Aviation Investigation Final Report

Location:	Christoval, Texas	**Accident Number:**	CEN24FA064
Date & Time:	December 14, 2023, 12:18 Local	**Registration:**	N188PC
Aircraft:	Pilatus PC-12/45	**Aircraft Damage:**	Substantial
Defining Event:	Loss of control in flight	**Injuries:**	2 Fatal
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The instrument-rated pilot and a passenger departed on an instrument flight rules (IFR) flight. After about 4.5 hours, while approaching the first planned fuel stop, the airplane was in instrument meteorological conditions (IMC). According to air traffic control (ATC) data, the controller instructed the pilot to turn left to heading 210° for vectors to the final approach course for an RNAV (GPS) approach. About three minutes later, the controller issued a heading of 270°. Thirty-seven seconds later, the controller instructed the pilot to turn right to 030° and maintain 4,300 ft mean sea level (msl) until established on the final approach course. The final approach course heading was 002° magnetic (6.7° true). About 15 seconds later, the airplane crossed the final approach course from east to west on a track of 298° true, an angle of about 69° left of the final approach course. About three seconds later, the pilot reported to ATC “we overshot it,” to which the controller replied, “I know, that’s why I gave you a 030.” According to onboard GPS data, at about the same time, the airplane was in a 26.5°-roll right turn when the roll abruptly steepened. Over the next 10 seconds, the right roll increased from 26.5° to 92.4°. With the airplane rolled 92° to the right, the pilot reported “we got a problem.” This was the last transmission from the airplane. Between the pilot’s transmissions of “we overshot it” and “we got a problem,” the pitch angle decreased from about 1° to about -32°, the airspeed increased from 200 knots indicated airspeed (KIAS) to 240 KIAS, and the rate of descent increased from 0 feet per minute (fpm) to 13,000 fpm. Shortly before impact, the pitch angle reached -37° before starting to recover. At the end of the recorded GPS data, the pitch angle was -22.5°, the roll angle was 51.6° right, the airspeed was 283 KIAS, and the rate of descent was about 15,000 fpm. The airplane impacted terrain about 2.3 nm west and 14.7 nm south of the runway 36 threshold.

Postaccident examination of the accident site revealed a long debris field consistent with a high-speed impact and a right-wing-low and a nose-low pitch attitude. The surrounding vegetation exhibited fuel blight. All major components of the airplane were located in the debris field. Examination of the airframe did not reveal evidence of any mechanical malfunctions or failures that would have precluded normal operation. However, the degree of fragmentation and fire damage precluded a complete evaluation of the airplane's flight controls and autopilot system. Rotational contact signatures on the internal engine components were consistent with the engine producing power at impact. Three propeller blades exhibited pronounced bending opposite the direction of rotation. No evidence of preimpact mechanical malfunctions or failures of the engine or propeller was identified that would have precluded normal operation.

Postaccident examination of the airplane's central advisory and warning system (CAWS) annunciator lights revealed that the master caution, autopilot trim and autopilot disengage lights were illuminated at the time of impact. The airplane's configuration was commensurate with flight in precipitation but not icing conditions. The illuminated annunciators were consistent with the airplane's upset and autopilot disconnect sequence.

A performance and simulation study supports several observations regarding the airplane's performance during the descent from 4,300 ft msl, its increasingly steep descending right turn shortly after it flew across the final approach course, and its final dive and impact with terrain. Based on the sequence of events and the recorded autopilot parameters, the autopilot remained engaged while the roll angle increased past normal autopilot limits (typically 30°), until it disconnected after the roll angle increased past the autopilot's engagement limit of 75°. The study further suggested a scenario consistent with the data where, while the pilot was receiving vectors for the approach, the autopilot's lateral mode was likely "heading hold", because the ADS-B "SelHdg" parameter matched the headings provided by the controller, except for the final 030° heading. After the controller gave the 030° heading, the pilot changed SelHdg to 300°, and not 030°. After the airplane crossed the final approach course, the ADS-B LNav discrete switched from 0 to 1, which indicated that lateral navigation was engaged. The active waypoint at that time was likely the final approach fix (FAF), with a bearing of 003°. Under these circumstances, it is improbable that the autopilot would have steered the airplane to the 030° heading assigned by the controller. Instead, with heading hold selected, the autopilot would have continued on the selected heading of 300°.

