Aviation Investigation Final Report

Location:	Newport News, Virginia	**Accident Number:**	ERA15LA212
Date & Time:	May 12, 2015, 11:44 Local	**Registration:**	N80PG
Aircraft:	GATES LEAR JET 35	**Aircraft Damage:**	Substantial
Defining Event:	Sys/Comp malf/fail (non-power)	**Injuries:**	2 None
Flight Conducted Under:	Public aircraft		

Analysis

Before departure, the pilot and copilot completed a preflight inspection of the airplane and found everything to be normal. After taking off without incident, the flight crew started running the after-takeoff checklist and the pilot moved the landing gear selector handle to the up position. The crew then felt and heard a loud "clank" in the nose of the airplane and observed that the red or unsafe nose gear light had illuminated; recycling the landing gear handle had the same result. As the flight crew returned to the departure airport, they selected the landing gear handle to the down position and received three green landing gear down indications and completed the before landing checklist; the air traffic controller advised that the nose landing gear appeared to be straight. During the landing, the airplane touched down on the main wheels first, but once the nosewheel touched down and weight was on the nose landing gear, the airplane suddenly turned sharply 30° to 40° to the left and application of right rudder did not counter the turn. The airplane then partially traveled off the left side of the runway pavement, its left main landing gear struck a concrete runway edge-light base, then the airplane turned about 180° from its original direction of travel and came to rest on the left side of the runway about 1,500 ft from the end of the runway. The copilot was unable to open the main door to egress, so he removed the emergency exit window and the pilot and copilot egressed. The airplane sustained substantial damage to the wings and fuselage.

The nose landing gear strut normally uses its internal gas pressure to fully extend at takeoff, then the centering cams inside the strut engage and ensure that the lower portion of the strut assembly and nosewheel are aligned straight ahead. The nosewheel must be aligned straight ahead for the wheel to retract into the narrow nosewheel bay. Tire marks were observed inside the wheel well at a location consistent with a strut that was not fully extended. Further, if the strut was not fully extended, the uplock hook assembly could not connect to a pin that was on the lower strut and engage. Thus, a takeoff with a deflated strut would result in the strut not having enough internal pressure to fully extend into the centering cams. Forces on the strut would then cause it to turn to the left due to the asymmetric design of the nose landing gear.

The most recent nose landing gear strut service was performed about 70 hours before the accident. However, examination of the strut fluid level immediately following the accident revealed that it was slightly low and that the strut was completely collapsed and devoid of nitrogen. Examinations of the nose landing gear strut also revealed that it had likely been leaking fluid for some time before the accident; as a result of the leak, the strut was flat before the takeoff, which should have been noticeable during the preflight inspection and during taxi, and that the nose landing gear was most likely not aligned straight during retraction.

Examination of the steering servo also revealed that the friction material in the servo clutch was completely worn away in the drive area, giving a metal-to-metal drive from the motor to the steering system, which produced a high residual torque condition. The high residual torque likely prevented the nosewheel from self-centering and castering during the landing, causing the nosewheel to remain in a cocked position during nose landing gear touchdown, which led to the runway departure.

Probable Cause and Findings

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

The flight crew's inadequate preflight inspection of the nose landing gear strut, which resulted in the nosewheel not being aligned during retraction and the subsequent loss of directional control. Contributing to the accident was the failure of the nose landing gear strut due to inadequate pressure and excessive wear.

Findings

Personnel issues	Preflight inspection - Flight crew
Aircraft	Landing gear steering system - Related maintenance info
Aircraft	Nose/tail gear strut/axle - Fatigue/wear/corrosion
Aircraft	Landing gear steering system - Failure
Aircraft	Nose/tail gear strut/axle - Design
Aircraft	Directional control - Attain/maintain not possible

Factual Information

History of Flight

Prior to flight	Miscellaneous/other
Prior to flight	Aircraft inspection event
Initial climb	Sys/Comp malf/fail (non-power) (Defining event)
Landing	Landing gear not configured
Landing-landing roll	Loss of control on ground
Landing-landing roll	Runway excursion
Landing-landing roll	Collision with terr/obj (non-CFIT)
Landing-landing roll	Landing gear collapse

On May 12, 2015, about 1144 eastern daylight time, a Gates Lear Jet 35, N80PG, call sign "Riptide 80", operated by Phoenix Air Group Inc. was substantially damaged during landing rollout, following a return to the airport after an unsafe nose landing gear indication at Newport News/Williamsburg International Airport (PHF), Newport News, Virginia. The airline transport certificated pilot and airline transport certificated copilot were not injured. Visual meteorological conditions prevailed, and an IFR flight plan had been filed for the public use flight contracted by the United States Navy, that departed PHF around 1115.

