NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594
April 12, 2016

AIRWORTHINESS GROUP CHAIRMAN'S FACTUAL REPORT

ENG11IA047

A. INCIDENT:

Operator:	ExpressJet Airlines
Location:	Moline, IL
Date:	August 29, 2011
Time:	12:36 CDT
Airplane:	EMB 145 XR, N27152

B. SYSTEMS GROUP:

Chairman:	Adam Huray National Transportation Safety Board Washington, DC
Member:	Eric West FAA Washington, DC
Member:	Daniel Ramirez Embraer Ft Lauderdale, FL
Member:	Kevin O'Connor ExpressJet Atlanta, GA
Member:	Mike Shanks Air Line Pilots Association Humble, TX

C. INCIDENT SUMMARY:

On August 29, 2011, at 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.

D. AIRCRAFT DESCRIPTION:

Registration number:	N27152
Aircraft Serial Number:	145759
Aircraft Manufacturer:	Embraer
Model:	EMB 145 XR
Engine Manufacturer:	Rolls Royce
Model:	AE3007 SER
Aircraft Year:	2003
Total Time:	22,705 hours
Total Cycles:	12,180

E. DETAILS OF THE ON-SCENE INVESTIGATION:

The FAA, Atlantic Southeast Airlines, and ExpressJet arrived on scene after the aircraft was recovered from the runway. The NTSB did not travel to the incident aircraft. The following details were provided to the NTSB by the group members on scene.

E.1 Aircraft Condition:

Figure 1: Aircraft Condition Following Runway Departure

The aircraft hit a taxiway sign, crossed taxiway Echo, and came to rest in the grass with the nose wheel approximately 144 ft from the runway edge (see Figure 1). 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. Initial photos taken by the MLI airport police show the nose wheels were turned to the left after the aircraft came to a stop (see Figure 2).

Figure 2: Nose Landing Gear Position When Aircraft Came to Rest

E.2 Runway:

Figure 3: Tire Marks On Runway and Grass

Figure 4: Close Up View of Tire Marks near Runway Departure Point

The runway was grooved. The nose tires, left main tires, and right main tires all deposited faint but identifiable witness marks on the runway throughout the initial uncommanded left turn (see Figure 3). Other tire marks were identified on the runway prior to the left turn and after runway departure on the grass (see Figure 4 for tire marks in grass). The following approximate measurements related to the tire marks were obtained by on-scene personnel using a measuring wheel:

- First identifiable mark on runway to first departure point off runway was 393’11” (Left Main)
- Runway departure edge to taxi sign echo was 293’1” (Left Main Wheel)
- Runway departure edge to taxi light prior to echo was 387’8” (Left Main Wheel)
- Runway departure edge to near side of taxiway echo was 398’4” (Left Main Wheel)
- Runway departure edge to far side of taxiway echo was 483’4” (Left Main Wheel)
- Runway departure edge to final stop was 676’8” (Left Main Wheel)

- Left main wheel stopped even with 2000’ distance remaining marker
- Nose wheel stop to runway edge was 143’7”
- Runway departure edge to Nose Wheel Stop was about 732’

E.3 Aircraft Examination and Testing:

E.3.1 Nose Wheel Steering System Description:

The nose wheel steering (NWS) system permits moving the nose wheels when the landing gear is down and locked and the airplane is on the ground. The nose wheel steering system is electronically controlled and hydraulically operated. It is powered by the Number 1 hydraulic system. The nose wheel steering system is comprised of the following components (see Figure 5):

- Tiller (steering handle)
- Rudder pedals
- Control wheel disengage pushbuttons
- External steering disengagement switch
- Feedback potentiometer
- Load potentiometer
- Steering Electronic Control Module
- Hydraulic manifold assembly
- Steering actuating cylinder
- Feedback Unit Sensor (7-degree position sensor)

The nose wheel steering can be controlled by either the rudder pedals or a tiller located on the Captain’s side. In either case, the commanded displacement is measured by a potentiometer, which transmits the signal to the Steering Electronic Control Module (SECM). The SECM monitors each potentiometer signal individually for a short or open circuit. If a short or open circuit is detected the SECM will send a signal to disengage the nose wheel steering. If the input signals are valid the SECM will process them and send nose wheel steering command signals to the hydraulic manifold assembly. The hydraulic manifold assembly provides hydraulic pressure to the steering actuator to move the nose wheel in the commanded direction. A feedback potentiometer on the nose landing gear transmits nose wheel displacement information back to the SECM.

The nose wheel steering can be commanded to a maximum angle of approximately 71 degrees when using the tiller, 5 degrees when using the rudder pedals, or 76 degrees using both tiller and rudder pedals. A proximity sensor connected to the feedback unit sensor disengages the system if the nose wheel is rotated beyond 7 +/- 1 degrees when the tiller is not engaged. If the NWS system disengages in this manner, the system can be reengaged by engaging the tiller when speed is below 25kts. The steering system may also be manually disengaged through switches located on either control wheel provided the tiller is not engaged. If the NWS system is disengaged for any reason while the aircraft is on the ground a caution oral alert will sound, the master caution light will illuminate, and the message “STEER INOP” will display on the EICAS. The system allows for the nose wheel to free caster any time the nose landing gear is on the

ground and the NWS is disengaged.

