Aviation Investigation Final Report

Location:	Springfield, Illinois	**Accident Number:**	CEN14LA127
Date & Time:	January 31, 2014, 13:12 Local	**Registration:**	N700FE
Aircraft:	Piaggio P180 - AVANTI II	**Aircraft Damage:**	Substantial
Defining Event:	Landing gear collapse	**Injuries:**	5 None
Flight Conducted Under:	Part 91: General aviation		

Analysis

The landing gear did not extend when the copilot selected gear-down during the initial instrument approach to the destination airport. The flight crew was able to extend the landing gear using the emergency extension procedure; however, following the emergency extension, the pilot decided to reengage the hydraulic system to have power-assisted braking and nosewheel steering during landing. The pilot stated that the wheel brakes were less effective than normal and the nosewheel steering was inoperative during the landing roll, which he concluded was because the emergency landing gear selector valve handle was still extended. The pilot reported that in an attempt to resolve the braking and steering issues he reached for the emergency landing gear selector valve, but the landing gear collapsed before his hand touched the valve handle.

Postaccident testing determined the directional control valve that controls the flow of hydraulic fluid to the landing gear actuators was stuck in the gear-up position. Examination of the directional control valve revealed a metallic particle trapped between one of the spool lands and the valve housing, which prevented the spool from moving into the gear-down position. The source of the trapped particle could not be conclusively determined. A teardown examination did not reveal any mechanical anomalies that would have resulted in a malfunction of the hydraulic pump package.

The airplane flight manual specified that the hydraulic system be turned off before the landing gear was manually extended using the emergency procedures. The flight manual did not include a provision for the hydraulic system to be reengaged following the emergency landing gear extension. As such, the hydraulic system should have remained off during landing.

Postaccident testing concluded that the landing gear would immediately retract if the emergency landing gear selector valve was in the stowed position with the hydraulic system turned on. Consequently, because the airplane landed with its gear extended, the emergency landing gear selector valve handle had to be in the extended position upon touchdown.

One scenario for the unintended landing gear retraction was if the pilot repositioned the emergency

landing gear selector valve to its normal (retracted) position during the landing roll. This would have allowed the unintended pressure in the normal hydraulic system lines to retract the landing gear. Although this scenario is consistent with the reported sequence-of-events, the pilot stated that he did not touch the emergency landing gear selector valve handle during the landing roll. Additionally, the emergency valve handle was found extended after the accident.

Another possible scenario was if the pressure in the emergency extension line decreased below that necessary to hold the gear down locks in position. Postaccident testing completed on an exemplar airplane with a simulated failure of the directional control valve and the hydraulic system turned on, concluded that the down locks could release and allow the landing gear to retract if the line pressure in the emergency system decreased sufficiently.

After considering the test data and the variables involved, the investigation was unable to conclusively determine which scenario had triggered the down locks to release during landing roll. However, the landing gear would not have retracted had the pilot not reengaged the hydraulic system following the successful extension of the landing gear using the emergency extension procedures. The hydraulic system being turned on, in combination with the failure of the directional control valve in the gear-up position, resulted in unintended pressure within the hydraulic lines associated with gear retraction and created the means for the gear to retract when the gear locks released for undetermined reasons.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be: The pilot's decision to reengage the hydraulic system following the successful extension of the landing gear using the emergency extension procedures. Contributing to the accident was the failure of the directional control valve in the gear-up position and the release of the gear down locks for undetermined reasons.

Findings

Aircraft	Hydraulic, main system - Incorrect use/operation
Personnel issues	Decision making/judgment - Pilot
Aircraft	Gear extension and retract sys - Failure

Factual Information

History of Flight

Other	Sys/Comp malf/fail (non-power)
Landing-landing roll	Landing gear collapse (Defining event)

On January 31, 2014, at 1312 central standard time, a Piaggio P180 airplane, N700FE, was substantially damaged when the landing gear retracted during landing roll at Abraham Lincoln Capital Airport (SPI), Springfield, Illinois. The pilot, copilot, and 3 passengers were not injured. The airplane was registered to Peregrine Falcon, Inc. and operated by Mountain Aviation, Inc., under the provisions of Title 14 *Code of Federal Regulations* (*CFR*) Part 91 while on an instrument flight rules flight plan. Day instrument meteorological conditions prevailed for the cross-country business flight that departed Dane County Regional Airport (MSN), Madison, Wisconsin, at 1156.

