



AVIATION



HIGHWAY



MARINE



RAILROAD



PIPELINE

# Aviation Investigation Final Report

<b>Location:</b>	Moline, Illinois	<b>Incident Number:</b>	ENG111A047
<b>Date &amp; Time:</b>	August 29, 2011, 12:36 Local	<b>Registration:</b>	N27152
<b>Aircraft:</b>	Embraer EMB145	<b>Aircraft Damage:</b>	Minor
<b>Defining Event:</b>	Loss of control on ground	<b>Injuries:</b>	53 None
<b>Flight Conducted Under:</b>	Part 121: Air carrier - Scheduled		

## Analysis

Shortly after the nose wheel touched down during the landing, the airplane turned hard left and departed the runway. Review of the Flight Data Recorder data revealed that the crew attempted to counter the initial left turn using rudder and differential braking, and that their inputs were not the cause of the left turn. The nose wheel steering, brakes, spoilers, thrust reversers, and rudder were inspected at the aircraft level with no anomalies found. In addition, many components from the nose wheel steering system were removed and tested at the component level. Two of these components, the Steering Manifold Assembly and the EHSV, were found to have defects that could potentially affect nose wheel steering operation.

The Steering Manifold Assembly failed flow tests related to bypass valve operation and a piece of plastic was discovered on the C2 filter screen of the bypass valve. The bypass valve operates when the nose wheel steering is disengaged. It connects the two steering actuating cylinder hydraulic chambers which allows the nose wheel to free caster. The observed low flow condition caused by the plastic debris could result in the reduced effectiveness of the bypass function when the nose wheel steering is disengaged. In addition, the plastic debris was in a location where it could have potentially reduced or blocked fluid flow through the C2 hydraulic port during normal nose wheel steering operation. This could have resulted in the inability or reduced capability of the nose wheel to turn in the commanded direction. Any blockage caused by this plastic debris would result in reduced performance only and could not have initiated or caused the nose wheel to turn uncommanded.

The EHSV passed the manufacturer's acceptance test; however, disassembly revealed that the C1 orifice filter seal was damaged and the C2 orifice filter seal was missing material. The missing material was not located, but the void that remained on the seal from the missing fragment was larger than the C2 nozzle orifice. Depending on how the missing material separated from the C2 orifice filter seal, the size of the material was potentially large enough to block the C2 nozzle. A blocked C2 nozzle would allow hydraulic fluid pressure to build within the C2 fluid chamber, causing the control spool to move in a direction that would command a left nose wheel turn. The undersized condition of the C1 and C2 filter

plug outer diameters likely contributed to the premature deterioration of the C1 and C2 orifice filter seals. The plug diameters were required to be checked when the EHSV was subjected to Service Bulletin (SB) 145-32-0099; however, the out of tolerance condition remained.

## Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: The uncommanded left deflection of the airplane's nose wheel likely due to seal deterioration and subsequent contamination within the Electrohydraulic Servo Valve (EHSV).  Contributing to the incident was the undersized condition of the filter plugs within the EHSV which likely caused the C2 orifice filter seal to extrude and deteriorate.

### Findings

Aircraft	Landing gear steering system - Malfunction
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## Factual Information

### History of Flight

<b>Landing-landing roll</b>	Loss of control on ground (Defining event)
<b>Landing-landing roll</b>	Runway excursion

On August 29, 2011, about 1236 central daylight time, an Embraer EMB 145 XR, registration N27152, operated by ExpressJet Airlines as United Express flight 5821, departed the left side of runway 10 during the landing roll out at Quad City International Airport, Moline, Illinois. There were 50 passengers and 3 crew members on board with no injuries reported. The airplane sustained minor damage. The flight was operated under the provisions of 14 Code of Federal Regulations Part 121 as a domestic passenger flight from Denver International Airport.

Winds were calm and visual meteorological conditions prevailed at the time of the incident. According to crew statements the approach, flare, touchdown, and landing were normal until the nose wheel touched down. At that time the aircraft began to veer left of centerline. The crew used right rudder and right differential braking to attempt to stay on the centerline; however, at an airspeed of approximately 90 kts the aircraft began to turn hard left. The aircraft departed the left side of runway 10, regained a heading parallel to the runway for a brief moment, then turned left again coming to rest at a magnetic heading of approximately 76 degrees. During the excursion the aircraft hit a taxiway sign and crossed taxiway Echo. The Captain and First Officer both reported that they pressed the nose wheel steering disengage switch during the event.