According to the flight crew, prior to departure at PHF, they preflighted the airplane and found everything to be normal including the nose gear strut and oleo gear extensions. On this flight the copilot was flying from the left seat and the pilot was flying from the right seat. They taxied to runway 25 and took off about 1115 without incident.

The flight crew started running the after-takeoff checklist and at "positive rate", the pilot moved the landing gear selector handle to the up position, and when he did, they felt and heard a loud "clank" come from the nose of the airplane. They also observed that the red unsafe nose gear light had illuminated. The flight crew then recycled the landing gear handle with the same result.

The flight crew elected to return to PHF because of the nose gear issue. They jettisoned fuel to get below maximum landing weight and then returned to the airport for landing. The pilot asked the air traffic controller in the control tower for permission to do a low approach to runway 20, and to visually inspect their nosewheel to make sure it was not in any other position than "straight." The flight crew then selected the landing gear handle to the down position and received three green landing gear down indications (everything normal) and completed the before landing checklist.

The flight crew executed a low approach for runway 20 and the air traffic controller advised that the nose landing gear appeared to be straight. The flight crew then kept the airplane in the landing configuration and entered a left downwind for runway 25.

During the landing, they touched down main wheels first, and held the nose off for as long as possible. Once the nose wheel touched down and weight was on the nose landing gear, the airplane suddenly turned sharply, 30° to 40° to the left. Both flight crewmembers then applied right rudder to counter the turn without effect. The airplane then partially traveled off the left side of the runway pavement and struck a concrete runway edge-light base, with its left main landing gear, turned about 180° from its original direction of travel, and came to rest on the left side of the runway, about 1,500ft from the end.

The pilot then instructed the copilot to open the main door to egress but the copilot was unable to get the door to open, so he removed the emergency exit window on the right rear side of the cabin. The pilot then completed the emergency evacuation procedures and egressed from the airplane after the copilot had egressed.

Pilot Information

Certificate:	Airline transport; Commercial	**Age:**	34,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	5-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	October 23, 2014
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	April 9, 2015
Flight Time:	4800 hours (Total, all aircraft), 2300 hours (Total, this make and model), 3000 hours (Pilot In Command, all aircraft), 76 hours (Last 90 days, all aircraft), 15 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Commercial	**Age:**	68,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	5-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	November 24, 2014
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	April 5, 2014
Flight Time:	22600 hours (Total, all aircraft), 1867 hours (Total, this make and model), 17686 hours (Pilot In Command, all aircraft), 46 hours (Last 90 days, all aircraft), 6 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

Pilot

According to Federal Aviation Administration (FAA) and pilot records, the pilot held an airline transport pilot certificate with a rating for airplane multi-engine land, and commercial privileges for airplane single-engine land. He also held a flight instructor certificate with ratings for airplane single, and multi-engine, and instrument airplane, as well as type ratings for the CL-65, G-159, LR-45, and LR-JET

His most recent FAA first-class medical certificate was issued on October 23, 2014. He reported that he had accrued 4,800 total hours of flight experience, 2,300 of which was in the accident airplane make and model.

Copilot

According to FAA and pilot records, the Copilot held an airline transport pilot certificate with a rating for airplane multi-engine land, and commercial privileges for airplane single-engine land. He also held a flight instructor certificate with ratings for airplane single engine, and instrument airplane, as well as type ratings for the A-300, B-737, B-757, B-767, CE-500, DC-9, and LR-JET.

His most recent FAA first-class medical certificate was issued on November 24, 2014. He reported that he had accrued 22,542 total hours of flight experience, 1,867 of which was in the accident airplane make and model.

Aircraft and Owner/Operator Information

Aircraft Make:	GATES LEAR JET	**Registration:**	N80PG
Model/Series:	35	**Aircraft Category:**	Airplane
Year of Manufacture:	1976	**Amateur Built:**	
Airworthiness Certificate:	Restricted (Special)	**Serial Number:**	063
Landing Gear Type:	Retractable - Tricycle	**Seats:**	2
Date/Type of Last Inspection:	January 18, 2015 Continuous airworthiness	**Certified Max Gross Wt.:**	18300 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:	11784.3 Hrs as of last inspection	**Engine Manufacturer:**	GARRETT
ELT:	C126 installed, not activated	**Engine Model/Series:**	TFE 731-2-2B
Registered Owner:	PHOENIX AIR GROUP INC	**Rated Power:**	3500 Lbs thrust
Operator:	PHOENIX AIR GROUP INC	**Operating Certificate(s) Held:**	On-demand air taxi (135), Certificate of authorization or waiver (COA)
Operator Does Business As:		**Operator Designator Code:**	ESPA

The accident airplane was a pressurized, turbofan powered, low wing monoplane, of conventional metal construction. The swept-back wings and tail surfaces were fully cantilevered. The wing was an 8-spar, wet wing design with large external fuel tanks at the tips. The spars were continuous from tip to tip (except for Spar 6 which only extended from the landing gear ribs outboard) with all loads transferred to the fuselage through four fittings on each side. It was a derivative of wings used on previous Learjet models, with the most noticeable differences being the wing tip extensions and internal modifications, incorporated to accommodate the increased gross weight of the Model 35.