The pilot reported that he told the copilot to select landing gear down and to reposition the flaps as the airplane approached the outer marker for the instrument landing system (ILS) runway 4 approach at SPI. The pilot stated that after repositioning the landing gear selector handle to gear-down the hydraulic system pressure indicated 3,000 pounds per square inch (psi), but he did not observe a safe landing gear indication. The pilot made a missed approach at the final approach fix to troubleshoot the landing gear system anomaly. The landing gear selector handle was cycled several times, each time without a safe gear-down indication. The copilot then declared an emergency with air traffic control. The pilot and copilot then completed the emergency landing gear extension checklist procedure; landing gear selector handle in the down position, hydraulic system off, emergency landing gear selector valve pulled, and then manually pump the landing gear down. The pilot reported that after completing the emergency landing gear extension they observed a safe gear-down indication. The copilot then advised the air traffic controller that they were ready to continue to the instrument approach and canceled their emergency.

The pilot reported that while they were being vectored back to the final approach course he and the copilot discussed if the hydraulic system could be turned back on to have power-assisted braking and nosewheel steering available upon landing on the snow-covered runway. The pilot stated that after the hydraulic system was turned on he observed a system pressure indication of 750 psi and did not observe an unsafe indication for the hydraulic system. Additionally, the safe gear-down indicators remained illuminated after the hydraulic system was turned back on.

The pilot reported that the flight was vectored for the ILS runway 4 approach at SPI and the airplane descended below clouds about 600 ft above ground level (agl) while on final approach. He stated that the touchdown was as slow and as soft as possible, and that he gradually applied wheel braking to slowly decelerate the airplane during the landing roll. He noted that the wheel brakes were less effective than normal and that the nosewheel steering was inoperative, but the airplane still decelerated to a walking speed as it approached the foxtrot taxiway turnoff. The pilot stated that he believed the diminished braking and lack of nosewheel steering was because the emergency landing gear selector valve was still in the extended position. The pilot reported that the landing gear collapsed as he "reached

for" the emergency landing gear selector valve handle. The pilot further stipulated that he "did not make contact with the emergency selector" before the landing gear collapsed.

According to a transcript of the cockpit voice recorder (CVR), while inflight, at 1255:34, the copilot began pumping the landing gear down and 1 minute 3 seconds later the pilot stated "Okay, three green." At 1256:38, the copilot stated "ahhh, alright [exhaling]" and the sound of his pumping the emergency handle ceased. At 1259:43, the copilot asked the pilot "do you want the hydraulic pressure on for steering and braking?" The pilot replied "I was going to say. I think, ah, we should do that. Do you think that's acceptable?" At 1259:49, the pilot replied "okay… I do." At 1259:50, the pilot said "alright, I like that" and the sound of the hydraulic motor commences. At 1301:17, the pilot asked the copilot "there wasn't anything else in the checklist after pumping it down, correct?" The copilot replied, "it comes down, three green." At 1301:22, the pilot asked the copilot "okay, it didn't say go to any others?" The copilot replied "no." At 1301:35, the copilot told the pilot "checklist doesn't regard it… doesn't really have a checklist for… gear stuck." The copilot then said, "it has hydraulic failure, which would say pump the gear down." The copilot then told the pilot the remaining landing gear emergency checklists were for a gear-up landing, nose gear unlocked, and main gear unlocked.