This aircraft was equipped with an external steering disengagement switch which allows ground personnel to disengage steering prior to towing operations. The disengagement switch inhibits the steering actuation commanded by the steering handle and the rudder pedals. A caution message is displayed on the EICAS whenever the steering system is disengaged by the external switch. The NWS system is also automatically disabled when the aircraft is airborne. Nose wheel centering when weight is off wheels (strut extended) is mechanically provided by a cam.

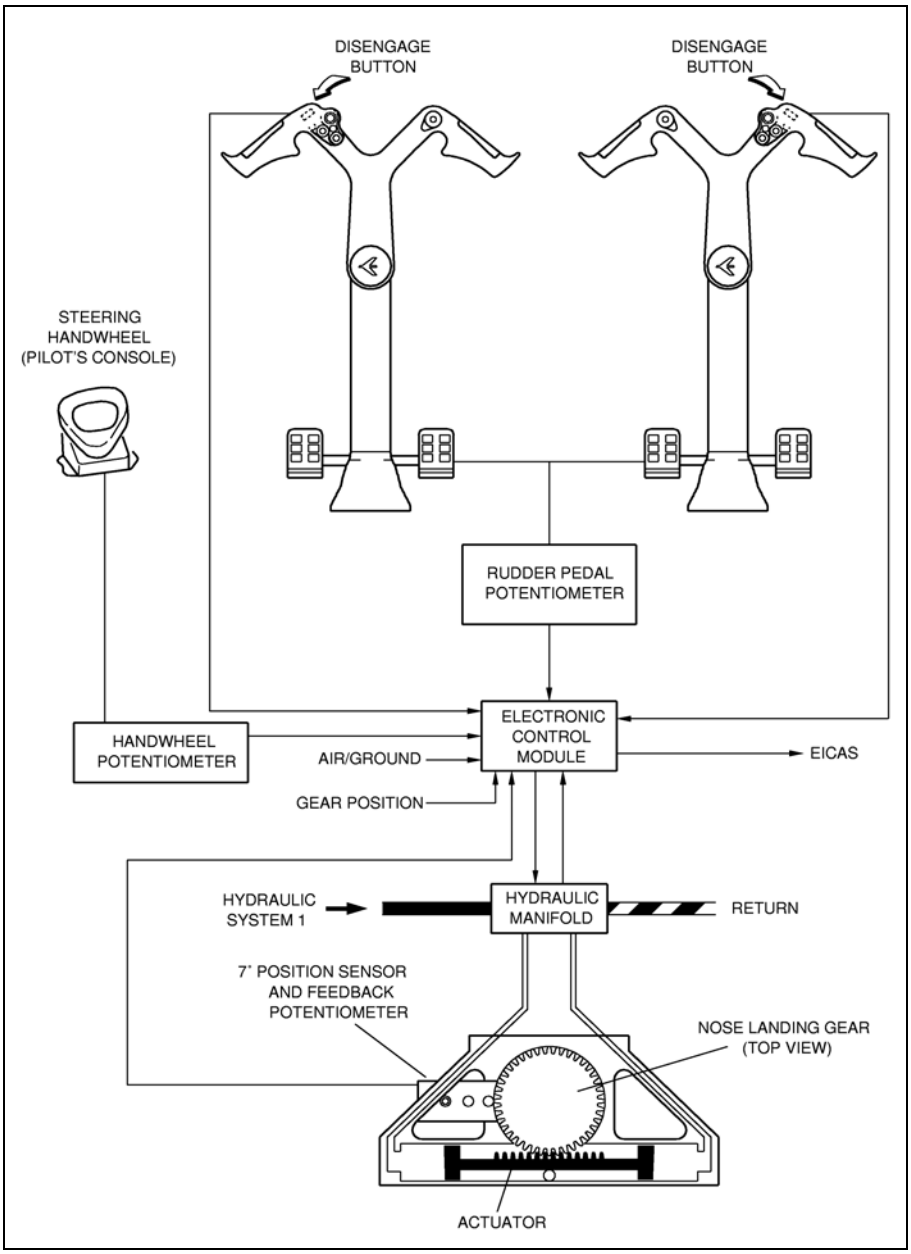

Figure 5: Nose Wheel Steering System Schematic

E.3.2 Central Maintenance Computer Download:

The Central Maintenance Computer (CMC) was downloaded prior to any testing being performed on the aircraft. There were no faults recorded in the CMC at the time of the download; however, ExpressJet had records of CMC maintenance logs that were recorded prior to the event. ExpressJet downloads the CMC on a 70 cycle interval and also on condition to support maintenance, and the logs are stored in a company database. The database revealed that the following logs were stored in the CMC for 29-Aug-2011 (time stamp for fault occurrence follows each fault)[1]: ENG1 SCHED MAINT REPAIR (13:48:52); ENG2 SCHED MAINT REPAIR (13:48:52); DIG.TEMP.CONTROLLER 1 FAIL (13:48:52); DIG.TEMP.CONTROLLER 2 FAIL (13:48:52); PRECOOLR2 TEMPCTL SYS FAIL (13:57:41); PRECOOLR1 TEMPCTL SYS FAIL (13:57:44). The next most recent log was dated 25-Aug-2011.

