Aviation Investigation Final Report

Location:	Milwaukee, Wisconsin	**Incident Number:**	CEN11IA379
Date & Time:	June 6, 2011, 21:32 Local	**Registration:**	N866AS
Aircraft:	BOMBARDIER INC CL-600-2B19	**Aircraft Damage:**	Minor
Defining Event:	Landing gear not configured	**Injuries:**	44 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

During final approach, the transport-category airplane's right main landing gear (MLG) did not extend when the landing gear selector was placed in the "down" position. Shortly after, the flight crew noted a "gear disagree" warning message displayed on the engine indication and crew alerting system showing that the nose gear and the left MLG were down and locked but that the right MLG was in transit. The flight crew followed the quick reference handbook directions to troubleshoot the landing gear issue without success. The flight crewmembers then tried to manually extend the landing gear by pulling the landing gear alternate release handle multiple times; however, the right MLG failed to extend, and they subsequently landed the airplane with the right MLG retracted. During postincident activities, the airplane was lifted and an examination revealed that the right MLG remained in its full-up position within the wheel well.

The airplane's right MLG uplock pin exhibited signs of slight wear, consistent with in-service usage, and no abnormalities were found with the right MLG uplock assembly. Normal wear patterns were observed on the uplock latch with no discernable depth at the pin contact locations. The uplock pin's slight wear indicates that it might not have always rotated freely when it was in contact with the upper and lower surfaces of the uplock assembly latch as it should have per the system's design. Further, the worn pin could have increased the friction forces between the pin and the latch.

Functional testing of the incident airplane's 3A and 3B hydraulic system pumps showed that their output pressures were lower than specified. Analysis of hydraulic fluid samples taken from the No. 3 hydraulic system, including the right sidestay actuator and selected landing gear components, revealed that some of the fluid samples contained particles and fibers that exceeded the in-service size limits specified in the airplane's maintenance manual, and these contaminants likely restricted the hydraulic flow within the hydraulic assembly.

It is unlikely that any of these factors (the slightly worn uplock pin, the operation of the hydraulic pumps below their specified operating pressures, or the contamination within the landing gear hydraulic

system) would have individually prevented the right MLG from extending; however, it is likely that the combination of these factors prevented the right MLG from extending. In addition, the overall landing gear system design, including modifications made in accordance with an airworthiness directive, did not preclude the consequence that the intermittent combination of these factors prevented the right MLG from extending normally.

Postincident examination of the cockpit revealed that the landing gear alternate release handle remained extended about 7 inches. Pulling up on the handle resulted in it moving about 3 additional inches to its fully extended position. The additional handle displacement resulted in the right MLG extending out of its wheel well. When the handle was released from its fully extended position, the handle automatically began to slowly retract, which caused the right MLG to stop extending. The handle had to be pulled and manually held in its fully extended position for the right MLG to extend to its down-and-locked position.

During postincident functional testing of the landing gear alternate release handle assembly, the handle's locking mechanism failed to maintain the handle in its fully extended position when a specified retract load was applied to the assembly. Disassembly of the handle assembly did not reveal any mechanical discrepancies. However, the assembly's inner housing and outer slider were found coated with an oily material consistent with lubricant; the origin of the oily material could not be determined. The alternate release handle assembly design specifications do not call for the application of lubricant on the inner housing or the outer slider; therefore, it is likely that the lubricant prevented the handle from remaining in its fully extended position.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: The failure of the right main landing gear (MLG) to extend normally, which resulted from the combination of a slightly worn uplock pin, the operation of the hydraulic pumps below their specified operating pressures, and contamination within the landing gear hydraulic system. Also causal to the accident was the failure of the right MLG to extend manually using the alternate gear selector handle due to the improper use of lubricant within the alternate release handle assembly, which prevented the handle from remaining in its fully extended position.

