:	Lansing, Michigan	**Accident Number:**	CEN20FA001
Date & Time:	October 3, 2019, 08:58 Local	**Registration:**	N700AQ
Aircraft:	Socata TBM 700	**Aircraft Damage:**	Substantial
Defining Event:	Loss of control in flight	**Injuries:**	5 Fatal, 1 Serious
Flight Conducted Under:	Part 91: General aviation - Business		

Analysis

The pilot was conducting an instrument approach at the conclusion of a cross-country flight when the airplane entered a shallow climb and left turn away from the runway heading about 0.5-mile from the intended runway. According to airspeeds calculated from automatic dependent surveillance-broadcast position data, the airplane's calibrated airspeed was 166 knots when it crossed over the final approach fix inbound toward the runway and was about 84 knots when it was on a 0.5-mile final approach. The airplane continued to decelerate to 74 knots while it was in a shallow climb and left turn away from the runway heading. At no point during the approach did the pilot maintain the airframe manufacturer's specified approach speed of 85 knots. The airplane impacted the ground in an open grass field located to the left of the extended runway centerline.

The airplane was substantially damaged when it impacted terrain in a wings level attitude. The postaccident examination did not reveal any anomalies that would have precluded normal operation of the airplane.

The altitude and airspeed trends during the final moments of the flight were consistent with the airplane entering an aerodynamic stall at a low altitude. Based on the configuration of the airplane at the accident site, the pilot likely was retracting the landing gear and flaps for a go-around when the airplane entered the aerodynamic stall.

The airplane was operating above the maximum landing weight, and past the aft center-of-gravity limit at the time of the accident which can render the airplane unstable and difficult to recover from an aerodynamic stall. Additionally, without a timely corrective rudder input, the airplane tends to roll left after a rapid application of thrust at airspeeds less than 70 knots, including during aerodynamic stalls. Although an increase in thrust is required for a go-around, the investigation was unable to determine how rapidly the pilot increased thrust, or if a torque-roll occurred during the aerodynamic stall.

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 airspeed during final approach, which resulted in a loss of control and an aerodynamic stall at a low altitude, and his decision to operate the airplane outside of the approved weight and balance envelope.

Findings

Personnel issues	Aircraft control - Pilot
Aircraft	Airspeed - Not attained/maintained
Personnel issues	Decision making/judgment - Pilot
Aircraft	Maximum weight - Capability exceeded
Aircraft	CG/weight distribution - Capability exceeded

Factual Information

History of Flight

Approach-IFR final approach	Loss of control in flight (Defining event)
Approach-IFR final approach	Aerodynamic stall/spin
Approach-IFR final approach	Collision with terr/obj (non-CFIT)

On October 3, 2019, about 0858 eastern daylight time, a Socata TBM 700 C2 airplane, N700AQ, was substantially damaged when it was involved in an accident near Lansing, Michigan. The commercial pilot and four passengers were fatally injured; and one passenger sustained serious injuries. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 business flight on an instrument flight rules (IFR) flight plan.

According to Federal Aviation Administration (FAA) automatic dependent surveillance-broadcast (ADS-B) data, about 0800, the flight departed runway 19 at Indy South Greenwood Airport (HFY), Greenwood, Indiana, turned northeast toward MAREO intersection, and then turned north toward Capital Region International Airport (LAN), Lansing, Michigan.

The airplane subsequently climbed to flight level 190 (19,000 ft pressure altitude). At 0834:24, the flight entered a cruise descent from flight level 190 and was progressively cleared down to 3,000 ft mean sea level (msl). According to air traffic control communications, the flight was provided radar vectors to join the localizer for the instrument landing system (ILS) runway 10R approach at LAN. The published inbound course for the ILS runway 10R approach at LAN was 96° magnetic, the crossing altitude for the final approach fix (FAMLI) was 2,367 ft msl, the distance between FAMLI and the runway 10R threshold was 4.5 miles, and the decision altitude was 1,061 ft msl (200 ft above ground level).