The ENG1/2 SCHED MAINT REPAIR messages are considered nuisance messages and Embraer stated they have no significance to the nose wheel steering or braking systems. The DIG.TEMP.CONTROLLER 1/2 FAIL messages occur when a failure of the respective digital temperature controller is detected by the CMC. The PRECOOLR1/2 TEMPCTL SYS FAIL messages occur when the bleed air precooler outlet temperature for the related pneumatic system is below the specified set point.

E.3.3 Brakes and Brake Control Unit:

The Brake Control Unit (BCU) was downloaded prior to any aircraft testing. The BCU was later examined and a non-volatile memory download was performed by the unit's manufacturer (see section G.9). The braking system was checked in accordance with Embraer 145 Aircraft Maintenance Manual (AMM), Section 32-41-00. No faults were found. The aircraft remained connected to the computer required for the brake system check and each wheel speed transducer was moved by hand. The test verified that each transducer was installed correctly. This test did not verify the magnitude of the transducer output signal. Embraer reviewed the brake pressure data recorded on the FDR with no anomalies noted.

E.3.4 Nose Wheel Steering System Examination:

The NWS was functionally tested using Embraer 145 AMM, Section 32-50-00 dated Jul 28/06, as a guide. The nose gear centered correctly at 0º. Using the tiller only, the gear turned a maximum of 72º to the left and a maximum of 72º to the right. For a properly rigged system, the requirement is for a fully turned tiller to command a nose wheel angle of 71º +5º/- 2º left and right. Using both the tiller and rudder, the gear turned a maximum of 77º degrees to the left and 75º degrees to the right. For a properly rigged system, rudder pedal input will add 5º +1º/-1.5º of nose wheel angle to the left and right in addition to that commanded by the tiller. The NWS disengage buttons worked properly and disconnected the NWS. No anomalies were noted during this testing.

[1] The time stamp is according to the captain's clock. This clock is typically set to Coordinated Universal Time (UTC).

E.3.5 Additional Tests:

The spoilers, thrust reversers, and rudder were all functioned with no anomalies identified with their operation.

E.3.6 Hydraulic Systems:

The panels covering the hydraulic fluid filers for the #1 and #2 hydraulic systems were removed. All differential pressure indicators were flush and not extended. The system #1 pressure and case drain filters were removed and found to be clear of debris. The system #1 return filter contained bits of visible black sediment. The system #2 pressure and return filters contained bits of visible sediment, and the system #2 case drain filter and bowl contained significant sediment.

F. Maintenance Records:

The incident aircraft was an EMB 145 XR, Registration N27152, Serial Number 145759. At the time of the incident, the aircraft had accrued 22,705 hours and 12,180 cycles.

ExpressJet performed a historical records search for gripes and component replacements related to the nose wheel steering 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.

G. COMPONENT EXAMINATIONS:

G.1 Nose Wheel Steering Electronic Control Module:

MFG: Parker
P/N: 308560-1019M
S/N: 1332
DMF: 2Q03

The Steering Electronic Control Module (SECM) is an electronic system consisting of a cover plate, circuit card assembly, and two connectors. The SECM receives electronic inputs from the nose wheel steering commands and feedback components and outputs an electrical signal to the hydraulic manifold assembly to command the steering actuator. The SECM also relays system status information. The unit does not record any data in NVM.

The SECM was examined at the Parker facility in Irvine, CA on October 25, 2011. The NTSB, FAA, Parker, Embraer, and ExpressJet witnessed the examination. The SECM was visually inspected and appeared in good physical condition. The unit was functionally tested in accordance with Chapter 2 “Testing and Fault Isolation” of the Abbreviated Component Maintenance Manual 32-50-11, Rev 5 dated Aug 31, 2006. Section 2.C(1) did not apply to this unit. Section 2.C.(2)(3) was performed last. The test included three phases, one at room

temperature, one at 0 (+/- 5) degrees Fahrenheit, and one at 158 (+/- 5) degrees Fahrenheit. The unit passed all performed sections of the test.

Parker had no records of repair for this unit.

G.2 Nose Wheel Steering Manifold Assembly:

MFG: Parker
P/N: 308570-1007
Rev: None Marked
S/N: 0823B
MFG Date: 1Q03

The nose wheel steering manifold assembly is an electrohydraulic unit that provides fluid pressure to the actuator that controls the steering of the nose wheel. The manifold supports and contains an electrohydraulic servo valve, solenoid, three check valves, a bypass valve, an electrical connector, a filter, and a compensator.