Findings

Aircraft	Gear extension and retract sys - Malfunction
Aircraft	Gear extension and retract sys - Fatigue/wear/corrosion
Aircraft	Gear extension and retract sys - Design
Aircraft	Hydraulic fluid - Fluid condition
Aircraft	(general) - Incorrect use/operation
Aircraft	Pump, main - Damaged/degraded
Aircraft	Gear extension and retract sys - Incorrect service/maintenance

Factual Information

History of Flight

Approach	Sys/Comp malf/fail (non-power)
Landing	Landing gear not configured (Defining event)

On June 6, 2011, about 2132 central daylight time, N866AS, a Bombardier CL-600-2B19, operated as Skywest Airlines flight 4443, landed with the right main landing gear retracted on runway 19R at the General Mitchell International Airport (MKE), Milwaukee, Wisconsin. The 2 pilots, 1 flight attendant, and 41 passengers reported no injuries. The airplane sustained minor damage. The scheduled domestic passenger flight was conducted under 14 Code of Federal Regulations Part 121. Visual meteorological conditions prevailed and an activated instrument flight rules flight plan was on file. The flight departed Cincinnati/Northern Kentucky International Airport (CVG), near Covington, Kentucky, about 1951, and was destined for MKE. All airplane occupants evacuated the airplane via the main cabin door.

During an interview with the operator's safety staff personnel, the flight crew reported that visual meteorological conditions and calm wind prevailed during the approach. The airplane was on final approach when the gear did not come down, the flight crew informed the tower they needed to go around and flew east over Lake Michigan where they proceeded to complete the quick reference handbook (QRH). They indicated that the gear operated normally on all previous flights.

When the landing gear selector lever was first placed in the down position, the flight crew first noticed that the right main gear did not indicate down and locked. They then received the triple chime warning, gear disagree, and proceeded to go around. Upon running the QRH for "Gear Down Disagree" they would receive different indications from right main to both main landing gear unsafe, and they got the nose gear door open warning and oral messages. They also got a No. 3 hydraulic system high temperature caution message. The flight crew stated that about 28 seconds elapsed between the time that the landing gear selector lever was positioned in the down position to the "Gear Disagree" message posting.

The flight crew stated that the engine indication and crew alerting system (EICAS) primary page landing gear indications with the landing gear selector lever in the up position, initially, was that all lights were out. When the landing gear selector lever was selected down the first time, the flight crew received nose green, left main green and right main unsafe indications.

During the go around, the landing gear selector lever was put in the up position and they received the gear up normal indication. The first officer remembered that the right main would indicate a red unsafe indication very quickly, while the other landing gear would show transit, and then green safe indications. During the third or fourth landing gear selector lever selections, both main landing gears showed unsafe indications, which also happened very quickly.

The flight crew stated that the QRH procedures were followed during the attempted manual landing gear extension. They turned the No. 3 hydraulic system off as directed by the QRH and the system pressure

subsequently indicated zero.

The flight crew pulled the landing gear alternate release T-handle as the QRH directed. The T-handle had slipped back a few inches from the fully extended position, which they had achieved during the manual extension.

The EICAS page exhibited red hash marks for the right main landing gear the entire time on the approaches. During one approach, the indications showed both main landing gears were unsafe and a low approach was performed to confirm which of gear were extended. The tower reported that the nose and left main landing gear were down. While returning for the last approach and landing, the left main landing gear subsequently indicated green safe and the right main landing gear still indicated unsafe.

During the alternate landing gear extension, the first officer initiated the QRH. He reported his seat height typically is in a very low seat position and he did not reposition its height. He tilted the seat-back forward. He then moved the seat to the aft position. He pulled the T-handle from his seat and felt like he had complete ability to apply all his strength to move the T-handle. The first time he pulled the T-handle it was an abrupt pull and he felt the T-handle reach the stop. The T-handle then sank back a few inches as if a spring was pulling it back down. The gear did not extend and he pulled the T-handle multiple times holding it at the stop for 5 to 10 seconds each time. The only sound that was heard was oil bypassing under their feet. The first officer, who was right-handed, was using his right hand but at one point used both hands to pull the T-handle. He told the captain that the T-handle would not stay up and the captain decided that he would try manually extending the T-handle himself.

The captain's seat was low and all the way to the aft position. This is the position he always sits when flying. He reached over with both hands, pulled the T-handle and held it there for ten seconds, and then re-pulled the handle a second time even harder. He could feel the T-handle hit a stop at full extension. He then took back the controls from the first officer. Neither crewmember got out of their seats to pull the T-handle.

The flight crew estimated that the elapsed time between the first landing gear selector lever down command and the airplane's touchdown was about 35 to 45 minutes.

The airplane sustained minor damage to its right wing tip, right flap assemblies, and right flap pylon assemblies. The right main landing gear door was up, and the right main gear was in its wheel well.

