# Aviation Investigation Final Report

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| **Location:** | Marco Island, Florida | **Accident Number:** | ERA15LA140 |
| **Date & Time:** | March 1, 2015, 16:15 Local | **Registration:** | N600NP |
| **Aircraft:** | Bombardier Canadair CL600-2A12 | **Aircraft Damage:** | Substantial |
| **Defining Event:** | Miscellaneous/other | **Injuries:** | 1 Serious, 1 Minor, 7 None |
| **Flight Conducted Under:** | Part 91: General aviation - Executive/Corporate | | |

## Analysis

Earlier on the day of the accident, the pilot-in-command (PIC) and second-in-command (SIC) had landed the airplane on a 5,008-ft-long, asphalt-grooved runway. After touchdown with the flaps fully extended, the ground spoilers and thrust reversers were deployed, and normal braking occurred. The PIC, who was the flying pilot, and the SIC subsequently departed on an executive/corporate flight with a flight attendant, the airplane owner, and five passengers onboard. The PIC reported that he flew a visual approach to the dry, 5,000-ft-long runway while maintaining a normal glidepath at Vref plus 4 or 5 knots at the runway threshold with the flaps fully extended. He added that the touchdown was "firm" and between about 300 to 500 ft beyond the aiming point marking. After touchdown, the PIC tried unsuccessfully to deploy the ground spoilers. He applied "moderate" brake pressure when the nose landing gear (NLG) contacted the runway, but felt no deceleration. He also attempted to deploy the thrust reversers without success.

The PIC then informed the SIC that there was no braking energy, released the brakes, and turned off the antiskid system. He then reapplied heavy braking but did not feel any deceleration, and he again tried to deploy the thrust reversers without success. He maintained directional control using the nosewheel steering and manually modulated the brakes. However, the airplane did not slow as expected. While approaching the runway end and realizing that he was not going to be able to stop the airplane on the runway, the PIC intentionally veered the airplane right to avoid water ahead. However, the airplane exited the runway end into sand, and the NLG collapsed. The airplane then came to rest about 250 ft past the departure end of the runway. The passengers exited the airplane, and shortly after, airport personnel arrived and rendered assistance. The airplane owner, who was a passenger in the cabin, stated that he left his seat and moved toward the cabin door when he realized that the airplane would not stop on the runway, and he sustained serious injuries.

Examination of the airplane revealed that there was minimal pressure at the No. 2 (left inboard) brake due to failure of a spring in the upper brake control valve (BCV), and the coupling subassembly of the

No. 1 wheel speed sensor (WSS) was fractured. A representative from the airplane manufacturer reported that, during certification of the brake system, the failure of the BCV spring was considered acceptably low and would be evident to flight crewmembers within five landings of the failure. Because the airplane did not pull while braking during the previous landing earlier that day to a similar length runway, the spring likely failed during the accident landing.

Although the PIC was unable to manually deploy the ground spoilers and thrust reversers during the landing roll, they functioned normally during the landing earlier that day and during postaccident operational testing and examination, with no systems failures or malfunctions noted. Additionally, there were no malfunctions or failures with the weight-on-wheels system found during postaccident examinations that would have precluded normal operation. Therefore, the PIC's unsuccessful attempts to deploy the ground spoilers and thrust reversers were likely due to errors made while multitasking when presented with an unexpected situation (inadequate deceleration) with little runway remaining.

Airplane stopping distance calculations based on the airplane's reported weight, weather conditions, calculated and PIC-reported Vref speed, flap extension, and estimated touchdown point (300 to 500 ft beyond the aiming point marking as reported by the PIC and SIC and corroborated by security camera footage) and assuming the nonuse of the ground spoilers and thrust reversers, operational antiskid and steering systems, and the loss of one brake per side (symmetric half braking) showed that the airplane would have required 690 ft of additional runway; under the same conditions but with thrust reversers used, the airplane still would have required 27 ft of additional runway. Even though there were no antiskid failure annunciations, the PIC switched off the antiskid system, which led to the rupture of the Nos. 1, 3, and 4 tires and likely fractured the No. 1 WSS's coupling subassembly, both of which would have further contributed to the loss of braking action. Therefore, the combination of the failure of a spring in the No. 2 brake's upper BCV and the fracture of the coupling subassembly of the No. 1 WSS, the pilot's failure to attain the proper touchdown point, the slightly excess speed, and the subsequent failure of three of the tires resulted in there being insufficient runway remaining to avoid a runway overrun.

Although the BCV manufacturer reported that there was 1 previous case involving a failed BCV spring and 43 instances of units with relaxed springs within the BCVs, none of these failed or relaxed springs would have been detected by maintenance personnel because a focused inspection of the BCV was not required.

## Probable Cause and Findings

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

The failure of a spring inside the No. 2 brake's upper brake control valve and the fracture of the coupling subassembly of the No. 1 wheel speed sensor during landing, which resulted in the loss of braking action, and the pilot-in-command's (PIC) deactivation of the antiskid system even though there were no antiskid failure annunciations, which resulted in the rupture of the Nos. 1, 3, and 4 tires, further loss of braking action, and subsequent landing overrun. Contributing to accident were the PIC's improper landing flare, which resulted in landing several hundred feet beyond the aiming point marking, and his unsuccessful attempts to deploy the thrust reversers for reasons that could not be determined because postaccident operational testing did not reveal any anomalies that would have precluded normal operation.

