NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594
July 23, 2014

SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT

CEN11IA234

A. INCIDENT:

Location:	Akron-Canton Regional Airport, Canton, OH USA
Date:	March 18, 2011
Time:	12:08 AM EDT
Aircraft:	Express Jet, Embraer EMB 145 XR, N11187

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:	Trey Ables Express Jet Houston, TX
Member:	Mike Shanks Air Line Pilots Association Humble, TX

C. SUMMARY:

On March 18, 2011, at 12:08 am EDT, an Embraer EMB 145 (N11187) operated by Express Jet as United Express flight 5916, Chicago to Canton, Ohio, departed the left side of runway 23 into the grass on landing. There were 46 persons on board, 3 crew, 42 passengers and 1 infant lap child. There were no apparent injuries reported. The flight crew reported that when the nose wheel touched down on the runway, the airplane immediately veered toward the left side of the runway and then went off the runway into the grass.

D. AIRCRAFT DESCRIPTION:

Operator:	Express Jet
Registration number:	N11187
Aircraft Serial Number:	14500927
Aircraft Manufacturer:	Embraer
Model:	EMB 145 XR
Engine Manufacturer:	Rolls Royce
Model:	AE3007 A1E
Aircraft Year:	2005
Total Time:	11681
Total Cycles:	7430

E. DETAILS OF THE ON-SCENE INVESTIGATION:

The FAA, Atlantic Southeast Airlines, Express Jet, and NTSB arrived on scene after the aircraft was recovered from the runway. The aircraft was moved to a private hanger on the morning of March 19th, 2011, for the duration of the on-scene investigation.

E.1 Aircraft Condition:

Figure 1: Aircraft Condition Following Runway Departure

The leading edges of the aircraft's wings were covered with splattered mud. The right wing exhibited more mud splatter than the left, and the inboard section of the right wing exhibited more mud splatter than the outboard section. The engine intakes and underside of the fuselage also exhibited mud splatter. The wheels and tires were caked in mud. The only visual damage to the aircraft was to the right wing outboard flap fairing. This fairing hit a runway sign during the runway departure and was removed by maintenance during aircraft recovery.

E.2 Runway:

Figure 2: Runway Tire Marks

The runway was a grooved runway. The nose tires, the inboard left main tire, and both right main tires all deposited solid line witness marks on the runway. The outboard left main tire deposited an intermittent witness mark on the runway (see Figure 2). A distinct mark from the right nose wheel tire chine was visible along the track of the turn. The aircraft came to rest in the grass approximately 260 feet left of the runway center line. Significant coordinates were taken using a handheld GPS and are plotted in Figure 3.

Figure 3: GPS Coordinates

1. First Visual Right Main Tire Mark: 40°54'59.36"N, 81°26'26.92"W
2. First Visual Left Main Tire Mark: 40°54'56.60"N, 81°26'30.96"W
3. First Visual Nose Tire Marks: 40°54'54.24"N, 81°26'34.66"W
4. Beginning of Turn To The Left (Coordinates from Right Main Tire Mark): 40°54'52.84"N, 81°26'36.66"W
5. Shortest Distance Between Nose and Left Main Tire Marks (Coordinates from Nose Tire Marks): 40°54'51.81"N, 81°26'37.42"W
6. Runway Exit Marks (Coordinates from Left Main Tire Mark): 40°54'50.63"N, 81°26'38.15"W
7. Shortly After Runway Departure (Coordinates from Left Main Tire Ground Track): 40°54'49.75"N, 81°26'38.41"W
8. Approximately Halfway between Coordinates 7 and 9 (Coordinates from Left Main Tire Ground Track): 40°54'48.84"N, 81°26'38.63"W
9. Final Aircraft Position (Coordinates from end of Nose Wheel Ground Track): 40°54'47.48"N, 81°26'39.07"W

E.3 Aircraft Examination and Testing:

E.3.1 Nose Wheel Steering System Description and Examination:

E.3.1.1 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 4):

- 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 the tiller with the tiller having authority any time it is engaged. 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 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.