It was powered by two aft fuselage mounted Garrett TFE 731-2-2B, twin spool, turbofan engines, each rated at 3,500 pounds of thrust. It was equipped with a fully retractable tricycle type landing gear with dual wheels, an anti-skid braking system, and a steerable nose wheel. Engine driven hydraulic pumps provided power for extending and retracting the landing gear, wing flaps, and spoilers. The ailerons, elevators, and rudder were manually controlled by utilizing conventional cables, bell cranks, pulleys, and push-pull tubes.

The airplane could be operated at speeds of up to .81 Mach and altitudes of up to 41,000 ft, and it had been modified from its original configuration by the installation of hardpoints under each wing, along with cabling which had been installed from inside the airplane's pressurized fuselage through the pressure vessel, and out to the hard points, enabling the airplane to carry external pods or other array.

According to FAA and airplane maintenance records, the accident airplane was manufactured in 1976. Its restricted category special airworthiness certificate was issued on April 1, 1996. The airplane's most recent continuous airworthiness inspection was completed on January 18, 2015. At the time of the accident, the airplane had accrued about 11,850.5 total hours of operation.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	PHF,42 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	11:54 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	11 knots / None	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:	250°	**Turbulence Severity Forecast/Actual:**	N/A / N/A
Altimeter Setting:	30.02 inches Hg	**Temperature/Dew Point:**	31°C / 21°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Newport News, VA (PHF)	**Type of Flight Plan Filed:**	IFR
Destination:	Newport News, VA (PHF)	**Type of Clearance:**	IFR
Departure Time:	11:23 Local	**Type of Airspace:**	Air traffic control;Class C

The recorded weather at PHF, at 1154, approximately 10 minutes after the accident, included: winds 250 at 11 knots, 10 miles visibility, clear skies, temperature 31° C, dew point 21° C, and an altimeter setting of 30.02 inches of mercury.

Airport Information

Airport:	Newport News PHF	**Runway Surface Type:**	Asphalt
Airport Elevation:	42 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	25	**IFR Approach:**	None
Runway Length/Width:	8003 ft / 150 ft	**VFR Approach/Landing:**	Precautionary landing;Traffic pattern

PHF was owned by the Peninsula Airport Commission and was a public use, tower controlled airport. It was located nine miles northwest of Newport News, Virginia. The airport elevation was 42 ft above mean sea level.

There were two runways oriented in an 2/20 and 7/25 configuration.

Runway 25, had a left-hand traffic pattern, was asphalt, grooved, and in good condition. The total length was 8,003 feet-long and 150 feet-wide.

It was marked with precision markings in good condition and equipped with high intensity runway edge lights. A 4-light precision approach path indicator was located on the left side of the runway which provided a 3.00° glide path to touchdown. It was also equipped with runway end identifier lights and an ILS/DME instrument approach.

Obstructions were present off the approach end of the runway in the form of 41 ft trees, located 1,100 ft from the runway, which took a 21:1 slope to clear.

Examination of runway 25 revealed the presence of tire marks that matched the geometry of the airplane's right main, and nose landing gear which led off the left side of the paved surface of the runway to a damaged runway-edge light, and from the runway edge light back up on to the paved surface of the runway.

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:**	37.131942,-76.493057(est)

Examination of the airplane revealed that the airplane's wing structure had been substantially damaged when the lower portion of the left main landing gear shock strut separated, the landing gear forward trunnion was torn out from its mounting location on Spar 5, and the actuator tore through the pillar in the wing structure, when the left main landing gear struck the concrete runway edge-light base. The right main landing gear then collapsed in the opposite direction of its normal direction of retraction (outward instead of inward). Further examination also revealed that the fuselage had been damaged in numerous areas along with the wing leading edges, and a mission pod which was mounted under the left wing, and both the left-wing and right-wing integral wet wing tanks had been punctured by the landing gear, resulting in a fuel spill of about 600 gallons.