The NWS manifold assembly was examined at the Parker facility in Irvine, CA on October 25, 2011. The NTSB, FAA, Parker, Embraer, and ExpressJet witnessed the examination. A visual inspection was performed and the unit appeared in good condition except for a small dent on one corner of the mounting base.

A functional test was performed on the unit per the Component Maintenance Manual 32-50-15, Rev 9 dated July 15, 2011 (Tests 3.C thru 3.M). Tests 3.C "Dielectric Strength" and 3.D "Insulation Resistance" were performed last. Tests 3.F "Proof Pressure" and 3.G "Return Proof" were not performed. The unit passed all tests with the exception of test 3.E "Bypass Mode" and 3.I "No Load Flow Rate and Phasing". Test 3.E requires a minimum flow of 0.21 gpm from port C2 when the bypass valve is open; actual flow was 0.01 gpm. Test 3.E also requires a minimum flow of 0.21 gpm from port C1 when the bypass valve is open; actual was 0.16 gpm. Test 3.I requires a flow of 1.26 to 1.54 gpm; actual was 1.55 gpm.

The bypass valve (P/N 308130-103, S/N 3582) was removed and visually examined. A few very small black particles were noted in the residual hydraulic fluid. A clear plastic like material measuring 0.335 x 0.202 inch was discovered on the C2 filter screen on the steering actuator side. Material analysis provided by Parker revealed the material was similar to a low density polyethylene. The bypass valve was disassembled with no other anomalies found.

The inlet filter, three check valves, solenoid valve, and return port compensator were removed and inspected. A small sliver of clear plastic like material measuring .125 x .025 inch was discovered in the return port cavity (downstream side of the compensator piston housing). Material analysis provided by Parker revealed the material was similar to a scotch tape. No other anomalies were noted for any of the other components.

The electrohydraulic servovalve was removed and sealed for later testing at Woodward/HR Textron.

Service history was provided by Parker. The unit was sent to Parker on January 14, 2010 for "NWS INOP message on EIC". Repair action included replacement of the EHSV due to low flow and incorporation of Service Bulletin 32-112 to upgrade the 321130 check valves. Service history also showed that the unit was sent to Parker on February 28, 2007 for incorporation of Parker Service Bulletin 308570-32-111 to upgrade the EHSV. Parker had no other records of repair or other actions for this unit.

G.3 Electrohydraulic Servo Valve:

MFG: HR Textron
P/N: 22253282-103
S/N: 278A
MFG Date: 1Q09

The electrohydraulic servo valve (EHSV) is a three position, four-way type valve. The EHSV receives electrical signals from the SECM. A torque motor within the EHSV responds to the electrical signals and hydraulic fluid is ported to the commanded steering actuator cylinder chamber to turn the nose wheel.

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. An "A" suffix is applied to the end of 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.

The EHSV was removed from the manifold assembly following the NTSB examination of the manifold assembly at Parker on October 25, 2011 (see section G.2). The EHSV was examined at the Woodward HRT facility in Santa Clarita, CA on October 26, 2011. The NTSB, FAA, Woodward HRT, Parker, Embraer, and ExpressJet witnessed the examination. The EHSV was made by HR Textron, who was later purchased by Woodward Inc. and is now known as Woodward HRT.

The EHSV was visually examined. The unit appeared in good overall condition and all safety wire was intact. Some slight damage was noted to the outside diameter of the electrical connector shell. A blocker plate was installed over the hydraulic ports following the removal of the EHSV from the manifold assembly at Parker. This plate was removed prior to the following tests and examinations.

A functional test was performed on the unit per the manufacturer's Acceptance Test Procedure HR72700412, Rev D, dated June 18, 2009. Tests 4.4 "Dielectric Strength" and 4.5 "Insulation Resistance" were performed last. The unit passed all sections of the acceptance test. The pressure gain plots created in step 4.10 showed a few minor blips typically attributed to normal wear of the feedback wire pin (ball). The pressure gain plots and hysteresis plot remained within required limits.

Following the functional test the EHSV was disassembled and examined. The following observations were made:

A. The electrical interface was unscrewed from the EHSV and inspected. All wires, pins, and connections were in good condition.

B. The wires were unsoldered from the electrical interface and the coil cover was removed. A gold colored flake measuring approximately 0.0375 inch at its widest point was found on the bottom of the coil. The armature gap at the top of the frame assembly was inspected for debris; no debris was found.

C. The coil was removed from the frame assembly and inspected. No anomalies were noted.

D. The end plates were removed and the C1 and C2 nozzle plugs were removed. The plugs were inspected and the seals appeared in good condition. The nozzles were clear of debris.

