Aviation Investigation Final Report

Location:	Boyne City, Michigan	**Accident Number:**	CEN13FA038
Date & Time:	October 31, 2012, 09:30 Local	**Registration:**	N401WS
Aircraft:	Piaggio P180	**Aircraft Damage:**	Substantial
Defining Event:	Flight control sys malf/fail	**Injuries:**	2 None
Flight Conducted Under:	Part 91: General aviation - Positioning		

Analysis

The pilot stated that, during landing, the nosewheel steering was not engaged and that, after the airplane touched down, it made an uncommanded left turn. The pilot used landing gear braking and reverse thrust to control the airplane, but it still continued to veer left and then off the runway. The airplane struck the airport perimeter fence and a tree and came to rest.

Postaccident examinations and tests of the nosewheel steering system and its associated components revealed that the steering actuator did move uncommanded at varying rates and directions when electrical power was off and hydraulics were engaged to the nosewheel steering system. Further, this occurred as a result of the select/bypass valve's failure to seal properly when in an unpowered state due to incorrect shimming within the select/bypass valve, which allowed hydraulic fluid to enter the servo valve when the system was off. The available hydraulic pressure was then ported to move the steering actuator relative to the position of the servo valve spool. Examinations also confirmed that, when the servo valve was electrically powered off, the spool could slightly free-float, and the unpowered spool position could be biased in the direction of the last commanded travel from when the system was last engaged. Examination of the rest of the airplane revealed no other mechanical malfunctions or failures that would have precluded normal operation.

The nose landing gear assembly was overhauled 7 days before the accident. However, the postaccident examinations revealed that the overhaul was not conducted in accordance with the manufacturer's component maintenance manual and did not meet the requirements of Service Bulletin 80-0249, which was required by Airworthiness Directive (AD) 2009-21-08 rev 1, even though the maintenance records indicated that the AD was completed and signed off by the operator for the accident airplane.

Probable Cause and Findings

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

The select/bypass valve's failure to seal correctly because of improper shimming, which resulted in an uncommanded and uncontrollable left turn during landing. Contributing to the accident was the overhaul facility's improper overhaul of the steering manifold.

Findings

Aircraft	Landing gear actuator - Failure
Aircraft	Landing gear actuator - Not serviced/maintained
Personnel issues	Total experience w/ equipment - Maintenance personnel
Personnel issues	(general) - Maintenance personnel

Factual Information

History of Flight

Landing-landing roll	Loss of control on ground
Landing-landing roll	Runway excursion
Landing-landing roll	Flight control sys malf/fail (Defining event)

On October 31, 2012, about 0930 eastern daylight time, a Piaggio P180 Avanti airplane, N401WS, exited the runway while landing at the Boyne City Municipal airport (N98) Boyne City, Michigan. The airline transport pilot and commercial pilot were not injured. The airplane sustained substantial damage. The airplane was registered to Ann Arbor Aviation Partners LLC and operated by Flagship Private Air under the provisions of 14 Code of Federal Regulations Part 91 as a positioning flight. Instrument meteorological conditions prevailed for the flight and an instrument flight rules (IFR) flight plan was filed. The flight originated from the Willow Run Airport (KYIP) about 0820.

The pilot stated that the nose wheel steering was not engaged during the landing, and that after the airplane touched down, it made an uncommanded left turn. The pilot used landing gear braking and reverse thrust to control the airplane but it still continued to veer left and continued off of the runway. The airplane struck the airport perimeter fence and a tree and came to rest.

The airplane was moved to a secured location at N98 for further examination. The initial investigative team met at N98 and conducted a postaccident examination of the nose wheel steering system and its associated components. After the examination, the nose landing gear was removed and sent to the manufacturer's facility in England for further examination and testing.