To keep the airplane turning right toward the 030° assigned heading, the pilot could have pressed and held the control wheel steering (CWS) button on the yoke or manually overpowered the autopilot servos, which would have allowed him to manually roll the airplane further to the right without disengaging the autopilot. The apparent pitch angle—that is, the pitch attitude perceived by the pilot's vestibular system—would have ranged between -1° and 1°, and so conditions consistent with the production of a somatogravic illusion of level flight were present.

As the airplane rolled through a right roll angle of 75°, the autopilot would have disconnected automatically, consistent with the change in the ADS-B autopilot discrete. Shortly after, the pilot announced that “we got a problem.” The sudden increase in the recorded normal load factor immediately before impact was consistent with an abrupt recovery attempt. Because the airplane had descended beneath the cloud base, the pilot may have acquired outside visual references and attempted to recover, but there was insufficient altitude to return the airplane to level flight before impact.

The circumstances of this accident are consistent with the pilot experiencing spatial disorientation, most likely the somatogravic illusion. The performance and simulation study determined the apparent pitch angle remained nearly level during the initial 20 seconds of the final descent. In the absence of reliable outside visual references, such an apparent pitch attitude is conducive to the somatogravic illusion.

In addition, the controller did not provide an appropriate intercept angle to the final approach course and did not advise the pilot that vectors would take the airplane through the final approach course and state the reason for doing so, as required by FAA Order JO 7110.65. While operating in IMC, the pilot was required to respond to an abrupt and unusually large heading change to re-intercept the final approach course. These atypical vectors required the pilot to rapidly modify the approach while operating in IMC, increasing his workload and cognitive demand as he attempted to quickly re-intercept the final approach course, a procedure that he likely did not anticipate. By increasing the pilot’s workload during a critical phase of flight, the deficient ATC services likely increased the pilot’s workload and contributed to the pilot’s spatial disorientation.

Probable Cause and Findings

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

The pilot’s loss of control due to spatial disorientation while operating in instrument meteorological conditions. Contributing to the accident were the controller’s failure to issue an appropriate intercept angle for the final approach course, failure to advise the pilot that vectors would take the airplane through the final approach course, and the pilot’s entry of an incorrect heading into the autopilot.

Findings

Personnel issues	Aircraft control - Pilot
Aircraft	Lateral/bank control - Not attained/maintained
Aircraft	Pitch control - Not attained/maintained
Aircraft	Descent rate - Not attained/maintained
Personnel issues	Spatial disorientation - Pilot
Personnel issues	Incorrect action selection - Pilot
Personnel issues	Issuing instructions - ATC personnel
Personnel issues	Cognitive overload - Pilot

Factual Information

History of Flight

Approach-IFR initial approach	Loss of control in flight (Defining event)

On December 14, 2023, about 12:18 central standard time (CST), a Pilatus PC-12/45 airplane, N188PC, was destroyed when it was involved in an accident near Christoval, Texas. The pilot, one passenger, and three pets were fatally injured. The flight was conducted under Title 14 *Code of Federal Regulations* Part 91 as a personal flight.

FAA ATC recordings and ADS-B data revealed that the airplane departed Jacksonville Executive at Craig Airport (KCRG), Jacksonville, Florida, about 07:51 CST, and was enroute to San Angelo Regional Airport (KSJT), San Angelo, Texas. At 12:03, the accident pilot contacted San Angelo Approach control and was instructed to descend to 6,000 ft and expect radar vectors for the RNAV (GPS) runway 36 approach to KSJT. At 12:07:23, the controller instructed the pilot to turn left to heading 230° and descend to 4,300 ft. At about 12:11, the pilot reported to ATC that the tops of the clouds were variable between 4,100 ft and 4,400 ft msl.

At 12:13:50, the controller instructed the pilot to turn left to heading 210° for vectors to the final approach course. At 12:16:40, the controller issued a heading of 270°, and at 12:17:17 instructed the pilot to "turn right heading 030° maintain 4,300 until established on the final approach course, cleared RNAV runway 36 approach." The KSJT RNAV runway 36 final approach course heading is 002° magnetic, or 6.7° true. At 12:17:32, the airplane flew across the final approach course from east to west on a track of 298° true, an angle of about 69° left of the final approach course. At 12:17:35, the pilot reported to ATC that "we overshot it," to which the controller replied, "I know, that's why I gave you a 030." Based on data recorded by the Garmin GTN 750Xi panel-mounted GPS receivers, at 12:17:34, the airplane was in a 26.5° right roll when the roll abruptly steepened; between 12:17:34 and 12:17:45, the right roll increased from 26.5° to 92.4°. At 12:17:46, with the airplane rolled 92° to the right, the pilot reported "we got a problem." This was the last transmission from the airplane.