Pilot Information

Certificate:	Airline transport; Flight instructor	**Age:**	37
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	July 2, 2010
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	May 19, 2011
Flight Time:	(Estimated) 8618 hours (Total, all aircraft), 438 hours (Total, this make and model)		

Co-pilot Information

Certificate:	Commercial; Flight instructor	**Age:**	34
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane single-engine	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	March 13, 2011
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	October 11, 2010
Flight Time:	(Estimated) 5156 hours (Total, all aircraft), 2997 hours (Total, this make and model)		

The captain held an airline transport certificate with a multiengine land airplane rating and commercial privileges for single engine land airplanes. He held a first class medical certificate with no limitations. The operator reported that he had accumulated about 8,618 hours of total flight time, which included about 438 hours in the Bombardier CL-600-2B19. The captain had flown about 187 hours in the last 90 days, 69 hours in the last 30 days, and 6 hours in the last 24 hours.

The first officer held a commercial certificate with single-engine land, multiengine land, and instrument airplane ratings. He held a first class medical certificate without limitations. The operator reported that he had accumulated about 5,156 hours of total flight time, including about 2,997 hours in the Bombardier CL-600-2B19. The first officer had flown about 197 hours in the last 90 days, 44 hours in the last 30 days, and 6 hours in the last 24 hours.

Aircraft and Owner/Operator Information

Aircraft Make:	BOMBARDIER INC	**Registration:**	N866AS
Model/Series:	CL-600-2B19	**Aircraft Category:**	Airplane
Year of Manufacture:	2001	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	7517
Landing Gear Type:	Retractable - Tricycle	**Seats:**	55
Date/Type of Last Inspection:	June 1, 2011 Continuous airworthiness	**Certified Max Gross Wt.:**	53000 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:	24969 Hrs at time of accident	**Engine Manufacturer:**	GE
ELT:	Installed, not activated	**Engine Model/Series:**	CF34-3B1
Registered Owner:	ATLANTIC SOUTHEAST AIRLINES INC	**Rated Power:**	9140 Lbs thrust
Operator:	SKYWEST AIRLINES INC	**Operating Certificate(s) Held:**	Flag carrier (121)
Operator Does Business As:		**Operator Designator Code:**	SWIA

The airplane was a Bombardier Canadair model CL-600-2B19, twin engine, transport category Regional Jet (CRJ), with serial number 7517. It was manufactured on June 15, 2001. The CRJ had a maximum takeoff weight of 53,000 pounds. The engines were General Electric model CF-34-3B1 engines that delivered 8,900 pounds of thrust each. The airplane was on a continuous airworthiness maintenance program. The last service check was conducted on June 1, 2011. At the time of the incident, the airplane had 24,969.4 flight hours and 20,132 flight cycles. The airplane was configured with 53 seats, of which 50 were passenger seats located in the main cabin.

The airplane was equipped with a retractable tricycle landing gear system that comprised two main landing gear (MLG) assemblies mounted on the inboard part of each wing, and a nose gear assembly mounted directly below the flight compartment. Both MLG retract inward into recesses in the wing and center fuselage, and the nose landing gear (NLG) retracts forward. The landing gear system, operated by a selector lever, is electrically controlled by a proximity sensor electronic unit (PSEU) and hydraulically operated by the no. 3 hydraulic system. The MLG system comprises a selector valve, run-around and bypass valve, a left and right MLG sidestay actuator and uplock mechanism. The NLG system comprises a selector valve, extension/retraction actuator, uplock assembly, downlock, nose selector valve, and priority valve, bypass valves, restrictors, and check valves.

Two of the three NLG doors are operated hydraulically and are sequenced to operate independently of the NLG position, while the other (single door) is mechanically linked to the nose gear position. During extension, the forward doors open before the NLG is released from the uplock. The nose gear assembly will then extend, simultaneously opening the rear door. Upon reaching full extension (when the NLG is down and locked), the forward doors close and remain in that configuration until a retraction command is selected.

The cockpit is equipped with a landing gear control panel, which contains a landing gear selector lever.

When the selector lever is manipulated, an electrical command is sent to the PSEU to extend or retract the landing gear. Both MLG are extended in the outboard direction by their respective MLG sidestay actuators and are hydro/mechanically locked in place for landing. Each gear is retracted by the MLG side stay actuator in the inboard direction and locked in the MLG wheel wells during flight by their respective uplock mechanism.