Contributing to the passenger's injury was his leaving his seat intentionally while the airplane was in motion.

## Findings

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| **Aircraft** | Landing gear brakes system - Malfunction |
| **Aircraft** | Anti-skid section - Incorrect use/operation |
| **Personnel issues** | Incorrect action selection - Pilot |
| **Personnel issues** | Use of equip/system - Pilot |
| **Aircraft** | Landing flare - Not attained/maintained |
| **Not determined** | (general) - Unknown/Not determined |
| **Personnel issues** | Decision making/judgment - Passenger |

# Factual Information

## History of Flight

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| **Landing-landing roll** | Miscellaneous/other (Defining event) |
| **Landing-landing roll** | Runway excursion |
| **Landing-landing roll** | Landing gear collapse |

HISTORY OF FLIGHT

On March 1, 2015, about 1615 eastern standard time, a Bombardier Canadair CL-600-2A12 airplane, N600NP, experienced a landing overrun and subsequent collapse of the nose landing gear at Marco Island Airport (MKY), Marco Island, Florida. The two pilots, one flight attendant, and four passengers were not injured; one passenger sustained serious injuries; and one passenger sustained minor injuries. The airplane was substantially damaged. The airplane was being operated as a 14 *Code of Federal Regulations* (*CFR*) Part 91 executive/corporate flight. An instrument flight rules flight plan was filed, and visual meteorological conditions prevailed at MKY about the time of the accident. The flight originated about 1554 from Florida Keys Marathon Airport (MTH), Marathon, Florida.

Earlier on the day of the accident, the pilot-in-command (PIC) and second-in-command (SIC) landed the airplane on a 5,008-ft-long, asphalt-grooved runway at MTH. After touchdown with the flaps fully extended, the ground spoilers and thrust reversers were deployed, and normal braking occurred. The flight crewmembers reported no discrepancies pertaining to the normal brake system, antiskid system, thrust reversers, or ground spoilers.

The PIC, who was seated in the left seat, stated that, after takeoff from MTH, they proceeded to MKY and obtained information from the automated weather observing station (AWOS), which indicated the wind was from 250° at 5 knots. Before the approach, the pilots reviewed the speeds and landing distance; the calculated required landing distance assuming a Vref of 133 knots was 3,166 ft for a dry runway and 4,166 ft for a wet runway; runway 17 was 5,000 ft long. About 10 miles south of MKY, they had the runway in sight and then requested and were approved for a visual approach from Fort Myers Approach Control. The airplane then entered the downwind leg of the airport traffic pattern from the south while slowing; the flaps were extended to 20°. The PIC noted that there was rain about 2 to 3 miles east of MKY but that the runway appeared to be dry. Because of the rain, the PIC chose to fly the traffic pattern closer to the runway (0.5 mile) on the downwind leg, which he extended 1 mile to avoid the rain. When the airplane was abeam the approach end of runway 17, the SIC extended the landing gear and the flaps to 30°. The pilots then performed the Landing checklist and the antiskid test, which was normal. The PIC then armed the thrust reversers and made a "teardrop turn" to the final approach leg of the airport traffic pattern. The airplane owner, who was pilot-rated and seated in the cabin, recalled a greater bank angle on the turn from downwind to final.

During the approach, the flaps were extended to 45°, and while flying Vref plus 10 knots, the airplane encountered a couple of wind gusts. The SIC checked the AWOS again, but the wind information was the same. The flight did not encounter rain during the approach, and at 50 ft above ground level (agl), the automated callout occurred. The PIC maintained a normal glidepath at Vref plus 4 or 5 knots at the runway threshold, at which point, he placed the thrust levers in the" idle" position. The owner later reported that, while over the runway, it felt like they were floating slightly longer than normal.

The PIC reported that the touchdown was "firm" occurring between 300 and 500 ft beyond the "aiming point marking." After touchdown, he tried to extend the ground spoilers without success. He later attributed that to the complex process requiring the lever to be pulled up then moved rearward through an integral gate. When the nose landing gear (NLG) contacted the runway, he applied forward control yoke pressure and brake pressure but felt no deceleration. He indicated that he also attempted to deploy the thrust reversers but did not believe they deployed and did not see any thrust reverser deploy lights. He further stated that each piggyback lever never unlocked and that he could not get the levers into the reverse position. The owner later reported that he heard what he thought was a "tire go" during the landing roll, that he felt "heavy braking," and that he became concerned when he did not feel or hear the thrust reversers deploy.