Between the pilot's transmissions of "we overshot it" at 12:17:35 and "we got a problem" at 12:17:46, the pitch angle decreased from about 1° to about -32°, the airspeed increased from 200 KIAS to 240 KIAS, and the rate of descent increased from 0 fpm to 13,000 fpm. The pitch angle reached -37° at 12:17:48 before starting to recover. At the end of the data at 12:17:50, the pitch angle was -22.5°, the roll angle was 51.6° right, the airspeed was 283 KIAS, and the rate of descent was about 15,000 fpm. The airplane impacted the ground about 2.3 nm west and 14.7 nm south of the KSJT runway 36 threshold at an elevation of 2,219 ft msl.

Pilot Information

Certificate:	Private	**Age:**	64,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:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 3 With waivers/limitations	**Last FAA Medical Exam:**	May 4, 2022
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	August 2, 2023
Flight Time:	(Estimated) 3100 hours (Total, all aircraft), 416 hours (Total, this make and model), 27.7 hours (Last 90 days, all aircraft), 7.2 hours (Last 30 days, all aircraft), 2.1 hours (Last 24 hours, all aircraft)		

The pilot reported on his most recent FAA medical examination that he had accumulated 2,900 flight hours. At the time of the accident, the pilot had logged more than 3,100 flight hours.

According to the pilot's electronic flight logbook, he had accumulated 266.9 flight hours in the accident airplane during the previous two years, including 47.3 in actual IMC and 5.7 hours in simulated IMC. During the same period, the pilot completed 39 instrument approaches, 12 of which were GPS approaches.

Aircraft and Owner/Operator Information

Aircraft Make:	Pilatus	**Registration:**	N188PC
Model/Series:	PC-12/45	**Aircraft Category:**	Airplane
Year of Manufacture:	1997	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	188
Landing Gear Type:	Retractable - Tricycle	**Seats:**	6
Date/Type of Last Inspection:	November 22, 2023 Annual	**Certified Max Gross Wt.:**	9921 lbs
Time Since Last Inspection:		**Engines:**	1 Turbo prop
Airframe Total Time:	3990.1 Hrs as of last inspection	**Engine Manufacturer:**	P&W CANADA
ELT:	C126 installed, not activated	**Engine Model/Series:**	PT6A-67B
Registered Owner:	TIMELESS USA LLC	**Rated Power:**	1200 Horsepower
Operator:	On file	**Operating Certificate(s) Held:**	None

The pilot had co-owned the accident airplane since 2009 and became the sole owner in 2020.

In 2020, the airplane was upgraded under supplemental type certificates (STCs) that installed Garmin avionics and components that included a Garmin G600 integrated avionics display system, Garmin GTN 750Xi flight navigators, and a Garmin GI 275 electronic attitude indicator. In March 2023, the original King KFC 325 autopilot was replaced with a Garmin GFC 600 five-axis autopilot system and a Garmin GMC 605 autopilot mode controller in accordance with an STC.

The most recent inspection was completed from August 2023 to November 2023. According to the maintenance records, the facility completed the 12-month, 300-hour, 600-hour, and 1,200-hour inspections in accordance with the PC-12 maintenance manual.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KSJT,1911 ft msl	**Distance from Accident Site:**	15 Nautical Miles
Observation Time:	11:51 Local	**Direction from Accident Site:**	10°
Lowest Cloud Condition:		**Visibility**	10 miles
Lowest Ceiling:	Overcast / 1100 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	6 knots / None	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	100°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.31 inches Hg	**Temperature/Dew Point:**	10°C / 8°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Jacksonville, FL (CRG)	**Type of Flight Plan Filed:**	IFR
Destination:	San Angelo, TX (SJT)	**Type of Clearance:**	IFR
Departure Time:	08:51 Local	**Type of Airspace:**	Class E

The pilot obtained an electronic weather briefing via ForeFlight before departure. The archived briefing indicated that the Graphic Forecast for Aviation (GFA) depicted basic IFR conditions, although the METAR and TAFs available at the time of the briefing did not.

Archived meteorological information and the accident pilot's report to ATC revealed that the airplane was in IMC during the approach and that there was a potential for turbulence within clouds, no icing below 11,000 ft, and no significant precipitation.