E. The orifice plugs were removed and the plug seals appeared in good condition. The orifices were inspected and were clear of debris. The orifice filter seals were then removed and inspected under a 25X magnification. The C1 orifice filter seal exhibited one area of material deformation and one small area of partial material separation (the material fragment was still connected to the seal along one edge) measuring approximately 0.01 inch in length. The C2 orifice filter seal exhibited a shallow delaminated lip with an area of missing material approximately 0.017 X 0.048 inch.[2] The area of missing material was on the outside diameter of the seal where it is in contact with the filter bore of the housing. Laboratory analysis revealed that the seals met the material requirements for NAS1613 and the basic dimensional requirements as provided by HR Textron. These seals reside within hydraulic chambers that terminate at nozzles with an orifice diameter of 0.0095-0.0105 inch. By design, a flapper will open and close the nozzle orifice, controlling pressure within the hydraulic chamber and therefore controlling the position of the control spool.

F. The filter was removed and inspected. No anomalies were noted.

G. The armature/flapper assembly was removed. The feedback wire ball on the end of

[2] These dimensions were taken by the NTSB Materials Lab after the examination at HR Textron. The dimensions are documented in the Materials Lab Factual Report and can be found in the public docket for this incident.

the flapper assembly demonstrated some flat spotting and wear on one side in the area where it contacts the spool. The return seal was inspected with some black fibers from the mold flash noted on the inner diameter of the seal. No other anomalies were identified.

H. The end chamber plugs were removed and inspected. Some hair like fibers were noted on the C1 spool plug seal. The spool was then removed and inspected. A small shiny area was identified in the area where the feedback wire ball contacts the spool on the C1 side. No other anomalies were identified.

I. The diameter of the filter bore was measured at 0.2104 inch. Per HR Textron document DV1719, the filter bore diameter requirement is 0.2095 – 0.2105 inch. The C1 filter plug outer diameter was measured at 0.2077 inch and the C2 filter plug outer diameter was measured at 0.2075 inch. These dimensions did not meet the requirements of HR Textron document DV1719, which requires the filter plugs outer diameters to be 0.2088-0.2093 inch. 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 manufacturer, as this gap increases, so does the tendency of the corresponding orifice filter seal to extrude.

J. The distance from the edge of the housing to the end of the K-cut edge break in the filter orifice measured 0.155 inch for the C1 side and 0.150 for the C2 side. DV1719 requires that this dimension must measure 0.157 inch maximum.

Woodward HRT service records revealed that the EHSV was first assembled in April of 1999. The unit was returned to HRT in March 2005 for a leaking valve and was repaired. The unit was inspected per Woodward spec DV1719 and identified with an “A” after the serial number. The unit was also returned in February 2008 for null position failure/sensitivity and was repaired in March 2009.

G.4 Feedback Unit Potentiometer Assembly:

Feedback Unit Potentiometer Assembly
MFG: Liebherr
P/N: 1170A3500-02
S/N: 00758
MFG Date: 09.01

Potentiometer
MFG: Vishay
P/N: 2000A1067K01; Lot # 22

The feedback unit potentiometer is a rotary potentiometer, assembled with a shaft, gear, and support ring in a two-part housing. The potentiometer is installed with a cap and electrical connector on the top part of the housing. Its function is to give an electrical signal relative to the position of the strut wheel axle.

The feedback unit potentiometer assembly was examined at the Liebherr facility in Saline, MI on December 13-14, 2011. The NTSB, FAA, Liebherr, Embraer, and ExpressJet witnessed the examination. The unit was unpackaged and visually inspected.

The feedback unit potentiometer assembly was shipped to the Liebherr facility by ExpressJet for the examination. The shipping box was damaged and contained a large hole. The item was unpackaged and visually inspected. The cannon plug receptacle on the top of the unit was bent to the right when viewed from the front of the unit, and the left side of the cannon plug mounting bracket was bent slightly upward creating a hole in the sealant. The unit was dirty and there were a few scratches on the housing. All locations that require sealant during build at the manufacturer contained sealant. The two bolts restraining the cap assembly (top side of housing) and the joint between the cap assembly and top housing did not contain sealant. These areas should be sealed by maintenance personnel during unit adjustment on the aircraft per AMM (Aircraft Maintenance Manual) 32-50-07 (700-801-A) dated Apr 28/10, page 504. The restraining tabs typically securing the two bolts on top of the cap assembly were not bent up. The safety wire on the two pressure relief valve screws was intact.

The protective cover that was placed over the gear cavity for shipping was removed. The unit's hardware was covered in grease but the cavity was empty.

The unit was subjected to the test and fault isolation procedures as described in the Component Maintenance Manual 32-21-12, Rev 2, dated Mar 01/06. The results were recorded on LSL Form TR 105, Rev 4, dated 08-28-06. The unit passed all tests. A graph of voltage output was created as the gear was turned over its full operational spectrum. The graph was linear with no voltage spikes noted.