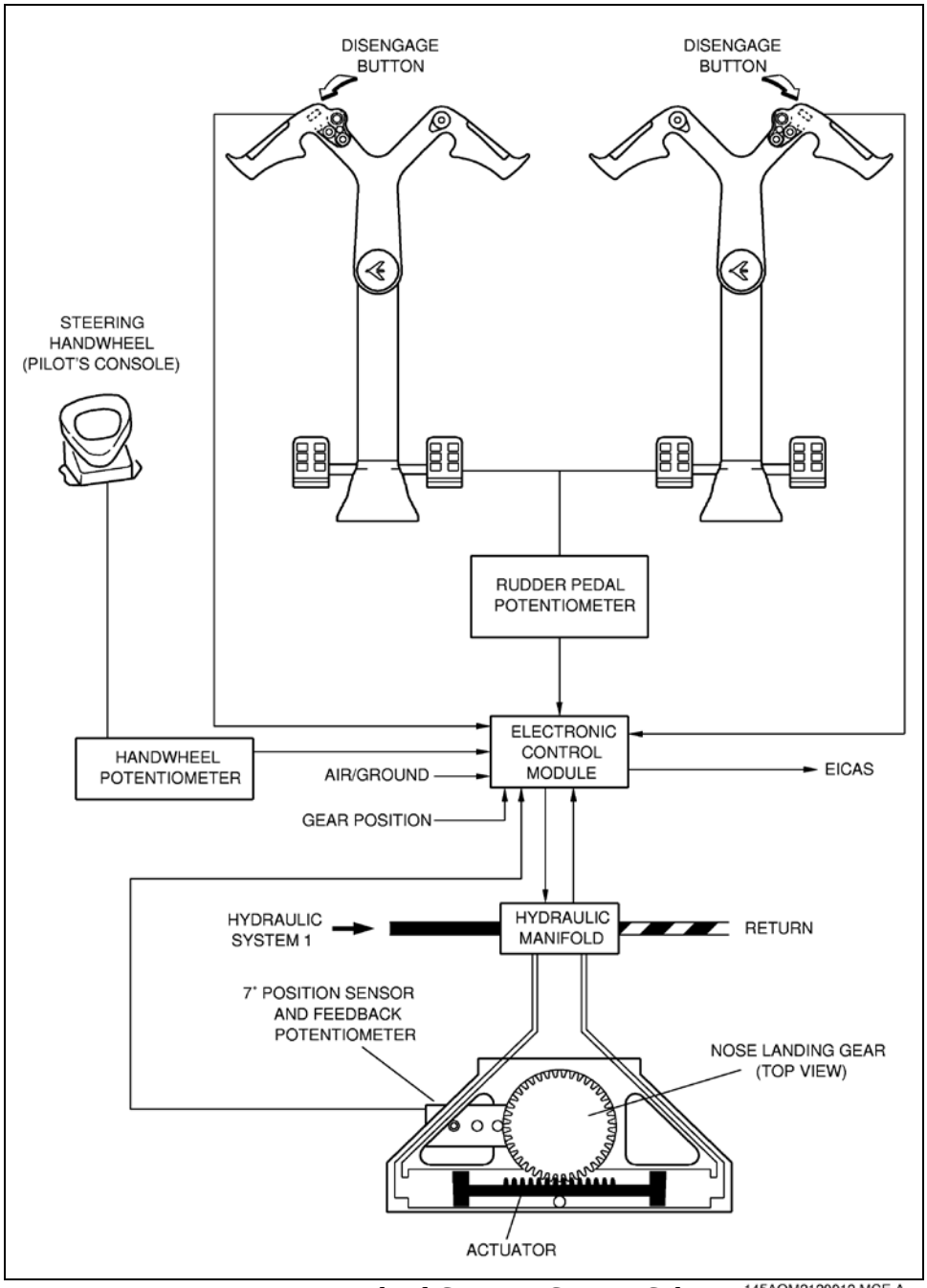

Figure 4: Nose Wheel Steering System Schematic

E.3.1.2 Nose Wheel Steering System Examination:

Figure 5: Nose Landing Gear

The NWS was hydraulically energized and actuated by maintenance personnel during aircraft recovery from the runway. Maintenance personnel noted that the nose wheel centered and functioned properly when the crew energized the system.

The NWS was functionally tested in accordance with Embraer 145 Aircraft Maintenance Manual (AMM), Section 32-50-00 dated Jul 28/06. No faults were found during the test. When the nose wheels were lifted off the ground to facilitate the test, the nose wheels centered automatically as expected. While the nose wheels were off the ground, the rudder pedals and tiller were moved and the nose wheel remained centered.