A National Weather Service High-Resolution Rapid Refresh (HRRR) model sounding for 11:00 CST near the accident site depicted the convective condensation level at 550 ft above ground level (agl), with the lifted condensation level (LCL) and level of free convection (LFC) at about

700 ft agl. A defined frontal inversion was noted near the LFC to about 6,000 ft. The sounding was saturated from the LCL through 5,000 ft. Relative humidity exceeded 85% through 13,000 ft, supporting cloud formation. The freezing level was identified at 11,700 ft or near the cloud tops. The sounding wind profile indicated a surface wind from 135° at 10 knots, with wind veering to the southwest and increasing in speed with altitude. A low-level jet stream was identified at 5,650 ft with winds from 170° at 31 knots, consistent with a potential for moderate turbulence between 3,000 and 5,000 ft.

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Substantial
Passenger Injuries:	1 Fatal	**Aircraft Fire:**	On-ground
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	2 Fatal	**Latitude, Longitude:**	31.100508,-100.54491

The airplane impacted the ground and was heavily fragmented on a 100° magnetic heading; the debris field extended about 500 yards. The initial impact was defined by a impact marks and severed branches on a small tree, cut at an angle of about 24°, consistent with a right-wing-low airplane attitude at impact. The first 150 yards of debris consisted of very small, fragmented pieces and several areas with thermal damage and black sooting. There was evidence of fuel blight to the surrounding vegetation. The next 75 yards consisted of larger pieces of debris scattered among thick trees and vegetation. Near the end of this debris section was a large piece of the top of the cabin/fuselage structure. A large section of the left wing and a small inboard section of the right wing were near the main wreckage and exhibited thermal damage. Small pieces of the outboard right wing were found near the initial point of impact. The remainder of the right wing was destroyed and could not be identified.

Postaccident examination partially established flight control continuity through overload and impact-related separations. All recovered connections on the recovered flight control surfaces were found intact and safety wired, and observed fractures were consistent with impact forces. In the cockpit area, both control yokes and parts of the control column behind the instrument panel were located. The left control yoke was impact-damaged and its right grip, which contained the control wheel steering (CWS) button, was not recovered. The right control yoke was intact with minimal impact damage. No other components of the flight control system in the cockpit area, including the rudder pedals, were located. The aileron quadrant was located; however its associated cables, push-pull tube, and rudder/aileron interconnect mechanism were not recovered. The aileron push-pull tubes in the wings had fractured into numerous pieces; some had remained with the wing structure and some were found in the

debris field. The rudder control cables were found attached to the rudder quadrant. The end-stops on the rudder quadrant did not show any indications of contact damage. The elevator control cables were found attached to the bellcrank in the vertical stabilizer. The elevator balance weight was attached. The push-pull tube to the elevator had fractured from overload at the aft rod end. The end stops on the elevator torque tube did not show any evidence of contact damage. The positions of the four flap actuators were consistent with the flaps being retracted. The aileron, rudder, and elevator trims were all positioned near neutral. Examination of the airframe wreckage did not reveal evidence of any mechanical malfunctions or failures that would have precluded normal operation, though the degree of fragmentation and fire damage precluded a complete evaluation of the airplane's flight controls and autopilot system.

The engine and propeller were impact-separated from the airplane and were found in the debris field. The engine and associated components were separated into numerous pieces during the accident sequence. The first stage compressor blades exhibited rotational rubbing at the blade tips and leading edge bending opposite the direction of rotation. Significant rotational contact was observed on the compressor turbine and power turbine discs and blades. These conditions, combined with ingestion of dirt and environmental debris found in the combustion chamber liner, are consistent with the engine producing power at the time of impact. The reduction gearbox (RGB) second stage carrier was sheared at the slotted holes near the center of the hub, the second stage flexible coupling was found sheared, and the rear compressor hub coupling shaft was found with a spiral fracture all consistent with an engine producing high power at the time of impact. The rotational contact signatures observed on the internal components were also characteristic of the engine producing power at the time of impact.

