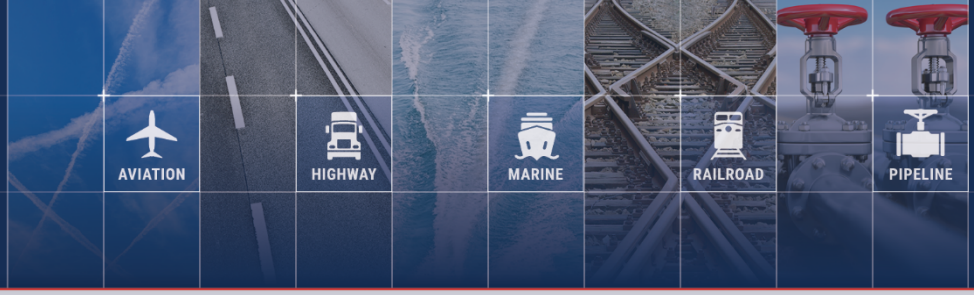

Aviation Investigation Final Report

Location:	Truckee, California	**Accident Number:**	WPR21FA286
Date & Time:	July 26, 2021, 13:18 Local	**Registration:**	N605TR
Aircraft:	BOMBARDIER INC CL-600-2B16	**Aircraft Damage:**	Destroyed
Defining Event:	Loss of control in flight	**Injuries:**	6 Fatal
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The captain and first officer (FO) departed on a non-revenue flight operating under instrument flight rules with four passengers bound for Truckee, California. Most of the flight was uneventful. During the descent, air traffic control (ATC) told the flight crew to expect the area navigation (RNAV [GPS]) approach for runway 20. The captain (pilot flying [PF]) stated and the FO (pilot monitoring [PM]) calculated and confirmed that runway 20 was too short for the landing distance required by the airplane at its expected landing weight. Instead of making a request to ATC for the straight-in approach to runway 11 (the longer runway), the captain told the FO they could take the runway 20 approach and circle to land on runway 11, and the FO relayed this information to ATC. ATC approved, and the flight crew accepted the circle-to-land approach. Although the descent checklist required that the flight crew brief the new circle-to-land approach, and the flight crew's acceptance of the new approach invalidated the previous straight-in approach brief, they failed to brief the new approach.

ATC instructed the flight crew to hold, but the captain was slow in complying with this instruction, so the FO started the turn to enter the holding pattern and then informed ATC once they were established in the hold. About 20 seconds later, ATC cleared them for the approach. Before the FO confirmed the clearance, he asked the captain if he was ready for the approach, and the captain stated that he was. The FO subsequently commented that they had too much airspeed at the beginning of the approach and then suggested a 360° turn to the captain, but the captain never acknowledged the excessive airspeed and refused the 360° turn.

After the FO visually identified the airport, he told the captain to make a 90° right turn to put the airplane on an approximate heading of 290°, which was parallel to runway 11 and consistent with the manufacturer's operating manual procedures for the downwind leg of the circling approach. However, the FO instructed the captain to roll out of the turn prematurely, and the

captain stopped the turn on a heading of about 233° magnetic, which placed the airplane at an angle 57° left of the downwind course parallel with runway 11. As a result of the early roll-out, the flight crew established a course that required an unnecessarily tight turning radius. When they started the turn to final, the airplane was still about 1.3 nautical miles (nm) from the maximum circling radius that was established for the airplane's approach category. The FO also deployed flaps 45° after confirming with the captain (the manufacturer's operating manual procedures for the downwind leg called for a flaps setting of 30°, but the manufacturer stated that a flight crew is not prohibited from a flaps 45° configuration if the approach remains within the limitations of the airplane's flight manual).

The airplane's airspeed was 44 kts above the landing reference speed (Vref) of 118 kts that the flight crew had calculated earlier in the flight; the FO told the captain, "I'm gonna get your speed under control for you." The FO likely reduced the throttles after he made this statement, as the engine fan speeds (N1) began to decrease from about 88% to about 28%, and the airplane began to slow from 162 kts. After the FO repeatedly attempted to point out the airport to the captain, the captain identified the runway; the captain's difficulty in finding the runway might have been the result of reduced visibility in the area due to smoke. The FO continuously reassured and instructed the captain throughout the circle-to-land portion of the approach. On the base leg to the runway and about 25 seconds before impact with the ground, the FO started to repeatedly ask for control of the airplane, but neither flight crewmember verbalized a positive transfer of control as required by the operator's general operating manual (GOM); we could not determine who had control of the airplane following these requests.

As the airplane crossed the runway extended centerline while maneuvering toward the runway, the FO noted that the airplane was too high. One of the pilots (recorded flight data did not indicate which) fully deployed the flight spoilers, likely to increase the airplane's sink rate. (The flight spoilers are deployed using a single control lever accessible to both pilots.) The airspeed at the time was 135 kts, 17 kts above the Vref based on the erroneous basic operating weight (BOW) programmed into the airplane's flight management system (FMS). About 7 seconds later, the left bank became steeper, and the stall protection system (SPS) stick shaker and stick pusher engaged. The captain asked the FO, "What are you doing," and the FO again asked the captain multiple times to "let [him] have the airplane." The stick shaker and stick pusher then briefly disengaged before engaging again. The airplane then entered a rapid left roll, consistent with a left-wing stall, and impacted terrain. A postcrash fire consumed most of the wreckage.

Analysis of data retrieved from the flight data recorder (FDR) indicated that the engines were functioning normally at the time of impact and there were no indications of a flight control or system malfunction. Most of the wreckage was consumed by postcrash fire, and the flight control linkages were destroyed either by high energy impact forces or the postcrash fire, which precluded a complete examination of the wreckage. Examination of the primary flight control surfaces did not reveal any preimpact mechanical anomalies. Engine data from the

accident flight did not show any interruptions in power or suggest any mechanical anomalies with the power production capabilities of either engine.

Flight Crew Performance

The captain and FO were appropriately qualified to perform their respective duties as pilot-in-command (PIC) and second-in-command of the accident flight, which was the first pairing of this crew for the operator. A review of operator documentation revealed that the flight complied with the requirements of Title 14 *Code of Federal Regulations* (*CFR*) Part 91, General Operating and Flight Rules, and was not conducted under the operator's 14 *CFR* Part 135 certificate. Although toxicology testing detected ethanol in the FO's tissue, given the different concentrations of ethanol, the presence of n-propanol, and the state in which the body was found, it is likely that the identified ethanol was from sources other than ingestion.

The flight crew elected to conduct a circling approach to runway 11 and never asked ATC for the straight-in RNAV (GPS) approach to the desired runway. The crew also failed to brief the new circling approach after previously briefing the anticipated straight-in approach. The flight crew's failure to brief the circling approach prevented them from sharing a mental model for how the approach should have been conducted and points to poor crew resource management (CRM) because they failed to prepare for adverse situations and contingencies, such as a missed approach. Because of their lack of preparation, they made critical errors on the approach that reduced the safety margin, which included:

- flying the circling approach at a higher airspeed than the upper limit specified for the airplane's category C approach category;
- failing to establish the airplane on the downwind leg of the circle-to-land approach; and
- failing to visually identify the runway early in the approach, likely due to obscuration by smoke.