### Information

<b>Certificate:</b>	<b>Age:</b>
<b>Airplane Rating(s):</b>	<b>Seat Occupied:</b>
<b>Other Aircraft Rating(s):</b>	<b>Restraint Used:</b>
<b>Instrument Rating(s):</b>	<b>Second Pilot Present:</b>
<b>Instructor Rating(s):</b>	<b>Toxicology Performed:</b>
<b>Medical Certification:</b>	<b>Last FAA Medical Exam:</b>
<b>Occupational Pilot:</b>	<b>Last Flight Review or Equivalent:</b>
<b>Flight Time:</b>	

## Aircraft and Owner/Operator Information

<b>Aircraft Make:</b>	Embraer	<b>Registration:</b>	N27152
<b>Model/Series:</b>	EMB145 XR	<b>Aircraft Category:</b>	Airplane
<b>Year of Manufacture:</b>	2003	<b>Amateur Built:</b>	
<b>Airworthiness Certificate:</b>	Transport	<b>Serial Number:</b>	145759
<b>Landing Gear Type:</b>	Retractable - Tricycle	<b>Seats:</b>	
<b>Date/Type of Last Inspection:</b>		<b>Certified Max Gross Wt.:</b>	
<b>Time Since Last Inspection:</b>		<b>Engines:</b>	2 Turbo fan
<b>Airframe Total Time:</b>	22705 Hrs at time of accident	<b>Engine Manufacturer:</b>	Rolls Royce
<b>ELT:</b>		<b>Engine Model/Series:</b>	AE 3007
<b>Registered Owner:</b>	Wells Fargo Bank Northwest	<b>Rated Power:</b>	
<b>Operator:</b>	EXPRESSJET AIRLINES INC	<b>Operating Certificate(s) Held:</b>	Flag carrier (121)
<b>Operator Does Business As:</b>		<b>Operator Designator Code:</b>	C2XA

The airplane was an Embraer EMB 145 XR, registration N27152, serial number 145759. It was built in 2003, and had accrued 22,705 hours and 12,180 cycles at the time of the incident.

## Meteorological Information and Flight Plan

<b>Conditions at Accident Site:</b>	Visual (VMC)	<b>Condition of Light:</b>	Day
<b>Observation Facility, Elevation:</b>		<b>Distance from Accident Site:</b>	
<b>Observation Time:</b>		<b>Direction from Accident Site:</b>	
<b>Lowest Cloud Condition:</b>	Clear	<b>Visibility</b>	
<b>Lowest Ceiling:</b>	Unknown	<b>Visibility (RVR):</b>	
<b>Wind Speed/Gusts:</b>	/	<b>Turbulence Type Forecast/Actual:</b>	/
<b>Wind Direction:</b>		<b>Turbulence Severity Forecast/Actual:</b>	/
<b>Altimeter Setting:</b>		<b>Temperature/Dew Point:</b>	
<b>Precipitation and Obscuration:</b>			
<b>Departure Point:</b>	DENVER, CO (DEN )	<b>Type of Flight Plan Filed:</b>	
<b>Destination:</b>	Moline, IL (MLI )	<b>Type of Clearance:</b>	Unknown
<b>Departure Time:</b>		<b>Type of Airspace:</b>	

## Airport Information

<b>Airport:</b>	QUAD CITY INTL MLI	<b>Runway Surface Type:</b>	
<b>Airport Elevation:</b>	589 ft msl	<b>Runway Surface Condition:</b>	Dry
<b>Runway Used:</b>	10	<b>IFR Approach:</b>	Unknown
<b>Runway Length/Width:</b>	10002 ft / 150 ft	<b>VFR Approach/Landing:</b>	Unknown

## Wreckage and Impact Information

<b>Crew Injuries:</b>	3 None	<b>Aircraft Damage:</b>	Minor
<b>Passenger Injuries:</b>	50 None	<b>Aircraft Fire:</b>	None
<b>Ground Injuries:</b>	N/A	<b>Aircraft Explosion:</b>	None
<b>Total Injuries:</b>	53 None	<b>Latitude, Longitude:</b>	41.448612,-90.507499

The nose tires, left main tires, and right main tires all deposited faint but identifiable witness marks on the runway throughout the initial hard left turn. The aircraft departed the left side of runway 10, regained a heading parallel to the runway for a brief moment, hit a taxiway sign, crossed taxiway Echo, then changed heading to the left again coming to rest at a magnetic heading of approximately 76 degrees. The aircraft final position was in the grass with the nose wheel approximately 144 ft to the left side of the runway edge. The aircraft had multiple skin tears on the left and underside of the fuselage. There were also numerous dents on the left side of the fuselage. The outboard wheel fairing for the right main gear was damaged. The nose wheel doors had identical gouges on the leading edges. The nose wheel drag brace pin was bent and the nose wheel landing lights were broken.

## Flight recorders

The Flight Data Recorder (FDR) on the aircraft was a Honeywell SSFDR, Model 980-4700-042, Serial Number 9753. The recorder was in good condition and the data were extracted normally from the recorder. The event landing and roll out was captured in the data. The Flight Data Recorder Specialist's Factual Report can be found in the public docket for this incident.

## Tests and Research

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The spoilers, thrust reversers, and rudder all functioned following the event with no anomalies identified with their operation. The braking system was checked in accordance with the Embraer 145 Aircraft Maintenance Manual (AMM). No faults were found. Embraer reviewed the brake pressure data recorded on the FDR with no anomalies identified. In addition, the non-volatile memory in the Brake Control Unit and the Central Maintenance Computer was downloaded with no recorded information identified as being relevant to the event.