At 0853:03, the approach controller stated, "TBM zero alpha quebec, five miles from FAMLI, turn right, ah, right heading zero seven zero, maintain three thousand until established on the localizer, cleared the ILS one zero right." The pilot responded, "zero seven zero, ah, we're cleared for the ILS ten right into, ah, Lansing." The ADS-B data indicated that the airplane entered a right turn and joined the localizer inbound.

At 0854:27, the approach controller stated, "TBM zero alpha quebec, contact Lansing tower one one niner point niner, good day." The pilot responded, "One nineteen ninety, seven hundred alpha quebec." At 0855:29, the airplane crossed over FAMLI at 2,303 ft msl and continued to descend on the glideslope while established inbound on the localizer toward runway 10R. The airplane had a calculated calibrated airspeed of 166 knots when it crossed over the final approach fix. Between 0855:29 and 0857:45, while inbound on the instrument approach, the airplane continued to decelerate from 166 knots to 74 knots, as shown in figure 1.

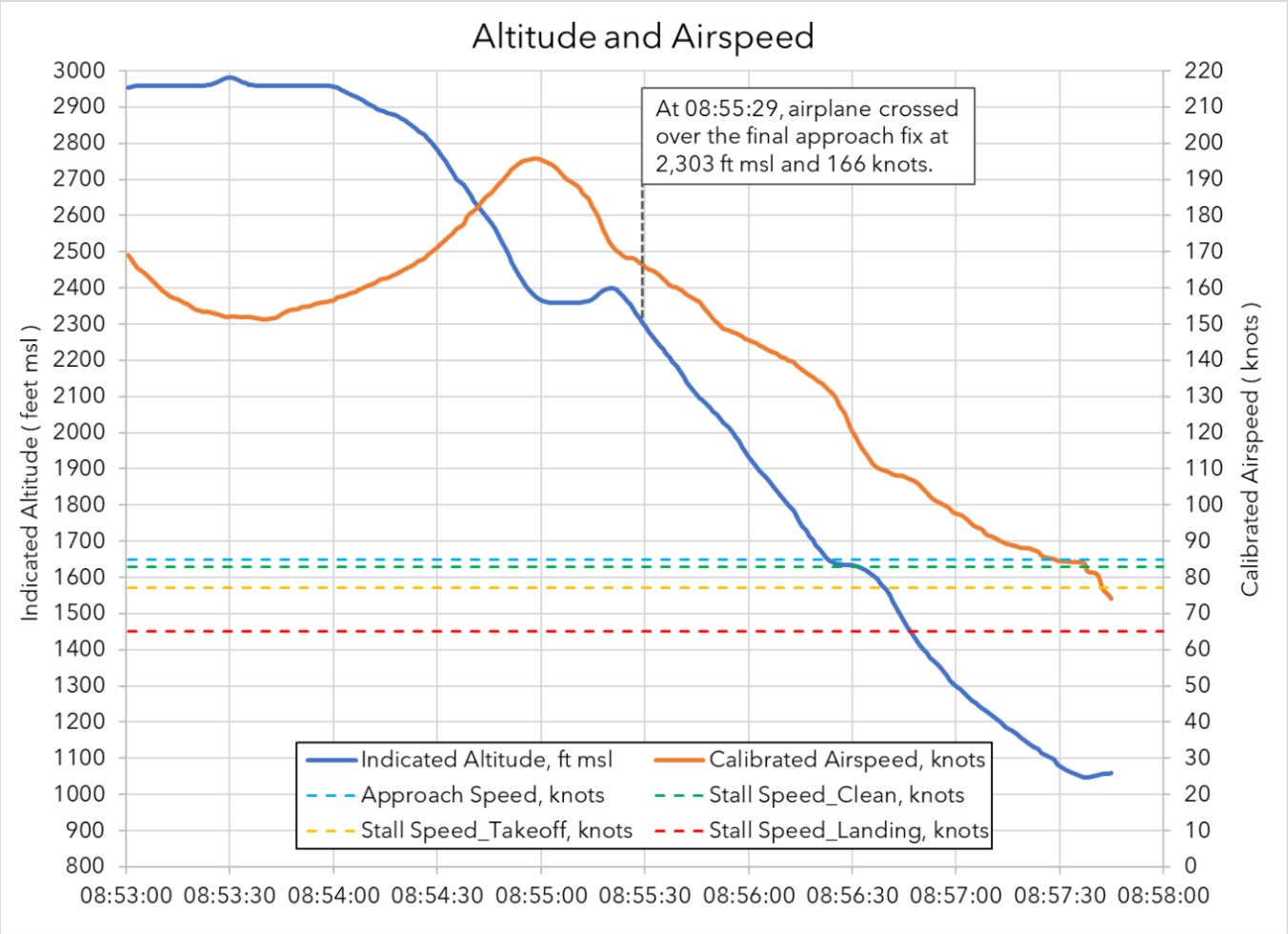

Figure 1. Altitude and airspeed during instrument approach.

At 0854:36, the pilot established contact with the LAN tower controller and reported that the airplane was established on the ILS runway 10R instrument approach. At 0854:39, the tower controller stated, "seven zero zero alpha quebec, Lansing, ah, tower, the winds are calm, one zero right cleared to land." The pilot responded, "Cleared to land, ah, ten right, seven hundred alpha quebec." There were no additional communications received from the pilot.

The ADS-B data indicated that at 0857:06 the airplane was about 1.3 miles from the runway threshold at 1,250 ft msl (about 400 ft above the runway elevation) and established on the localizer inbound to the runway. At 0857:37, the airplane was 0.5 miles from the runway threshold at 1,047 ft msl (about 180 ft above the runway elevation) and 84 knots when it entered a shallow climb and left turn away from the runway heading. Between 0857:37 and 0857:45, the airplane climbed to 1,059 ft msl and decelerated to 74 knots, as shown in figure 2. At 0857:45, the final ADS-B datapoint was located about 315 ft north of the localizer centerline and 0.35 miles west of the runway 10R threshold. The final ADS-B datapoint was about 475 ft southwest of the initial impact point with terrain. Figure 3 shows ADS-B position data during the airplane's final approach.