During normal landing gear extension, when the landing gear selector lever is placed in the gear down position, the selector lever module sends an electrical extension command to the proximity sensor system and provides electrical signals to command the MLG and the NLG selector valves to their gear down position. When the MLG selector valve transitions to its gear down position, the valve is designed to allow no. 3 hydraulic system fluid, from the priority valve, to be ported, via the run-around and bypass valve, simultaneously to the uplock assembly and the extend side of the sidestay actuator for each MLG. The hydraulic pressure causes each uplock assembly to unlatch and release the MLG assembly. When unlatched, an uplock sensor (on the uplock mechanism) provides an input to the PSEU, which in turn signals the data concentrator units (DCUs) to generate an amber 'IN TRANSIT' gear indication on the EICAS display for each of the gear. When hydraulic pressure is supplied to the extend side of the gear actuators (sidestay), the actuator extends causing each MLG to extend to its full down and locked position; the extension rate is controlled by a restrictor in the actuator up line.

The landing gear alternate release system provides the flight crew with another means to extend the landing gear in the event that an electrical or hydraulic failure within the landing gear system prevents the landing gear from being extended normally. The alternate extension system is controlled by the vertical movement of a T-shaped alternate release handle. To extend the landing gear manually, a flight crew member must pull up on the alternate release handle. Movement of the T-handle is transmitted by a cable circuit to the NLG uplock release mechanism and to the MLG release mechanism.

For the NLG system, the mechanisms activates the NLG door bypass valve and the NLG bypass valve and releases the NLG uplock and nose door lock. For the MLG system, rotation of the interconnect lever results in three actions: 1) the displacement is transmitted by two cables to the release levers on the left and the right uplock mechanism to unlock the uplock mechanism permitting the gear to extend by gravity and 2) re-positions the runaround and bypass valve into bypass mode and 3) positions the assist valve to pressurize the assist actuator.

In bypass mode, the runaround and bypass valve connects the extend pressure from the selector valve and both extend and retract pressure from the sidestay actuators and the extend pressure of the uplock assembly to an independent return line. The extend pressure of the uplock assembly is sent to the return line via the selector valve and check valves. The removal of all hydraulic pressure from the uplock mechanisms and sidestay actuators is designed to allow the gear to free-fall regardless of the position of the MLG selector valve. The activation of the downlock assist selector valve results in the valve porting no. 2 hydraulic system pressure to the MLG downlock assist actuators to assure down locking of the main gears after free-falling.

The landing gear indication system provides the status of each landing gear position on the landing gear display area on the EICAS primary page. The primary page contains three rectangles that will change color depending on the position of the landing gear. When a gear assembly is "up and locked", its respective rectangle will be colored white and display "UP". When the indication system detects that a

gear assembly is not "up and locked" or "down and locked", its respective rectangle will transition to amber and when a gear assembly is "down and locked", its respective rectangle will be colored green and display "DN". If any landing gear remains in transit for longer than 28 seconds, the amber intransit indication of that affected gear will change to red (gear unsafe). Simultaneously a red 'GEAR DISAGREE' message will be displayed, accompanied by a 'GEAR DISAGREE' aural warning message. When any landing gear assembly remains in its up and locked position for longer than 6 seconds after the landing gear has been commanded down, this will result in a landing gear disagree aural warning being annunciated along with an EICAS red gear disagree warning message. This warning will also be annunciated when any landing gear assembly remains in its downlock position for longer than six seconds when the landing gear has been commanded up.

If the landing gear selector lever remains "UP" during the manual extension, the EICAS immediately displays a "GEAR DISAGREE" message and the master warning illuminates and the corresponding cancelable voice message sounds.

The landing gear indication and warning system comprises a PSEU and multiple proximity sensors and switches located within the control system. The PSEU logic analyzes inputs from these various proximity sensors and switches to determine the status of the landing gear and doors. Its output is displayed on the EICAS system (primary page) and master caution/warning panel on the glare shield.

The No. 3 hydraulic system is an independent hydraulic system that supplies the landing gear system, braking system, and certain flight control systems with hydraulic pressure. This hydraulic system comprises two alternating current motor pumps, identified as ACMP 3A and ACMP 3B, to generate hydraulic power (3000 psi), a pressure manifold, and a return manifold. Pressure generation comes primarily from ACMP 3A. However, because the system No. 3 accumulator had been removed from the airplane in accordance with the requirements of FAA Airworthiness Directive 2010-22-012, ACMP 3B is also ON at all times during the flight.

According to the airplane's component maintenance manual, the published wear limits for the uplock assembly's latch was:

1. The maximum permitted wear limit at overhaul is 0.003 in. (0,07 mm) on either or both upper and lower wear surfaces. Between overhauls, the maximum permitted wear limit can be a further 0.003 in. (0,07 mm), for a total of maximum 0.006 in. (0,15 mm) per surface.
2. If the wear on either upper or lower surface is greater than 0.006 in. (0,15 mm), replace the latch.