The nose wheel steering system was functionally tested following the incident per the Embraer 145 AMM. The nose wheel steering functioned normally in response to commands from both the rudder pedal position and the tiller. A nose wheel steering disengage button is located on each control wheel. Both buttons worked properly and disconnected the nose wheel steering when activated. No anomalies with the nose wheel steering were noted during this testing.

Many of the nose wheel steering components were removed from the aircraft and examined by the investigative group at their respective manufacturer. The Electronic Control Module, Feedback Unit Potentiometer Assembly, Feedback Unit Sensor, Tiller Assembly, Load Potentiometer, Rudder Pedal Potentiometer, and Brake Control Unit were inspected with no anomalies identified as contributing to the event. In addition, the Steering Manifold Assembly and the Electrohydraulic Servo Valve (EHSV) were removed and examined. The significant findings from these two examinations are detailed below.

The Steering Manifold Assembly is an electrohydraulic unit that provides fluid pressure to the steering actuator. The EHSV is a subcomponent of the Steering Manifold Assembly, and converts electrical steering signals from the Electronic Control Module into hydraulic fluid flow. It accomplishes this by applying the electrical steering signal to a torque motor which then produces a mechanical deflection of a flapper. The flapper moves to restrict fluid flow at the C1 or C2 nozzles, which increases hydraulic pressure in the corresponding hydraulic circuit. The increased pressure moves a control spool, porting hydraulic fluid to turn the nose wheel left or right.

The Steering Manifold Assembly was functionally tested per steps in the Component Maintenance Manual. During testing, it was discovered that the flow rate through the bypass valve when the valve was open was much lower than required. When the manifold was disassembled, a flat piece of clear plastic was discovered on the bypass valve "C2" filter screen. The bypass valve opens when the steering system is disengaged. It connects the two steering actuating cylinder hydraulic chambers and allows the nose wheel to free caster.

The EHSV, P/N 22253282-103, S/N 278A, was removed from the Steering Manifold Assembly and functionally tested per the manufacturer's Acceptance Test Procedure. The unit passed all sections of the acceptance test. Following the functional test the EHSV was disassembled. The C1 orifice filter seal exhibited a small area of material deformation and a small area of partial material separation. The outside diameter of the C2 orifice filter seal exhibited an area of missing material. These seals are located within hydraulic chambers that terminate at the C1 or C2 nozzles. If a nozzle becomes blocked, pressure can build within the C1 or C2 chamber, causing the control spool to move and therefore commanding the nose wheel to turn. The void that remained on the seal from the missing fragment of

material was larger than the nozzle orifice.

Further examination of the EHSV found that the C1 and C2 filter plug outer diameters were smaller than required for the unit's labeled modification status. As the outer diameter of the filter plug decreases, the gap between the filter plug and the filter bore increases. The orifice filter seal seats against this gap. Per the EHSV manufacturer, as this gap increases, so does the tendency of the corresponding orifice filter seal to extrude. For this reason, the correct outer diameter of the filter plug is considered critical to preventing premature deterioration of the orifice filter seals.

ExpressJet performed a historical records search for write-ups and component replacements related to the nose wheel steering on the incident aircraft for the two months prior to the incident. There were no items identified in the search. Regarding the landing gear in general, the Landing Gear Electronic Unit was replaced on 7/31/2011 due to an air/ground failure after takeoff. The nose wheel steering manifold assembly was installed on the aircraft on October 4, 2010. During the incident flight, the APU Starter generator was deferred per the Minimum Equipment List 24-34-01-2.

### **Additional Information**

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Embraer issued Service Bulletin (SB) 145-32-0099 (current revision 03, dated April 8, 2005) to address premature deterioration of O-ring seals within the EHSV. The bulletin states: "Instances of aircraft uncommanded swerving on the ground have been reported and in three of them a failure in the Nose Wheel Steering Hydraulic Manifold Electro Hydraulic Servovalve (EHSV) has been confirmed. In all cases, the Nose Wheel Steering system did not respond to steering commands in the cockpit. The manifold failures have been traced back to a premature deterioration of an O-ring in the electro-hydraulic servovalve (EHSV), which converts the electrical steering command into hydraulic pressure." The SB requires that the manifold assembly be fitted with an EHSV that has been screened and meets the requirements of HR Textron document DV1719. This document calls out critical dimensional requirements, including specific dimensions for the filter plug outer diameters. An "A" suffix is applied to the end of the valve serial numbers that have been screened and meet the requirements of this document. The incident EHSV serial number was stamped with the "A" suffix.

## Administrative Information

**Investigator In Charge (IIC):** Huray, Adam

**Additional Participating Persons:**

**Original Publish Date:** May 19, 2016

**Last Revision Date:**

**Investigation Class:** [Class](#)

**Note:** The NTSB did not travel to the scene of this incident.

**Investigation Docket:** <https://data.nts.gov/Docket?ProjectID=81641>

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