The airplane's higher airspeed reduced the flight crew's time to configure the airplane, assess their position relative to the runway, and make corrections to their trajectory, which further reduced the safety margin. During the approach, the FO made several announcements to the captain that the airplane was fast. The captain rejected the FO's suggestion to take a 360° turn early in the approach, which would have provided additional time and distance for speed control. The circling approach maneuver began at 160 kts, which was 20 kts higher than the upper limit of the circle-to-land approach speed established for this airplane's approach category (category C) and did not drop below the category C maximum speed until the flight crew was preparing to start their base leg turn.

The captain's failure to establish the airplane on the downwind leg and the airplane's proximity to the airport during the approach also reduced the safety margin by limiting the space available to align the airplane with the runway centerline. The captain did not establish the airplane on a downwind leg parallel to the destination runway, as depicted in the

manufacturer's operating manual, but instead flew a downwind leg that converged on the runway centerline. This tightened the pattern and resulted in an overshoot of the runway centerline only 0.8 nm from the runway threshold during the base-to-final turn, limiting the flight crew's ability to properly align the airplane with the runway centerline for final approach.

The FO received updated weather information from an automated weather observation system (AWOS) early in the approach, which included an advisory of reduced visibility due to heavy smoke in the area, but he did not relay this visibility advisory to the captain, further reducing the safety margin. The smoke likely made it more difficult for the captain to visually identify the airport.

The FO reassured the captain throughout the approach about needing to be patient and having plenty of time (despite the time constraints resulting from the fast and tight circling maneuver). These reassurances demonstrated that the FO was aware of the adverse effects of self-induced pressure to perform; however, he exhibited self-induced pressure to salvage a deteriorating approach. In addition, despite the captain not properly setting up the approach, he failed to ask for more time in the holding pattern and rejected the FO's suggestion to use a 360° turn to slow the airplane. Without any external pressure to land immediately, the captain's actions indicated a self-induced pressure to perform without being corrected.

Following the turn to the base leg, the airplane was not in a position from which it could align with the runway without overshooting the centerline, nor could the pilots execute a normal descent to the runway. Further, the airspeed was not on target or approaching the flight crew's target Vref of 118 kts. The stabilized approach criteria in the operator's GOM required that the airplane be in a position to execute a normal descent to the runway and that the airspeed be on target or approaching target no later than 500 ft above field elevation in visual meteorological conditions (VMC). The accident approach did not meet those criteria and was therefore unstabilized.

Once the approach became unstabilized, the crew should have abandoned the approach and gone around but did not. The operator's GOM empowered both pilots to perform a go-around, and the circumstances of the approach did not preclude a go-around; there was no time- or fuel-related pressure to land. Even so, the flight crew never announced a go-around, and the FO did not make callouts for going around as required in his role as PM (as the PM, it would have been the FO's duty to call for a go-around once the operator's stabilized approach criteria were violated). The flight crew's choice to continue the unstabilized approach rather than go around was consistent with self-induced pressure to perform and degraded decision-making.

About 8 seconds after the FO asked for control of the airplane the first time, he said, "We're gonna go through it and come back okay?", likely referring to the runway centerline, and indicating an intent to salvage the unstable approach. As the airplane crossed the centerline, the captain said, "It's here" (also likely referring to the centerline), and the FO responded, "Yes yes it's here we are very high," indicating that he was aware that the airplane was not in a position to make a normal descent to the runway. At the same time, the spoilers were

deployed. Given the FO's stated intent to overshoot the runway centerline and then return to it and his recognition that they were high, it is likely that the FO deployed the spoilers in an attempt to descend quickly toward a nominal glidepath to the runway.

Once the airplane crossed the extended runway centerline, it approached a stall and the stick shaker engaged; the FO again requested control of the airplane multiple times, likely motivated by a desire to continue the approach. However, the cockpit voice recorder (CVR) did not record a positive transfer of control or any indication that the captain had relinquished control to the FO. The FO had acted as an instructor to the captain throughout the flight; seeing himself in this role might have driven his desire to take the controls in the final moments of the flight. Given the FO's clear motivation to continue the approach and his multiple requests for control of the airplane, it is likely that he improperly attempted to take control of the aircraft without permission from the captain and increased the bank angle of the left turn, which contributed to the left wing's stall. In his leadership position as PIC, the captain should have taken decisive action to exercise his authority to ensure airplane control when the FO likely improperly attempted to take control; however, he failed to do so.

In addition, both the FO's decision to attempt to salvage the unstabilized approach and the captain's failure to intervene demonstrated degraded performance and vigilance. Further, during the final 10 seconds of the flight, the CVR captured reactive statements from both crewmembers, including the FO's multiple requests for control of the airplane, that suggest they were not working together. The captain's lack of assertiveness in exercising his authority, each flight crewmember's failure to recognize their own psychological stresses, and the flight crew's disregard for safety while attempting to salvage the approach all point to improper CRM in the final moments of the accident flight. Failures in CRM generally describe a lack of clear communication and a failure to recognize degraded performance and vigilance in the cockpit. In this case, poor CRM contributed to the flight crew's degraded performance and competition for control of the airplane, ultimately resulting in a stall.

Airplane Performance

Examination of paperwork for previous maintenance done on the airplane established that the weight and balance information was incorrect in the airplane's FMS. About 10 months before the accident, a maintenance facility serviced the airplane's FMS units to comply with a scheduled battery replacement. Although the maintenance facility reinstalled the required databases, which included the approach speeds and performance databases, it did not input a weight specific to the accident airplane. As a result, the airplane had likely been operating with an incorrect empty weight since the maintenance; the operator reported flying the airplane for four flights since the operator took possession of it in May 2021.

The default empty weight in the FMS was about 3,000 lbs lighter than the estimated actual airplane empty weight for the accident flight. Because of the inaccurate empty weight, the FMS had computed for the flight crew an erroneous Vref of 118 kts, which was 6 kts slower than the correct reference landing speed of 124 kts. Although this oversight showed a lack of attention

to detail by the operator, an airplane performance study determined that the weight and balance discrepancy did not contribute to the stall because the airplane was flying several kts above the correct reference speed in its final moments.

The performance study and accident data revealed that the full deployment of the flight spoilers about 12 seconds before the accident had a significant effect on the stall margin of the airplane in the final moments before impact. Performance analysis showed that the airplane would have been at a bank angle of about 36° when the stick shaker engaged at a calibrated airspeed of 130 kts. Had the flight spoilers been stowed at this airspeed, the stick shaker would not have engaged until the airplane reached a calculated bank angle of about 50°. Therefore, the airplane's stall margin was significantly reduced by the deployment of the flight spoilers.

