EXECUTIVE SUMMARY

On January 27, 2009, at approximately 0437 Central Standard Time, an Aérospatiale Alenia ATR 42-320, Registration N902FX, operating as Empire Airlines flight 8284, sustained substantial damage when it landed short of the runway while executing the Instrument Landing System (ILS) approach to RWY 17R at Lubbock Preston Smith International Airport (LBB), Lubbock, Texas. The airplane was registered to Federal Express Corporation of Memphis, Tennessee, and operated by Empire Airlines of Hayden, Idaho. The airline transport pilot rated captain was seriously injured and the commercial rated first officer sustained minor injuries. An instrument flight rules flight plan was filed for the flight that departed Fort Worth Alliance Airport (AFW), Fort Worth, Texas, at approximately 0319. Night instrument meteorological conditions prevailed for the supplemental cargo flight operated under 14 Code of Federal Regulations Part 121.

Despite the fact that Flight 8284 was operating in icing conditions during the approach to LBB, extensive post-crash analysis and simulations based on DFDR data indicate that the airplane's icing protection system, which the flight crew had correctly activated, protected the aircraft's performance from degrading beyond its certified flight envelop. Thus, the airplane's operation in icing conditions was not a cause of the accident.

The results of the investigation into the accident show that the crash occurred because the flight crew, after identifying that the flaps had not properly extended on approach to LBB, failed to maintain the minimum safety speed appropriate for that configuration, failed to initiate a go-around and failed to apply the proper procedure for a no flaps approach. Instead, despite three stall warning activations (stick shaker and aural cricket sound) and one TAWS "pull up" alert, the captain decided to continue with the destabilized approach and to try to land the airplane, even though the first officer, who was flying the airplane at the beginning of the approach, suggested a go-around. The flight crew's failure to keep the airspeed above the minimum required for the attempted zero flap approach in icing conditions during the final approach resulted in the airplane going into an aerodynamic stall from which it did not recover.

1. FACTUAL INFORMATION

1.1 History of the Flight[1]

On January 27, 2009, at approximately 4:37 a.m. Central Standard Time (CST), an Aérospatiale/Alenia ATR 42-320, Registration N902FX, operating under 14 C.F.R. Part 121 of the Federal Aviation Regulations (FARs), crashed when it collided with terrain approximately 300 feet short of the runway at Lubbock Preston Smith International Airport (LBB), Lubbock, Texas. The aircraft was registered to Federal Express Corporation (FedEx) of Memphis, Tennessee, and was operated as Flight 8284 by Empire Airlines of Hayden, Idaho. The airplane crashed while executing an instrument landing system (ILS) approach to Runway 17R. The captain was seriously injured in the crash, and the first officer sustained minor injuries. The impact and post-accident fire substantially damaged the aircraft.

Flight 8284 had departed Forth Worth Alliance Airport (AFW), Fort Worth, Texas, at approximately 3:19 a.m. CST. The flight crew had reviewed a weather briefing package from Empire's dispatch center prior to departure from AFW that showed light freezing drizzle conditions at LBB and occasional moderate icing conditions along the intended route. No ice was detected during a preflight inspection of the aircraft by Empire's maintenance personnel at AFW, and the airplane did not receive any deicing treatment prior to departure.

Instrument meteorological conditions (IMC) prevailed throughout the flight to LBB. With the first officer flying the airplane, Flight 8284 climbed to its initial cruise altitude of 18,000 feet where it encountered ice, which the captain described as moderate, bordering on severe. Level 3 icing protection, which included activation of the airframe de-icing boots, was selected. Although the airplane had a normal cruise speed of 200 to 210 knots, the captain reported the aircraft indicated a speed of 180 knots during the icing encounter. The crew requested a descent to 14,000 feet where the ice accumulation ceased and a substantial amount of ice was shed. As the airplane descended from 14,000 feet, the ice light on the memo panel began to flash indicating that the ice accretion had stopped, and the Level 3 ice protection was turned off.