The PIC added that he applied "moderate" brake pressure but did not feel any deceleration, which the SIC characterized the landing roll as similar to skidding on ice. The PIC informed the SIC there was no braking energy, released the brakes, turned off the antiskid, and then "re-applied the brakes pressing hard." The SIC also reported he too applied the brakes because he felt no deceleration. The PIC reported he did not feel any deceleration and again tried to deploy the thrust reversers without success. He maintained the runway centerline using the nosewheel steering and began modulating the brakes. However, the airplane did not slow as expected. After the PIC realized that he was not going to be able to stop the airplane on the runway and because there was water beyond the runway end, he intentionally veered the airplane to the right. The SIC reported the airplane departed the runway travelling about 35 knots, and rolled about 250 ft into sand. The airplane owner, who had stood up to go to the cabin entry door when it became clear to him that the airplane was not going to stop on the runway, was bounced against the sidewall between the Nos. 1 and 2 seats on the airplane's left side and sustained serious injuries.

The PIC ordered an emergency evacuation and secured the engines. At that time, the piggyback levers were still up; he then pushed them down, pulled the firewall shutoff valves, and secured the auxiliary power unit. The passengers exited the airplane, and power was secured. Shortly after, airport personnel arrived and rendered assistance. Subsequently, a passenger occupying the cockpit jumpseat complained of back pain and was taken to a hospital for treatment. The PIC later confirmed that he used nosewheel steering to maintain the runway centerline, and that, during the landing roll, he did not detect any abnormal issues with the nosewheel steering.

The SIC later reported that there was no antiskid or weight-on-wheels (WOW) annunciations or failed lights and no warnings from the enhanced ground proximity warning system (EGPWS). He indicated that he and the PIC did not discuss whether to go-around because the problem became evident when the airplane was too far down the runway.

PERSONNEL INFORMATION

PIC

The PIC held a Federal Aviation Administration (FAA) airline transport pilot certificate with a multiengine airplane rating and type ratings in several aircraft, including the CL-600. He also held a commercial pilot certificate with an airplane single-engine land rating and a flight instructor certificate with airplane single-engine, airplane multiengine, and instrument airplane ratings. He was issued a first-class medical certificate on January 15, 2015, with the limitation that he "must wear corrective lenses," which he was wearing at the time of the accident.

The PIC's total flight time was 8,988 hours, 840 hours of which were in the accident airplane make and model, 625 hours of which were as PIC in the accident airplane. In the 90 days before the accident, his total flight time was 65 hours, 25 hours of which were as PIC and 40 hours of which were as SIC.

He obtained his initial type rating in the CL-600 in March 2011 from CAE SimuFlite (CAE), Fort Worth, Texas. His last 14 *CFR* 135.297 check was performed in a Level D simulator at CAE on February 3, 2015, and his last 14 *CFR* 135.293 check in a CL600 was performed at CAE in August 2014.

The operator hired the PIC in February 2009 as a captain. After obtaining his PIC type rating in the CL-600 in March 2011, he flew a rotation of different aircraft for 2 years. From May 2013 to the accident date, he only flew the CL-600.

SIC

The SIC held an FAA airline transport pilot certificate with an airplane multiengine land rating and type ratings in several aircraft, including the CL-600. He also held a commercial pilot certificate with an airplane single-engine land rating.

The SIC estimated that his total flight time was more than 17,000 hours, about 1,500 hours of which were in the accident airplane make and model and 10 hours of which were in the 90 days before the accident. He obtained his type rating in the CL600 in December 2008 from CAE, and his last 14 *CFR* 61.58 check in the CL600 was performed at CAE in June 2014.

The operator hired the SIC in 2007 as the chief pilot. He had flown with the captain for years. In July 2014, he took a Director of Operations position for another company but continued to be a contract pilot for the operator.

AIRCRAFT INFORMATION

The airplane, serial number (S/N) 3002, was manufactured in 1983 by Canadair Ltd. A Certificate for Airworthiness for Export was issued on September 9, 1983, and 20 days later, the FAA issued a transport-category Standard Airworthiness Certificate. The airplane was powered by two General Electric CF34-3A engines.

The airplane was equipped with steer-by-wire nosewheel system, which was controlled by an electronic control module that operated a hydraulic steering control valve (SCV) in response to the commands via either the handwheel and/or rudder pedals. The SCV controlled an actuator, which through a rack-and-pinion arrangement, rotated a steering cuff. The steering cuff in turn rotated the nosewheels through torque links (or scissors). The steering system was normally switched on continuously during flight and was enabled only when the aircraft was on the ground with WOW input. With no WOW input, the NLG was free castoring.

The airplane was equipped with a normal brake system, and each four-wheel brake system provided one-quarter of the total stopping force in the four-tire set (Nos. 1 and 2 on the left main landing gear [MLG] and Nos. 3 and 4 on the right MLG). Each pilot had a left and right brake pedal, which were mechanically linked at the brake control assembly located beneath the cockpit floor. The brake control assembly contained two brake control valves (BCV) that manipulated hydraulic valves via mechanical inputs. Each of the four BCVs regulated the amount of hydraulic pressure provided to each of the four-wheel brake systems through the antiskid braking system and hydraulic fuses. There were two BCV assemblies installed in the nose hydraulics compartment as a part of the brake control mechanism assembly. The upper BCV controlled the inboard brakes, and hydraulic pressure was supplied by the No. 3 hydraulic system; the lower BCV controlled the outboard brakes, and hydraulic pressure was supplied by the No. 2 hydraulic system. The BCVs were considered on-condition components.