As discussed above, the CVR evidence suggests that the FO most likely deployed the spoilers. We were unable to determine if any of the statements recorded by the CVR at the time of spoiler deployment were specifically related to that action. For example, the CVR captured the captain questioning an action taken by the FO just before the stall warning; it was unclear whether this statement might have been in response to a specific control input made by the FO or to the FO's continued and repeated requests to take control of the airplane in general. Although the stall warning disengaged briefly, this was likely the result of the stick pusher providing angle of attack (AOA) recovery rather than a timely response of the flight crew to the stall warning; in any case, the stall warning subsequently re-engaged.

The combination of the FO's improper deployment of the flight spoilers and the airplane's bank angle and airspeed at the time resulted in the airplane exceeding the critical AOA, followed by an asymmetric stall (of the left wing), a rapid left roll, and impact with terrain.

Probable Cause and Findings

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

The first officer's (FO's) improper decision to attempt to salvage an unstabilized approach by executing a steep left turn to realign the airplane with the runway centerline, and the captain's failure to intervene after recognizing the FO's erroneous action, while both ignored stall protection system warnings, which resulted in a left-wing stall and an impact with terrain. Contributing to the accident was the FO's improper deployment of the flight spoilers, which decreased the airplane's stall margin; the captain's improper setup of the circling approach; and the flight crew's self-induced pressure to perform and poor crew resource management, which degraded their decision-making.

Findings

Personnel issues	Decision making/judgment - Copilot
Personnel issues	Aircraft control - Copilot
Personnel issues	Lack of action - Pilot
Aircraft	Angle of attack - Incorrect use/operation
Aircraft	(general) - Not attained/maintained
Personnel issues	Use of equip/system - Flight crew
Personnel issues	Incorrect action performance - Pilot
Personnel issues	Motivation/respond to pressure - Flight crew
Personnel issues	CRM/MRM techniques - Flight crew

Factual Information

History of Flight

Approach-circling (IFR)	Loss of control in flight (Defining event)
Approach-circling (IFR)	Collision with terr/obj (non-CFIT)

On July 26, 2021, about 1318 Pacific daylight time, a Bombardier Inc. Challenger 605, N605TR, was destroyed when it was involved in an accident near Truckee-Tahoe Airport (TRK), Truckee, California. The captain, FO, and four passengers were fatally injured. The airplane was operated as a Part 91 personal flight.

According to automatic dependent surveillance-broadcast (ADS-B) data, the nonrevenue flight operating under instrument flight rules departed Coeur d'Alene Airport - Pappy Boyington Field (COE), Coeur d'Alene, Idaho, about 1145 for TRK. (All times in this report are referenced to the airplane's FDR clock unless otherwise indicated. The ADS-B clock was 1.625 seconds behind the FDR clock and has been shifted by 1.625 seconds in this report.) CVR data indicated that about 1155, ATC cleared the flight to 37,000 ft mean sea level (msl) where it remained for the rest of the cruise phase of the flight.

About 1220, the captain started the approach briefing for the RNAV (GPS) approach for runway 11 at TRK with the FO. At 1248, ATC began issuing descent instructions for the airplane's approach into TRK. At 1249:31, the FO received the updated weather observations for 1251 from the AWOS at TRK, which included an advisory of "visibility may be different than what is shown on AWOS due to heavy smoke in the area." However, when the FO subsequently relayed the weather to the captain, he did not include the smoke advisory. At 1251:22, the FO informed the captain, "New numbers are sent… eighteen, twenty-nine, forty-five" (referring to a Vref speed of 118 kts, approach climb speed of 129 kts, final segment speed of 145 kts). During this time, the CVR recorded the captain asking the FO for the descent checklist twice before the FO initiated the checklist. The flight crew stated they had completed the approach briefing for the RNAV (GPS) approach for runway 11 about 1252.

At 1255, the FO asked ATC if they could proceed direct to the waypoint ALANT for the RNAV (GPS) approach for runway 11 at TRK and the controller cleared them as requested. About 1258, as the airplane descended below 26,000 ft msl, ATC informed the flight crew that they could expect the RNAV (GPS) runway 20 approach at TRK. The captain informed the FO that runway 20 was too short and that they "cannot accept that," and added that the runway 20 approach would require them "to circle to land" for runway 11. The FO then computed the required landing distance and concluded that runway 20 was "4,655" ft long (4,654 ft according

to the TRK airport chart) and they required a minimum landing distance of 4,600 ft. The captain noted that the margin was “too tight,” and the FO agreed.

At 1259:57, the captain told the FO they could make the approach into runway 20 and circle to land. Fifteen seconds later, the FO informed ATC that they could take the runway 20 approach but would need to circle to runway 11 because they needed the longer runway. The controller approved their request and told them to plan on the circling approach, then told them to expect some delays. The flight crew did not brief the new approach, which was required by the descent checklist because the flight crew had changed their approach after briefing the original approach.

At 1302:54, the FO asked the controller if they should enter the published hold at AWEGA waypoint, but the controller instructed the flight crew to expect a hold at waypoint ALVVA, an initial approach fix (IAF) west of AWEGA. The FO then asked for and was given a clearance and instructions to hold at ALVAA. When the airplane was about 11 nm southeast of waypoint ALVVA, the FO told the captain he would start the turn for him toward the waypoint and did so. The FO then helped the captain program the hold into the FMS.

At 1311:43, ATC cleared the flight for the RNAV (GPS) runway 20 approach. After the FO asked and the captain confirmed that he was ready for the approach, the FO provided an abbreviated readback of the clearance. At 1312:13, the FO asked the captain, “Are you gonna be able to get down?” According to the ADS-B data, the airplane was at an altitude of 15,725 ft msl at the time and the first altitude of the approach was 12,000 ft msl at AWEGA, about 3.5 nm away.

At 1312:39, the FO then stated to the captain, “We’ve got a ways to go,” and added, “You got plenty of time.” About this time, FDR data showed the airplane’s indicated airspeed was at 241 kts. At 1313:24 the FO said, “We gotta get this thing slowed down,” then asked if the captain wanted “a right three sixty [degree turn],” but the captain declined. The airplane was about 3 nm south of AWEGA, heading toward OSTIE waypoint at an airspeed of about 252 kts (OSTIE is about 2 nm north of LUMMO, the final approach fix [FAF]) (see the locations of flight crew comments and waypoints in figure 1 below).