All the major propeller components were recovered in the wreckage debris. The propeller impact-separated from the engine with the propeller shaft and associated RGB bearings still attached. The cylinder, piston, and feathering spring assembly impact-separated from the hub and was found near the propeller assembly near the end of the wreckage debris path. The propeller assembly and two blades remained attached and were found east of the main wreckage and south of the engine. Two of the four blades impact-separated from the propeller assembly. One blade fractured from the blade retention pocket and was found in the initial impact crater. The other blade fractured at the shank and was found just east of the initial impact crater in the debris field. All four blades exhibited chordwise/rotational scoring, leading edge gouging and compound bend and twist features. Three blades exhibited pronounced bending opposite the direction of rotation.

There was no evidence of preimpact mechanical malfunctions or failures of the engine or propeller that would have precluded normal operation.

Central Advisory and Warning System (CAWS) and Master Caution/Warning

The CAWS panel and the pilot side master caution/warning panel were submitted to the NTSB Materials Laboratory for examination. The panels were submitted to determine the filament

status for the annunciator lights within each of the panels. In the CAWS panel, there were 42 lights within the panel. Each light contained 2 bulbs. Only one annunciator light was missing both bulbs with no filament present, which was WSHLD HEAT. The following lights exhibited hot filament stretching consistent with the light being illuminated at the time of impact: MASTER CAUTION, INERT SEP, PROBES DE ICE, COOL, A/P TRIM, and A/P DISENG.

According to the airframe manufacturer, the MASTER CAUTION annunciator indicated that the central advisory computer unit had detected a caution condition. The illuminated INERT SEP annunciator indicated that the engine air intake inertial separator door was selected open. The illuminated PROBES DE ICE annunciator indicated that the pitot-static heating system was on. The illuminated COOL annunciator indicated that the air conditioning compressor was operating.

The illuminated A/P TRIM annunciator indicated an autopilot trim system failure, and the illuminated A/P DISENG annunciator indicated that the autopilot had been disengaged within 30 seconds before impact. The Garmin GFC 600 autopilot may disengage automatically when specific attitude limits are exceeded or when certain system faults are detected, or it may be disengaged manually by the pilot.

Electronic Devices

The following electronic devices were recovered from the accident site and sent to the NTSB Vehicle Recorders Laboratory for potential data extraction: two Garmin GTN 750Xi flight navigators, a Garmin GI 275 electronic attitude indicator, a Garmin G600 integrated avionics display system, a Garmin GMC 605 autopilot mode controller, and a CAWS control unit. Data were recovered from the Garmin GI 275 and both Garmin GTN 750Xi units. No data were recovered from the Garmin G600, Garmin GMC 605, or the CAWS due to the damage sustained during the accident. Recovered data from the GI 275 and GTN 750Xi's were compared and were redundant.

Medical and Pathological Information

An autopsy of the pilot was conducted by South Plains Forensic Pathology, Lubbock, Texas. According to the autopsy report, the pilot's cause of death was blunt force injuries of the head, neck, torso, and extremities.

Toxicology testing performed at the FAA Forensic Sciences Laboratory detected the following: Ethanol was detected in the muscle tissue but not in lung tissue. The ideal specimen, vitreous fluid from the eye, was not available. The level of ethanol detected in muscle was low and the

absence of ethanol in lung tissue suggests decomposition likely produced the ethanol detected in the muscle tissue.

Cetirizine was detected in lung tissue at 29 ng/g and in muscle tissue at 20 ng/g. Cetirizine (Zyrtec) is a second-generation antihistamine medication that is available over the counter and is commonly used to treat allergy symptoms.

Loperamide was detected in the lung and muscle tissue. Loperamide (Imodium) is an opioid receptor agonist used to decrease the frequency of diarrhea. Side effects may include dry mouth and sleepiness. Loperamide is acceptable for plots for occasional acute use and if the underlying condition is acceptable.

Metoprolol was detected in the lung and muscle tissue. Metoprolol (Lopressor) is a beta-blocker used to treat high blood pressure and is acceptable for pilots.

Tadalafil was detected in the lung and muscle tissue. Tadalafil (Cialis) is a PDE5 inhibitor used to treat erectile dysfunction, benign prostatic hyperplasia, and pulmonary arterial hypertension. Side effects include vision and hearing changes. Tadalafil is conditionally acceptable for pilots depending on the dosage and the condition being treated. Higher doses require 24-hour waiting periods.

Diclofenac was detected in the lung tissue and was inconclusive in the muscle tissue. Diclofenac (Voltaren) is a prescription NSAID-type anti-inflammatory medication and is acceptable for pilots.

Pravastatin was detected in the muscle tissue but not the lung tissue. Pravastatin (Pravachol) is an HMG-CoA enzyme reductase inhibitor used to treat high cholesterol and is acceptable for pilots.