According to the CVR transcript, while on final approach to the runway, at 1310:37, the copilot stated "We're set. We've got three green, no red. Hydraulic pressure is seven fifty and we've got zero diff." At 1311:25, the airplane touched down on the runway and the pilot told the copilot to move the propeller levers full forward and set the engine power to ground idle. At 1312:05, the pilot stated, "I don't think I'm getting very good brakes… I don't have any pressure." At 1312:08, the copilot replied, "no pressure?" At 1312:09, the pilot stated, "no pressure." At 1312:10, the copilot stated, "try the steering." At 1312:12, pilot replied, "oh, you know we have the ah T-bar in." At 1312:15, the copilot stated, "okay." At 1312:17, the copilot stated, "pull it." Between 1312:17 and 1312:23, the landing gear warning horn was heard, the sound of the hydraulic system momentarily decreased before it increased back to normal, and there was the sound of rumbling and scraping consistent with the landing gear retracting and the airplane impacting the ground.

Pilot Information

Certificate:	Airline transport; Flight instructor	**Age:**	28,Male
Airplane Rating(s):	Single-engine land; Multi-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):	Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	August 20, 2013
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	December 13, 2013
Flight Time:	5040 hours (Total, all aircraft), 1164 hours (Total, this make and model), 832 hours (Pilot In Command, all aircraft), 30 hours (Last 90 days, all aircraft), 30 hours (Last 30 days, all aircraft), 0 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Flight instructor	**Age:**	31,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	April 29, 2013
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	September 27, 2013
Flight Time:	5270 hours (Total, all aircraft), 1900 hours (Total, this make and model), 3388 hours (Pilot In Command, all aircraft), 52 hours (Last 90 days, all aircraft), 19 hours (Last 30 days, all aircraft), 0 hours (Last 24 hours, all aircraft)		

--- Pilot ---

According to Federal Aviation Administration (FAA) records, the 28-year-old pilot held an air transport pilot certificate with ratings for airplane single-engine land, airplane multiengine land, and instrument airplane. His airplane single-engine landing rating was limited to commercial privileges. He held a type rating for Bombardier Dash 8 100/300 airplanes. He also held a flight instructor certificate with ratings for airplane single-engine land and instrument airplane. His most recent FAA first-class medical certificate was issued on August 20, 2013, without any limitations.

The pilot reported having 5,040 total hours of flight experience, of which 4,685 hours were flown in multiengine airplanes. The pilot had flown 1,164 hours in Piaggio P180 airplanes. He had flown 832 hours as pilot-in-command, 1,240 hours at night, and 2,190 hours in actual instrument meteorological conditions. His most recent flight review, as required by 14 *CFR* 61.56, was completed on December 13, 2013, in a P180 airplane. During the period December 16, 2013, through December 19, 2013, the pilot successfully completed ground and simulator training for the Piaggio P180 airplane at FlightSafety International, West Palm Beach, Florida.

--- Copilot ---

According to Federal Aviation Administration (FAA) records, the 31-year-old copilot held an air transport pilot certificate with ratings for airplane single-engine land, airplane multiengine land, and instrument airplane. His airplane single-engine landing rating was limited to commercial privileges. He held a type rating for Fairchild Swearingen Metroliner airplanes. He also held a flight instructor certificate with ratings for airplane single-engine land and instrument airplane. His most recent FAA first-class medical certificate was issued on April 29, 2013, without any limitations.

The copilot reported having 5,270 total hours of flight experience, of which 3,893 hours were flown in multiengine airplanes. The copilot had flown 1,900 hours in Piaggio P180 airplanes. He had flown 3,388 hours as pilot-in-command, 685 hours at night, and 340 hours in actual instrument meteorological

conditions. His most recent flight review, as required by 14 *CFR* 61.56, was completed on September 27, 2013, in a P180 airplane. During the period February 11, 2013, through February 14, 2013, the copilot successfully completed ground and simulator training for the Piaggio P180 airplane at FlightSafety International, West Palm Beach, Florida.