A visual inspection of the NWS system, nose landing gear assembly, and nose tires was performed (see Figure 5). Inspection revealed that the electrical connector connected to the 7 degree position sensor was ¼ turn loose. Following the functional test the nose wheels were moved back and forth using the tiller and then the rudder pedals while shaking this connection by hand. The system functioned normally during this test.

The external steering disengage switch was found in the engaged position. The switch was functioned during the above testing and operated normally.

The left nose wheel tire was visually inspected. The tire was a Goodyear 19.5X6.75-8. The pressure measured 70 psi[1] and the minimum tread depth measured 1mm. The inboard side of the tire was caked with dirt while the outboard side appeared much cleaner. The outboard edge of the inboard groove appeared rough and had heavy abrasion. There was no sign of flat spotting or rubber reversion identified.

The right nose wheel tire was visually inspected. The tire was a Goodyear 19.5X6.75-8. The pressure measured 70 psi[1] and the minimum tread depth measured 1mm. The tire was visually inspected. The outboard side of the tire was caked with dirt. The inside of the tire was also caked in dirt but to a lesser extent than the outside. The tire appeared to have normal wear except for the outboard edge of the tread and the inboard side of the outboard groove. These edges appeared rough and had heavy abrasion. There was one noticeable rub mark that measured approximately four inches in length. One edge of the mark was located at the second groove from the outboard side, and following along in the direction of tire rotation, ended at the first groove from the outboard side. The tire also contained small cuts, nicks, and gouges. There were no signs of flat spotting or rubber reversion identified.

The strut assembly appeared dirty but in good mechanical condition. No fluid leaks were identified. The chrome extension measured 5 ¼ inch.

E.3.2 Central Maintenance Computer Download:

The Central Maintenance Computer was downloaded by maintenance personnel prior to any testing being performed on the aircraft. The download revealed that the following four faults were recorded (time stamp for fault occurrence in UTC follows each fault): PRECOOLR2 TEMPCTL SYS FAIL (03:23:35), PRECOOLR1 TEMPCTL SYS FAIL (03:23:15), DIG.TEMP.CONTROLLER 2 FAIL (03:09:15 and 03:12:08), DIG.TEMP.CONTROLLER 1 FAIL (03:09:15 and 03:12:03). All four faults contained a date stamp of 17.03.11[2] and a flight number stamp of 5916. 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. The DIG.TEMP.CONTROLLER 1/2 FAIL messages occur when a failure of the respective digital temperature controller is detected by the CMC.

[1] Ambient temperature was not recorded at the time the tire pressure readings were obtained.

[2] Based on FDR data, the aircraft clock was off by one day. The FDR showed that the accident occurred at approximately 00:09 on March 17, 2011.

E.3.3 Brakes:

The Brake Control Unit (BCU) was removed prior to any aircraft testing and set aside for future non-volatile memory (NVM) download (see section F.8). The BCU was identified as P/N 142-093 (Rev A) and S/N 162. For aircraft testing, a new BCU (P/N 142-093 (Rev A) and S/N 373) was installed in the aircraft. The braking system was checked in accordance with Embraer 145 AMM, Section 32-41-00 dated Apr 28/08. No faults were found. All brake wear indicators were of sufficient length per the AMM.

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.

E.3.4 Left Main Gear:

The left main gear assembly appeared dirty but in good physical condition. The outboard tire was a Goodyear H30X9.5-16 (no retread) with a measured tire pressure of 130[1] psi. Per a placard on the MLG door, pressure should be 175 +/- 4 psi. The outboard tire minimum tread depth was 8mm and the tire appeared to be in good condition with no signs of flat spotting or rubber reversion. The inboard tire was a Goodyear H30X9.5-16 (retread 1) with a measured tire pressure of 170 psi[1]. The minimum tread depth was 2 mm. Multiple small nicks were noted on this tire and the inboard edge of the outboard groove was rough and showed signs of abrasion. No signs of flat spotting or rubber reversion were identified.