The hydraulic pumps are replaced on condition of failure.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Night
Observation Facility, Elevation:	KMKE,693 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	20:52 Local	**Direction from Accident Site:**	295°
Lowest Cloud Condition:	Few / 5500 ft AGL	**Visibility**	9 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	7 knots / None	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	230°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.77 inches Hg	**Temperature/Dew Point:**	31°C / 20°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Covington, KY (CVG)	**Type of Flight Plan Filed:**	IFR
Destination:	Milwaukee, WI (MKE)	**Type of Clearance:**	IFR
Departure Time:	19:51 Local	**Type of Airspace:**	

At 2052, the MKE weather was: wind 230 degrees at 7 knots; visibility 9 statute mile; sky condition few clouds at 5,500 feet; temperature 31 degrees C; dew point 20 degrees C; altimeter 29.77 inches of mercury.

Airport Information

Airport:	GENERAL MITCHELL INTL MKE	**Runway Surface Type:**	Asphalt;Concrete
Airport Elevation:	729 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	19R	**IFR Approach:**	None
Runway Length/Width:	9690 ft / 200 ft	**VFR Approach/Landing:**	Full stop

MKE was a field elevation of 723 feet and was five runways. Runway 13/31 was concrete-surfaced, 5,868 feet long and 150 feet wide. Runway 7R/25L was asphalt-surfaced, 8,012 feet long and 150 feet wide. Runway 7L/25R was asphalt and concrete surfaced, 4,800 feet long and 100 feet wide. Runway 1R/19L was concrete-surfaced, 4,183 feet long and 150 feet wide. Runway 1L/19R was asphalt and concrete-surfaced, 9,690 feet long and 200 feet wide.

Wreckage and Impact Information

Crew Injuries:	3 None	**Aircraft Damage:**	Minor
Passenger Injuries:	41 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	44 None	**Latitude, Longitude:**	42.951667,-87.894165(est)

First responders found the airplane resting on runway 19R. Its nose gear and left MLG were found extended to their down and locked position and the right MLG was found in its full up position in the wheel well. The operator's responding maintenance personnel were asked to pull and collar the FDR and CVR circuit breakers. No circuit breakers were found extended when the recorders' circuit breakers were pulled and collared. Responding maintenance personnel also found that the landing gear selector lever was in the down position, the emergency landing gear extension T-handle remained fully extended, and the air driven generator was deployed.

The airplane was lifted by inflating airbags positioned beneath the right wing and the tail. A jack was placed under the right wing to support the airplane. A visual inspection of the landing gear revealed that the right MLG remained within its respective wheel well and its door was flush with the aircraft fairing. An inspection of the cockpit revealed that the landing gear manual release T-handle remained extended approximately 7 inches. An operator's maintenance technician pulled up on the T-handle resulting in the T-handle moving approximately three additional inches to its fully extended position of 10 inches. The additional T-handle displacement resulted in the right MLG extending out of its wheel well. When the maintenance technician released the T-handle from its fully extended position, the T-handle automatically began to slowly retract causing the right MLG to stop extending. The T-handle had to be re-pulled and manually held in its fully extended position for the right MLG to extend to its down and locked position. A slight push on the right MLG was required to bring the gear down and into its down and locked position.

Flight recorders

The airplane was equipped with a L-3 Communications model FA2100-1020 cockpit voice recorder (CVR) with serial number 000228060. This model is a solid-state CVR that records 2 hours of digital cockpit audio. Specifically, it contains a two-channel recording of the last two hours of operation and separately contains a four-channel recording of the last 30 minutes of operation. The two-hour portion of the recording is comprised of one channel of audio information from the cockpit area microphone (CAM) and one channel that combines three audio sources: the captain's audio panel information, the first officer's audio panel information, and the observer's audio panel information. The 30-minute portion of the recording contains four channels of audio data; one channel for each flight crew and one channel for the CAM audio information. The CVR was received at the recorder laboratory where it did not exhibit any heat or structural damage. The audio information was extracted from the recorder normally, without difficulty. Timing of the summary was established by correlating CVR events to

common events on the flight data recorder (FDR).