The airplane was equipped with an antiskid braking system that consisted of a skid control unit and two dual antiskid control valves and wheel speed sensors (WSS) located in the axle of each main wheel. The system independently controlled the braking of each main wheel by automatically varying the hydraulic pressure output of each dual BCV before these outputs reached the brakes. WSSs were considered on-condition components. An arming switch on the antiskid panel controlled power to the antiskid valves from the 28-volt direct current main bus via the inboard and outboard antiskid relays and the parking brake microswitch. Therefore, the system cannot be armed when the parking brake is on (parking brake shutoff valve closed). When the parking brake is applied, the INBD FAIL and OUTBD FAIL antiskid warning lights illuminated.

The antiskid system had the following features: (1) modulated skid protection of each wheel via the primary antiskid circuits; (2) locked-wheel protection, which provided a pressure dump signal in the event of a deep skid or failure of a wheel to spin up at touchdown and a coarse backup circuit in the event of a primary antiskid circuit failure; (3) pretouchdown protection which, via input from the WOW circuitry, dumped all the wheels' brake pressure while the airplane was still airborne, but the protection was overridden as soon as the wheels have spun up to allow normal skid-controlled braking; (4) built-in test equipment to provide a check of virtually all the system circuits, both on the ground (before takeoff) and in the air (before landing); and (5) spin-up relays to inhibit thrust reverser deployment until after touchdown.

The airplane was equipped with ground spoilers that were controlled electrically via a control unit located in the underfloor avionics bay, which received electrical signals from the ground spoilers on/off/test switch, spoiler control lever, landing gear control unit, antiskid control unit, and throttle levers. Upon receiving all required signals concurrently, the spoiler control unit transmitted a signal to energize the solenoid valves of a manifold assembly located in each MLG wheel well, which, in turn, directed hydraulic pressure to the extend port of each ground spoiler actuator to extend the spoilers. The ground spoilers are armed for deployment at touchdown by setting the ground spoilers switch to the "on" position and moving the spoiler control lever to the "extend" position. The lever must be pulled up, then moved rearward through an integral gate to achieve the required position. In addition to the lever selection, the throttle levers must be set at idle and the aircraft weight must be on the landing gear (and/or wheels spin-up) before the ground spoilers can deploy.

The airplane was equipped with thrust reversers that redirected engine fan air flow forward over the nose cowl assembly. Thrust reverser selection and control are accomplished primarily by a throttle-quadrant-mounted thrust lever for each engine. Each lever is held in the stow position by a thrust reverser lever stop, which is released by lifting the stop release latch. A deploy switch for each thrust reverser was mounted in the throttle quadrant and was operated by moving the appropriate thrust reverser lever to the "deploy" position.

The airplane was maintained in accordance with the manufacturer's maintenance steering group (MSG) 3 program since January 30, 2009, which consisted of hours- or months-interval inspections of systems or components. Review of the program revealed no requirement to periodically perform an operational test of the antiskid system; however, it contained a general zonal visual inspection every 120 months of the lower internal left nose compartment, which contained the upper and lower BCVs. The zonal inspection did not require inspection of either the upper or lower BCVs input rods extension lengths. The last inspection of that zone was completed on January 18, 2013, at an airframe total time of 15,155.5 hours and 9,303 cycles.

Review of the maintenance records revealed that the airplane's last 800-hour inspection was completed on January 14, 2015, at an airplane total time of 15,737.0 hours and 9,684 cycles. The 800-hour inspection included an operational test of the nosewheel steering electronic control module and the landing gear control unit.

A review of the Aircraft Reporting Form (used by flight crewmembers to report discrepancies) for the 90 days before the accident revealed no discrepancies regarding the brakes, antiskid system, ground spoilers, or thrust reversers.

According to the current status document provided by the operator, there was no record that the upper BCV or No. 1 WSS had been removed, replaced, or repaired since the airplane was manufactured. Maintenance record entries indicated that the No. 1 tire, part number (P/N) 256K43-3, S/N 33097507, was installed on November 10, 2014, at an airframe total time of 15,699.7 hours and 9,657 cycles. At the time of the accident, the airplane had a total time of 15,771.2 and 9,705 cycles.

METEOROLOGICAL INFORMATION

The MKY AWOS reported about the time of the accident wind from 250° at 8 knots, visibility 10 statute miles, few clouds at 9,000 ft, temperature 27°C, dewpoint 20°C, and altimeter setting 30.22 inches of mercury.

The Weather Surveillance Radar 0.5°-elevation scan depicted the conditions from between 3,740 and 10,990 ft over the accident site. The scan images for 1611 and 1626, which were 4 minutes before and 11 minutes after the accident, respectively, depicted an area of echoes with maximum intensities from 45 to 50 dBZ immediately east of MKY. Plotting of the approach path to MKY onto the weather images showed that the airplane flew under the leading edge of the echoes as it entered the traffic pattern turning onto final approach. The main area of the echoes began to move over the accident site about 7 minutes after the accident with echoes of 35 to 40 dBZ, which are associated with moderate-to-heavy rain. No strong outflows or divergent signatures with the area of echoes were noted, indicating that no strong winds, gust fronts, or microbursts were associated with the echoes. Additionally, no lightning was detected, indicating that the strong echoes were only associated with rain showers and not thunderstorms during the period.