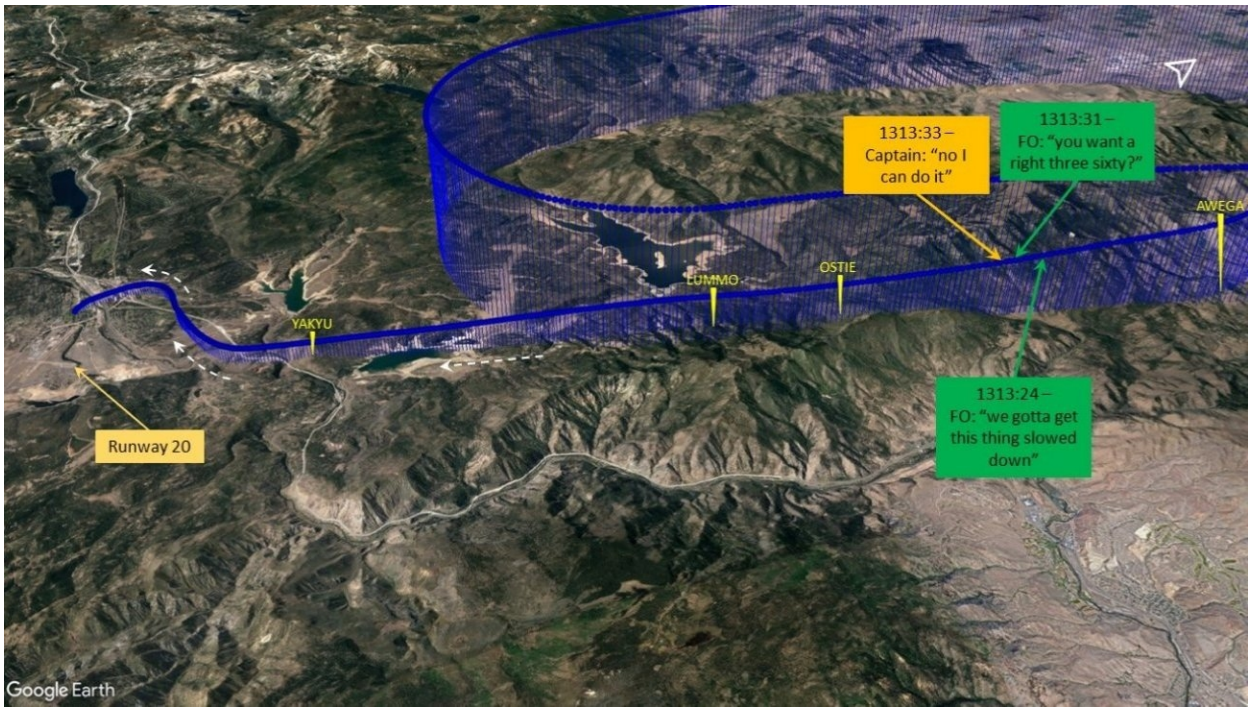

Figure 1. Airplane flightpath and crew discussion on runway 20 approach

At 1313:41 the captain instructed the FO, "Now just below two fifty give me flaps twenty please"; however, the FO responded, "Below two-fifty? how about below two-thirty?" (consistent with the published flap speeds of 231 kts in the manufacturer's operating manual that were also placarded in the airplane), and the captain agreed. The FO then stated again that they should start slowing down the airplane. A few seconds later, the controller terminated radar services and asked the flight crew to contact Truckee tower. At 1314:15, when the airspeed was about 228 kts, the captain again asked the FO to deploy flaps 20°, which the FO stated had been selected (and FDR data showed the flaps setting was selected 4 seconds later).

About the same time, the FO contacted Truckee tower and informed them that they were passing the FAF inbound (which ADS-B data confirmed) and would circle to runway 11. The tower acknowledged the communication and asked them to report when the airport was in sight. The captain asked the FO to deploy the landing gear, then the FO responded, "… You came off… what are you… ah nevermind," and then said, "How 'bout gear down flaps thirty before landing checklist." The captain then asked the FO again to deploy the landing gear.

At 1315:20, the flaps were at 30° and the landing gear was down when the captain asked for "flaps, thirty please" and the FO responded, "No, we're at flaps thirty, gear down." The captain then immediately restated, "Flaps thirty." About 15 seconds later, the captain asked the FO to confirm the airport's location on the left. The FO confirmed the airport's location then added,

“We’re gonna have to make a right hand turn to get to it,” and the captain acknowledged him. At 1315:55, the FO stated the airport was 5 miles away.

At 1316:20, the FO deployed full flaps (45°) after confirming with the captain. A second later (near YAKYU waypoint), the FO said, “There’s the airport,” told the captain to make a 90° right turn, and contacted Truckee tower, which cleared the airplane to land. The FO attempted to point out the airport to the captain, and the captain asked “where?” twice. At 1316:43, the FO told the captain to roll out (level the wings, stopping the turn) and turn the autopilot off. The airplane was at the beginning of the downwind leg turn (about 213° magnetic) when the FO told the captain to roll out, and the airplane rolled out on a heading of about 233°. Figure 2 depicts the turns taken by the airplane in the approach and the maximum circling radius of 3 nm allowed for category C aircraft at TRK in the airport’s approach charts (the airplane was at least 1.3 nm from that maximum circling radius).

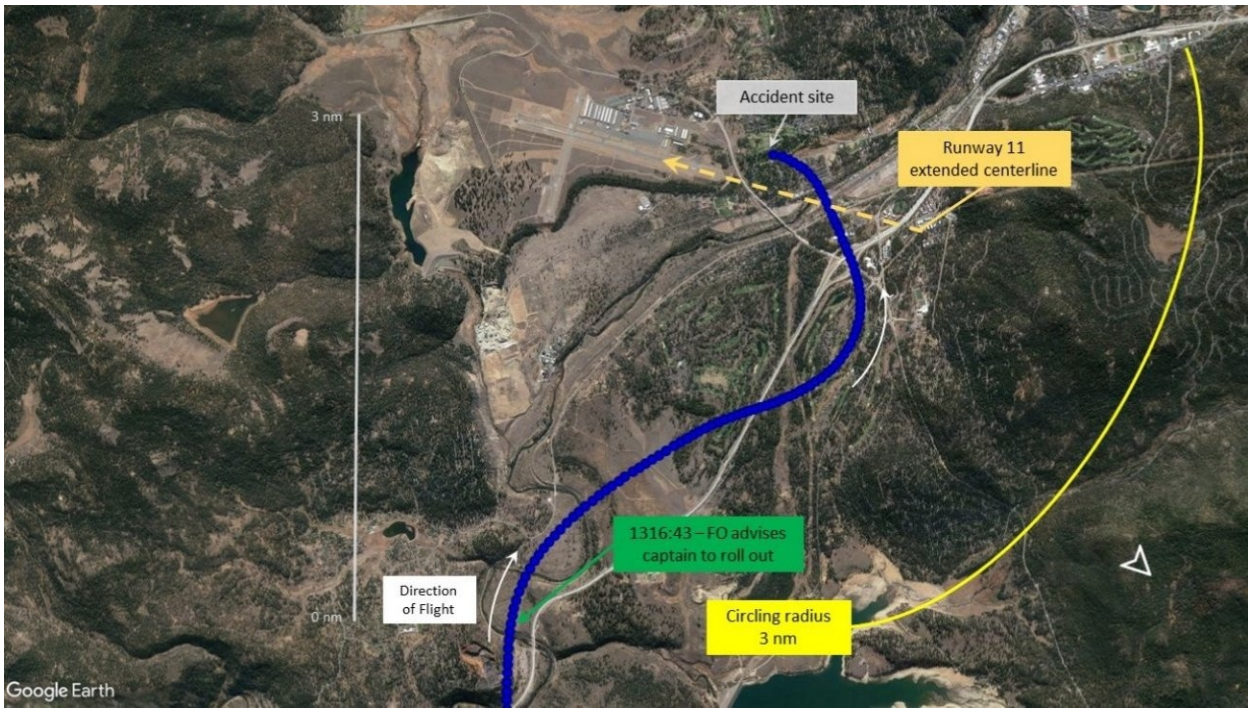

Figure 2. The airplane’s downwind leg and allowed circling radius.