Aircraft and Owner/Operator Information

Aircraft Make:	Piaggio	**Registration:**	N700FE
Model/Series:	P180 - AVANTI II	**Aircraft Category:**	Airplane
Year of Manufacture:	2013	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	1232
Landing Gear Type:	Retractable - Tricycle	**Seats:**	10
Date/Type of Last Inspection:	December 20, 2013 Continuous airworthiness	**Certified Max Gross Wt.:**	12100 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo prop
Airframe Total Time:	45.5 Hrs at time of accident	**Engine Manufacturer:**	Pratt & Whitney Canada
ELT:	C126 installed, not activated	**Engine Model/Series:**	PT6A-66B
Registered Owner:	Peregrine Falcon, LLC	**Rated Power:**	850 Horsepower
Operator:	Mountain Aviation, Inc.	**Operating Certificate(s) Held:**	None

The 2013-model-year airplane, serial number 1232, was a twin-engine airplane of aluminum and composite construction. The airplane was powered by two 850 shaft-horsepower Pratt & Whitney Canada PT6A-66B turbo-propeller engines, through 5-blade, counter-rotating, constant speed, full-feathering, Hartzell HC-E5N-3A propellers. The airplane was equipped with a retractable tricycle landing gear and a pressurized cabin that was configured to seat 10 individuals. The airplane was approved for operations in instrument meteorological conditions and known icing conditions. The airplane had a maximum allowable takeoff weight of 12,100 pounds. On November 22, 2013, the airplane was issued a standard airworthiness certificate and a registration number when it was imported into the United States after manufacture in Italy. The current airplane owner, Peregrine Falcon, LLC, purchased the airplane on December 20, 2013. According to the operator, the airplane had been maintained under the provisions of an approved manufacturer inspection program and had accumulated 45.5 total hours since new.

The airplane landing gear are extended and retracted by hydraulic fluid delivered to an actuator on each landing gear. Each actuating cylinder is provided with internal up and down locks. The locks are a normally closed type and can be only opened by applying positive pressure. Each lock directly actuates the switches controlling the landing gear position indicating lights on the instrument panel. An internal shuttle valve in each actuating cylinder allows landing gear extension on the main or on the emergency hydraulic lines.

The hydraulic system provides power for the actuation of the landing gear, nosewheel steering, and main wheel brake system. The modular hydraulic power package consists of a variable displacement pump

driven by an electric motor, an integral hydraulic fluid reservoir, a solenoid-operated directional valve, a pressure transducer, and filter assembly. The hydraulic power package operates in three different modes (high duty, low duty, and non-operating mode). The high duty mode delivers hydraulic pressure in the nominal range from 1,800 to 3,100 psi for landing gear extension and retraction. The solenoid-operated directional valve directs hydraulic pressure to the landing gear actuators during normal extension and retraction. When the landing gear reaches a fully retracted position, the gear-up stop switch turns off the hydraulic system (non-operating mode). When the landing gear reaches a fully extended position, the gear-down stop switches signal the hydraulic power package to enter low duty mode (800 to 1,200 psi) to deliver hydraulic pressure for nosewheel steering and wheel brake actuation. The airplane flight manual prohibits the engagement of nosewheel steering until after the landing is completed, after which the use of nosewheel steering is permitted in the TAKE OFF mode. Landing gear squat switches prevent the directional control valve from delivering hydraulic pressure to the retract lines if the landing gear control lever is inadvertently moved to the gear-up position while the airplane is on the ground.

The emergency landing gear extension system consists of an emergency selector valve and a hand pump. The emergency selector valve is installed on the left side of the center pedestal and the hand pump is on the right side of the pedestal. When the emergency selector valve handle is extended, the hand pump hydraulic line is connected to the emergency gear extend line at each landing gear actuator and the normal hydraulic return line is connected to the emergency return line. Operation of the hand pump operates shuttle valves in each landing gear actuator to provide hydraulic pressure to unlock and extend the landing gear. The hand pump, emergency selector valve, and associated hydraulic plumbing are designed to extend the landing gear only. The emergency extension procedure requires the hydraulic system to be turned off, the gear selector handle to be in the down position, and the emergency selector valve handle to be extended. About 60 hand pump strokes over about 90 seconds are required for a positive down lock of all landing gear.