The airplane was equipped with a L-3 Communications/Fairchild model FA2100 FDR with serial number 000174026, which was designed to meet the crash-survivability requirements of TSO-C124a. This model records airplane flight information in a digital format using solid-state flash memory as the recording medium. The FA2100 can record a minimum of 25 hours of flight data. It is configured to record 128 12-bit words of digital information every second. Each grouping of 128 words (each second) is called a subframe. Each subframe has a unique 12-bit synchronization (sync) word identifying it as subframe 1, 2, 3, or 4. The sync word is the first word in each subframe. The data stream is "in sync" when successive sync words appear at proper 128-word intervals. Each data parameter has a specifically assigned word number within the subframe. The FDR was received at the recorder laboratory in good condition and its data was extracted normally from the recorder.

The FDR recording contained approximately 119.4 hours of data. Timing of the FDR data is measured in subframe reference number (SRN), where each SRN equals one elapsed second. The incident flight was the last flight of the recording and its duration was approximately 1 hour and 42 minutes. The FDR incident data was converted from SRN to the incident local time.

Tests and Research

A National Transportation Safety Board (NTSB) vehicle recorder specialist chaired a CVR group and produced a CVR factual report. The CVR group reviewed recorded cockpit communications starting from the airplane's time while parked on the ramp at CVG. The report summarized communications during the flight's initial approach descent at MKE and continued through the final landing. The flight crew statements are consistent with the CVR factual report's findings. The report findings confirm the flight crew used QRH references during their six landing gear extensions attempts.

A NTSB vehicle recorder specialist downloaded, decoded, and produced a factual report to include graphic plots in reference to data from the FDR. The FDR incident data, in part, indicated that about 20:52, while descending through a pressure altitude of approximately 2,745 feet, the left MLG data transitioned from "Not Down and Locked" to "Down and Locked." The NLG data transitioned from "Not Down and Locked" to "Down and Locked" while the airplane's data indicated it was approximately at a pressure altitude of 2,618 feet. The landing gear disagree warning transitioned from "Not Active" to "Active" while the airplane was approximately at a pressure altitude of 2,217 feet. About 20:54, the right MLG transitioned from "Not Down and Locked" to "Down and Locked" and the airplane's pressure altitude increased to approximately 2,869 feet. A second later, the landing gear disagree warning transitioned back to "Not Active." About 20:54, the right MLG transitioned back to "Not Down and Locked." By 20:55, both the left MLG and NLG transitioned back to "Not Down and Locked."

Over approximately the next 10 minutes until 21:04, the NLG data transitioned six times from "Not Down and Locked" to "Down and Locked" and it remained at "Down and Locked" until touchdown. From 21:00:36 to 21:01:06, the right MLG transitioned to "Down and Locked" and back to "Not Down and Locked" while the airplane was at a pressure altitude about 4,150 feet. About 43 seconds later, the No. 3 hydraulic pressure decreased from approximately 2,720 pounds per square inch (psi) to 14 psi.

The airplane remained at about 4,150 ft.

While the airplane was at a pressure altitude 4,150 feet and over the next, approximately, 7.5 minutes until about 21:13, the No. 3 hydraulic pressure increased to about 2,720 psi, decreased to about 10 psi, increased to about 2,700 psi, decreased to about 14 psi and then increased to about 2,680 psi where it remained until touchdown.

About six and one half minutes later about 21:19, the left MLG transitioned from "Not Down and Locked" to "Down and Locked" and it remained at "Down and Locked" until touchdown. The airplane's pressure altitude had decreased to about 900 feet at that time.

About 13 minutes and 14 seconds later at 21:33:04, the left MLG weight on wheels data transitioned from "Air" to "Ground" and one second later at 21:33:05 CDT, the NLG weight on wheels data transitioned from "Air" to "Ground." The FDR recorder specialist's factual report is appended to the docket material associated with this case.

The pressure and return hydraulic filters were examined with computed tomography scans and digital radiography. A NTSB aerospace engineer produced a computed tomography specialist's factual report based on the radiographic examination. The examination showed that there were three particles found in the pressure filter and one particle found in the return filter. There were several cracks noted in the epoxy material in the end caps of the return filter, and there were some high-density areas noted in both filters within the filter material itself. The specialist's report is appended to the docket material associated with this case.