E.3.5 Right Main Gear:

The right main gear assembly appeared dirty but in good physical condition. The inboard tire was a Goodyear H30X9.5-16 (no retread) with a measured tire pressure of 165 psi[1]. Per a placard on the MLG door, pressure should be 175 +/- 4 psi. The inboard tire minimum tread depth was 3mm. Multiple small nicks were noted on this tire and the edges of the inboard tread were smooth while the inboard edge of the outboard tread was rough and had heavy abrasion. No signs of flat spotting or rubber reversion were identified on this tire. The outboard tire was a Goodyear H30X9.5-16 (retread 1) with a measured tire pressure of 166 psi[1]. The minimum tread depth was 3 mm. Small nicks were noted on this tire and the groove edges appeared smooth. No signs of flat spotting or rubber reversion were identified.

E.3.6 Spoilers:

The spoilers were deployed and retracted during testing and functioned correctly.

[1] Ambient temperature was not recorded at the time the tire pressure readings were obtained.

E.3.7 Rudder:

The rudder was operated left and right using the rudder pedals. The rudder responded by moving in the correct direction in response to pedal movement. The magnitude of the movement also appeared normal but no rudder deflection measurements were obtained.

E.3.8 Hydraulic Systems:

The #1 and #2 hydraulic filter manifold assemblies were visually inspected. The # 1 hydraulic system differential pressure indicator located above the return filter assembly was found extended. The #1 hydraulic system return, case drain, and pressure filters from the manifold assembly were removed for analysis of the hydraulic fluid. During removal the return filter was visually inspected. The filter did not visually appear to be contaminated and a reason for the pressure indicator extension could not be identified. Parker agreed to perform a patch test on the fluid from the filters and bowls. See the Parker Materials and Processes Lab Report Number 233269 attached to the public docket for this accident for the lab results labeled “Pressure Filter, Pressure Fluid sample, Return Filter, Return Fluid sample, Case Drain Filter, and Case Drain Fluid sample”.

E.3.9 Engines/Thrust Reversers:

The engine data plate was not viewed. Airline records indicated that the engines were Rolls Royce AE3007 A1E engines. The left engine was S/N CAE312763 with a total time of 15639.27 hours and 9084 total cycles. The right engine was S/N CAE312842 with a total time of 12578.83 hours and 7817 total cycles.

The thrust reversers were deployed by maintenance personnel. The reverser doors on both engines opened and closed normally and appeared to extend to the fully open position. The lower door on both engines contained evidence of mud splatter on the lower inside surface.

E.3.10 Flight Deck:

Many of the flight deck control positions were manipulated during aircraft recovery which was prior to cockpit documentation. The auxiliary power unit and hydraulics were turned on, the nose wheel steering was energized and actuated, and flaps were moved to 0 degrees before investigators arrived. When the cockpit was documented, the landing gear handle was in the down position, the thrust levers were at idle, and the gust lock was engaged.

The aircraft recovery crew reported that only the FDR and CVR circuit breakers were open when they first entered the flight deck. They subsequently opened the FLAP 1, FLAP 2, and LDG GEAR STEER circuit breakers to facilitate aircraft recovery.

E.4 Maintenance Records:

A review of aircraft maintenance log book pages, work packages, and routine/non-routine M-602 work cards was performed on-scene. The following notable discrepancies were found for aircraft N11187 for dates ranging from 2/5/11 to 3/17/11:

1. 3/16/11 log page #2755399: #1 tire worn to limits. Removed and replaced #1 main tire.
2. 2/27/11 work package #20110200374: maintenance performed A-5 check.
3. 2/26/11 M-602 work card #0558616: #2 brake locks up when hydraulics are applied. Removed and replaced #2 brake.
4. 2/21/11 log page #2774779: removed and replaced Captain's disconnect steering switch.
5. 2/18/11 log page #2753870: Captain's steering disconnect switch deferred in accordance with MEL 32-50-02.
6. 2/10/11 M-602 work card #0559155: loud bang on takeoff. Removed and replaced landing gear control lever and brake control unit.
7. 2/9/11 M-602 work card #0559906: loud bang on takeoff. Removed and replaced NLG proximity switch and harness.
8. 2/8/11-2/11/11 log pages #2753851 thru #2753858: all relate to loud bang from NLG on retraction. The following parts were replaced during this time: NLG solenoid valve, NLG actuator, NLG down lock proximity switch and harness, landing gear electronic unit, NLG uplock actuator, landing gear handle, and brake control unit. Multiple failed test flights occurred during this period.