Tests and Research

Aircraft Performance & Simulation Study

A postaccident performance and simulation study was completed by the NTSB's Vehicle Performance Division. The study was based on ADS-B data and recorded data on the Garmin GTN 750Xi, wreckage location and debris field evidence, weather information, airplane performance information in the pilot’s operating handbook, and output from aircraft performance analysis programs and simulations. The airplane was not equipped with a flight data or cockpit voice recorder, nor was it required to be. Consequently, no measures of the

control inputs or engine power during the flight were available since these parameters were not recorded on the GTN 750Xi.

The objective of this study was to determine and analyze the motion of the airplane and the physical forces that produce that motion. In particular, the study intended to define the airplane's position and orientation during the relevant portion of the flight and determine the airplane's response to control inputs, external disturbances, and other factors that could affect its trajectory. The information listed above is used to define the trajectory of the airplane during its maneuvers toward the GPS final approach course, and its sudden turning descent from about 4,300 ft msl into the ground after flying through the final approach course. An NTSB simulation incorporating aerodynamic, flight controls, and engine models of the Pilatus PC-12 provided by Pilatus was used to find a set of simulator flight control and throttle inputs that result in a simulated trajectory that approximately matches the trajectory defined by the recorded data. The control forces required to achieve the resulting flight control inputs are also computed.

The material in this study is consistent with the autopilot remaining engaged while the roll angle increased past normal autopilot limits (typically 30°), until it disconnected after the roll angle increased past the autopilot's engagement limit of 75°.

The study further suggested a scenario consistent with the data where, while the pilot was receiving vectors for the GPS approach to runway 36, the autopilot lateral mode was likely "heading hold", since the ADS-B "SelHdg" parameter matched the headings provided by the controller, except for the final 030° heading. After the controller gave the 030° heading, the pilot changed the SelHdg to 300°, rather than the assigned heading of 030° (a difference of 90°). Then, after the airplane crossed the final approach course at 12:17:32, the ADS-B LNav discrete switched from 0 to 1. The active waypoint at that time was likely the FAF, bearing 003°. Under these circumstances, it is improbable that the autopilot would have steered the airplane to the 030° heading assigned by the controller. Instead, with heading hold mode selected, the autopilot would have continued on the selected heading of 300°. If the approach or navigation modes were selected, the autopilot would have followed the active course on the approach.

To keep the airplane turning right toward the 030° assigned heading, the pilot could have pressed and held the CWS button on the yoke or manually overpowered the autopilot servos, which would have allowed him to manually roll the airplane further to the right without disengaging the autopilot. The "apparent pitch" during this turn would have ranged between -1° and 1°, and so conditions consistent with the production of a somatogravic illusion of level flight were present.

As the airplane rolled through a roll angle of 75°, the autopilot would have disconnected automatically, consistent with the change in the ADS-B autopilot discrete between 12:17:42 and 12:17:44. Shortly after, the pilot announced that "we got a problem." The sudden increase

in the recorded normal load factor at 12:17:47 was consistent with an abrupt recovery attempt after the airplane descended beneath the cloud base.

Additional Information

Air Traffic Control Services

According to FAA Order JO 7110.65AA, chapter 5, section 9, paragraph 5-9-2, final approach course interception, the controller was to assign headings that would permit final approach course intercept on a track that does not exceed a 30° angle if an aircraft intercepts the approach course more than 2 miles from the approach gate.

Paragraph 5-9-3 of the order stated that the controller was to inform the aircraft whenever a vector will take it across the final approach course and state the reason for such action.

Paragraph 5-9-4 of the order stated that the controller was to issue arrival information and clearance prior to the approach gate.

A review of ATC services by an NTSB ATC specialist revealed that the controller issued vectors to intercept the final approach course at least 2 miles outside of the approach gate and issued arrival information and a clearance before the approach gate. However, the controller vectored the aircraft to intercept the final approach course on a track that exceeded a 30° angle. The controller issued a heading of 030°, which created an intercept angle of about 88° from the final approach course. Additionally, the controller did not advise the pilot that the assigned vector would take it across the final approach course. Recorded ATC communications indicated that the controller knew the aircraft would cross the final approach course.