LBB approach control informed the flight crew of light freezing drizzle conditions at the Lubbock Airport, with a 500 feet overcast ceiling, two miles visibility and a 10 knot tailwind. Before being cleared to Runway 17R, the captain briefed the approach in anticipation of having to fly it, as he was concerned that the first officer did not have the minimums necessary to land in the reported conditions. He soon determined, however, that visibility would not be a problem and that the first officer could fly the approach. The first officer stated that ice again began to

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[1] Excepted where noted, the factual information contained in this "History of the Flight" section is taken from the Operations Group Chairman's Factual Report, NTSB Docket No. SA-533, Exh. 2-A ("Operations Report"), and from the transcript of the Opening Statement of the Investigator-in-Charge (IIC) from the NTSB's Public Hearing in the matter of Empire Airlines Flight 8284, Docket No. SA-533, held on September 22 and 23, 2009, L'Enfant Plaza, in Washington, D.C. ("Public Hearing"), 13:10-24:5.

accumulate as the aircraft descended through 6,000 feet. Level 3 ice protection was again activated.

As Flight 8284 approached the outer marker beacon, the first officer called for 15˚ flaps, gear down and landing checks. The Captain selected flaps 15° and the crew did the pre-landing checklist. The first officer reduced power on both engines as she noticed the airplane was accelerating. Approximately 40 seconds after flaps 15° selection, the captain told the first officer they had no flaps. He stated that he repositioned the flap handle several times and checked the circuit breakers with a flashlight. He then placed the flap handle in the up, or retracted, position, because he stated that he did not want it to inadvertently travel during the approach. The captain did not perform the reduced flap landing procedure, and did not brief speed references for a no flap approach. After the airplane crossed over the outer marker, at about 1000 feet above ground level (AGL), the first of several stall warnings occurred, and the autopilot disengaged. The first officer asked the captain if she should go-around, and he said no. The first officer stated she suggested to go around because they had a flap issue and they needed to figure out their speeds and get themselves situated.[2] The captain stated his decision to continue with the approach was based on the runway conditions, icing conditions, and the flap problem. He stated, "I just wanted to land as soon as possible."[3]

The captain stated that he then noticed that the airplane was drifting off the localizer and saw that the first officer was hand flying the approach when the aircraft's autopilot should have been coupled to the ILS. He did not realize that the autopilot had disconnected, and did not hear the aural disconnect alert. The captain then asked the first officer if she wanted him to take control of the airplane, and she said yes. At that time, the airplane was high and to the right of the intended course. The captain made corrections in both longitudinal and lateral axis. Shortly thereafter, another stall warning occurred, and a "pull up" warning sounded from the Terrain Avoidance Warning System (TAWS). Moments later, the first officer called the runway in sight, and the captain requested maximum RPM. The stall warning again activated and remained on until the airplane impacted the ground approximately 300 feet short of the runway. The crew safely exited the burning airplane after it came to a stop. At no time during the approach did the non-flying pilot call out localizer, glide slope, speed or vertical speed deviations, and there was no reaction to either the stall warning activations or to the "pull up" warning.

1.2 Meteorological Information

According to the Operations Group Chairman's Factual Report, "[a] weather observation taken about 16 minutes after the accident recorded the wind from 020 degrees at 11 knots gusting to 18 knots, visibility 2 miles in light freezing drizzle and mist, ceiling overcast to

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2 NTSB Docket No. SA-533, Exhibit 2G, August 11, 2009 Interview of First Officer Heather Cornell ("Cornell Interview"), p. 2.

3 NTSB Docket No. SA-533, Exhibit 2F, January 29, 2009 Summary of Interview of Captain Rodney Holberton ("Holberton Interview Summary"), p. 2.

500 feet, temperature minus 08 degrees Celsius, dew point minus 09 degrees Celsius, and an altimeter setting of 30:13 inches of mercury."[4]

According to the Meteorology Group Chairman's Factual Report, charts generated by the National Center for Atmospheric Research (NCAR) Research Applications Laboratory demonstrated that there was a high probability that the aircraft encountered moderate icing conditions after it departed AFW while en route at 18,000 feet, and again on descent into LBB below 6,000 feet.[5]

1.3 Flight Crew Information

The airline transport rated captain was hired by Empire on May 9, 1988.[6] He reported 13,200 total hours of flight experience as of September 19, 2008, with approximately 1,500 hours in the ATR 42.[7] The first officer, who held a commercial pilot certificate, reported 2,000 total hours of flight experience as of December 4, 2008, with approximately 100 hours in the ATR 42.[8] The two crew members had never flown together before this flight pairing.[9]

1.4 Aircraft Information

The accident ATR 42-320 twin turboprop airplane was manufactured in France and Italy in 1989. It had later been converted for use in freight operations through a Supplemental Type Certificate (STC). The airplane was also modified by another STC in order to comply with 14 CFR 121.344 recorded parameters requirement. The airplane's most recent inspection was completed on January 9, 2009. At the time of the accident it had accrued 28,768.0 total hours of operation and 32,379.0 cycles.[10]

1.4.1 Flap System

1.4.1.1 Flap Activation and Indications

The flap system on the ATR 42 is operated by a handle on the right side of the central pedestal in the cockpit. The handle allows the flight crew to select one of four flap positions: 0˚, 15˚, 30˚ and 45˚ (for emergencies only). When the flap position is selected in the cockpit, an

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4 Operations Report, § 2.0.