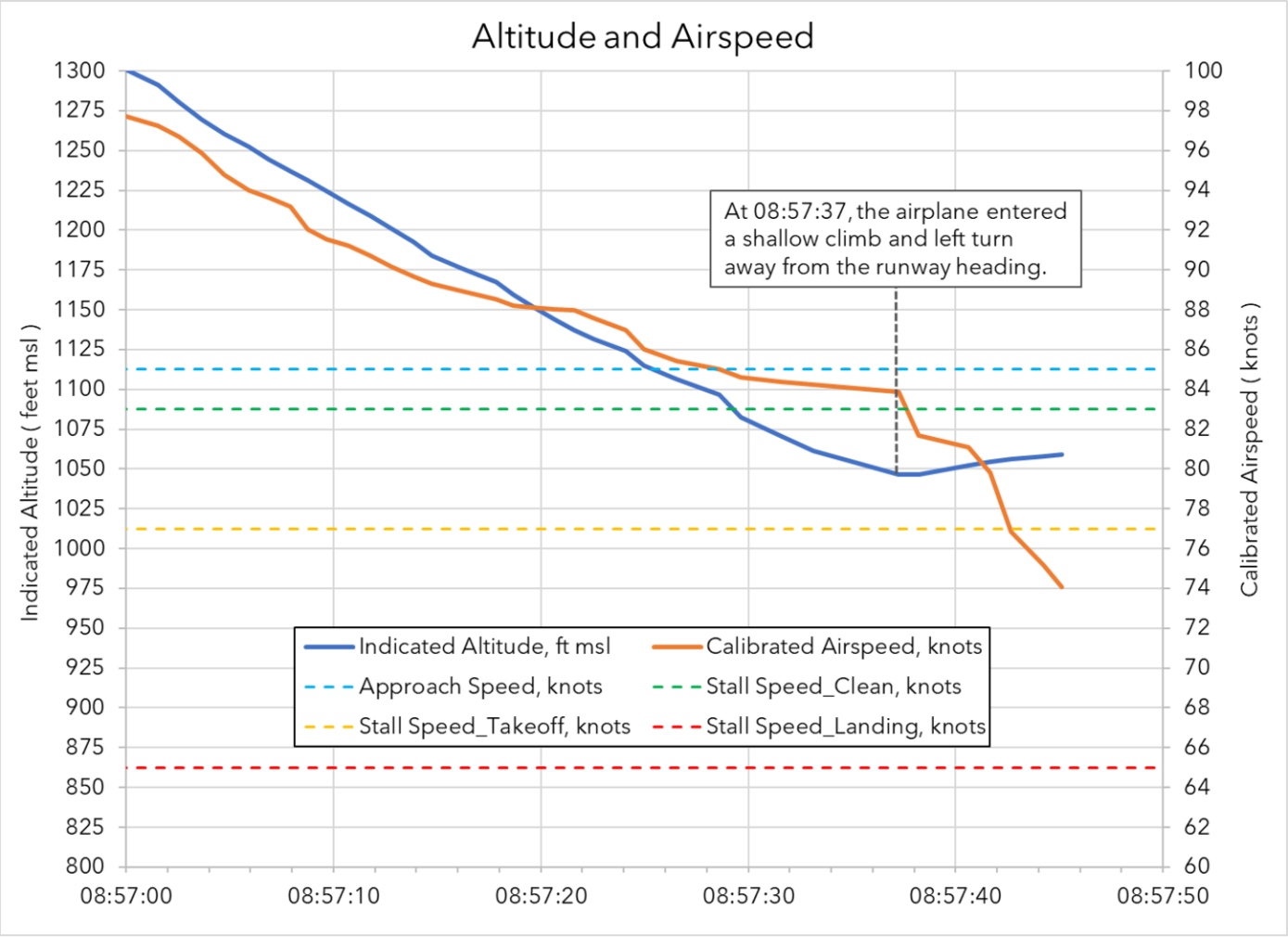

Figure 2. Altitude and airspeed during final approach.