At 1316:53, the FO told the captain, “I’m gonna get your speed under control for you.” FDR data indicated the airplane’s airspeed was about 162 kts at this time. FDR data showed that the airplane began to slow after the FO made this statement. At 1316:56, the captain stated, “Oh I see the runway,” when the airplane had already started the circling approach to runway 11.

Two seconds later, the FO told the captain that he could start descending, and the captain replied, “’Kay, full flaps.” The FO replied, “You do have full flaps,” and then stated, “Patience

patience patience you got all the time in the world"; 13 seconds later, he stated, "You are looking very good my friend." At 1317:24, the airspeed was about 123 kts and the airplane was on a west heading about 1.5 nm from the approach end of runway 11 when the FO told the captain to "bring that turn around," then the airplane began a left turn toward the runway.

At 1317:46, as the airplane was turning through a heading of 188°, the FO made the first of several requests for control of the airplane, asking the captain, "Let me see the airplane for a second." Eight seconds later, the FO told the captain, "We're gonna go through it [the runway centerline] and come back [to the centerline] okay?" and the captain acknowledged the FO. About 1317:59, when the airplane flew through the runway 11 extended centerline about 0.8 nm from the runway threshold, FDR data showed that the flight spoilers were fully deployed (40°). At the time, the airspeed was 135 kts, and the N1 had reduced from about 60% rpm to about 28% rpm. At 1318:01, the FO said, "We are very high" (the airplane was about 6,390 ft msl, or about 489 ft above the runway 11 threshold elevation of 5,901 ft msl).

At 1317:59, the airplane began a left turn that reached a bank angle of 36° about 4 seconds later. According to the CVR data, the stick shaker engaged at 1318:04, then the captain asked, "What are you doing," which was followed by a stall warning sound. The airplane was on a south heading about 0.75 nm from the runway threshold as it continued to turn back toward the extended runway centerline (see figure 3). The stick pusher engaged about 1318:05. (For more information about the stick shaker and stick pusher, see the section below about the SPS.) The captain again asked the FO, "What are you doing?" and the FO then asked the captain three times over 2 seconds to "let me have the airplane." The stick pusher disengaged at 1318:07 followed immediately by the stick shaker disengaging. At 1318:09, the stick shaker engaged again followed immediately by the stick pusher engaging, and the airplane was about 6,075 ft msl on a southeasterly heading when it entered a rapid left roll. The airplane was in a 111° left-wing-low bank angle at 1318:11 and 1 second later it was in a 146° right-wing-low bank angle and an approximate 30° nose-low attitude, just before the airplane impacted terrain and a postcrash fire ensued.

Figure 3. Accident airplane's flightpath during final approach after crossing the runway centerline.

Surveillance video from a business located along the airport perimeter captured the airplane in its final moments. At 1318:09 (according to the time captured by the recording device), the airplane was in a descending left turn on a southeasterly heading at a low altitude. About 1318:12, it entered a rapid left roll and disappeared below the tree line, and smoke appeared in the same location 5 seconds later.

Pilot Information

Certificate:	Airline transport	**Age:**	43,Male
Airplane Rating(s):	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):	None	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	June 2, 2021
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	July 16, 2021
Flight Time:	5680 hours (Total, all aircraft), 235 hours (Total, this make and model), 3080 hours (Pilot In Command, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Flight instructor	**Age:**	56,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Glider	**Restraint Used:**	Unknown
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane single-engine; Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	January 27, 2021
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	June 17, 2021
Flight Time:	14308 hours (Total, all aircraft), 4410 hours (Total, this make and model), 8000 hours (Pilot In Command, all aircraft)		

Captain

The captain, who had signed an employment contract with the operator but was not yet an employee at the time of the accident, was operating the flight under contract to the operator until he could be onboarded. A review of training records from the captain's training provider showed that the captain, who was the PF and PIC during the accident, completed his most recent proficiency training as PIC in a Challenger 605 simulator 10 days before the accident flight. This most recent ground training included CRM training, and the captain's overall rating for ground training was proficient.

Records showed that the captain passed his checkride, which included a non-precision approach, stall prevention, and a go-around/rejected landing; however, the instructor comments for the practice simulator sessions noted that he rushed checklists, needed to slow down and read the checklist requirements, and needed to setup approach procedures without PM prompts. The captain also enrolled online for the accident flight operator's basic indoctrination training, which included instruction on the flight operator's GOM, 12 days before the accident flight.

Federal regulations do not require any leadership and command training for Part 91 or Part 135 operations, and the captain had not taken any leadership training. However, according to both 14 *CFR* 91.3(a) and the flight operator's GOM, the captain as PIC would have been "directly responsible for, and is the final authority as to, the operation of" the accident airplane.

First Officer

The FO, who was the PM and second-in-command during the accident flight, was not the accident operator's employee at the time of the accident and had been hired as a contract pilot for the accident flight. The flight was the first pairing of this crew with the operator. A review of training records from the FO's training provider showed that the FO completed a simulator

session in a Challenger 604 in May 2021 and completed Challenger 604 recurrent training as PIC in June 2021. The recurrent training program included 15 hours of ground training and 8 hours of simulator training, which were split evenly as the PF and PM with five non-precision approaches and one circle-to-land approach. The simulator training sessions included CRM, in which the FO was rated proficient. The FO's training was not specific to the operator's policies and procedures and the FO did not receive training on the operator's GOM. According to Federal Aviation Administration (FAA) Order 8900.1, Volume 5, Chapter 2, Section 19, the accident airplane, a Challenger 605, was under the same type rating designation as the Challenger 604.

Aircraft and Owner/Operator Information

Aircraft Make:	BOMBARDIER INC	**Registration:**	N605TR
Model/Series:	CL-600-2B16	**Aircraft Category:**	Airplane
Year of Manufacture:	2007	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	5715
Landing Gear Type:	Retractable - Tricycle	**Seats:**	12
Date/Type of Last Inspection:	August 26, 2020 Continuous airworthiness	**Certified Max Gross Wt.:**	48300 lbs
Time Since Last Inspection:	17 Hrs	**Engines:**	2 Turbo fan
Airframe Total Time:	5220.4 Hrs as of last inspection	**Engine Manufacturer:**	General Electric
ELT:	C126 installed	**Engine Model/Series:**	CF-34-3B
Registered Owner:	TARCO AIRCRAFT FUNDING LLC	**Rated Power:**	20000 Lbs thrust
Operator:	AEOLUS AIR CHARTER	**Operating Certificate(s) Held:**	On-demand air taxi (135)
Operator Does Business As:		**Operator Designator Code:**	RHAA

Flight Management System

The airplane was equipped with a triple FMS, including three control display units in the cockpit, and three flight management computer (FMC) units in the underfloor avionics equipment bay. The flight crew used the control display units to input, modify, and execute flight plans; calculate airplane performance; and determine the airplane's approach speeds (including Vref), maximum landing weight, and landing field length.