Eight hydraulic system filters were shipped to the NTSB material laboratory along with hydraulic fluid that was collected with the filters for examination. A NTSB chemist examined the filters and fluid and produced a materials laboratory factual report. The report indicated that all of the filters were comprised of an inner metallic perforated tube with two additional types of filtration media laid over the top: an outer layer of stainless steel wire screen; and a filter consisting of several layers of woven fiber mesh located between the tube and the steel mesh. A measurement of the openings in the outer wire screen found the openings to be 166 by 198 micrometers (µm). The inner fiber mesh consisted of irregularly shaped and sized openings with an average opening size between 25 µm to 50 µm. The filter mesh layers for all of the filters were examined under a 5X to 50X stereo zoom-microscope. The examination of the filters revealed no significant particulates within the mesh.

Each filter was rinsed with acetone to remove any material trapped within the filter material. There was no evidence of metallic particles present in the filtrate rinse. The filtrate from both the fluid and the filters samples was further examined and it exhibited spectra was consistent with characteristic traits of a straight chain, aliphatic hydrocarbon. Materials containing these types of bonds are present in airplane hydraulic systems. The chemist's factual report is appended to the docket material associated with this case.

After the removal and replacement of the pressure and return filters, the operator flushed and retained the hydraulic fluid from the No. 3 hydraulic system. The retained fluid was shipped to the Air Force Petroleum Office (AFPET) laboratory at Wright-Patterson Air Force Base, Ohio, for fluid analysis. The operator then acquired hydraulic fluid samples from selected landing gear components and sent them to

the AFPET laboratory for fluid analysis. The AFPET reports show that the fluids from the No. 3 system flush contained an amount of specified sized particles per 100 microliters that exceeded the recommended amount of those sized particles, in specified ranges, per 100 microliter as indicated in service limit values in the aircraft's maintenance manual. A sample from the No. 2 system had visible particles present. This sample included white and red colored fibers. Particles included a black hydrocarbon plastic material and black fluorocarbon grease droplets. A sample from the return manifold revealed the presence of visible particles. This sample included clear and black colored fibers. These particles included a few red particles, clear sticky flat tape adhesive, black dirt, shiny magnesium aluminum alloy pieces, and shiny copper metal particle. A sample from the pressure manifold filter exhibited it contained clear, brown, and black colored fibers. The majority of particles were black spongy pieces consistent with hydrocarbon gasket material. Other particles included black flat film, shiny magnesium aluminum alloy pieces, and clear particles of silicon oxide as sand. Particles observed in a sample from the extend side of the right hand sidestay actuator included clear, red, and brown colored fibers. These particles included shiny magnesium aluminum alloy pieces, green flat paint chip, black spongy hydrocarbon gasket material, and clear particles of silicon oxide as sand. Particles observed in a sample from the retract side of the right hand sidestay actuator included clear and red colored fibers. These particles included vermiculite (a shipping material), shiny magnesium aluminum alloy pieces, black dirt, and clear particles of silicon oxide as sand. The AFPET laboratory reports are appended to the docket material associated with this case.

A NTSB systems engineer chaired a systems group, which performed follow-on examinations of removed parts, and produced a factual on the group's findings. The report, in part, showed that the airplane's ACMP-3A pump was originally installed on another aircraft in 2001. It was removed in March of 2008 when the pump did not produce specified output pressure. The pump was repaired in reference to discovered insufficient clearance between the piston shoes and the shoe bearing plate and the repaired pump was installed on the incident airplane on May 3, 2008. The incident airplane's total time on that date was 18,069.9 hours and the airplane accumulated 14,516 cycles. Functional testing was performed on the pump and its output pressure was found to be lower than specified. The pump's compensator was adjusted to increase the pump's output pressure to within specified tolerances. Further functional testing found that the pump was unable to meet the minimum requirement for full outlet flow delivery and exceeded the maximum requirement for case flow.

The airplane's ACMP-3B pump was installed in its position 3B at the time of delivery from the factory in 2001. Functional testing was performed on the pump and its output pressure was found to be lower than specified. The pump's compensator was adjusted to increase the pump's and it subsequently passed all test requirements. Disassembly of the compensator revealed its spool assembly was difficult to remove from within its sleeve. Inspection of the sleeve showed that "coking" was present within the sleeve.

The right sidestay was examined and some items did not conform to manufacturer specifications. This actuator was rebuilt by a third party vendor. These inconsistencies did not exhibit any functional issues with the actuator.

The right and left MLG uplock assemblies were examined. Visual inspection of the right uplock assembly at the working area of the latch revealed wear marks on its upper surface and wear marks and a dent on the lower surface. Visual inspection of the hook on left uplock assembly revealed contact

marks on its upper surface. According to Messier Dowty, these marks are minor and consistent with normal in-service wear patterns. Both up lock assemblies met acceptance test specifications. The hydraulic fluid contained with the locks was analyzed. The fluid's observed color was yellow to amber and particles were found in the fluid.