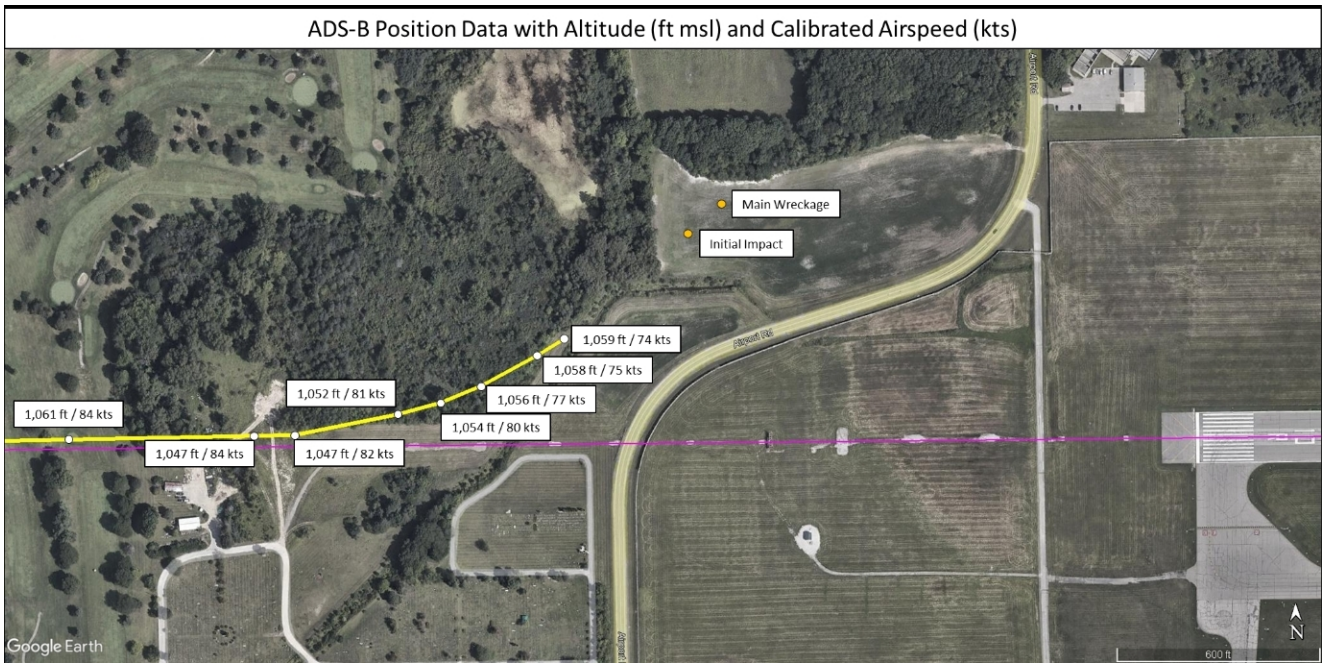

Figure 3. ADS-B position data during final approach.

Pilot Information

Certificate:	Commercial	**Age:**	48,Male
Airplane Rating(s):	Single-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 Without waivers/limitations	**Last FAA Medical Exam:**	January 4, 2019
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	May 8, 2019
Flight Time:	1404.8 hours (Total, all aircraft), 76.4 hours (Total, this make and model), 1365 hours (Pilot In Command, all aircraft), 88.2 hours (Last 90 days, all aircraft), 35.5 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

The pilot received his commercial pilot certificate on May 8, 2019. The pilot's last instrument proficiency check was completed in a Redbird SR22 simulator on September 12, 2019. He completed the SIMCOM TBM 700 initial course on September 30, 2018. According to the pilot's logbook, he had flown 76.4 hours and 9.8 hours in Socata TBM 700 and TBM 850 airplanes, respectively. The pilot had logged all his Socata TBM 700 flight time during the year before the accident.

Aircraft and Owner/Operator Information

Aircraft Make:	Socata	**Registration:**	N700AQ
Model/Series:	TBM 700 C2	**Aircraft Category:**	Airplane
Year of Manufacture:	2003	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	252
Landing Gear Type:	Retractable - Tricycle	**Seats:**	6
Date/Type of Last Inspection:	June 1, 2019 Annual	**Certified Max Gross Wt.:**	7394 lbs
Time Since Last Inspection:	38.3 Hrs	**Engines:**	1 Turbo prop
Airframe Total Time:	3550.6 Hrs at time of accident	**Engine Manufacturer:**	Pratt & Whitney
ELT:	C126 installed, activated, did not aid in locating accident	**Engine Model/Series:**	PT6A-64
Registered Owner:	N700AQ LLC	**Rated Power:**	700 Horsepower
Operator:	N700AQ LLC	**Operating Certificate(s) Held:**	None

Weight and Balance

The airplane had a total fuel capacity of 290.6 gallons (281.6 gallons usable). According to available fueling and historical flight information, the airplane had about 202 gallons (1,374 lbs) of fuel onboard before the flight departed. Based on historical fuel consumption data, the airplane used about 70 gallons (476 lbs) during the 58 minute accident flight.

According to the current weight-and-balance record, dated May 24, 2017, the airplane had an empty weight of 4,674.28 lbs and a useful load of 2,719.92 lbs. The empty weight center-of-gravity (CG) was 187.17 inches aft of the datum. At maximum takeoff weight, 7,394 lbs, the forward and aft CG limits were 187 inches and 193.65 inches, respectively.

The airplane's weight and balance at takeoff were calculated using the reported weights and seat positions for the pilot and the 5 passengers, and 202 gallons (1,374 lbs) of fuel. The takeoff weight and CG location were estimated to be 7,626.28 lbs and 196.18 inches, respectively. At takeoff, the airplane was about 232 lbs over the maximum allowable takeoff weight and about 2.53 inches past the aft CG limit. The engine burned about 70 gallons (476 lbs) of fuel during the flight. The estimated airplane weight and CG location at the time of impact were 7,150.28 lbs and 196.60 inches, respectively. At impact, the airplane was about 126 lbs over the maximum allowable landing weight and 2.95 inches past the aft CG limit (Figure 4).