5 NTSB Docket No. SA-533, Exh. 5-A, Meteorology Group Chairman's Factual Report ("Meteorology Report"), Fig. 21; Public Hearing Testimony of Don Eick, NTSB Office of Aviation Safety ("Eick Test."), 126:12-127:10.

6 Operations Report, § 3.1.

7 *Id.*

8 *Id.*

9 *Id.* at § 3.0.

10 *Id.* at § 3.1.

electrical command is transmitted from the flap control switch unit to the flap block valve, which controls the hydraulic actuators. There is one actuator for each of the aircraft's four flaps (two inboard and two outboard). The two inboard flaps are linked by a torque shaft. Average flap position is indicated by a needle indicator in the cockpit. This indicator is illuminated so that flap position can be seen at night. There are also exterior markings on each wing's flap fairing that can be seen from the cockpit side windows. These markings enable the crew to check actual flaps positions. At night, these markings are illuminated by the wing detection lights.[11]

1.4.1.2 Flap Asymmetry Detection System

A flap asymmetry detector, located on one end of the inboard flaps' interconnection torque shaft, detects the relative rotation between both ends of the shaft. It will cause an internal microswitch to close when an asymmetry of 8° to 10° between the left wing and right wing inboard flaps occurs. As soon as the asymmetry is detected, an electrical signal is sent to the flap system which shuts off the flap hydraulic block valve electrical supply. This stops the flaps in position and prevents the asymmetry from increasing beyond 8˚ to 10˚.

The ATR 42 was certified without a specific flap asymmetry indicator in the cockpit. During the certification process, it was demonstrated by wind tunnel tests and analysis that flap asymmetry limited to 8° to 10° does not constitute an unsafe flight condition, even in adverse lateral wind conditions (more than 25 knots).[12] In the event of an asymmetrical flap extension, at flap 15° selection, for example, the flap indicator needle -- which shows the average position between the left and right flaps -- will stop as soon as the asymmetry is detected. This will indicate that the flaps have not reached the selected position. When the flap indicator needle shows an anomaly, the flight crew can confirm actual flap positions by looking at the under-wing flap fairing markings. The non-flying pilot should then call out the problem to the flying pilot.[13] In addition, when the autopilot is engaged, the rolling moment induced by the flap asymmetry will generate a "RETRIM ROLL R(L) WING DOWN" message on the Advisory Display Unit (ADU), which advises the flight crew of the need to trim the aircraft to cancel the excess load.[14]

There is no record of any prior flap asymmetry event occurring on an ATR 42-300/-320. ATR is aware of one event on an ATR 42-500, which has a comparable flap system. The cause of the asymmetry was not determined. The asymmetry occurred after the flight crew had selected Flap 15. The aircraft was then flown manually with the autopilot disengaged. The crew re-trimmed the aircraft and landed safely.[15]

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11 Public Hearing Testimony of Didier Cailhol, ATR Safety and Continued Airworthiness Manager ("Cailhol Test."), 248:13-250:12.

12 *Id.* at 250:20-251:23; NTSB Docket No. SA-533, Exhibit 13E, ATR Presentation -- ATR Flap and Stall Warning Systems ("ATR Flap Presentation"), p. 11.