The main wheel brakes are hydraulically actuated. When the airplane is on the ground, the hydraulic pump normally supplies flow to operate the brakes at a regulated pressure of 1,000 psi. When the rudder pedals are depressed, the brake valves allow fluid under pressure to flow the normal lines to the shuttle valves on each brake unit. If the system pressure drops below 500 psi due to a hydraulic power package failure or line breakage, an integral automatic diverter allows the brake valve to operate as a master cylinder, which converts brake pedal action to a fluid pressure directly applied to each brake unit through a separate emergency line that is controlled by the shuttle valve on each brake unit. Emergency brake operation requires about 50% more force on the brake pedals than normal.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	SPI,598 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	13:02 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:		**Visibility**	2.5 miles
Lowest Ceiling:	Broken / 1000 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	3 knots /	**Turbulence Type Forecast/Actual:**	Unknown / Unknown
Wind Direction:	10°	**Turbulence Severity Forecast/Actual:**	Unknown / Unknown
Altimeter Setting:	30.13 inches Hg	**Temperature/Dew Point:**	-4°C / -8°C
Precipitation and Obscuration:	Light - None - Snow		
Departure Point:	Madison, WI (MSN)	**Type of Flight Plan Filed:**	IFR
Destination:	Springfield, IL (SPI)	**Type of Clearance:**	IFR
Departure Time:	11:56 Local	**Type of Airspace:**	Class C

A postaccident review of available meteorological data established that day instrument meteorological conditions prevailed at the accident site. At 1302, about 10 minutes before the accident, the SPI automated surface observing system reported: wind 010° at 3 knots, 2.5 miles surface visibility with light snow, broken cloud ceiling at 1,000 ft agl, broken cloud ceiling at 5,000 ft agl, temperature -4°C, dew point -8°C, and an altimeter setting of 30.14 inches of mercury.

Airport Information

Airport:	Abraham Lincoln Capital SPI	**Runway Surface Type:**	Concrete
Airport Elevation:	598 ft msl	**Runway Surface Condition:**	Snow
Runway Used:	04	**IFR Approach:**	ILS
Runway Length/Width:	8001 ft / 150 ft	**VFR Approach/Landing:**	Full stop

Abraham Lincoln Capital Airport (SPI), a public airport located about 3 miles northwest of Springfield, Illinois, was owned and operated by the Springfield Airport Authority. The airport field elevation was 598 ft msl. The airport was served by three runways, runway 4/22 (8,001 ft by 150 ft), runway 13/31 (7,400 ft by 150 ft), and runway 18/36 (5,300 ft by 150 ft). The airport was equipped with an air traffic control tower that was operational at the time of the accident.

Wreckage and Impact Information

Crew Injuries:	2 None	**Aircraft Damage:**	Substantial
Passenger Injuries:	3 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	5 None	**Latitude, Longitude:**	39.844165,-89.678054(est)

The airplane's landing gear was found retracted at the accident site. The aviation mechanic who coordinated the recovery of the airplane reported that he observed the landing gear selector handle in the gear-down position, the hydraulic system switch off, the electric master switch off, the emergency landing gear selector valve handle pulled out, and none of the circuit breakers were pulled or tripped. The mechanic noted that when he placed his hand on the emergency landing gear selector valve it retracted slightly. The airplane was suspended by a crane before the mechanic attempted to extend the landing gear. The mechanic pushed the emergency landing gear selector valve down, turned the hydraulics system switch on, and then turned on the electric master switch. When the electric master switch was turned on the landing gear did not extend, and the hydraulic system remained in the non-operating mode. The mechanic then turned the hydraulic system off, pulled the emergency landing gear selector valve handle, and extended the landing gear with the hand pump. The mechanic stated that he continued to actuate the emergency pump handle until he obtained a safe gear-down indication and was unable to move the emergency pump handle due to increased pressure. After successfully extending the landing gear, the electric master switch was turned off and the airplane lowered to the ground before being towed to a hangar.