No pilot reports were made in the area surrounding the accident time nor were any Convective SIGMETs, Severe Weather Forecast Alerts, or Center Weather Advisories issued along the accident route.

Airport security cameras captured portions of the approach, landing, landing roll, and accident sequence. A review of the footage revealed that it began raining about 10 minutes after the accident.

AIRPORT INFORMATION

MKY was a public airport with a single, grooved asphalt runway, 17/35, which was 5,000 ft long by 100 ft wide and reported to be in "fair condition." Left traffic was specified for runway 17, which was a slight upsloping runway.

FLIGHT RECORDERS

The airplane was equipped with an L-3 Communications/Fairchild A100A Cockpit Voice Recorder (CVR); it was not equipped nor was it required to be equipped with a flight data recorder. Audio was extracted from the CVR normally and without difficulty; however, the accident flight was not recorded. Further examination of the CVR revealed that the drive mechanism's mylar belt was broken.

According to the CVR manufacturer, the broken drive belt rendered the unit incapable of recording and would not have passed the operational test required by the flight crewmembers before flight and by maintenance personnel every 800 hours. Maintenance records revealed that maintenance personnel's last operational check of the CVR occurred on January 14, 2015, about 34 hours before the accident.

The airplane was also equipped with a Honeywell Mark VII EGPWS. Examination of the unit revealed that the terrain inhibit was not active, and there were no warnings associated with the accident flight. The landing record occurred when the flight was about 800 ft before the runway threshold, which, according to the EGPWS manufacturer, occurred when the radio altimeter indicated the airplane passed below 50 ft and the landing gear were down.

WRECKAGE AND IMPACT INFORMATION

The airplane reportedly came to rest about 250 ft past the departure end of runway 17. Examination of the runway revealed that the first identified skid mark associated with the No.1 tire was about 2,094 ft from the approach end of the runway. Alternating light and dark skid marks with rain grooves and gaps continued for about 780 ft, at which point a dark skid mark continued for about 128 ft. At the end of the dark skid mark from the No. 1 main tire, or about 3,002 ft from the approach end of the runway, the skid mark was distorted. Along the dark skid mark associated with the No. 1 tire, minor skid marks from the No. 2 tire were noted. Dark skid marks from the Nos. 3 and 4 tires were noted 3 ft right of the runway centerline beginning just beyond the heavy skid mark from the No. 1 main tire, or about 2,900 ft from the approach end of the runway. The skid marks made on the runway by the Nos. 3 and 4 tires changed direction multiple times, which continued to the end of the runway. At the departure end of the runway, a rubber transfer skid mark associated with the NLG tire was noted inboard of the skid mark from the No. 3 tire.

Beyond the departure end of the runway, marks from all landing gear tires were noted; however, the mark from the NLG stopped about 81 ft 10 inches before the resting position of the left MLG, which was consistent with the collapse of the NLG.

Examination of the airplane revealed a hole in the lower portion of a bulkhead, a tear in the skin and frame from the right NLG trunnion attachment, a buckle in the right NLG wall, and displacement of the left NLG wall. The NLG was separated from its attachment point but remained partially attached by two flexible hydraulic hoses. The P62 and P63 connections associated with the WOW harness in the NLG area were tightly secured.

The NLG WOW harness, NLG steering harness, and hydraulic lines were disconnected due to partial separation of the NLG. The WOW harness was properly secured to the NLG, and the WOW sensors were tightly secured and safety wired. Although the gap of the NLG WOW sensors was not measured before the WOW harness was removed, according to the mechanic who removed it, the gap appeared normal. Further, a review of a picture provided by Bombardier revealed some overlap of one WOW sensor, although the strut was not compressed. The left and right NLG tires were within 2 and 1 pound per square inch (psi) of the specified limit, and the NLG strut pressure was within limits. The No. 3 system hydraulic return lines in the NLG wheel well, which were damaged, were removed, and the lines were capped.

Examination of the left wing revealed that the wing tip fairing was crushed upward. The inboard flap fairing of the inboard flap was damaged by the left MLG door, and the outboard flap fairing of the outboard flap was damaged. The thrust reverser was fully stowed. There was no observed damage to the right wing, vertical stabilizer, horizontal stabilizer, or engines; the right thrust reverser was also fully stowed.

Examination of the cockpit revealed that the nosewheel steering switch was in the "arm" position and that the ground spoiler and the antiskid switches were in the "off" position. The thrust levers were in the "cutoff" position, and the thrust reverser levers were stowed.

With electrical power applied, the WOW annunciator illuminated, and both thrust reverser switches "arm" lights illuminated. The Nos. 1, 2, and 3 quantity indicators were in the green arc range. With momentary activation of the Nos. 1, 2, and 3 hydraulic systems, the pressure in each increased to 3,000 psi, and the quantity in each indicated 60, 40, and 50%, respectively. The brake inboard and outboard pressures indicated 3,000 psi due to momentary activation of the Nos. 2 and 3 system hydraulic pumps.