13 Public Hearing Testimony of Cptn. Jerome Bonetto, ATR Flight Instructor and Examiner ("Bonetto Test."), 345:2-346:10.

14 Cailhol Test., 251:24-252:19; ATR Flap Presentation, *passim*.

15 Cailhol Test., 253:18-25, 259:11-23.

1.4.2 Stall Protection System

The ATR 42 is equipped with two angle of attack (AOA) probes, one on each side of the forward fuselage. In non-icing conditions, if the aircraft reaches 18.1˚ AOA, an aural cricket (highest priority among aural alerts) will sound and each crew member will feel a stick shaker on its control column. The aural cricket and the stick shakers are two components of the airplane's stall warning system. If engaged, the autopilot will disengage when the stall warning activates. When Level 2 ice protection is selected, the stall warning threshold is automatically reduced to 11˚ AOA. The 11˚ value was established according to flight tests performed with simulated ice shapes based on 14 CFR Part 25 Appendix C. In addition to the stall warning, the stall protection system includes a stick pusher that will activate at a higher AOA threshold, depending on the position of the flaps and the AOA increase rate.[16]

1.4.3 Icing Equipment and Systems

1.4.3.1 Ice Protection Equipment

Icing protection on the ATR 42 is provided by both electrical anti-icing equipment and pneumatic de-icing equipment.[17]

1.4.3.2 Electrical Anti-Icing Equipment

Electric anti-icing is provided for the windshields and probes. This protection is selected ON for all flights. Electric anti-icing is also available for the side windows, the flight control surface horns (ailerons, elevators, and rudder) and inner leading edge of propeller blades.

1.4.3.3 Pneumatic De-Icing

Pneumatic boot de-icing equipment protects the critical areas of the airframe, including the wing and horizontal tail leading edges and the engine air intakes and engine gas paths.

1.4.3.4 Ice Detection

Visual and electronic detection methods are available for monitoring ice accretion on ATR 42 aircraft. If installed, one of the first parts of the airplane that will accrete ice is the Ice Evidence Probe (IEP), which is a serrated probe visible near the left side of the cockpit window. The IEP is also the last part of the airplane from which ice will be shed. The IEP was not standard equipment when the accident aircraft was manufactured, but ATR made installation kits

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16 *Id.* at 252:20-253:11, 256:6-259:7.

17 A complete description of the ATR 42's ice protection equipment can be found at NTSB Docket SA-533, Exhibit 2-BBB, ATR Cold Weather Operations Guide (Be Prepared for Icing), pp. 30-33.

available free of charge to all operators around 1996.[18] The accident airplane was not equipped with an IEP.[19] In the absence of an IEP, ice accretion can be visually detected on the propeller spinners (visible from the cockpit of the ATR 42), the windshield, leading edges of the airframe, wipers, and the side windows. In the absence of an IEP, the propeller spinner is used to identify when all ice has shed off the airplane critical surfaces.

In addition to visual detection means, the accident aircraft was equipped with an anti-icing advisory system (AAS) that is designed to alert the flight crew of icing conditions and of the need to implement proper procedures. When ice accretion is detected by the electronic detector located under the left wing, an amber ICING light in the cockpit illuminates, a single aural chime is heard and a CAUTION light illuminates. The ICING light flashes when ice accretion is detected and the electric horns anti-icing equipment and/or the pneumatic airframe de-icing equipment have not been turned on. The ICING light stops flashing and remains illuminated when both systems are turned on. In addition, a green ICING AOA light illuminates in the cockpit as soon as one of the horn anti-icing buttons is selected "on" to remind the flight crew that the stall warning AOA is lower in icing conditions. A blue DE-ICING light illuminates when the airframe de-icing system is turned on. The blue DE-ICING light flashes when the airframe de-icing system remains on five minutes after the last ice accretion detection.[20]

1.4.3.5 Aircraft Performance Monitoring System

Additional cues of icing may be provided by the Aircraft Performance Monitoring (APM) system, if installed, which detects and alerts the flight crew via lights and chimes of aircraft performance degradation that could be caused by icing. The APM system compares actual in-flight drag to theoretical drag, and detects abnormal loss of aircraft performance. The APM system was developed to further enhance flight crew awareness of icing conditions and effect on aircraft performances. If installed, the APM is activated as soon as Level 2 icing protection is engaged, or ice accretion is detected by the AAS. While it is not required for aircraft certification, ATR has proactively recommended its installation to all operators. The accident aircraft was not equipped with the APM system.

1.5 Operations and Procedures Information

1.5.1 Minimum Airspeeds and Airspeed Bugs

As stated in the Operations Group Chairman's Factual Report, a review of the V Speed card for the aircraft loaded at 33,000 lbs, for a normal flaps 30 landing in icing conditions, the airspeed bugs would have been set as follows:

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18 Cailhol Test., 269:15-17.