N700AQ	Weight (lbs.)	Arm (in.)	Moment (in-lbs.)
Basic Empty Weight	4674.28	187.1737	874902.3
Forward Baggage (110 lbs. Max)	25	128	3200
Pilot	185	178.5	33022.5
Front Passenger	197	178.5	35164.5
Left-Mid Passenger	294	222.7	65473.8
Right-Mid Passenger (ballast)	287	222.7	63914.9
Left-Aft Passenger (ballast)	281	267.1	75055.1
Right-Aft Passenger (ballast)	299	267.1	79862.9
Aft Baggage (220 lbs. Max)	25	303	7575
Fuel (281 Gal Max Useable)	1374	189.8	260785.2
Zero Fuel Weight	6267.28	197.5611	1238171
Ramp Weight (7430 lbs. Max)	7641.28	196.1656	1498956
Fuel for start, taxi and runup	-15	189.8	-2847
Takeoff Weight (7394 lbs. Max.)	7626.28	196.1781	1496109
Fuel Burn (estimated 70 gal)	-476	189.8	-90344.8
Landing Fuel Weight	7150.28	196.6027	1405764

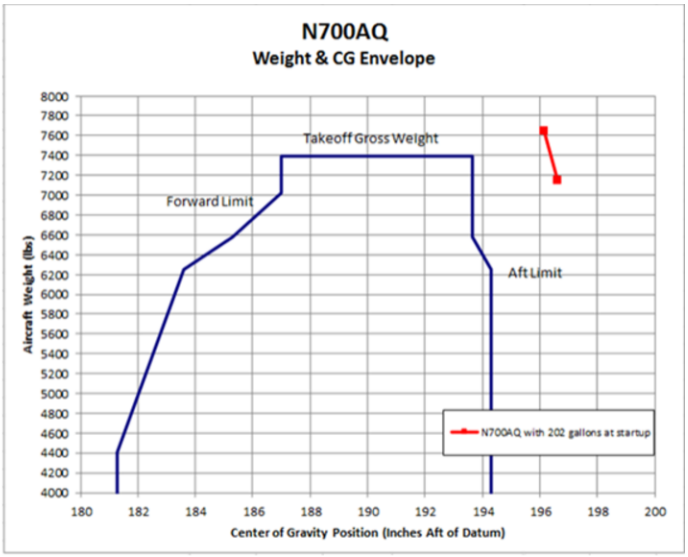

Figure 4. Weight and Balance Calculations and Plot

Aerodynamic Stall Speed

According to the Socata TBM 700 C2 *Pilot Operating Handbook* (POH), Supplement No. 41, the aerodynamic stall speed at maximum takeoff weight with the landing gear and flaps extended for landing is 65 knots. The aerodynamic stall speed at maximum takeoff weight with the landing gear and flaps extended for takeoff is 77 knots. The aerodynamic stall speed at maximum takeoff weight with the landing gear and flaps retracted is 83 knots. The approach speed with flaps in the landing position is 85 knots.

The airplane was operating above the maximum landing weight and past the aft CG limit. The airplane manufacturer provided calculated aerodynamic stall speeds for the airplane using the weight (7,150.28 lbs) and center-of-gravity position (196.60 inches) at the time of the accident. The aerodynamic stall speed was estimated to be about 62 knots with landing gear and flaps extended for landing, 74 knots with the landing gear and flaps extended for takeoff, and 79 knots with the landing gear and flaps retracted.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	LAN,861 ft msl	**Distance from Accident Site:**	1 Nautical Miles
Observation Time:	08:53 Local	**Direction from Accident Site:**	99°
Lowest Cloud Condition:		**Visibility**	1.25 miles
Lowest Ceiling:	Overcast / 400 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	/	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:		**Turbulence Severity Forecast/Actual:**	N/A / N/A
Altimeter Setting:	29.93 inches Hg	**Temperature/Dew Point:**	12°C / 11°C
Precipitation and Obscuration:	Moderate - None - Mist		
Departure Point:	Greenwood, IN (HFY)	**Type of Flight Plan Filed:**	IFR
Destination:	Lansing, MI (LAN)	**Type of Clearance:**	IFR
Departure Time:	08:00 Local	**Type of Airspace:**	Class C