Examination of the nose landing gear assembly revealed that it was fully intact, the nose wheel tire was intact, undamaged, and inflated, and though covered in mud, the nose landing gear up lock mechanism was intact. The nose landing gear actuator was also fully extended in the down and locked position, and when electrical power was supplied to the airplane, a green down and locked indication was observed in the cockpit. Further examination revealed however, that the oleo strut was fully compressed, and black scuff marks existed on both the left and right walls of the nose wheel well above the door hinges, consistent with the nose wheel tire not being centered during retraction.

Examination of the cockpit revealed that the circuit breaker for the terrain avoidance warning system (TAWS) which was installed to help prevent inadvertent flight into terrain was "out" (deactivated) and not collared, and the landing gear warning/mute test switch had a rubber band looped around it and the pressurization rate knob, which kept the landing gear/mute test switch in the mute position deactivating the landing gear warning horn.

Examination of the cabin revealed that the cabin was filled with unsecured equipment including a cooler, engine covers, electronic equipment, and miscellaneous items that had been thrown forward during the accident sequence. There were two means of egress, the cabin door, which was located on the forward left side of the cabin just behind the cockpit, and an emergency exit window that was located on the aft right side of the cabin.

The cabin door was 36" wide and consisted of an upper portion that formed a canopy when open and a lower portion with integral entrance steps. The upper portion had two torsion bars to provide opening assistance. The torsion bars had an over center design to retain the upper door in the open position.

The lower door had cables at each end that were attached to spring-loaded takeup reels to aid closing and prevent damage if the door was inadvertently dropped. A safety catch would hold the lower door half in place while the upper door half was being raised. Hinged arms provided travel limit for the lower door. These arms were attached to a torsion bar to provide additional aid when closing the lower door.

Each door half had a locking handle that when rotated, drove a series of pins into the fuselage structure and through interlocking arms that secured the door halves together. When locked, the door would become a rigid structural member. A 28-vdc actuator in the lower door half operated hooks that pulled the doors together against the door opening perimeter seal. This must be done before the locking pins would engage. According to the Pilot's Manual, the hooks must be released after the locking pins were engaged or the DOOR warning light in the readout panel would illuminate. Switches in the pin sockets would also energize the warning light if the pins were not fully engaged.

Examination of the main cabin door revealed that door hooks were still engaged, but no anomalies, with either the door latching mechanism, or door indication system, that would have precluded indication of the DOOR warning light or hampered egress was discovered. Both upper and lower door levers could be operated without issue, and the upper and lower doors were able to be opened and closed normally. When electrical power was applied to the airplane, the DOOR annunciator light would also extinguish when the hooks were fully cycled.

Examination of the emergency exit window revealed that it was equipped with external and internal handles, it was functional, and that it opened without issue when the flight crew had egressed.

Injuries to Persons

Narrative injuries to persons place holder

Damage to Aircraft

Narrative damage to aircraft place holder

Other Damage

Narrative other damage place holder

Communications

Narrative communications place holder

Flight recorders

As the airplane had been modified to a configuration that had fewer than 6 passenger seats, a cockpit voice recorder (CVR) was not required under Title 14 Code of Federal Regulations Parts 91 or 135.

Examination of the airplane revealed though, that a Fairchild A-100 CVR system was installed. According to FAA records, the CVR was installed through a Supplemental Type Certificate (STC) in February 1991.

This model CVR, would record a minimum of 30 minutes of analog audio on a continuous loop tape in a four-channel format: one channel for each flight crew, one channel for a cockpit observer, and one channel for the cockpit area microphone (CAM).

The A-100 was equipped with test functionality to assist pilots in determining that the CVR was functioning. When the test is initiated, a tone is recorded to each channel of the CVR and subsequently detected by the monitor head and played back through a headset jack in the CVR control panel. The tones would also trigger a test meter for a visual indication that the test was successful.

According to the STC documentation, an inertial, or "G" switch, was installed as part of the CVR installation. A "G" switch is designed to remove power from the flight recorders upon detection of an acceleration that reaches a certain factory preset threshold in order to prevent flight recorder information from being overwritten. The switch would be triggered when it sensed a 3 G acceleration along a single axis. The switch could be reset using a button on the unit, which would restore CVR functionality.

Examination of the CVR revealed that it had not sustained any heat or structural damage and the audio information was able to be extracted from the recorder normally. The tape compartment inside the crash protected portion of the CVR was clean and was not contaminated with debris or tape filings. When 28 volts DC was applied to the CVR through an inverter, the tape transport drive functioned normally.

Maintenance records indicated that, the underwater locator beacon battery was replaced on January 22, 2015, and a decal inside the insulation assembly of the CVR indicated that the last maintenance that had been performed internally on the unit itself, occurred as early as July 2009. Typically, during maintenance, the audio would be bulk erased, and a test would be performed prior to returning the unit to service.