The only item on the minimum equipment list for the incident flight was for a missing recline button on a passenger seat in accordance with MEL 25-21-05-1.

F. COMPONENT EXAMINATIONS:

The NTSB, FAA, Embraer, and Express Jet witnessed all examinations with the exception of the load potentiometer. The load potentiometer examination was witnessed by the NTSB only.

F.1 Nose Wheel Steering Electronic Control Module:

MFG: Parker
P/N: 308560-1019M
S/N: 1498
DMF: 2Q05

The 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 April 18-19, 2011. 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. 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 sections of the test.

Parker had no records of repair for this unit.

F.2 Nose Wheel Steering Manifold Assembly:

MFG: Parker
P/N: 308570-1007
Rev: A1
S/N: 0464B
MFG Date: 1Q01

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 April 18-19, 2011. An external visual inspection was performed and the unit appeared in good physical condition. The hydraulic fittings were replaced with fittings to match the test bench configuration. The unit was then flushed with clean hydraulic fluid and the flushed fluid was retained for particulate testing**.** See the Parker Materials and Processes Lab Report Number 233269 attached to the public docket for this accident for the lab results labeled “Skydrol Fluid Sample”.

A functional test was performed on the unit per the Component Maintenance Manual 32-50-15, Rev 8, dated November 11, 2010 (Tests 3.C thru 3.M). Tests 3.C “Dielectric Strength”, 3.D “Insulation Resistance”, and 3.F “Proof Pressure” were not performed. The unit passed all performed tests with the exception of Test 3.M “Inlet Check Valve & Low Pressure External Leakage”. The inlet check valve had a leakage rate of 2 drops per minute. The maximum allowable leakage rate per the test requirements was 1 drop per minute.

The inlet check valve was removed and visually examined. The valve appeared in good condition. The seals appeared in good condition and the check valve seat and poppet actuated and returned to the closed position correctly. The valve was flushed by pouring isopropyl through the orifice. Two small particles were visually identified in the flushed fluid. Parker retained the debris for identification at their lab. See the Parker Materials and Processes Lab Report Number 233269 attached to the public docket for this accident for the lab results labeled “Two Particles in Alcohol”.

The inlet filter was removed and visually inspected for debris. No debris was identified on the filter. The filter was flushed with isopropyl and no debris was identified in the flushed fluid. The electrohydraulic servo valve was removed and sealed for later testing at Woodward HRT.

Service history was provided by Parker. The unit was sent to Parker by Express Jet on May 19, 2006 for incorporation of Embraer Service Bulletin 145-32-0108 dated Oct 21, 2005. Parker had no other records of repair or other actions for this unit. Express Jet records show that the manifold assembly was installed on the event aircraft on 6/26/2006.

F.3 Electrohydraulic Servo Valve:

MFG: HR Textron (Woodward HRT)
P/N: 22253282-103
S/N: 781A
MFG Date: 1Q06

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.

The EHSV was removed from the manifold assembly following the NTSB examination of the manifold assembly at Parker on April 18-19, 2011 (see section F.2). The EHSV was examined at the Woodward HRT facility in Santa Clarita, CA on April 20, 2011. 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 condition. A blocker plate was installed over the hydraulic ports following the removal of the EHSV from the manifold assembly. This plate was removed prior to testing and examining the unit.

A functional test was performed on the EHSV per the manufacturer's Acceptance Test Procedure HR72700412, Rev D, dated June 18, 2009. The unit passed all sections of the acceptance test. The flow and leakage plot created in step 4.8 showed a small blip (.125 gpm) typically attributed to wear of the feedback wire pin ball. The flow gain remained within flow envelope 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. 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. The coil encapsulation demonstrated material separation on the outside corner of the face opposite the wire connections. The outside surface of the encapsulation material also appeared to have traces of an unidentified residual fluid.

D. Three slivers of the coil encapsulation material were found on the bottom of the frame assembly along the outside diameter. The slivers measured .100 x .011 inches, .260 x .02 inches, and .180 x .025 inches. The encapsulated material is non-magnetic.

E. 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.

F. 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 removed and inspected under a 25X magnification. The seals were in good condition with no anomalies found.

G. The armature/flapper assembly was removed. The feedback wire ball on the end of the flapper assembly demonstrated some flat spotting and wear in the area where it contacts the spool. No other anomalies were identified.