The safety wire securing the two pressure relief valve screws was removed and the unit was disassembled. The inside of the cap assembly appeared to have some white markings similar to water staining. The electrical wires were securely attached to both the potentiometer and the connector plug. The pins from the connector plug were removed and appeared in good condition with no sign of corrosion. The potentiometer shaft and pin appeared in good condition. The relief valve springs felt normal, the bearings rotated smoothly, and the gear appeared in good condition with no anomalies noted. No indication of corrosion was found inside the unit.

Service history was provided by Liebherr. The unit was sent to Liebherr for repair on 9/17/2009 with a discrepancy of erratic nose wheel steering movement. The repair included potentiometer replacement. The unit was also returned to Liebherr on 4/9/2010 with a discrepancy of repeated adjustments required on aircraft. The repair included a potentiometer replacement to fix a broken wiper wire. Liebherr had no other records of repair or other actions for this unit.

G.5 Feedback Unit Sensor:

MFG: Liebherr
P/N: 1170A3600-01
S/N: Not Serialized

The feedback unit sensor is a target ring, assembled with a shaft and gear in a two-part housing. A boss on the bottom housing is for installation of a proximity sensor. The feedback unit sensor's function is to give a target related to the position of the strut wheel axle for use with the installed proximity sensor. The proximity sensor will send a signal to disengage the nose wheel steering system if the strut wheel axle angle is greater than 7 degrees in either direction when the tiller is not engaged.

The feedback unit sensor assembly was examined at the Liebherr facility in Saline, MI on December 13-14, 2011. The NTSB, FAA, Liebherr, Embraer, and ExpressJet witnessed the examination. The unit was unpackaged and visually inspected.

The feedback unit sensor assembly was shipped to the Liebherr facility by ExpressJet for the examination. The box the unit was shipped in was damaged and contained a large hole. The item was unpackaged and visually inspected. The sensor proximity switch remained attached but was not safety wired to the unit. The switch could be easily rotated by hand. The wire harness remained attached to the sensor proximity switch and the cannon plug was loose and could be rotated by hand. All locations that require sealant during build at the manufacturer contained sealant. The safety wire on the two pressure relief valve screws was intact.

The wire harness and sensor proximity switch were removed from the assembly. The protective shipping cover that was placed over the gear cavity following removal from the aircraft was also removed. The unit contained an acceptable amount of grease but the cavity was mostly empty. Per AMM 32-50-06 dated Nov 28/04, a rig pin is required for installation. A rig pin was inserted into the unit during the examination and the pin fit snuggly.

The individual internal components of the assembly were visually inspected. The bearings rotated smoothly and the gear appeared in good condition. No anomalies were discovered during component inspection.

Liebherr had no records of repair or other actions for this unit based on the current name plate.

G.6 Tiller Assembly:

Tiller Assembly
MFG: Embraer
P/N: 123-02328-407
S/N: 145764
MFG Date: 06-September-03
Inspection: 115

Potentiometer
MFG: Betatronix
MOD (P/N): 7029
S/N: 3530
MFG Date: 03-12

The tiller is a steering handle that controls the nose wheel steering during aircraft taxiing maneuvers. The limit of movement for the tiller is 71° in both directions from the potentiometer center position. The tiller has two movements of actuation. The first occurs when a small pressure is applied on the steering handle which permits engaging the steering select reset switch. The second movement is the turning movement and causes the actuation of the potentiometer.

The tiller was examined at the Embraer Aircraft Maintenance Services facility in Nashville, TN on April 11, 2012. The NTSB, Embraer, ExpressJet, and the Air Line Pilots Association witnessed the examination.

The tiller was visually inspected. The "Push to Operate" and the identification labels were beginning to peel off the assembly in some areas. One corner on the bottom side of the component contained traces of a sticky dark residue. The unit showed typical handle wear and the cannon plug and wires appeared in good condition. The handle had some slight bearing play when applying force to the handle base. There was considerable dust noted around the engagement switch. The cover screws contained the original production torque seals.

The unit was subjected to the testing and fault isolation procedures as described in the Component Maintenance Manual (CMM) 32-50-00, Task 32-50-00-99F-005-A, Rev 6. The housing plate covering the potentiometer and microswitch was removed to facilitate testing. The inside of the unit contained significant dust build up but was considered typical for a unit of this age. The unit passed all tests except Step 1(C)2(b). This step requires that continuity exists between pins E and H when the handle is in the rest position. During testing there was no continuity between these pins. Per EMB-AWM 32-53-50, pin H is unused and this failure would have no effect on the system. A wiring check confirmed that the failure was in the microswitch. The microswitch appeared to have sufficient over-travel beyond engagement.

In addition to the CMM testing, an analog multimeter was connected to pins A-B and pins B-C and the tiller handle was depressed and rotated through its full travel. The resistance change was generally smooth and did not drop out at any point during the test. However, during both tests, the resistance did show a slight fluctuation when the handle was moved just to the right of center. The approximate resistance at the needle fluctuation location is noted below.