Review of the recording revealed that none of the audio was pertinent to the accident investigation, and the audio contained indications that the tape had been bulk erased. Test tones were also present on each channel near the end of the tape.

Medical and Pathological Information

Narrative medical and pathological information place holder

Fire

Narrative fire place holder

Survival Aspects

Narrative survival aspects place holder

Tests and Research

Nose Landing Gear and Nose Wheel Steering

The nose landing gear consisted of the nose wheel and chined tire mounted on a conventional air/hydraulic shock strut which was housed in, and attached to, the fuselage structure by bearing plates.

The nose landing gear strut used its internal gas pressure to fully extend the strut at take-off. When fully extended, the centering cams inside the strut would engage and ensure that the lower portion of the strut assembly and nose wheel were aligned straight ahead. The nose gear strut and the nose wheel bay were designed in such a way, that the nose wheel must be aligned straight ahead, for the wheel to go into the narrow bay. In addition, the uplock hook assembly would connect to a pin which was on the lower strut. Therefore, if the strut was not fully extended, even if it was aligned straight ahead, the uplock would not engage.

The variable authority nose wheel steering was electronically controlled by the rudder pedals through a system of switches, relays, a computer-amplifier, follow-ups, and a servo.

Nose wheel travel was inversely proportional to ground speed: i.e., from zero to 10 knots, 45° degrees of nose wheel steering was available, decreasing to 8° at 45 knots.

The system used the left inboard, right outboard and right inboard wheel speed transducers to provide input signals to the computer-amplifier, and rudder pedal movement would drive the rudder pedal follow-up which would apply a voltage displacement signal to the input of the nose-steering computer-amplifier. The computer-amplifier would apply a clockwise or counter-clockwise signal to the steering actuator.

This signal application would cause the actuator clutch to engage the actuator motor. The clutch output torque would drive the actuator gear train and position the nose wheel to the related position.

The nose wheel steering system was controlled by the Nose Steering switch on the control wheels or by depressing the STEER LOCK switch. The STEER ON light on the glare shield would come on when the nose wheel steering was on. STEER LOCK was released by pressing the control wheel Nose Steering Switch.

After recovery of the airplane from runway 25, the airplane was moved to a parking ramp where field testing of the functionality of the nose landing gear and nose wheel steering was conducted. The testing was performed after servicing of the nose landing gear shock strut per Chapter 12-10-03, of the Learjet Maintenance Manual. During servicing for the testing, only one ounce of hydraulic fluid was required to fully service the strut which indicated that the strut was nearly full of fluid when the accident occurred.

The strut however was found to be devoid of nitrogen. Prior to servicing the strut with nitrogen, the nose wheel was turned 40° to the left to see if it would center after servicing. Then as outlined in the maintenance manual, the nose landing gear shock strut was serviced to the recommended pressure of 58 psi using nitrogen, The nose strut slowly extended, and the nose wheel rotated to center.

With the nose landing gear strut assembly fully serviced, the nose landing gear was lowered onto a nose wheel steering protractor and rotated 40° right. The nose landing gear assembly was then quickly jacked up, lifting the nose wheel off the protractor to observe the action of the strut extension and centering cam operation. The process was repeated multiple times at 40° and 10° degrees left and right. In most cases, the nose wheel appeared to be sluggish as it centered, and on one occurrence the nose wheel failed to center fully when turned 40° left.

Given the condition of the landing gear, only a limited nose wheel steering system operational test could be performed. The steering system could be engaged with both squat switches rigged in ground mode/zero-wheel speed condition. About 42°of left and right nose wheel deflection was achieved. However, the steering system appeared to be out of rig because the nose wheel would not fully center.

Review of Maintenance Records

According to maintenance records, on October 21, 2013, about a year and three months prior to the accident, the nose wheel steering servo had been removed from service and sent out for repair due to weak torque. After disassembly, it was noted that the unit was "completely oil soaked", and the clutch bearing was coming apart. The unit was then cleaned, lubricated, and the defective bearing was replaced. It was then functionally tested and returned to service per the LearAvia Steering Systems Nose Wheel Steering Actuator Maintenance Manual.

On February 7, 2014, less than 4 months after the nose wheel steering servo had been removed from service and sent out for repair, the nose wheel steering computer was also found to be out of tolerance, and it would not adjust correctly. The computer was tested, and it was found that the peak signal detection circuit was defective. The computer was then disassembled, and leaking capacitors, out of tolerance diodes, and corroded hardware for the resistors, was discovered. The computer was cleaned, the cover was painted and labeled, the out of tolerance resistors, transistors, and capacitors, were replaced, and the circuit board was labeled and sealed. The computer was then functionally tested and returned to service per the LearAvia Steering Systems Nose Wheel Steering Actuator Maintenance Manual.