Airport Information

Airport:	Capital Region International LAN	**Runway Surface Type:**	Asphalt
Airport Elevation:	861 ft msl	**Runway Surface Condition:**	Wet
Runway Used:	10R	**IFR Approach:**	ILS
Runway Length/Width:	8506 ft / 150 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	2 Fatal	**Aircraft Damage:**	Substantial
Passenger Injuries:	3 Fatal, 1 Serious	**Aircraft Fire:**	None
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	5 Fatal, 1 Serious	**Latitude, Longitude:**	42.780277,-84.606109

The accident site was in an open grass field located about 0.3 miles west-northwest of the runway 10R threshold. The initial impact point was in a large, depressed grass area that preceded a 135-ft-long ground scar oriented on a 060° bearing. The initial impact area measured 42 ft wide, consistent with the wingspan of the airplane (figure 5). The lower VHF

antenna, the left main landing gear door, and several flap track fairings were located along the wreckage debris path.

Figure 5. Initial impact point and ground scar.

Figure 6. Main airplane wreckage.

The main wreckage consisted of the entire airplane (figure 6). Both wings and the empennage remained attached to the fuselage. All flight control surfaces remained attached to their respective hinges. Flight control continuity for the elevator, rudder, and right aileron were confirmed from each flight control surface to the forward cabin. Flight control continuity to the left aileron could not be established due to impact damage; the observed cable separations near the left wing root were consistent with overstress. Both spoilers were retracted and remained connected to their respective ailerons. Both the rudder and elevator trim surfaces were found in their neutral positions.

The flap selector was found in the up and locked position. The wing flap actuator jack screws were found about halfway between the takeoff and landing positions. The landing gear selector switch was found in the gear-up position. The left main landing gear and nose gear were fully retracted and on their respective actuator uplocks. The right main landing gear was retracted into its wheel well, but the right gear was not secured by its respective actuator uplock.

The throttle was found in the flight idle position, the propeller lever was full forward, and the condition lever was full forward. The fuel manual override was closed and gated. The fuel

system switch was found on AUTO, and the engine was using fuel from the left fuel tank at the time of impact. Both fuel tanks ruptured during impact and there was a strong odor of Jet A aviation fuel at the accident site.

The engine remained attached to its respective engine mounts. There was a complete fracture of the propeller shaft and reduction gearbox housing forward of the 2nd stage reduction gears. There was evidence that engine oil was discharged out of the engine after impact; engine oil was found on the outside of the engine cowling, windscreen, and extending 20 ft in front of the engine (Figure 7). There was compressive impact damage to the exhaust case at the 6 o'clock position. Engine control continuity was established from the cockpit to the fuel control unit. The propeller speed setting lever and reset cables were found separated from the propeller governor, but these cables moved freely when the associated cockpit levers were moved by hand. The compressor rotor turned freely with no anomalies and had continuity with the accessory gearbox. Fuel discharged from hoses when the fuel pump was rotated. The fuel filter bowl was about one-half full, and the fuel appeared clear with no significant debris or phase separation. Both magnetic chip detectors were free of any metallic particles. Some minor foreign object debris was found on the leading edge of several first-stage compressor blades and vegetation debris in the inlet screen.

The compressor turbine (CT) and power turbine (PT) were intact with all blades present. There were rotational contact signatures observed on the CT blades downstream platforms from contact with the inner shroud of the upstream side of the 1st stage PT vane ring. The first-stage PT blade tips displayed rubbing, with corresponding rubbing observed on the shroud at the 6 and 12 o'clock positions. Some of the upstream blade platforms displayed rubbing with the inner shroud of the downstream side of the first-stage PT vane ring.