H. The end chamber plugs were removed and inspected. The seals appeared in good condition. The spool was removed and inspected. Some light polishing marks were found in the area where the feedback wire ball contacts the spool. No other anomalies were identified.

Woodward HRT service records revealed that the EHSV was first assembled in November of 2001 and was overhauled in March of 2006.

F.4 Feedback Unit Potentiometer Assembly:

MFG: Liebherr
P/N: 1170A3500-01
S/N: 00345P
MFG Date: 08.99

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 July 12-13, 2011. The unit was unpackaged and visually inspected. The unit was dirty and there was a scratch on the front face of the upper 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 as required per Embraer 145 Aircraft Maintenance Manual, Section 32-50-07 (700-801-A) dated Apr 28/10.

The protective shipping cover that was placed over the gear cavity following removal from the aircraft was removed. The unit contained a substantial amount of grease. 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 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 potentiometer (P/N: 9070B0022-01, S/N: 3347) was manufactured by Betatronix and met the requirements of the most recent revision. The electrical wires were securely attached to both the potentiometer and the connector plug. 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 modified to 1170A3500-01 on 3/5/2003 per Service Bulletin 145-32-0081, repaired on 12/4/2003 for a defective potentiometer, and modified again on 11/1/2004 per SB 145-32-0100. Liebherr had no other records of repair or other actions for this unit.

F.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 the nose wheel steering system that is used 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 was examined at the Liebherr facility in Saline, MI on July 12-13, 2011. The feedback unit sensor demonstrated proper operation during the on-scene testing of the NWS system and therefore a functional test was not performed at Liebherr. A visual inspection was performed to make sure that the unit was complete and not otherwise damaged. The exterior of the unit was dirty but appeared in good physical condition. All locations that require sealant during build at the manufacturer contained sealant. The safety wires on the two pressure relief valve screws were intact. The proximity sensor remained attached and safety wired to the unit.

The proximity sensor was removed from the assembly. The proximity sensor (P/N 80-057-01, S/N 10575, MFG: ELDEC) was tightly installed and no anomalies were noted with the installation. This proximity sensor did not undergo further testing as it demonstrated proper operation during on-scene testing of the NWS system. The protective shipping cover that was placed over the gear cavity following removal from the aircraft was removed. The unit contained

a substantial amount of grease. Per the Embraer 145 Aircraft Maintenance Manual, Section 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.

There was no service history for the Feedback Unit Sensor as it is not a serialized component.

F.6 Tiller Assembly:

MFG: Embraer
P/N: 123-02328-607
S/N: 145248
MFG Date: 14 MAR 00

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 July 26, 2011. The exterior of the unit appeared worn and there was a groove dug into the housing where the base of the tiller handle made contact when it was depressed and rotated. No other anomalies were noted.

The unit was subjected to the testing and fault isolation procedures as described in the Component Maintenance Manual 32-50-00, Task 32-50-00-99F-005-A, dated Jan 09/08. The housing plate covering the potentiometer and microswitch was removed to facilitate Subtask 32-50-00-750-001-A, Step C(2) (Harness Continuity Test). The inside of the unit contained significant dust build up. The unit passed all tests.

During completion of Subtask 32-50-00-750-001-A, Step C(2)(e), it was noticed that there was an inconsistency in the resistance readings between pins E and F at the point of switch disengagement as the handle was slowly released from the depressed position. When the handle was held at the exact point of switch disengagement the resistance would bounce from 0 to 12 kOhms, but would average readings in the 0.4-0.6 kOhm range. This inconsistency could not be duplicated at the point of switch engagement as the tiller was depressed. Pins E and F are not used on the EMB 145 XR aircraft.

In addition to the CMM testing, an analog multimeter was connected to pins AB and pins BC and the tiller handle was depressed and rotated through its full travel. The resistance change was smooth and did not drop out at any point during the test. The approximate resistance readings were as follows:

Pins AB:

Center: 2.8 kOhms
Full Left Travel: 1.5 kOhms
Full Right Travel: 4.2 kOhms

Pins BC:

Center: 2.8 kOhms
Full Left Travel: 4.2 kOhms
Full Right Travel: 1.5 kOhms

A force gauge was used to determine the minimum force required to engage the steering select reset switch. The switch would engage with approximately 2 lbs force applied to the tiller handle.