On January 18, 2015, About 70 hours prior to the accident, a visual inspection of the landing gear shock struts for leaks and general condition had been performed and the nose landing gear shock strut had been serviced (checked for proper hydraulic fluid level and inflation pressure).

Phoenix Air Group Testing

On June 9 2015, Phoenix Air Group advised the NTSB of the results of in-house testing that was conducted by their maintenance department on three of the airplanes in their Learjet fleet (N32PA, N545PA, and N547PA), to help determine what occurred with the accident airplane. The testing was conducted while all three airplanes were in their maintenance facility for routine maintenance.

On all three airplanes during the testing, they deflated the nose landing gear strut and lowered the nose landing gear on to a nose wheel steering protractor. The nose wheel was then turned 45° to the left, and the nose of the airplane was jacked upwards until the nose wheel tire was off the nose wheel steering protractor. After the nose wheel tire was off the protractor, the nose wheel would remain turned to the left and would not center.

This test was conducted three times on each of the three airplanes, and in each instance, the results were the same.

Learjet Engineering Laboratory Examination and Testing

At the request of the NTSB, after removal of the accident airplane's nose landing gear assembly, nose wheel steering servo, and nose wheel steering computer, they were shipped to Bombardier Learjet in Wichita, Kansas, where on July 7th through July 9th, 2015, examination and testing was performed on the nose landing gear assembly, and nose wheel steering servo.

Examination revealed, that the strut appeared to be in good condition, and there were no signs of fluid leakage at the lower gland nut. There were no obvious signs of any marks on the chrome portion of the shock strut. Some rotational type marks were noted on both the lower surface of the lower housing and the lower surface of the cylinder. The strut had flaking paint and appeared to have been touched up with spray paint. A small scratch mark was observed on the end of the actuator attach fitting. The red band around the top of the wheel fork (which was used for a dimensional check when servicing) was missing.

Centering checks were conducted with the strut assembly mounted vertically in a test fixture. The wheel fork was pulled to full extension and appeared to be in the centering cam. The Schrader valve was still wire locked. The wire was then cut, and the valve removed. Compressing the strut confirmed that the fluid level was to the level of the valve port.

The wheel fork of the strut was manually turned to the right 30°. The strut was then pressurized with nitrogen and the pressure to extend to contact the centering cam was recorded as 10 psi; the pressure to fully extend and engage the cam was recorded as 34 psi. This check was repeated with the wheel fork part of the strut turned to the left to 30° The recorded pressures were 15 and 36 psi respectively. These tests were repeated with the wheel fork part of the strut turned to 45°. The pressures recorded were 10 and 47 psi for left and 10 and 55 psi for right.

A leak test was then performed by pressurizing the strut to 58 psi (service pressure). No obvious leaks were observed, and the strut was placed in a secure location overnight in order to observe for the presence of a slow leak.

The following day, the strut assembly was removed from the secure location. The pressure in the strut was recorded as 55 psig, representing a pressure loss of 3 psig when compared to the pressure recorded the previous day.

The strut assembly was then moved to the test laboratory and connected to the test bench. With the strut still pressurized and fully extended, the voltage for the steering position follow up was measured as 0.965 V. This exceeded the manufacturer's maximum specified reference value of 0.035 V.

With the strut still pressurized, and the servo connected to the laboratory test equipment, the servo was powered, then commanded left, and then commanded right. It was observed that the servo was able to drive the steering in both directions, against the centering cam. The wheel fork part of the strut was observed to rotate about 45° and partially retract as it followed the centering cam. However, by design, a servo unit should be unable to power the steering in this condition. The test was retried. On this second test, it was observed that the servo was unable to move the steering.

The strut was then depressurized, and the wheel fork retracted so that it would clear the centering cam. The servo was again powered, and the steering turned both left and right to about 45°. A wheel speed simulated signal was then applied via the test bench and the steering position was limited to about 8°. This was the expected response for this condition.

The servo unit was removed from the gearbox. The washer for one of the mounting screws was missing. There were signs of slight hydraulic fluid leakage at the top of the servo. All gear teeth were observed to be intact and the unit appeared to be in good condition. The servo unit was then installed in the test fixture and tested per the component maintenance manual and LearAvia Test Procedure 800129. Testing Revealed that:

- Stall torque. The requirement was 70-110 in lb. The unit was measured at 110 in lb. in the clockwise direction (CW) which was at the specified upper limit, and 125 in lb. in the counterclockwise direction (CCW) which was above the specified upper limit. To verify these results, the test was repeated. The torque reading was observed to be erratic as the gauge would fluctuate between 100 and 150 in lb.