Pilot Information

Certificate:	Airline transport; Commercial	**Age:**	63
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane; Helicopter	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	July 18, 2012
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	May 23, 2012
Flight Time:	11506 hours (Total, all aircraft), 685 hours (Total, this make and model), 8656 hours (Pilot In Command, all aircraft), 85 hours (Last 90 days, all aircraft), 19 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Commercial; Flight instructor	**Age:**	28,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane single-engine	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	March 12, 2012
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	April 7, 2012
Flight Time:	645 hours (Total, all aircraft), 109 hours (Total, this make and model), 523 hours (Pilot In Command, all aircraft), 33 hours (Last 90 days, all aircraft), 14 hours (Last 30 days, all aircraft), 0 hours (Last 24 hours, all aircraft)		

The pilot, age 63, held an airline transport pilot certificate with airplane single engine land, multi-engine land, rotorcraft-helicopter, and instrument airplane ratings. The pilot was issued a first class medical certificate on July 18, 2012 with the limitation to wear corrective lenses. He reported that he had accumulated 11,506 total flight hours, 665 of which were in the accident airplane make and model. He had accumulated 85 flight hours in the previous 90 days. He met the currency requirements for IFR flying.

The co-pilot, age 28, held a commercial pilot certificate with airplane single engine land, multi-engine land, and instrument airplane ratings. He was also a certified flight instructor for single engine land airplanes. He was issued a first class medical certificate on March 12, 2012 with no limitations. He reported that he had accumulated 645 total flight hours, 109 of which were in the accident airplane make and model. He had accumulated 33 flight hours in the previous 90 days. He also met the currency requirements for IFR flying.

Aircraft and Owner/Operator Information

Aircraft Make:	Piaggio	**Registration:**	N401WS
Model/Series:	P180 Avanti	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	1057
Landing Gear Type:	Tricycle	**Seats:**	11
Date/Type of Last Inspection:	October 10, 2012 Continuous airworthiness	**Certified Max Gross Wt.:**	12100 lbs
Time Since Last Inspection:	2 Hrs	**Engines:**	2 Turbo prop
Airframe Total Time:	3002 Hrs at time of accident	**Engine Manufacturer:**	Pratt and Whitney
ELT:	Installed, activated, did not aid in locating accident	**Engine Model/Series:**	PT6-66
Registered Owner:	ANN ARBOR AVIATION PARTNERS, LLC	**Rated Power:**	850 Horsepower
Operator:	Flagship Private Air, LLC	**Operating Certificate(s) Held:**	On-demand air taxi (135)
Operator Does Business As:	Flagship Private Air	**Operator Designator Code:**	2FPA

According to the aircraft maintenance logbooks the airplane was in compliance with an Approved Aircraft Inspection Program (AAIP) and the most recent inspections were competed on October 24, 2012.

The accident flight was reported by the operator to be the third flight following the airplane's completion of a D-Check, which included an overhaul of the nose landing gear, both main landing gears, and both engines. The Federal Aviation Administration (FAA) Airworthiness Directive (AD) 2009-21-08 Rev 1 was last completed and signed off by the operator on October 24, 2012. The reason for the AD was listed as:

Some cases of uncommanded steering action were observed, while the steering system was switched off. A leakage in the Steering Select/Bypass Valve, installed in the Steering Manifold, when closed, is suspected to have caused the uncommanded steering.

The nose landing gear and steering manifold were overhauled by Advantage Aviation Technologies II, LLC (AAT) on September 12, 2012, and August, 17, 2012 respectively. According to the AAT work order, the steering manifold was overhauled in accordance with Component Maintenance Manual (CMM) 32-50-50, Revision 6.

The aircraft maintenance logbook entry dated October 24, 2012, revealed that the nose landing gear was re-installed on the accident airplane.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KCVX	**Distance from Accident Site:**	13 Nautical Miles
Observation Time:	09:05 Local	**Direction from Accident Site:**	300°
Lowest Cloud Condition:	Thin Overcast / 1600 ft AGL	**Visibility**	10 miles
Lowest Ceiling:	Overcast / 1600 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	16 knots / 25 knots	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	360°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.68 inches Hg	**Temperature/Dew Point:**	5°C / 2°C
Precipitation and Obscuration:	Light - None - Drizzle		
Departure Point:	Detroit, MI (KYIP)	**Type of Flight Plan Filed:**	IFR
Destination:	Boyne City, MI (N98)	**Type of Clearance:**	IFR
Departure Time:	08:22 Local	**Type of Airspace:**	Class G

At 0914, the automated weather report for Charlevoix, Michigan, which was 13 miles northwest of the accident site, reported: wind from 360 degrees at 14 knots, gusting to 24 knots, visibility 7 miles, sky condition overcast clouds at 1,600 feet, temperature 39 degrees Fahrenheit (F), dew point 36 degrees F, and altimeter setting 29.69 inches of mercury.