Pins A-B:
- Center: 2.8 kOhms
- Full Left Travel: 1.6 kOhms
- Full Right Travel: 4.2 kOhms
- Analog needle fluctuation position during right rotation: 3.1 kOmhs

Pins B-C:
- Center: 2.8 kOhms
- Full Left Travel: 4.2 kOhms
- Full Right Travel: 1.6 kOhms
- Analog needle fluctuation position during right rotation: 2.6 kOhms

A force gauge was used to determine the minimum force required to engage the engagement switch. The switch would engage with approximately 1 lb force applied to the tiller handle.

Embraer Aircraft Maintenance Services had no records of repair or other actions for this serial number. ExpressJet records show that the unit was the original unit installed on the aircraft.

G.7 Load Potentiometer:

MFG: BI Technologies Corporation
Part Number: 8146R5KL.25SL
Serial Number: Not a serialized part
Date Code: 0634 (34th week of 2006)

The load potentiometer is a 10-turn 5 kOhm potentiometer. It sends a constant signal load to the SECM when the tiller is not engaged. It gives precision zero centering adjustment to the nose wheel. This potentiometer is adjusted during maintenance of the nose wheel steering system and is locked in a constant position until the next time it is adjusted by maintenance.

The examination of the load potentiometer was conducted at the BI Technologies Corporation facility in Fullerton, California on March 10, 2012. The NTSB and BI Technologies Corporation witnessed the examination. The unit is constructed in the BI Technologies Corporation facility in Mexicali, Mexico. The potentiometer is not a repairable component and BI Technologies Corporation had no records of service for this particular unit.

A visual examination was performed. The unit appeared free of major external damage and odor. The solder joints appeared clean with some resin color noticeable near the joint bases. The overall resistance was measured to be 5.15 K Ohm. The resistance from the slider solder joint to the "CCW" solder joint was measured to be 3.72 K Ohm. The resistance from the slider solder joint to the "CW" solder joint was measured to be 1.53 K Ohm.

The shaft lock nuts were removed and the shaft was observed to be in an atypical pulled out (extended) position. The retaining clip that is typically flush against the base of the housing was measured to be approximately 0.054 to 0.070 inch from the housing. The difference between these two measurements is the approximate end play. The actual end play measurement as taken per the specification can be found below in examination test D. The shaft was rotated by hand and a small catch (increase in friction) could be felt during rotation.

The unit was examined in accordance with the Standard Specifications Series 8140, Revision 10, dated July 18, 2006. The following tests were accomplished per this specification.

A) Resistance/Tolerance Test - PASS
The resistance of the potentiometer coil was measured utilizing a digital ohm-meter. The resistance of the coil indicated 5.15 K Ohm. The acceptable range was 5 K Ohm +/- 10 %.

B) Independent Linearity – PASS
Linearity was measured utilizing the automated potentiometer tester, HED I675. The results indicated a linearity of 0.0325%, with an acceptable range of 0.25%.

C) Start/Run Torque - PASS
The breakout torque required to turn the shaft was measured utilizing a torque gauge. The torque required was 0.3 inch/ounces. The acceptable tolerance was any value below 0.8 inch/ounces.

D) Shaft End Play - FAIL
The longitudinal shaft endplay dimension was measured utilizing a height gauge. The value measured was 0.013 inches. The acceptable tolerance was any value less than 0.01 inches.

E) Output Smoothness – PASS

According to BI Technologies Corporation documentation, the output smoothness is a measurement of any variation in electrical output not present in the input. Smoothness includes the effects of resistance variation, resolution, and other nonlinearities in the output. The requirement is that no spikes can exceed 0.05% of the input voltage.

F) Runout Tests: - PASS

The shaft radial play was measured to be 0.0015 inch, the specification requires 0.003 inch max. The shaft runout measured 0.0013 inch, the specification requires 0.003 inch max. The pilot diameter runout measured 0.0008 inch, the specification requires 0.004 inch max. The lateral runout measured 0.0012 inch, the specification requires 0.005 inch max.

Additional testing was performed. The potentiometer was connected to an oscilloscope. The shaft was turned at varying speeds and the outputs were studied for any anomalies. The only anomaly identified was a few minor voltage spikes approximately one turn from the CW stop. The spikes were less than approximately 0.8 volts with 10 volts input.

The rear cover staking plastic material was removed utilizing a knife, and the cover was removed. The coil, contacts, slider assembly, and all other components appeared to be in serviceable condition with no anomalies noted.

G.8 Rudder Pedal Potentiometer:

MFG: Betatronix
Part Number: 13BF7184
Serial Number: 2507
Date Code: 02-45

The rudder pedal potentiometer is installed on the pilot's pedal mechanism. It sends electrical signals to the SECM that are proportional to the rudder pedal movement.