The year before the accident, a maintenance facility serviced the airplane's FMC units to comply with a scheduled battery replacement. Servicing the FMC units involved removing the FMCs from the aircraft, sending them to a third-party repair facility, and subsequently reinstalling them in the aircraft. Bombardier's (the airplane manufacturer's) maintenance manual instructed owners to "make sure that the default values and BOW value are appropriate for the aircraft" after reinstalling the FMC. According to the maintenance facility, it reinstalled the FMCs and the required databases, which included the approach speeds and performance databases, but did not input the BOW specific to the accident airplane.

During subsequent testing, the manufacturer of the FMS confirmed that the BOW defaults to 24,000 lbs after battery replacement and reinstallation of the databases. The FMC manufacturer also confirmed that the installation of the databases did not prompt the user to enter a BOW.

Flight Spoilers

The airplane was equipped with flight spoilers that provided lift dumping and speed control while airborne. A flight spoiler control lever on the center pedestal allows the pilot to select variable amounts of flight spoiler deployment up to a maximum of 40°. An amber caution message is posted on the engine indicating and crew alerting system if the flight spoilers are deployed in flight and another condition is met, such as an altitude between 10 and 300 ft above ground level (agl); the left or right N1 is greater than 79%; or, if radio altitude is not available, any time the landing gear is extended.

Stall Protection System

According to a technical memorandum prepared by Bombardier, the natural stall characteristics of its Challenger 600 series airplanes (including the Challenger 605) include an abrupt load factor reduction and uncontrollable roll at the instant of stall with no pre-stall warning. The memorandum notes that these natural stall characteristics are not certifiable to 14 *CFR* Part 25 Transport Category Airworthiness standards. Consequently, Challenger airplanes incorporate an SPS that provides certifiable stall characteristics (most critically, a stall warning and pitch down at the point of stall) by mechanical means.

To provide a stall warning, which is absent in the natural stall, Challenger control columns have stick shakers that engage when the airplane AOA increases above a predefined threshold (the shaker firing angle). To obtain certifiable stall characteristics if the AOA increases further, a stick pusher device abruptly commands full nose-down elevator once the AOA crosses a second higher threshold (the pusher firing angle). This nose-down elevator produces a nose-down pitching moment and pitch response similar to the pitch response associated with certifiable natural stall characteristics. The nose-down motion reduces the AOA and wing lift.

The pusher firing angle defines the airplane stall AOA for certification purposes and is tailored to provide stick pusher engagement and AOA recovery without encountering the natural stall. The pusher firing angle also accounts for higher pitch rates and consequent AOA overshoots

beyond that point. The shaker firing angle is offset to a lower AOA than the pusher firing angle to provide the stall warning margin required by certification standards. Bombardier programmed the shaker firing angle assuming that a crew experiencing the stick shaker will lower the nose and recover AOA promptly and thus avoid the stall AOA defined by the pusher firing angle.

Two AOA vanes mounted on the left and right sides of the forward fuselage provide the AOA signals for the SPS. If either AOA signal exceeds the shaker firing angle, the stick shaker on the corresponding control column will engage (and both columns will shake because they are mechanically connected). If one AOA signal exceeds the pusher firing angle, it will trigger an aural stall warning and flashing red STALL warning lights in the cockpit. If both AOA signals exceed the pusher firing angle, the stick pusher will engage, applying about 80 lbs of forward force to the control columns.

The accident airplane's FDR data showed a difference between the recorded left and right AOA vane data of about 0.5° to 0.75° during the cruise portion of the accident flight and 1.5° toward the end of the flight. Bombardier stated that some difference was not unusual, and 0.5° was the "normally expected maximum" difference. Bombardier noted that comparing AOA vane differences during the approach segment of a flight is more difficult due to turbulence and maneuvering. An NTSB aircraft performance study for this accident considered the effect of this AOA vane split on the SPS system's performance (see the Tests and Research section below) and concurred with Bombardier's conclusion that "the pusher did fire well before any natural stall in the first stall warning event, and the system did recover the aircraft, indicating that any effect of a split in delaying pusher response was not large or significant."

Engines

Both engines were colocated with the main wreckage. A review of the FDR engine data revealed that both N1 and core speeds remained stable and were about matched while the airplane was in cruise flight. During this time, both engines' inter-turbine temperatures and fuel flows were stable and consistent. Engine performance for both engines remained consistent during the 30-minute descent and the approach to landing as both engines decreased normally in response to the changes in thrust demand. During the final 6 seconds before the FDR recording ceased, the data showed that both engines started to increase thrust from a low setting consistent with the accelerating fan and core speeds at the time, which happened about the same time as the initial stick shaker and stick pusher engagements.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KTRK,5900 ft msl	**Distance from Accident Site:**	1 Nautical Miles
Observation Time:	13:50 Local	**Direction from Accident Site:**	106°
Lowest Cloud Condition:		**Visibility**	4 miles
Lowest Ceiling:	Broken / 2300 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	11 knots / 16 knots	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	280°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.13 inches Hg	**Temperature/Dew Point:**	33°C / 8°C
Precipitation and Obscuration:	Moderate - None - Smoke		
Departure Point:	Coeur d'Alene, ID (COE)	**Type of Flight Plan Filed:**	
Destination:	Truckee, CA	**Type of Clearance:**	IFR
Departure Time:	11:45 Local	**Type of Airspace:**	Class D

The weather observations at TRK for 1245 were captured by an AWOS at the airport and showed visibility of 4 statute miles, ceiling broken at 2,300 ft agl, and variable visibility between 3.5 and 5 miles from smoke in the area, with a density altitude of 8,997 ft. (The CVR captured that the FO received the weather observations for 1251 from the AWOS at TRK and relayed most of those observations to the captain.) Imagery data from a geostationary operational environmental satellite for 1316 depicted smoke near the surface with a band of cumulus to cumulus congestus clouds immediately west of the accident site and to the east and southeast of the accident site. Images from the National Aeronautics and Space Administration's Moderate Resolution Imaging Spectroradiometer revealed the presence of smoke from nearby forest fires over the accident site. At the time of the accident, the National Weather Service had an AIRMET advisory current for instrument flight rules conditions due to smoke over the area and a center weather advisory for developing thunderstorms.

The flight plan filed by the crew for the accident flight reported two passengers on the flight; however, according to the operator, the two additional passengers were added to the flight at the last minute. The flight crew did not update the flight plan to reflect the additional passengers. NTSB investigators on scene were eventually able to confirm the correct number of individuals on the airplane after consultation with law enforcement on scene.