Airport Information

Airport:	Boyne City Municipal Airport N98	**Runway Surface Type:**	Asphalt
Airport Elevation:	660 ft msl	**Runway Surface Condition:**	Wet
Runway Used:	27	**IFR Approach:**	Global positioning system
Runway Length/Width:	4001 ft / 75 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	2 None	**Aircraft Damage:**	Substantial
Passenger Injuries:		**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	2 None	**Latitude, Longitude:**	45.208889,-84.989997(est)

The airplane veered off the left side of the runway, continued through short grass and impacted the airport perimeter fence and a tree. This was verified by the tire skid marks on the runway and the tire marks in the grass leading to the airplane, which came to rest upright next to the fence. The nose wheel impacted the ground and the wheels remained fully deflected to the left.

Tests and Research

Initial Nose Landing Gear Testing:

The aircraft was moved into an unheated hanger located at Boyne City Municipal Airport prior to NTSB arrival on scene. The airplane was examined at this location on November 27-28, 2012. Recovery personnel stated they turned off the master battery before the aircraft was removed and that the electrical and hydraulic systems were not energized during the recovery process. They also stated that the steering pin was found engaged but was removed to facilitate aircraft recovery. The nose landing gear (NLG) system was examined and tested for proper function by the investigative team.

The left and right nose tires were both pressurized at 52 psi. (NOTE: The ambient air temperature was not recorded. For reference, Bellaire, Michigan, was located approximately 20 miles southeast of Boyne City and recorded a high of 33 degrees Fahrenheit and a low of 25 degrees Fahrenheit during the dates of November 27 and 28, 2012.) The pilot stated that during the preflight checks on the day of the accident all tire pressures were in the normal range. The Aircraft Maintenance Manual, Section 12-10-04, dated Oct 30/09, states that the nose landing gear tire pressure should be 64 +/- 2 psi. The nose assembly shock strut pressure was approximately 98 psi with weight off wheels. The placard on the aircraft states the pressure should be 120 +/- 10 psi. Both nose wheel assemblies spun freely using hand force when the nose of the airplane was on jacks. There was no significant damage identified on either tire.

A ground power unit supplying 28 volts was connected to the aircraft. An air compressor supplying 30 psi air was connected to the hydraulic pump reservoir to prevent cavitation within the hydraulic system. The nose wheel steering (NWS) system and hydraulics were verified to be in the off position. With the nose wheel centered and on the ground the steering pin was removed. The hydraulic system was then

turned on (the NWS system remained electrically powered off) and the NWS actuator began to extend. The actuator extended to a position of approximately 1.5 inch chrome extension.

The steering pin was then installed and with hydraulics on and the NWS system electrically powered off, the actuator did not move. The steering pin was again removed and with hydraulics on and the NWS system electrically powered off, the actuator extended at a rate of approximately 1 inch per minute.

Nose Landing Gear Testing per Service Bulletin 80-0249:

During investigative testing following the accident, the accident airplane was subjected to the SB in its entirety despite some observed failures which would have concluded the test before its completion.

Piaggio released Service Bulletin (SB) 80-0249 (Rev 1 dated 27/05/2009 with original issue dated 18/06/2008) after an incident involving uncommanded movement of the nose wheel. The reason for the SB stated:

One case of poor sealing of the Steering Select / Bypass Valve (installed in the Steering Manifold) was observed, resulting in an uncommanded steering action. The aim of the procedure described in this Service Bulletin is to verify the leakage proofness of the Steering Manifold when the system is turned OFF and hydraulic power is available, by directly observing the behavior of the Steering Actuator.

This SB was current at the time of the accident and was required by AD 2009-21-08 Rev 1 with effective date of December 14, 2009. The SB required completion a) at the next scheduled inspection, or within 6 months (whichever occurs first), b) at each "A" inspection as long as the SB is active, and c) whenever a new/overhauled manifold is installed. AD 2009-21-08 Rev 1 was completed and signed off by the operator on October 24, 2012, for the accident aircraft.