The potentiometer installed in the tiller was manufactured by Betatronix and was P/N 7029, S/N 2141.

Embraer had no records of repair or other actions for this unit.

F.7 Load Potentiometer:

MFG: BI Technologies Corporation
P/N: 8146R5KL.25SL
S/N: Not Serialized
MFG Date: 0418 (18th week of 2004)

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 August 3, 2011. 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.

The unit appeared free of external damage and odor and the solder joints were bright and clean. Rotation of the potentiometer shaft by hand through its full 10-turn range resulted in no binding or unusual friction. The endplay appeared appropriate, and the shaft threads were free of damage. The unit was examined in accordance with Standard Specifications Series 8140, Revision 10, dated July 18, 2006. The following tests required by the specifications were conducted:

Resistance/Tolerance Test - PASS

The resistance of the potentiometer coil was measured utilizing a digital ohm-meter. The resistance of the coil indicated 4.892 kOhm. The acceptable range was 5 kOhm +/- 10%.

Independent Linearity – PASS

Linearity was measured utilizing the automated potentiometer tester, HED I675. The results indicated a linearity of 0.0564%, with an acceptable range of 0.25%.

Start/Run Torque - PASS

The breakout torque required to turn the shaft was measured utilizing a torque gauge. The torque required was 0.4 oz-in. The acceptable tolerance was any value below 0.8 oz-in.

Shaft End Play - PASS

The longitudinal shaft endplay dimension was measured utilizing a height gauge. The value measured was 0.0039 inches. The acceptable tolerance was any value less than 0.01 inches.

Output Smoothness – FAIL

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 smoothness in the clockwise direction was measured utilizing the smoothness bench test stand and no anomalies were noted. The test was performed in the counterclockwise direction and multiple spikes exceeding the tolerance of 0.05% in excess of the input voltage were observed. Based on the failure of the smoothness test, the resistance between the common tag and the coil were measured utilizing a digital ohm-meter. Rotation of the potentiometer shaft by hand resulted in multiple “open” resistance points.