Airport Information

Airport:	TRUCKEE-TAHOE TRK	**Runway Surface Type:**	Asphalt
Airport Elevation:	5904 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	11/29	**IFR Approach:**	Circling;RNAV
Runway Length/Width:	7001 ft / 100 ft	**VFR Approach/Landing:**	None

TRK had two intersecting runways, in 02/20 and 11/29 configurations with lengths of 4,654 and 7,001 ft respectively.

Aids to Navigation

The published circling minimums provided obstacle clearance when pilots remained within the appropriate area of protection. Pilots would determine the category of airplane for the approach based on the approach speed of the airplane, which in turn would determine the minimum descent altitude and visibility requirements for the circle-to-land approach as depicted on the approach chart. In addition, according to the “Landing Minima Categories” of the Flight Standardization Board, the accident airplane “is considered category C aircraft for the purposes of determining ‘straight-in landing minima.’” The published minimums for a category C aircraft to circle-to-land from the runway 20 RNAV (GPS) approach at TRK included an airspeed less than 140 kts, a minimum decision height of 7,700 ft msl (1,796 ft agl) and a 3 nm radius from the airport. This approach listed ALVVA as an IAF and AWEGA as an intermediate fix with a published hold.

Wreckage and Impact Information

Crew Injuries:	2 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:	4 Fatal	**Aircraft Fire:**	On-ground
Ground Injuries:		**Aircraft Explosion:**	Unknown
Total Injuries:	6 Fatal	**Latitude, Longitude:**	39.325433,-120.16291

The airplane came to rest on a slope between a golf course fairway and a residential street. Most of the airplane was consumed by postcrash fire, but all the airplane’s primary flight control surfaces were identified at the accident site. A debris path, which measured about 225 ft long and 85 ft wide, was marked by several broken trees and was oriented on an easterly heading. The initial point of impact was identified by a severed tree that stood about 70 ft tall, located about 120 ft west of the main wreckage. Portions of the right and left wings and

control surfaces were found fragmented along the debris path. Additional airframe fragments were separated from the main wreckage, which included both engines, the empennage, and fuselage remnants. Most of the airplane's secondary flight control surfaces were identified at the accident site except the inboard left flap. However, the NTSB did not observe any parts or fragments from the airplane on the ground when a portion of the airplane's flightpath was surveyed.

Flight recorders

The CVR was a Fairchild FA2100-1020 and captured 2 hours, 4 minutes, 15 seconds of audio for each of its four channels: captain, FO, observer, and cockpit area microphone. Examination of the CVR's interior case and memory board showed no significant heat or structural damage.

The FDR was a Fairchild FA2100 that contained about 409 hours of data and included parameters related to the airplane's pitch, roll, autopilot, and engines. Examination of the FDR's interior case and memory board showed no heat or structural damage.

Medical and Pathological Information

Toxicology testing performed by the FAA Forensic Sciences Laboratory detected ethanol in the FO's muscle and kidney tissue concentrations approximately equivalent to 0.059 grams per deciliter and at 0.028 grams per deciliter, respectively. FAA toxicology testing also detected n-propanol, another form of alcohol, in his muscle tissue. FAA toxicology testing of the captain's muscle tissue was negative for ethanol and other tested-for drugs. Ethanol detected in postmortem specimens may result from ethanol production by microbes in a person's body tissues after death.

Tests and Research

Aircraft Performance Study

The NTSB conducted an aircraft performance study to define the accident airplane's position and orientation during the relevant portions of the accident flight and to determine the airplane's response to control inputs, external disturbances, and other factors that could affect its flight. The study used ADS-B, FDR, CVR, video, and weather data, along with the wreckage location and output from aircraft performance analysis programs and simulations.

The study determined that as the airplane was circling to land on runway 11, the left wing exceeded the natural stall AOA and stalled. Immediately following the first stick shaker and stick pusher engagements, the elevators moved to 10° trailing edge down, which decreased the AOA below the stick shaker and stick pusher firing angles, which disengaged the shaker and pusher. However, the elevators then moved about 18° trailing edge up, which increased the AOA above the natural stall AOA (engaging the stick shaker and stick pusher again). At 1318:09.4, the normal load factor (NLF) dropped suddenly from 1.62 to 1.29 g over 1/8 of a second. At the same time, the roll rate increased dramatically as the airplane abruptly rolled to the left from 27° to 147° in 2.3 seconds, consistent with the left wing stalling and the known natural stall characteristics of the accident airplane type and model. The airplane continued to roll to the left and impacted the ground.

The results of the study suggested that the FMS's erroneous airplane empty weight did not affect the sequence of events significantly. As noted above, the airplane empty weight programmed into the FMS was most likely the factory-default weight of 24,000 lbs, about 3,000 lbs lighter than the estimated actual airplane empty weight. With that discrepancy, the FMS would have computed a landing weight of about 28,300 lbs and a corresponding Vref of 118 kts. A review of the flight crew's ForeFlight accounts (a mobile application that can be used for flight planning among other purposes) showed that the captain and FO calculated landing weights of 31,540 lbs and 29,951 lbs respectively. According to FDR data, the airplane had 3,392 lbs of fuel before impact.

Bombardier used data from the airplane's December 2007 aircraft weight and balance report and FDR data of fuel quantities and stabilizer position to estimate the airplane's weight and balance information at the time of the accident, including a BOW of 27,034 lbs. Bombardier further validated through simulation analysis that the stabilizer position at various points in the accident flight was consistent with the estimated weight. The NTSB calculated that with the estimated BOW, the landing weight would have been 31,294 lbs with a corresponding Vref of 124 kts. After adding 10 kts to Vref for maneuvering, the target speed during the circling maneuver using the FMS weight would have been 128 kts, and the target speed using the estimated correct weight would have been 134 kts. The performance study determined that the calibrated airspeed when the stick shaker was first recorded was about 130 kts. Because that airspeed was 6 kts above the correct Vref (124 kts), the erroneous FMS weight did not

contribute to the airplane operating with a significantly reduced AOA margin to the stick shaker during the final maneuver.

The study determined that the full spoiler deployment (before the airplane turned left toward the runway centerline) resulted in a noticeable reduction in maneuvering capability during the final left bank turn and significantly reduced the AOA margin to the stick shaker, stick pusher, and natural stall. About 1318:04.4, before the stall and loss of control, the left vane AOA was high enough to engage the stick shaker at an airspeed of 130 kts, a left bank angle of 36°, and an NLF of 1.23 g. Stick shaker engagement would not normally be expected in these circumstances, but the full deployment of the flight spoilers as the airplane was crossing the extended runway centerline reduced the lift (and therefore NLF) capability of the airplane, contributing to the stick shaker engagement. If the spoilers had been stowed at the same airspeed, the stick shaker would not have engaged until an NLF of 1.54 g and a bank angle of about 50°, and the stick pusher would not have engaged until an NLF of 1.75 g and a bank angle of 55°.