The SB required that the manifold be replaced if the steering actuator moved and reached the full stroke within 1 minute during at least one test. At two different times during the SB testing, the actuator moved from center to full extension in 48 seconds and later the actuator moved from center to full extension in 22 seconds. Following completion of the SB test, the gear was centered and the steering pin was once again removed. Hydraulic pressure was applied, the NWS system was electrically powered off, and the actuator extended and stopped after 47 seconds.

Nose Landing Gear Assembly:

The nose landing gear and attached nose wheel steering components were removed from the airplane. The investigative team met at Messier-Bugatti-Dowty (MBD) in Gloucester, United Kingdom, for the examination and testing of these components. MBD was the original equipment manufacturer for the landing gear, but did not perform the most recent overhaul on the assembly.

Residual fluid from the manifold assembly was collected and was analyzed by MBD. The fluid sample was in accordance with all requirement and specifications and no contamination was found.

The metal hydraulic tubing was removed and the landing gear was attached to a test bench to perform Piaggio SB 80-0249, Rev 1, Part A. When the assembly was first installed the hydraulic power was

activated and the electrical power was off, the actuator slowly extended. After clearing the residual air from the hydraulic lines, the electrical power was engaged and the nose wheel centered. Electrical power was turned off and the actuator extended. Electrical power was then turned on and the nose wheel centered. Electrical power was again turned off and the actuator retracted. This test sequence was run two times with identical results. The actuation rate varied each time, ranging from a slow creep to an easily noticeable speed. These results failed the requirements of Piaggio SB 80-0249.

The gear was then tested per the steering sections of the Testing and Fault Isolation chapter of CMM 32-20-58, Rev 11, dated Nov 16, 2012. During Step 3.E.5 it was found that in order to obtain the feedback potentiometer centered position, the axle had to be rotated 3.9 degrees to the left of the axle center position. There was approximately 1 degree of play in this position. Following all testing, the axle had to be rotated 2.5 degrees to the left of the center position in order to obtain the feedback potentiometer centered position.

The unit failed step 3.K.8., which required that there was no change in the steered angle when 1,000 psi hydraulic pressure was supplied to the assembly, the steered input command was 34 degrees, and the solenoid valve was powered off. The unit under test steered to a hard-over position. It was noted that this test was added to the manual at Revision 11 and was not available when the subject unit was last overhauled.

MBD original equipment build records revealed that the nose landing gear was assembled on December 13, 2001. MBD Maintenance Repair and Overhaul had no records of repair for this unit.

The steering actuator was removed from the landing gear assembly. The unit was placed in a test jig per CMM 32-50-51, Rev 5 (page 702, Section 2.C titled Calculation of Shim Thickness). This test was used to ensure the linear feedback potentiometer was properly positioned to provide the correct reading when the piston was centered. While the actuator was in the test rig with the piston centered, the Linear Variable Differential Transformer/Transducer (LVDT) output was 5.4 Volts (4.91/4.93 Volts required).

The manifold assembly was removed from the landing gear assembly. To the extent possible, the manifold assembly was tested per portions of the Testing and Fault Isolation Chapter of CMM 32-50-50, Rev 6. The test procedure was performed in reverse order as the procedure was designed to be accomplished during manifold build.

The unit failed the following steps 3.G(8)(c), 3.H(7), 3.F(6) –3.F(10), 3.A(6), and 3.A(9)

The following additional observations were noted during testing and disassembly of the manifold assembly:

• During test setup it was noted that the flexible hydraulic line connections were torqued to the extent that the lines were not free to rotate about the M1 and M2 connections. Per CMM 32-50-50, Rev 6, Page 706, Step K(4), these flexible hose assemblies connections should have been able to rotate after they were installed.

• When the manifold was first connected to the test bench with 200 psi hydraulic power engaged and all electrical power disengaged, the pressure at M1 was observed to increase to 150 psi.

• While the manifold was connected to the test bench with electrical power engaged to the servo valve and disengaged to the select/bypass valve, the observed pressure at the output ports M1 or M2 was equal to the pressure at the input port depending on the position of the servo valve spool. When electrical power to the servo valve was disengaged, the fluid would port in the direction of the last spool movement.