Spatial Disorientation

The FAA's Pilot's Handbook of Aeronautical Knowledge contained the following guidance:

> *Under normal flight conditions, when there is a visual reference to the horizon and ground, the sensory system in the inner ear helps to identify the pitch, roll, and yaw movements of the airplane. When visual contact with the horizon is lost, the vestibular system becomes unreliable. Without visual references outside the airplane, there are many situations where combinations of normal motions and forces can create convincing illusions that are difficult to overcome.*

A rapid acceleration, such as experienced during takeoff, stimulates the otolith organs in the same way as tilting the head backwards. This action may create what is known as the 'somatogravic illusion' of being in a nose-up attitude, especially in conditions with poor visual references. The disoriented pilot may push the aircraft into a nose-low or dive attitude.

The FAA's Airplane Flying Handbook (FAA-H-8083-3) described hazards associated with flying when visual references, such as the ground or horizon, are obscured:

The vestibular sense (motion sensing by the inner ear) in particular tends to confuse the pilot. Because of inertia, the sensory areas of the inner ear cannot detect slight changes in the attitude of the airplane, nor can they accurately sense attitude changes that occur at a uniform rate over a period of time. On the other hand, false sensations are often generated; leading the pilot to believe the attitude of the airplane has changed when in fact, it has not. These false sensations result in the pilot experiencing spatial disorientation.

The FAA's publication "Spatial Disorientation Visual Illusions" (OK-11-1550), provided guidance on the prevention of spatial disorientation. One of the preventive measures was "when flying at night or in reduced visibility, use and rely on your flight instruments." The publication stated the following:

If you experience a visual illusion during flight (most pilots do at one time or another), have confidence in your instruments and ignore all conflicting signals your body gives you. Accidents usually happen as a result of a pilot's indecision to rely on the instruments.

Preventing Similar Accidents

Reduced Visual References Require Vigilance (SA-020)

The Problem

About two-thirds of general aviation accidents that occur in reduced visibility weather conditions are fatal. The accidents can involve pilot spatial disorientation or controlled flight into terrain. Even in visual weather conditions, flights at night over areas with limited ground lighting (which provides few visual ground references) can be challenging.

What can you do?

- Obtain an official preflight weather briefing, and use all appropriate sources of weather information to make timely in-flight decisions. Other weather sources and in-cockpit weather equipment can supplement official information.
- Refuse to allow external pressures, such as the desire to save time or money or the fear of disappointing passengers, to influence you to attempt or continue a flight in conditions in which you are not comfortable.
- Be honest with yourself about your skill limitations. Plan ahead with cancellation or diversion alternatives. Brief passengers about the alternatives before the flight.
- Seek training to ensure that you are proficient and fully understand the features and limitations of the equipment in your aircraft, particularly how to use all features of the avionics, autopilot systems, and weather information resources.
- Don't allow a situation to become dangerous before deciding to act. Be honest with air traffic controllers about your situation, and explain it to them if you need help.
- Remember that, when flying at night, even visual weather conditions can be challenging. Remote areas with limited ground lighting provide limited visual references cues for pilots, which can be disorienting or render rising terrain visually imperceptible. When planning a night VFR flight, use topographic references to familiarize yourself with surrounding terrain. Consider following instrument procedures if you are instrument rated or avoiding areas with limited ground lighting (such as remote or mountainous areas) if you are not.
- Manage distractions: Many accidents result when a pilot is distracted momentarily from the primary task of flying.

See https://www.ntsb.gov/Advocacy/safety-alerts/Documents/SA-020.pdf for additional resources.

The NTSB presents this information to prevent recurrence of similar accidents. Note that this should not be considered guidance from the regulator, nor does this supersede existing FAA Regulations (FARs).

Administrative Information

Investigator In Charge (IIC):	Lindberg, Joshua
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The National Transportation Safety Board (NTSB) is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant events in other modes of transportation—railroad, transit, highway, marine, pipeline, and commercial space. We determine the probable causes of the accidents and events we investigate, and issue safety recommendations aimed at preventing future occurrences. In addition, we conduct transportation safety research studies and offer information and other assistance to family members and survivors for each accident or event we investigate. We also serve as the appellate authority for enforcement actions involving aviation and mariner certificates issued by the Federal Aviation Administration (FAA) and US Coast Guard, and we adjudicate appeals of civil penalty actions taken by the FAA.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, "accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties … and are not conducted for the purpose of determining the rights or liabilities of any person" (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)). A factual report that may be admissible under 49 *United States Code* section 1154(b) is available here.