Organizational and Management Information

According to FAA Advisory Circular 120-12A (dated April 24, 1986) a flight must be conducted under Parts 135 or 121 when it "holds itself out" to the public or a segment of the public as willing to furnish transportation and is defined by four elements: "(1) a holding out of a willingness to (2) transport persons or property (3) from place to place (4) for compensation." According to the operator, Aeolus Air Charter Inc., the accident flight was a personal flight and not conducted or held out to the public for compensation or hire.

A review of documents related to the airplane's registration showed that on the day of the accident, the operator applied to the FAA flight standards district office in Fargo, North Dakota, to amend the company's operation specification and add the accident airplane to the company's Part 135 air carrier operating certificate. At the time of the accident, the operator had one airplane from its fleet on its Part 135 operations specification.

Approach Briefing

The manufacturer's operating manual included the approach briefing in section 5 of the descent checklist. According to the procedure:

> *The approach briefing should be accomplished well before entering the terminal control zone. The pilot-flying shall conduct the briefing and review and/or outline the operational aspects of the expected approach, which should include the following:*

(a) Type of approach
(b) Runway in use
(c) Landing minima
(d) Review of Vref and N1 values
(e) Altitudes (MSA [minimum safe altitude], Field elevation, Threshold elevation, Descent crossing altitudes)
(f) Outbound and procedure turn courses
(g) Final inbound course
(h) Decision Height (DH) or Minimum Descent Altitude (MDA)
(i) Missed approach point (non-precision)
(j) Missed approach procedure
(k) NAV equipment set-up
(l) Any questions or clarifications and other pertinent details.

Weight and Balance

Title 14 *CFR 135*.185 states that multiengine aircraft must have a current empty weight and balance based on actually weighing the aircraft within the preceding 36 months. In addition, the operator's general operations manual stated that its aircraft are weighed every 36 months. The accident airplane's operator, owner, and previous maintenance facility were unable to provide a 36-month certified weight of the airplane.

According to the operator's GOM, its director of maintenance was responsible for "ensuring weight and balance of Aeolus Air Charter, Inc. aircraft comply with 14 *CFR* Part 135.185." The operator's chief pilot stated that the operator's procedures were the same for flying and conducting a weight and balance for its Part 91 and Part 135 flights.

Circling Approaches

The manufacturer's operating manual for the accident airplane model directs pilots performing a circling approach to fly the downwind leg parallel to the runway about 1.5 miles away from the runway. The operating manual also directs pilots performing a circling approach to maintain flaps 30° at the "Flaps 30° speed + 10 KIAS [kts indicated airspeed]" and landing gear down from the FAF to the beginning of the turn towards final approach. However, the manufacturer also noted that, although the circling approach procedure in its operating manual calls for maintaining flaps 30°, a flight crew is not prohibited from a flaps 45° configuration if the approach remains within the limitations of the airplane's flight manual.

According to Bombardier, the operating manuals of older Challenger models included flaps 20° and flaps 30° as approved approach climb configurations, and the "Flaps 30° speed" referred to the flaps 30° approach climb configuration. Bombardier removed the approach climb speed data for a flaps 30° configuration when it introduced the Challenger 604. However, some references to "Flaps 30° speed" remained in the normal procedures section of the Challenger 604 operating manual, so at the time of the accident, the operating manual referred to an

undefined “Flaps 30° speed.” Bombardier stated that the appropriate speeds for approaches that refer to the “Flaps 30° speed” are taught in training, and that it would review and adjust the operating manual for consistency with the airplane’s flight manual.

The operator’s GOM included procedures for the PF to conduct an approach briefing before starting any approach, which included the following items (among others):

1. *Approach to be flown and backup approach, if available.*
2. *Special procedures during the approach, such as circling approach, interception of a radial from an arc, VDP [visual descent point], etc.*
3. *Altitudes of IAF, FAF, step-downs, sector altitudes, and obstacles.*
4. *Minimums (DH, MDA), HAT [height above touchdown], HAA [height above airport], and radio altimeter setting*

Based on the estimated actual weight and balance information, the Vref for the airplane at the time of the accident was 124 kts. According to 14 *CFR* 97.3, an airplane with Vref between 121 and 141 kts is a category C aircraft.

The FAA’s Instrument Procedures Handbook urges caution when attempting a circle-to-land maneuver, particularly for category C aircraft:

> *Circling approaches are one of the most challenging flight maneuvers in the NAS [National Airspace System], especially for pilots of Category C and Category D turbine-powered transport category airplanes. The maneuvers are conducted at low altitude, day and night, and often with precipitation present affecting visibility, depth perception, and the ability to adequately assess the descent profile to the landing runway… Circling approaches conducted at faster-than-normal, straight-in approach speeds require a pilot to consider a larger circling approach area.*

The operator’s GOM included procedures to complete a positive transfer of controls. According to these procedures:

> *A normal, non-emergency transfer of control with the autopilot not engaged will follow the protocol below:*
>
> 1. *PF will state, “You have the controls.”*
> 2. *The new PF will place his hands on the yoke and state, “I have the controls.”*
> 3. *The new PM will release the controls.*
>
> *Transfer of aircraft control when the autopilot is engaged will follow the protocol below:*
>
> 1. *The PF will verbalize the current course/heading and altitude assignment and state, “You have the aircraft.”*
> 2. *The new PF will state, “I have the aircraft.”*
>
> *When a positive transfer of controls is completed, the former PF should advise the new PF of the current course/heading and altitude assignment.*

Stabilized Approach Criteria

The operator's GOM included criteria for stabilized approaches:

G. *Approaches in VMC must be stabilized by no later than 500 ft AFE [above field elevation] and 1000 ft AFE in IMC [instrument meteorological conditions]. A stabilized approach is defined as:*

   1. *Aircraft in landing configuration.*
   2. *Aircraft in a position for a normal descent to the runway.*
   3. *Airspeed on target (IMC) or approaching target (VMC).*
   4. *Airspeed on target (VMC) by 500 feet AFE.*

H. *Go-around initiation may be made by either the PF or the PM.*

The operator's GOM's recommendations and standardized procedures also state that the PM makes call outs for going around at the missed approach point.

Crew Resource Management

The FAA's Risk Management Handbook defines CRM as "[t]he application of team management concepts in the flight deck environment." The handbook also states that CRM concepts can include situation awareness, communication skills, and teamwork, among others.

Additional Information

NTSB Safety Alert SA-084, Circling Approaches: Know the Risks, cautions that circling approaches can be riskier than other types of approaches. Specifically, circling approaches often require maneuvering at low altitude and low airspeed during the final segment of the approach, increasing the opportunity for loss of control or collision with terrain. These risks are heightened when conducting circling approaches in marginal or reduced visibility conditions.

Administrative Information

Investigator In Charge (IIC):	Stein, Stephen
Additional Participating Persons:	Michael Lemay; Bombardier, Inc.; Dorval David Gridley; General Electric Amy St. Pierre; Midwest ATC Donald Morgan; Federal Aviation Administration; Reno, NV
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