Flight recorders

The airplane was equipped with an L-3/Fairchild model FA2100-1020 CVR, serial number 851267. The CVR recording contained about 2 hours 4 minutes of digital audio, which was stored in solid-state memory modules. The CVR was not damaged during the accident and the audio information was extracted from the recorder normally. The recording consisted of four channels of audio information, ranging from good to excellent quality. The first 5 minutes of the recording were from the previous flight. The accident flight recording began about 1119 when the airplane, operated as Foothills 70, received its instrument clearance from MSN clearance delivery. The flight departed MSN about 1156 and climbed to flight level 270. About 1222, the flight received automatic terminal information service (ATIS) information at SPI. After receiving the ATIS information, the flight crew briefed the ILS approach to runway 4 at SPI. By 1239, the flight began receiving air traffic control (ATC) radar vectors toward the final approach course for ILS runway 4 at SPI. At 1243, the airplane had descended to 2,300 ft msl.

At 1247, the flight was cleared for the first ILS runway 4 approach to SPI. A full transcript was created for the flight from 1249:57 until 1313:39 as the passengers and flight crew members evacuated the airplane and electrical power was removed from the CVR. The transcript of the CVR audio information is included with the docket materials associated with the investigation. The airplane was not equipped with a flight data recorder, nor was it required to be so equipped.

Tests and Research

A follow-up examination was completed by Federal Aviation Administration (FAA) maintenance inspectors with assistance from the airplane manufacturer, airplane operator, and maintenance personnel. The airplane was placed on jackstands to test the landing gear extension/retraction system. An electrical continuity test confirmed the correct operation of the landing gear selector handle (up/down) to the solenoid-operated directional control valve. Before testing continued, the landing gear selector handle was confirmed to be in the gear-down position, the emergency landing gear selector valve handle was confirmed to be extended, and the electric master switch was turned on. When the hydraulic system was momentarily powered on, the nose and right main landing gear immediately showed an unsafe condition and the right main landing gear retracted slightly. Hydraulic power was immediately turned off and the emergency landing gear extension valve handle was pushed down to return the system to a normal configuration. Although the landing gear selector handle remained in the gear-down position and the emergency landing gear extension valve was stowed, all three landing gear retracted when the hydraulic system was turned back on. The emergency extension procedures were then used to return the landing gear to a down-and-locked position. The electrical connection to the solenoid-operated directional control valve was removed to ensure the solenoid remained deenergized (gear down). The landing gear still retracted when hydraulic power was turned back on, despite the landing gear selector handle in the gear-down position, the solenoid deenergized, and the emergency landing gear extension valve stowed. Based on the testing, it was determined that the solenoid-operated directional control valve was stuck in the gear-up position. No mechanical anomalies were identified with the emergency landing gear extension valve during several pull-force tests. The hydraulic pump package, which included the solenoid-operated directional control valve, and the emergency landing gear extension valve were removed from the airplane for additional testing.

The hydraulic pump package, solenoid-operated directional control valve, and emergency landing gear selector valve underwent x-ray computed tomography (CT) scanning to document their internal conditions. The results of the CT scanning revealed a single particle located between one of the spool lands and the directional control valve housing. The position of the trapped particle prevented the spool from returning to the default (deenergized) position for normal landing gear extension. Further review established that trapped particle and jammed spool would allow hydraulic flow to the landing gear retraction lines. Additional CT scanning did not identify any anomalies with the remaining components of the hydraulic pump package or the emergency landing gear selector valve.