Examination of the left MLG revealed that the Nos. 1 and 2 tires remained on the wheel assembly but that the No. 1 tire was on the inboard wheel half. The No. 1 tire showed evidence of flat spotting and a rupture tear, whereas the No. 2 tire pressure was within limits, but the tire was worn. The gaps of both WOW switches were within limits, and both were properly secured and safety wired. With about 1,300 lbs of fuel onboard and the airplane fully resting on the MLG, the forward end of the inboard and outboard WOW switches was flush with the forward end of the target. No defects were noted in the WOW wiring harness in the MLG area. Both WSSs were properly installed; however, the No. 1 WSS coupling subassembly, P/N 6002286, was fractured near the base. The No. 1 WSS and tire assembly were retained for further examination.

Examination of the right MLG revealed that the Nos. 3 and 4 tires and wheel halves exhibited flat spotting. The gaps of both WOW switches were within limits, and both were properly secured and safety wired. With about 1,300 lbs of fuel onboard and the airplane fully resting on the MLG, the forward end of the inboard and outboard WOW switches was 3/4 overlapped with the forward end of the target. No defects were noted in the WOW wiring harness in the MLG area. The Nos. 3 and 4 WSSs externally appeared normal, but the No. 3 WSS back shell was completely unscrewed. There was no damage to the threads.

To facilitate operational testing, the NLG WOW electrical harness was spliced back into the airplane's wiring harness, and hydraulic lines in the NLG area were capped. The airplane was configured to allow for testing without the engines operating and was then simulated being in the air. It was configured per the Approach checklist used by the flight crewmembers, which consisted of the following conditions: a) all hydraulic B pumps on, b) nosewheel steering switch armed, c) ground spoilers switch on, d) thrust reverser switches armed, and e) flaps extended 45°. Under these conditions, the antiskid was armed and tested satisfactorily, which included wheel spin-up. In the same configuration, the airplane was then simulated being on the ground with both thrust levers at idle; the ground spoilers were manually deployed 10 times satisfactorily; no discrepancies were noted.

While the airplane was simulated being on the ground, one engine was operated at a time only to idle thrust and with each thrust reverser armed, each thrust reverser solenoid on the throttle quadrant released, and each thrust reverser was deployed three times followed by a slight increase in power. Safety concerns prevented full reverse thrust application. No discrepancies were noted with either thrust reverser.

Operational testing of the brakes revealed extensive leakage from the damaged Nos. 3 and 4 brakes, which precluded further testing; they were removed for further examination, and exemplar brakes were installed. Subsequent testing revealed normal pressures at the No. 1 (left outboard), No. 3 (right inboard), and No. 4 (right outboard) brakes (between 1,850 and 2,000 pounds per square inch, gauge [psig]); however, only 150 psig was noted at the No. 2 (left inboard) brake. The issue was associated with the upper BCV. The No. 2 brake line was repositioned to the No. 3 position at the BCV, and normal pressure was noted at the No. 2 brake. The BCV assembly was retained for further examination.

Operational testing of the antiskid system was conducted at 2,000 rpm, which approximately correlated to the airplane's reported touchdown speed. Because of damage to the No. 1 WSS, no in-situ testing was performed. The Nos. 3 and 4 positions tested satisfactorily. Because the No. 1 WSS was not tested, the No. 3 WSS, which tested satisfactorily, was installed to the No. 1 wheel position and tested satisfactorily. Because of reduced brake pressure at the No. 2 brake, the No. 2 WSS was installed to the No. 3 wheel position and tested satisfactorily.

## MEDICAL AND PATHOLOGICAL INFORMATION

Following the accident, the PIC, SIC, and flight attendant submitted specimens for testing. The testing results for all of them were negative for drugs of abuse; testing for alcohol was not performed.

## TESTS AND RESEARCH

### Additional Examinations

Examination of the No. 1 tire revealed that it exhibited flat spots through the tread and a cross-shaped tear through the inner-most plies, consistent with sudden depressurization due to the rupture of the inner bladder. Detailed examination of the tire revealed no evidence of operation at low-pressure, preexisting damage, or manufacturing defects. The tire also had a tear/cut that extended to a hole at the edge of the flat-spotted area. A sharp-edged circular hole slightly more than 1/4-inch in diameter was found at the end of the cross-shaped tear. The wheel flange was found to have about the same lateral distance from center, straightness of cut/tear toward cross-shaped damage, parallel nature of the cut/tear with the wheel flange, and approximate diameter of the hole. No evidence of blue tinted rubber or reverted rubber on the interior, exterior, or in the bead areas nor of bead movement or damage was found. The interior liner exhibited no evidence of operation at low-pressure or with the sidewall collapsed. The flat-spotted and torn areas revealed the internal construction of the tire, and no design or construction anomalies were noted in these areas. The plies were straight and parallel in orientation. No loss of adhesion was found between the plies or between the tread construction and loss of tread. No evidence of repair-related damage was found.

Examination of the Nos. 3 and 4 brakes and No. 1 WSS was performed at the manufacturer's facility. Damage to both brake assemblies precluded operational testing; however, visual examination revealed no evidence of preimpact failure or malfunction.