• While the manifold was connected to the test bench with power engaged to the select/bypass valve, 0.00 mA applied to the servo valve resulted in a hydraulic pressure of approximately 150 psi at port M1.

• The electrical wires connected to the select/bypass valve coil were chaffed in the direction opposite of wire removal when pulled through the manifold body. One area of exposed wire was observed. A 2 inch insulation sleeve that is not called out in the CMM or component drawings surrounded the wires on the end connected to the electrical connector.

• Two parallel and uniform gouges were found on the outside diameter of the spool stop (Part Number 101459603) near the end opposite the nozzle. The ring (P/N 100668608) was scored in multiple places along the inner diameter edge on the face that is adjacent to the armature. In addition, the armature (P/N 100668609) exhibited a nozzle imprint in its center and multiple scratches on the side facing the return. The side of the armature facing the sleeve and spool exhibited a nozzle imprint in the center, a half nozzle imprint on the edge of one of the smaller center holes and a gouge connecting two of the larger holes on the outer circumference. Although these components are not specifically called out for special inspection in CMM 32-50-50, Rev 6, these surfaces should be free of visual defects.

• When the select/bypass valve armature was placed inside of the ring, the gap from the top of the ring edge to the armature surface measured 0.0023 inch. This is outside of the required limit of 0.0032 inch to 0.0035 inch per CMM 32-50-50, Rev 6, page 702, step 2.B.2.

• The lap tip of the return nozzle projection in the select/bypass valve measured 0.0003 inch. This is outside of the required limit of 0.0004 inch to 0.0006 inch per CMM 32-50-50, Rev 6, step 2.C.3 on page 702.

• The select/bypass valve was configured with one 0.002 inch thick shim installed next to the wave washer. Testing was performed using the manifold test block P/N 460006832 (not the actual manifold body) and using various shims and a new wave washer to determine if altering the shim thickness would result in a properly functioning unit. Using a new wave washer resulted in a spool that could not retract when electrical power was supplied to the coil. Using the original wave washer, the original shim of 0.002 inch thickness, and an additional 0.003 inch of shims (total of 0.005 inch of shimming) the spool repeatedly functioned correctly when power was engaged and removed up to a pressure of 2500psi.

MBD original equipment build records showed that the steering manifold body was assembled on February 17, 1992. The acceptance inspection was completed and passed with no discrepancies. The select/bypass valve was assembled on October 15, 1991. The acceptance inspection was completed and passed with no discrepancies. MBD Maintenance Repair and Overhaul UK had no records of repair for the manifold assembly or select/bypass valve.

Servo Valve Testing

The servo valve was removed and tested at Parker in Mainz-Kastel, Germany.

The servo valve assembly was externally inspected and appeared to be in good physical condition. The safety wire was intact and the electrical pins were straight and free of corrosion. The testing revealed no malfunctions.

During additional testing, the servo valve was commanded to various positions and electrical power was turned off. The servo valve would center with a bias dependent on the last position the spool was in while the servo valve was electrically powered. Drift was not observed when electrical power was removed and hydraulic power was supplied. Parker representatives stated that there is no requirement for the spool to be centered when electrical power is not supplied to the servo valve.

Additional Information

Cockpit Voice Recorder (CVR)

The airplane's CVR was reviewed for the accident flight and no anomalies were noted.

Similar Occurrence – CEN13IA270

On April 24, 2013, about 1720 eastern daylight time, a Piaggio P180 airplane, N139SL, received minor damage during a runway excursion at the St. Petersburg-Clearwater International Airport (KPIE), Clearwater, Florida. The nose landing gear system had been recently overhauled by the same overhaul facility. The NTSB's probable cause of that incident was listed as: "The failure of the nose landing gear steering manifold during landing, which resulted in an uncommanded and uncontrollable right turn, and the overhaul facility's improper overhaul of the nose landing gear steering manifold."

Administrative Information

Investigator In Charge (IIC):	Lindberg, Joshua
Additional Participating Persons:	John Farnham; Federal Aviation Administration; Grand Rapids, MI James Wise; Flagship Private Air; Belleville, MI Bill Holifield; Flagship Private Air; Belleville, MI
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Investigation Class:	Class
Note:	
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=85480