The examination of the rudder potentiometer was conducted at the Betatronix facility in Hauppauge, NY on May 23, 2012. The NTSB, FAA, and Betatronix witnessed the examination. The unit was constructed in the Hauppauge, NY facility in 2002. The potentiometer is not a repairable component.

The potentiometer was received as part of the rudder potentiometer assembly. This assembly consisted of a few structural brackets, a gear connected to the potentiometer shaft, and wires that were attached to the potentiometer leads on one end and a cannon plug on the other end. The potentiometer was covered in a rubber like sealant. A visual inspection of the assembly did not reveal any anomalies.

Prior to any disassembly of the rudder potentiometer assembly, the cannon plug leads were connected to a multimeter/oscilloscope. This test was to ensure that there were no obvious faults with the wiring attached to the potentiometer. The total resistance of the pot measured 4869 Ohms and was within limits per the manufacturers ATP. The contact resistance measured 182 Ohms and was within a typical range expected for a 5K potentiometer. The voltage output from 0 to 10 Volts input looked correct. The wiper output smoothness (noise) was within the required limits of 0.1% of the applied voltage of 10 volts +/- 1mV over the entire operational range.

The potentiometer was removed from the rudder potentiometer assembly and the sealant covering the potentiometer was mostly removed. The unit was then tested in accordance with the ATP-1000/7184, Rev B, dated 3/16/11. Test 1.1 (dimensions check per outline drawing) was not completed. Tests 2.4 (dielectric strength) and 2.5 (insulation resistance) were completed last. The unit passed all performed tests per the ATP with no anomalies noted.

Additional testing beyond the scope of the ATP was performed on the component. The unit was subjected to a backlash test as described in ATP-1000, Rev A, dated 5/19/04, section 3.2.11. Backlash is defined as the mechanical difference with reference to the same electrical output point. The backlash was determined to be 0.04 degrees. There are no defined requirements for this test, but Betatronix stated the results are typical for this potentiometer.

The unit was subjected to a hysteresis test as described in ATP-1000, Rev A, dated 5/19/04, section 3.2.12. Hysteresis is defined as the electrical difference with reference to the same mechanical point. The hysteresis was determined to be 0.0001 volts. There are no defined requirements for this test, but Betatronix stated the results are typical for this potentiometer.

The unit was subjected to an output smoothness test as described in ATP-1000, Rev A, dated 5/19/04, section 3.2.13. The results of the test were plotted and all points were within the required limits of 0.1% of the 10V applied input.

The unit was disassembled. The top cover was removed and the three electrical leads were cut. The contacts, wiper, and element were intact and free of debris and corrosion. The element showed some evidence of wear along the contact track. This wear is considered typical for a

potentiometer of this age.

Betatronix had no records of repair for this unit.

G.9 Brake Control Unit:

MFG: Crane
P/N: 142-093 Rev A
S/N: 241
MFD: 06/2003

The BCU contains the circuitry to control, monitor, and test the brake system's components. The BCU receives signals from the pedal position transducers, wheel speed transducers, and brake pressure transducers and commands the brake control valves to modulate required pressure to the wheel brakes. The unit contains fault history in non-volatile memory.

The examination of the BCU was conducted at the Crane facility in Burbank, California on October 27, 2011. The NTSB, FAA, Crane, Embraer, and ExpressJet witnessed the examination.

A visual inspection was performed and the unit appeared in good condition. All connector pins appeared straight and the four tamper resistant repair stickers were intact.

The BCU was connected to test set "Hydro-Aire 299-047" and the unit was powered on. The eeprom memory download option was selected from the test bench computer and all data within both channels (outboard and inboard) were downloaded to a digital file. The data contained 61 outboard pages with the last recorded page being 61. The data contained 120 inboard pages with the last recorded page being 74. A page is created when a fault or failure occurs. The page will contain the fault or failure identification as well as associated system status information. There is no date or time stamp associated with pages or faults/failures. Each page does contain squat switch status, gear handle position, and wheel velocity. The pages from this NVM download were compared to the BCU download that occurred following the incident but prior to aircraft level testing. The NVM comparison revealed that there were no additional inboard faults and one additional outboard fault recorded between the two downloads.

The 5 most recent events for the outboard channel occurred when the aircraft was on the ground, the gear handle was down, and there was 0 wheel velocity. The 6th most recent event occurred when the aircraft was on the ground, the gear handle was up, and there was 0 wheel velocity. This configuration is not typical and could be contributed to a previous maintenance action.

The 3 most recent events for the inboard channel occurred when the aircraft was on the ground, the gear handle was down, and there was 0 wheel velocity. The 4th most recent event occurred when the aircraft was on the ground, the gear handle was up, and there was 0 wheel velocity. This configuration is not typical and could be contributed to a previous maintenance action.

A functional test was then performed on the unit per the manufacture's acceptance test procedure TP142-093, Rev C, dated August 6, 2010. The unit passed all portions of the test. The test

verified that software version 200 was installed in the unit.

Crane had no records of service history related to this part.

Adam Huray
Mechanical Engineer