- No load RPM. The requirement is 52 – 92 RPM. The unit was measured at 76 RPM CW and 67 RPM CCW. Test results were within the required limits.

- Residual torque. The requirement is 3 in lb. maximum. The unit was measured as 7 in lb. in both the CW and CCW directions. The result was 2.33 times the requirement.

The servo unit was then torn down. The cover for the electronics was removed, and the wires were de-soldered to allow the circuit board to be removed. A jumper wire, not on the design drawing, was observed on the circuit board. The jumper wire was determined to be consistent with a normal repair.

The circuit board and motor were removed, and fluid contamination was observed on the outside of the motor casing. No abnormalities were noted with the gears. The clutch assembly was removed, and a small ring of friction material was observed on the outside of the clutch assembly casing. The clutch was disassembled. It was noted that the friction material between the two main parts of the clutch were completely worn away in the area where it provided the drive between the two parts of the clutch, leaving a metal to metal drive surface.

The lock wire for the gearbox cover screws was removed. The lockwire for the position follow up wiring clamp was observed to be missing. It was noted that the gearbox cover had one corner ground away, consistent with work carried out to dress out damage. The Gearbox cover screws were removed and then the cover was removed. A detailed visual examination of the inside of the Gearbox was conducted. There were no signs of any broken or missing gear teeth or any damage to any of the gears. However, there were indications that hydraulic fluid had been leaking into the gearbox, and it was observed that the gearbox lubrication grease was partly liquefied.

The bushing in the cover for the upper end of the cluster gear was measured as 0.381 in. the engineering drawing calls out 0.375-0.376 in. The castellated nut that holds the main gear was installed to 18-24 in lb. It was removed by hand. The main gear was removed. No abnormalities were noted. Wear was noted on the lower bearing of the cluster gear. The bearing was measured as 0.510. The shaft diameter of the cluster gear was measured as 0.372 in at the upper end, and 0.496 in at the lower end. Some minor wear was noted on the cluster gear servo gear teeth, as expected given the time in service of the landing gear. The thrust bearing was removed and examined. No abnormalities were noted. The gearbox housing was attached to the top of the strut by three screws. These screws are designed to be torqued to 50-70 in lb. and retained with Loctite 222. The breakaway torque for these 3 screws was measured as 50, 45, and 55, in lb. The screws were removed, and the gearbox housing was removed. The spacers/shims between the gearbox housing and the top of the strut were in place and appeared to be per the assembly instructions.

The strut was disassembled. The fluid removed was in good condition, which was expected as the strut had been serviced after the accident as part of the field testing. The lower seal was in good condition with no signs of fluid leakage. The upper seal was slightly deformed (likely due to age). The seal retainer was of the original design and was correct for the airplane. The centering cam was in good condition with no signs of wear or scoring. The upper cam was also in good condition. The retaining pins were in place and secure, with no signs of migration. A slight wear mark was noted on the bottom end of the metering pin. This would not affect the operation of the metering pin. The lower piston was pressed out of the wheel fork and checked for straightness on a calibrated granite table. It was determined to be straight.

Additional checks were carried out on the gearbox and follow up to determine if the earlier recorded off-set voltage could have been caused by the gear teeth on the follow up being able to jump a tooth, due to wear in the cluster gear bearings and the back drive into the system during gear retraction. The cluster gear was re-installed in the gearbox lid and all attempts to make it jump a tooth were unsuccessful. It was noted that the follow up gear was deflected slightly (the follow up shaft was slightly bent causing the gear to wobble) but still had over 90% engagement with the cluster gear. This would not have affected the operation of the follow up.

The wiring harness was inspected. It was found to be contaminated with hydraulic fluid. The protective sleeving was removed. A wire harness end to end continuity check was performed while the harness was jostled. The results of the continuity check were within expected parameters. A 300 Volt Hi Pot test was also performed. The results of the test were within expected parameters.

It was noted that a piece of lock wire was wedged under the operating nut of the Schrader charging valve. Review of the specification (MS 28889-2) confirmed that this would have had no effect on the sealing capability of the valve.

Nose Wheel Computer Testing

Nose wheel steering computer testing was carried out at Duncan Aviation in Lincoln, Nebraska, on July 17, 2015.