The right MLG uplock pin and assembly remained connected to the airplane at its respective attachment location. Inspection of the uplock pin revealed that it rotated smoothly and exhibited signs of wear, consistent with in-service usage. The diameter of the pin was not measured during the on-scene activities. The left MLG uplock pin was not documented during the on-scene activities.

The runaround and bypass valve was tested and it met testing specifications. Fluid from within the valve was observed to contain debris, which included a non-metallic seal strand.

The functional testing examination of the landing gear manual release T-handle revealed that the locking mechanism contained within the T-handle assembly failed to maintain the T-handle in its fully extended position when a specified retract load was applied to the assembly. When this load was applied, the T-handle fully retracted. Additional testing found that when a lesser load was applied to the T-handle, the T-handle began to slowly retract from its fully extended position. The T-handle stopped retracting and remained in a position outside of full retraction. Disassembly of the T-handle assembly did not find any mechanical discrepancies with the assembly, but did reveal that its inner housing and outer slider appeared to have an oily material coating of unknown origin. An examined sample revealed it was a lubricant. The design of the T-handle assembly does not call for the application of lubricants. The systems group's factual report is appended to the docket material associated with this case.

Additional Information

An NTSB preliminary report, ENG10IA055, in part stated:

On September 28, 2010, at 1710 central daylight time, a Bombardier CRJ-200, operated as Skywest Airlines flight 3074, landed with the left main landing gear retracted on runway 7R at General Mitchell Airport (MKE), Milwaukee, Wisconsin. The flight departed Omaha, Nebraska, at an unknown time, and was destined for MKE. There were 39 reported souls on board and no injuries reported. All airplane occupants evacuated the airplane via the main cabin door with no injuries reported during the evacuation.

According to local officials, air traffic, and the FAA, at 1659, the crew reported a gear indicator problem and performed a pass for air traffic control tower observation. The tower observed the left main landing gear in the retracted position. After some unknown troubleshooting, the crew landed the airplane with the left main landing gear retracted.

Preliminary damage assessment by on-site FAA inspectors revealed minor damage to the left wing tip, flap assemblies, and flap pylon assemblies. The left main landing gear door was up and locked, and the

left main gear was in the wheel well.

The NTSB received notification that on March 21, 2012, about 1830 eastern daylight time, a Bombardier CL-600-2B19, N457SW, aircraft operated as Skywest Airlines flight 4710, while on approach into the Cleveland – Hopkins International Airport (CLE), near Cleveland, Ohio, received a 'gear disagree' message. It was verified that the right main gear indication was amber indicating that it was not down and locked which indicative of the normal 'green' indication. As per QRH procedures, the gear handle was placed in the up position and then again in the down position. The same result occurred; the right main did not indicate down and locked – 'green'. The Captain instructed the gear to be cycled a third time and after this, the right main gear indicated down and locked. Due to the situation, the Captain felt best to declare an emergency and brief the passengers. The subsequent approach and landing at CLE was uneventful.

The right MLG uplock assembly and respective uplock roller were shipped to the NTSB materials laboratory for examination. The examination revealed that wear patterns were observed along the rolling surface of the uplock latch where the uplock roller contacted the slot surfaces and on the mounting ends that contacted the bushings. The rolling surface exhibited two regions of metal wear. The upper band had a dark and roughened appearance, consistent with adhesive wear and was approximately 0.11 inch wide. The lower band exhibited a repeating pattern of flat deformed facets around the circumference of the roller with steps at the edge of the wear region and was approximately 0.19 inch wide. Circumferential wear lines and zones of roughened deformed metal were also observed, consistent with adhesive wear and mechanical deformation from a sliding contact. The mounting ends had circumferential wear marks that were also consistent with sliding contacts with the bushings.

Subsequent to the incident, Bombardier revised the contamination limits in reference to hydraulic fluid in the aircraft maintenance manual.

Administrative Information

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Additional Participating Persons:	Connie Martin; Federal Aviation Administration; Milwaukee, WI John Britten; Transportation Safety Board of Canada; Gatineau David Montieth; Bombardier; Toronto Nigel Petch; Messier-Dowty; Ajax Eric West; Federal Aviatin Administration; Washington, DC Michael Eisenstat ; SkyWest Airlines ; Salt Lake City, UT
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