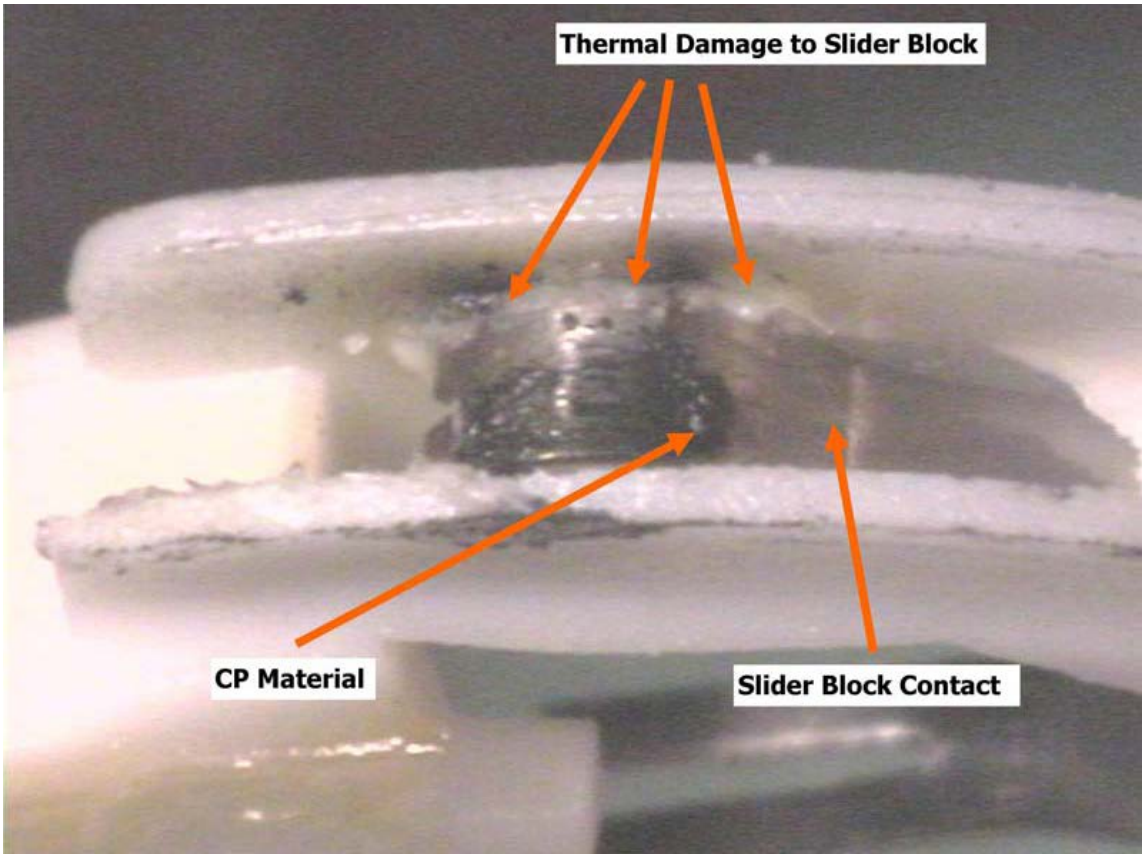

Figure 6: Slider Block and Contact

The rear cover was removed and thermal damage was noted to the plastic slider block area adjacent to the coil contact (see Figure 6). The coil slider pin appeared correctly installed within the plastic slider block. The slider plate and contact were removed and examined utilizing a microscope. Fragments of black material, consistent with thermally damaged conductive plastic were noted to both the contact surface and the adjacent slider block sleeve. Yellowing and thermal damage was also noted to the slider block guide plates.

The rear case slip ring and associate slider block and contacts were removed and appeared undamaged. Examination of the coil revealed an indentation in the conductive plastic in an area approximately 5mm from the counterclockwise tap point. The damage to the conductive plastic appeared consistent with thermal exposure.

F.8 Brake Control Unit:

MFG: Crane
P/N: 142-093 Rev A
S/N: 162
MFD: 11-02

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 April 21, 2011. A visual external 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) was downloaded. The data contained four pages for the outboard channel and 5 pages for the inboard channel. 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.

The most recent page for the outboard channel was page 4 and contained a Left LVDT Compare Failure. This page also contained a status message that the antiskid was powered while the solenoid shutoff valve was energized. This failure occurred while the aircraft was on the ground when the left outboard wheel velocity was 92 ft/sec and the right outboard wheel velocity was 89 ft/sec. Pages 3 through 1 contained failures that occurred while the aircraft was on the ground and when wheel speed was 0 ft/sec. Page three failures were labeled Right Pressure Pulse Test Failure and Right Pressure Pulse Failure; page 2 failures/faults were labeled Right Pressure Pulse Test Failure, Right Pressure Pulse Failure, Cycle Timing Failure, and Brake Control Computer Fault; and page 1 failures were labeled Right Pressure Pulse Test Failure and Right Pressure Pulse Failure.

The most recent page for the inboard channel was page 5 and contained a Left LVDT Compare Failure. This page also contained a status message that the antiskid was powered while the solenoid shutoff valve was energized. This failure occurred while the aircraft was on the ground when the left inboard wheel velocity was 92 ft/sec and the right inboard wheel velocity was 89 ft/sec. Page 4 was recorded when the aircraft was in air and wheel speed was 0 ft/sec. The failures were labeled Right Pressure Pulse Test Failure and Right Pressure Pulse Failure. Pages 3 through 1 contained failures that occurred while the aircraft was on the ground and when wheel speed was 0 ft/sec. These pages contained the failures that were labeled Right Pressure Pulse Test Failure and Right Pressure Pulse Failure.

The Left LVDT Compare Failure occurs when both the Captain's and First Officer's left brake pedals are depressed 50% at the same time for 0.5 seconds. This condition can be met in normal operation. The Pressure Pulse Test Failure and Pressure Pulse Failure typically occur when a failure is detected during the automatic brake system check during gear extension. The Cycle Timing Failure occurs when the software cycle time is out of limits. The Brake Control Computer Fault will typically occur when the Cycle Timing Failure occurs.

A functional test was 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 service history showed that this unit was repaired on 25-Feb-2003 due to spoilers staying up while the aircraft was on the ground. The unit was also returned to their facility on 13-May-2010 due to a brake degrade message displayed on EICAS. Crane did not find a fault with the unit; however, some components were upgraded at that time for product improvement.

Adam Huray
Mechanical Engineer