Figure 7. Overview Photo of the Engine and Propeller at Accident Site

The propeller assembly remained attached to the engine propeller shaft that fractured from the engine reduction gear box during impact. One propeller blade was bent in the forward/thrust direction. The remaining three propeller blades were bent in the aft direction. All four propeller blades exhibited chordwise/rotational scoring on the camber side with paint discoloration from the tip to the outboard end of the deice boot. Three blades exhibited chordwise/rotational scoring on the face side. The spinner dome was dented adjacent to one propeller blade with a counterweight impression area with the center/average angle of about 44°. The pitch change rod was in the feathered position. Three propeller blades could be rotated by hand force due to fractured pitch change mechanisms. One propeller blade had been forcefully rotated beyond the reverse stop position, two blades were in a low-pitch position, and one blade was in a feathered position. The beta ring appeared intact and undamaged with the carbon block and beta arm in position. The beta arm and valve moved freely.

The postaccident examination did not reveal any anomalies that would have precluded normal operation of the airplane.

Additional Information

Weight and Balance Effects

According to the FAA's *Aircraft Weight and Balance Handbook*, if the CG is maintained within the allowable limits for an airplane's weight, the airplane would have adequate longitudinal stability and control. If a loaded airplane results in a CG that is aft of the allowable limits, the airplane can become unstable and would be difficult to recover from an aerodynamic stall.

Propeller Thrust-Required Estimates

The propeller manufacturer provided thrust-required estimates based on the airplane's weight, altitude, airspeed, and airframe drag. The thrust estimates suggest the powerplant was running, capable of generating thrust, and responding to airframe configuration changes/power lever inputs necessary to maintain the approach path until the final moments of the flight. The average estimated propeller thrust over the final 11 recorded ADS-B data points was 412 lbs. The average flight condition during those final recorded data points were about 1,050 ft pressure altitude and 82 knots true airspeed. Assuming a propeller speed of 2,000 RPM, the engine power required to generate 412 pounds of thrust with those flight conditions is about 170 horsepower (24% torque) at about 15.6° propeller blade angle.

Safety Study

In February 2014, the French Bureau d'Enquêtes et d'Analyses (BEA) published a study concerning loss of control accidents involving Socata TBM 700 airplanes. The study reviewed 36 accidents, of which 6 involved a loss of control and left roll during final approach. In several of the accidents, the airplane deviated left of the intended flight path shortly before impact. The accidents generally involved the airplane flying at a low airspeed while in the landing configuration, combined with a rapid increase in thrust. The study highlighted a tendency for the Socata TBM 700 airplane to start rolling to the left, controllably, during go-around while at airspeeds equal to or greater than 70 knots, and from a fully reduced engine torque or adjusted to 20%. However, the left rolling tendency becomes increasingly pronounced as the airspeed decreases below 70 knots. A demonstration flight revealed that without corrective rudder input after a rapid application of thrust the airplane tended to roll to the left during an aerodynamic stall. The study acknowledged that a left roll during an aerodynamic stall is a recognized phenomenon associated with single engine airplanes, and that the Socata TBM 700 airplane design complied with federal regulations that limited how much left roll can be encountered during an aerodynamic stall. The study suggested that additional pilot training at slow airspeeds could be beneficial in preventing similar accidents in the future.

Administrative Information

Investigator In Charge (IIC):	Fox, Andrew
Additional Participating Persons:	Matthew Livingstone; Federal Aviation Administration, Grand Rapids FSDO; Grand Rapids, MI Michael Matthews; Federal Aviation Administration, Grand Rapids FSDO; Grand Rapids, MI Philippe Santoro; Daher; Pompano Beach, FL Jeremy Ganivet; Pratt & Whitney Canada; Longueuil Les Doud; Hartzell Propeller; Piqua, OH Sébastien David; Bureau d'Enquêtes et d'Analyses; Le Bourget Beverly Harvey; Transportation Safety Board of Canada; Gatineau
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