Operational testing of the No. 1 WSS revealed that, even without the coupler installed (it was removed for National Transportation Safety Board [NTSB] metallurgical examination), it produced a constant sinusoidal wave. The WSS manufacturer reported that, since 2010, 57 sensors had been returned but that no coupling failures had been reported. Metallurgical examination of the No. 1 WSS coupler revealed hackles and rib markings on the injection-molded polymer, consistent with overstress fracture. A shrinkage void was noted on the fracture surface. The fracture initiated in bending overstress at the corner with very small radii and reinitiated at the void.

Visual examination of the upper BCV at the manufacturer's facility revealed that the input pushrod for the No. 2 (left inboard) brake was displaced inward compared to the input pushrod for the No. 3 (right inboard) brake and was not in contact with the roller of its associated input linkage; no visible damage to the unit was noted. The upper BCV was placed on a test bench for operational testing, which confirmed the low pressure at the No. 2 (left inboard brake). Disassembly of the upper BCV revealed that the left power brake spring was fractured. Examination of the fractured spring by the NTSB Materials Laboratory revealed generally rounded and equiaxed-shaped dimple rupture features, consistent with tensile overstress, with little to no shear or torsional component. The spring composition and microstructure were consistent with the prescribed material.

Previous BCV Failures

The current BCV manufacturer reported to the NTSB that in the 385 BCVs that they repaired or overhauled between July 1992 and October 2016, excluding the accident unit, there was 1 other identified spring failure, and about 11%, or 43 units, had relaxed springs. The manufacturer did not report this information to the FAA through the service difficulty reporting (SDR) system. At the suggestion of the NTSB postaccident, the BCV manufacturer's Repair Station and Quality Control Manual were updated regarding SDR submissions.

A review of FAA SDRs concerning brakes and BCVs with the accident BCV P/N revealed no reports describing asymmetric braking or failure or malfunction of a BCV.

Bombardier reported that, since October 2003, excluding the accident airplane, operators of Challenger 600/601/3A/3R airplanes reported 142 instances in which the BCVs were removed from the airplane for various reasons (scheduled, unscheduled, etc.). In most of the 142 reports, the operator provided Bombardier with a description of the issue or reason for removal. Four of the reports noted asymmetric braking; three of these BCVs were sent to Tactair, the current manufacturer; however, all three of these BCVs had been modified without inbound evaluation; therefore, the reason for the reported asymmetric braking could not be determined.

Airplane Performance Study

The NTSB conducted a performance study using ASR-11 radar from Southwest Florida International Airport and from a tethered aerostat radar station located about 80 nautical miles from the accident site. According to the study, based on EGPWS altitude and location and shifting of radar data to align with the runway centerline, the final descent angle was 2.6°. The calculated groundspeed based on radar returns indicated that the airplane did not touch down faster than recommended. The study also indicated that, based on the security camera footage, the airplane touched down just past the 1,000 ft mark, which corroborated the flight crewmembers' statements.

Landing and Stopping Distance Information

The airplane flight manual (AFM) did not contain nor was it required to contain landing distance increases if one brake became inoperative.

The airplane manufacturer conducted stopping distance calculations based on the airplane's reported weight, weather conditions, calculated and PIC-reported Vref speed, flap extension, and estimated touchdown point and included nonuse of the ground spoilers and thrust reversers, operational antiskid and steering systems, and braking delay. The calculations showed that, with all four brakes functional, the airplane would stop on the runway with 959 ft of runway remaining. Calculations assuming the same parameters with loss of one brake per side (symmetric half braking), the airplane would have required 690 ft of additional runway; under the same conditions but with thrust reversers used, the airplane would have required 27 ft of additional runway. The calculations could not be conducted to determine the effect of the loss of two brakes on the same side (asymmetric half braking).

Brake Certification

A representative from the airplane manufacturer reported that, during certification of the brake system, the failure of the BCV power brake spring was considered acceptably low and would be evident to pilots within five landings of the failure. The airplane manufacturer representative also indicated that, during certification, the loss of two brakes on the same side was considered to be extremely remote and a low-risk condition. Failure of either the upper or lower BCV is not annunciated to the flight crewmembers.

## Pilot Information

| | | | |
|---|---|---|---|
| **Certificate:** | Airline transport; Commercial; Flight instructor | **Age:** | 46,Male |
| **Airplane Rating(s):** | Single-engine land; Multi-engine land | **Seat Occupied:** | Left |
| **Other Aircraft Rating(s):** | None | **Restraint Used:** | Unknown |
| **Instrument Rating(s):** | Airplane | **Second Pilot Present:** | Yes |
| **Instructor Rating(s):** | Airplane multi-engine; Airplane single-engine; Instrument airplane | **Toxicology Performed:** | Yes |
| **Medical Certification:** | Class 1 With waivers/limitations | **Last FAA Medical Exam:** | January 15, 2015 |
| **Occupational Pilot:** | Yes | **Last Flight Review or Equivalent:** | February 3, 2015 |
| **Flight Time:** | 8988 hours (Total, all aircraft), 844 hours (Total, this make and model), 7794 hours (Pilot In Command, all aircraft), 65 hours (Last 90 days, all aircraft), 30 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft) | | |