The nose wheel steering computer was connected to a test bench that simulated the aircraft nose wheel steering system installed on the airplane to check the computer calibration and if the computer was functioning correctly:

Test 1-1: No ground speed input to computer
Center: computer was 2° right of center
Left Turn: Full left 45°- computer drove to 42°
Right Turn: Full right 45° - computer drove to 46°

Test 1-2: High speed input to computer (800 Hz)
Center: computer was 1° to the right of center
Left Turn: Full left 45° - computer drove to 8°
Right Turn: Full right 45° - computer drove to 10°

Test 2: The nose wheel steering computer was connected to a nose wheel steering test set (LearAvia P/N 801711-3), to check the functionality of the computer per the LearAvia CMM test requirements.

The computer met all normal indications until the rudder, follow-up gain, and multiplier gain, (variable authority) circuits of the computer were tested. The test set checked all three variable authority circuits (V1 thru V3) of the computer.

The results for the low speed variable authority checks (below 45 knots) were outside of the normal indications. The results for the high speed (above 45 knots) checks, 800 Hz, were within normal indications.

Organizational and Management Information

Phoenix Air Group Inc. held a 14 CFR Part 135 certificate with worldwide operating authority. They were headquartered at Cartersville-Bartow County Airport (VPC), Cartersville, Georgia.

They provided passenger services, air ambulance services, air cargo services, and contracted airborne electronic warfare and weapons training/testing services.

Phoenix Air's maintenance, dispatch operations and headquarters staff were all located at VPC, and all "heavy" airplane maintenance and airplane modifications were also performed at VPC.

They also ran a fixed base operation as well as a flight school at VPC, and had offices, airplanes, and staff in several states, and around the world, where company airplanes and personnel were supporting various long-term contracts.

At the time of the accident Phoenix Air operated 13 Learjets, in addition to other multiple airplane types in their fleet.

Additional Information

Another Occurrence

On April 28, 2016, Phoenix Air Group advised the NTSB that during routine maintenance, they identified another airplane with a steering anomaly while conducting routine maintenance on a Learjet 36A. During the maintenance procedures it was identified that the nose wheel strut appeared to be underserviced and when jacking up the airplane (with the electrical power turned on) the nose landing gear turned to the left. After recognizing that the behavior was similar to what occurred on the accident flight and previous testing, maintenance personnel removed the top off the steering servo, and found that it was contaminated with hydraulic fluid from the strut leaking internally.

Review of Manufacturer's Guidance.

Review of the LearAvia Steering Systems Nose Wheel Steering Actuator Maintenance Manual and Bombardier Learjet's FAA approved inspection program revealed that no recommended scheduled overhaul requirement for the steering servo was listed.

Corrective Actions

In order to increase safety, the parties to the investigation took the following actions:

Phoenix Air Group

- On February 26, 2016, Phoenix Air Group stressed to their maintenance department and line personnel, that strut servicing and nose gear extension on preflight is critical and must be watched continuously on every airplane prior to launch.

- On April 22, 2016, as part of their 14 CFR Part 135 annual training, Phoenix Air Group advised their flight crews that deactivation of required safety systems such as TAWS and the landing gear warning horn were not acceptable and that loose gear needed to be netted or strapped down for flight. This was reiterated to their flight crews via an email from the director of operations on April 28, 2016, which included images from the investigation which emphasized the areas of concern.

Bombardier Learjet

The strut of the nose landing gear on the accident airplane was equipped with a P/N 2342107-001 upper seal retainer ring. Bombardier found that P/N 2342107-001 upper seal retainer rings could allow air to pass beyond the upper seal under certain conditions and that an available improved P/N 2342107-003 seal retainer ring could reduce the likelihood of this occurring. As a result, for all Learjet aircraft on which P/N 2342107-001 seal retainer rings were used, Bombardier modified the Illustrated Parts Catalog (IPC) to add the P/N 2342107-003 seal retainer ring as a spare and modified the applicable maintenance/service manuals to have the retainer ring added to the list of parts replaced at overhaul, to ensure that the upper seal retainer ring is upgraded during all overhauls, resulting in the elimination of the P/N 2342107-001 seal retainer ring by attrition over time.

With regards to the LearAvia steering servo, for all Learjet aircraft which use this equipment, Bombardier introduced a 2,400 hour or "within 2 years" overhaul inspection of the servo as a special inspection in the approved inspection program.

The above changes were communicated to Learjet owners and operators in May 2016.

All affected manuals have since been revised.

Useful or Effective Investigation Techniques

Narrative useful or effective investigation techniques place holder

Administrative Information

Investigator In Charge (IIC):	Gunther, Todd
Additional Participating Persons:	Michael L Dows; FAA/FSDO; Richmond, VA Barry Ivey; Bombardier Learjet; Wichita, KS George N Crim; Phoenix Air Group Inc.; Cartersville, GA
Original Publish Date:	December 3, 2020
Last Revision Date:	
Investigation Class:	Class 2
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=91169