The solenoid-operated directional control valve was examined at the manufacturer to extract the trapped particle. Disassembly of the directional control valve confirmed the spool was jammed and required the spool to be forced out by hand. There was a minor impact mark on the edge of the spool where it had been in contact with the trapped particle. Metallurgical examinations of the trapped particle indicated that it measured about 2.9 mm long, 0.98 mm wide, and 0.5 mm thick. According to the directional control valve manufacturer, the maximum aperture opening in any spool configuration is 0.470 mm. Energy dispersive x-ray spectroscopy determined the composition of the trapped particle was about 94% iron, 3% nickel, 2% chromium, and 0.5% manganese (consistent with 9300 or 3300 series steel). A review of materials used in the directional control valve did not match the material composition of the trapped particle. Trace amounts of aluminum, magnesium, and silicon were also identified during testing, which were attributed to incidental contact with an aluminum component within the directional control valve.

A review of hydraulic system schematics indicated that the fluid returning to the hydraulic pump package flowed through the directional control valve before reaching the pump filter. Additionally, according to the hydraulic pump package manufacturer, based on spool orientation and the clearances within the directional control valve, it was possible for debris to migrate, due to pressure pulsations and vibrations, into the central chamber of the spool when the actuator was at the end of its travel and the pump was in a zero-flow condition. A teardown examination of the hydraulic pump package did not reveal any mechanical anomalies that would have resulted in a malfunction of the pump. However, during removal of the actuator sleeve the stainless-steel threaded insert pulled-out with the threaded section of the actuator sleeve. A visual examination established that the threaded insert had jumped a thread and was deformed. Additionally, there was damage to the actuator sleeve thread and corresponding female thread in the valve plate subassembly. The actuator sleeve was a machined steel component. Although the actuator sleeve had a similar material composition to the trapped particle that was recovered from the directional control valve, a further review did not provide a positive match between the particle and the materials used in the hydraulic pump package.

The airplane manufacturer performed testing on an exemplar airplane to determine if they could duplicate an uncommanded landing gear retraction with a simulated failure of the directional control valve in the gear-up position. Without the hydraulic system on, the landing gear was extended using the emergency landing gear extension procedure. The test results indicted the emergency line pressure was 1,800-2,700 psi after receiving a gear safe indication and significant force was required to actuate the emergency hand pump. The test results also indicated that there was a pressure decay in emergency system line of 50-100 psi per minute. The pressure in the gear retraction lines was 560-600 psi with the landing gear manually extended and the hydraulic pressure turned on with a simulated failure of the directional control valve in a gear-up position. The landing gear did not unlock (gear unsafe indication) and/or retract while the pressure in the emergency line was above 100 psi. Additionally, the emergency landing gear selector handle had to be moved more than 70% of its total stroke before the emergency line lost pressure and the landing gear retracted.

Additional Information

The emergency procedure to extend the landing gear in the pilot operating handbook and airplane flight manual requires the hydraulic system to be turned off before the landing gear is manually extended. As a safety enhancement, after the accident, the airplane manufacturer amended the emergency procedure to include a specific caution that the hydraulic pump should not be turned on following an emergency landing gear extension and that the emergency landing gear selector valve should remain extended. Additionally, the amended emergency procedure cautions that, during such an emergency, the normal ground roll will increase about 55% if reverse thrust is not used, brake action would be less effective than normal, and the emergency brake operation procedure should be used during landing. The amended emergency procedure also notes the nosewheel steering will be inoperative with the hydraulic pump turned off and that a maintenance check is required following an emergency landing gear extension.

Administrative Information

Investigator In Charge (IIC):	Fox, Andrew
Additional Participating Persons:	Stephanie Williams; Federal Aviation Administration, Springfield FSDO; Springfield, IL Curt Lindauer; Federal Aviation Administration, Springfield FSDO; Springfield, IL Alessandro Cometa; Agenzia Nazionale per la Sicurezza del Volo (ANSV); Rome John McMillan; Air Accidents Investigation Branch (AAIB); Farnborough Giuseppe Caldarelli ; Piaggio Aero Industries S.p.A.; Finale Ligure Rich Bjelkevig; Mountain Aviation, Inc.; Broomfield, CO Mike Cruz; Valve Research & Mfg Co.; Deerfield Beach, FL Steve Badenoch; Eaton Limited; Bedhampton
Original Publish Date:	November 15, 2018
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=88754

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.