## Co-pilot Information

| | | | |
|---|---|---|---|
| **Certificate:** | Airline transport; Commercial | **Age:** | 65,Male |
| **Airplane Rating(s):** | Single-engine land; Multi-engine land | **Seat Occupied:** | Right |
| **Other Aircraft Rating(s):** | None | **Restraint Used:** | 5-point |
| **Instrument Rating(s):** | Airplane | **Second Pilot Present:** | Yes |
| **Instructor Rating(s):** | None | **Toxicology Performed:** | Yes |
| **Medical Certification:** | Class 1 Without waivers/limitations | **Last FAA Medical Exam:** | February 24, 2015 |
| **Occupational Pilot:** | Yes | **Last Flight Review or Equivalent:** | November 25, 2014 |
| **Flight Time:** | 18500 hours (Total, all aircraft), 1500 hours (Total, this make and model), 17000 hours (Pilot In Command, all aircraft) | | |

## Aircraft and Owner/Operator Information

| | | | |
|---|---|---|---|
| **Aircraft Make:** | Bombardier Canadair | **Registration:** | N600NP |
| **Model/Series:** | CL600-2A12 601 | **Aircraft Category:** | Airplane |
| **Year of Manufacture:** | 1983 | **Amateur Built:** | |
| **Airworthiness Certificate:** | Transport | **Serial Number:** | 3002 |
| **Landing Gear Type:** | Retractable - Tricycle | **Seats:** | 13 |
| **Date/Type of Last Inspection:** | January 14, 2015 Continuous airworthiness | **Certified Max Gross Wt.:** | 42102 lbs |
| **Time Since Last Inspection:** | 34 Hrs | **Engines:** | 2 Turbo fan |
| **Airframe Total Time:** | 15771.2 Hrs at time of accident | **Engine Manufacturer:** | GE |
| **ELT:** | C126 installed, activated, did not aid in locating accident | **Engine Model/Series:** | CF34-3A |
| **Registered Owner:** | SIX HUNDRED NP LLC | **Rated Power:** | 9140 Horsepower |
| **Operator:** | SIX HUNDRED NP LLC | **Operating Certificate(s) Held:** | None |

## Meteorological Information and Flight Plan

| | | | |
|---|---|---|---|
| **Conditions at Accident Site:** | Visual (VMC) | **Condition of Light:** | Day |
| **Observation Facility, Elevation:** | MKY,5 ft msl | **Distance from Accident Site:** | |
| **Observation Time:** | 16:15 Local | **Direction from Accident Site:** | |
| **Lowest Cloud Condition:** | Few / 9000 ft AGL | **Visibility** | 10 miles |
| **Lowest Ceiling:** | None | **Visibility (RVR):** | |
| **Wind Speed/Gusts:** | 8 knots / | **Turbulence Type Forecast/Actual:** | / None |
| **Wind Direction:** | 250° | **Turbulence Severity Forecast/Actual:** | / N/A |
| **Altimeter Setting:** | 30.21 inches Hg | **Temperature/Dew Point:** | 27°C / 20°C |
| **Precipitation and Obscuration:** | | | |
| **Departure Point:** | Marathon, FL (MTH ) | **Type of Flight Plan Filed:** | IFR |
| **Destination:** | Marco Island, FL (MKY ) | **Type of Clearance:** | IFR |
| **Departure Time:** | 15:54 Local | **Type of Airspace:** | |

## Airport Information

| | | | |
|---|---|---|---|
| **Airport:** | Marco Island Airport MKY | **Runway Surface Type:** | Asphalt |
| **Airport Elevation:** | 5 ft msl | **Runway Surface Condition:** | Dry |
| **Runway Used:** | 17 | **IFR Approach:** | None |
| **Runway Length/Width:** | 5000 ft / 100 ft | **VFR Approach/Landing:** | Full stop;Traffic pattern |

## Wreckage and Impact Information

| | | | |
|---|---|---|---|
| **Crew Injuries:** | 3 None | **Aircraft Damage:** | Substantial |
| **Passenger Injuries:** | 1 Serious, 1 Minor, 4 None | **Aircraft Fire:** | None |
| **Ground Injuries:** | N/A | **Aircraft Explosion:** | None |
| **Total Injuries:** | 1 Serious, 1 Minor, 7 None | **Latitude, Longitude:** | 25.987777,-81.671112 |

## Administrative Information

| | |
|---|---|
| **Investigator In Charge (IIC):** | Monville, Timothy |
| **Additional Participating Persons:** | Michael Spencer; FAA/FSDO; Miramar, FL<br>Steven Chase; Sage-Popovich; Valparaiso, IN<br>Beverley Harvey; TSB of Canada; Gatineau<br>Steve Moreno; Tactair Fluid Controls, Inc.; Liverpool, NY<br>Kevin Kurko; Meggitt; Akron, OH<br>Jimmy Avgoustis; Bombardier; Mirabel<br>John Brattain; Sage-Popovich; Gary, IN |
| **Original Publish Date:** | November 28, 2017 |
| **Last Revision Date:** | |
| **Investigation Class:** | Class |
| **Note:** | The NTSB traveled to the scene of this accident. |
| **Investigation Docket:** | https://data.ntsb.gov/Docket?ProjectID=90800 |