19 Operations Report, § 5.2.

20 *See* Cailhol Test., 272:17-278:15; NTSB Docket SA-533, Exhibit 13C, ATR Presentation -- Aircraft Performance Monitoring System.

- ***Internal Bug*** (minimum approach speed and target touchdown speed at landing): 116 KTS

- ***Yellow Bug*** (approach speed not considering wind effect plus 5 KTS): 121 KTS

- ***White Bug*** (minimum for flaps 0 (take off phase) and minimum for operation (cruise and approach phases) in non-icing conditions): 123 KTS

- ***Red Bug*** (minimum for flaps 0 (take off phase) and for operation (cruise and approach phases) in icing conditions): 143 KTS[21]

1.5.2 Flight Profiles and Briefings

The Operations Group Chairman's Factual Report also described Empire's standard calls procedures. It states:

> According to the Empire Airlines ATR 42 Pilot Handbook (PH) and FTM, during an Instrument Landing Systems (ILS) approach, the non flying pilot is to provide standard calls and procedures, keep the flying pilot advised of any deviations in altitude, airspeed, or course, and provide a progressive brief on the approach.[22]

1.5.3 Stabilized Approach Criteria

Empire Airlines had established stabilized approach procedures for the ATR 42 airplane at the time of the accident. The stabilized approach criteria are contained in the company's General Operations Manual (GOM) and its Flight Training Manual (FTM). As explained in the Operations Group Chairman's Factual Report:

> According to the FTM, approaches should be stabilized by 1000' height above touchdown (HAT) in IMC and by 500' HAT in VMC.
>
> The approach is considered stabilized when all of the following criteria are met:
>
> - The aircraft is on the correct track (correct track is one for which the correct localizer, radial, or other track guidance has been set, tuned, and identified, and is being followed by the flight crew);

21 Operations Report, § 13.0

22 *Id.* at § 8.2.

- Only small changes in heading and pitch are required to maintain the correct track;
- The bank angle is not more than 30 degrees;
- The rate of descent is, +/- 300 FPM deviation from target;
- The aircraft speed is not more than the required approach speed + 20 knots and not less than the required approach speed;
- The aircraft is in the proper approach configuration;
- The sink rate is a maximum of 1000 FPM, if an approach required a sink rate of greater than 1000 FPM a special briefing should be performed;
- The power setting is appropriate for the configuration;
- All briefing and checklists have been performed.[23]

Empire flight crews are trained to initiate a go-around if an approach is not stabilized.[24] A stall warning is a clear indication of a destabilized approach and calls for a missed approach and go-around.[25]

1.5.4 Terrain Avoidance Warning Procedure

Empire's GOM requires flight crews to react immediately to a TAWS warning/alert, except in daylight visual meteorological conditions (VMC) when the crew can immediately and without doubt confirm that an impact with the ground, water, or an obstacle will not take place.[26] As outlined in the Operations Group Chairman's Factual Report, when the crew receives a TAWS "pull up" warning, the GOM requires them to:

- Advance to go-around power;
- Disconnect the autopilot;
- Level the wings and simultaneously execute a positive pull up;
- Set flaps to go around position;
- Retract landing gear;
- Maintain Vmlb (in the ATR) until terrain clearance is assured using all available information.[27]

Empire flight crews are trained to initiate a go-around in the event of a TAWS "pull up" warning.[28]

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23 *Id.* at § 8.1.

24 Public Hearing Testimony of Cptn. Rodney Holberton, Empire Airlines ("Holberton Test."), 72:8-10.

25 *Id.* at 71:18-20.

26 Operations Report, §8.3.

27 *Id.*

28 Holberton Test., 106:3-9.

1.5.5 Flap Anomaly Procedure

The Empire QRH and the ATR 42 AFM prescribe the procedures to be followed in the event of a flap anomaly.[29] The same procedure applies for a flap jam, flap uncoupling or flap asymmetry. When the flap anomaly occurs on final approach, the crew is to maintain the minimum safe airspeed depending on aircraft configuration and atmospheric conditions, and should consider initiating a go-around to give it time to proceed with applicable checklists, compute new arrival and approach speeds, as well as new landing distance, for a reduced flaps landing.[30] The flight crew need not determine what type of flap anomaly has occurred before implementing these procedures.[31]

1.5.6 Procedures for Operation of Ice Protection Equipment

Three levels of ice protection equipment use are called for by the ATR-42 AFM:[32]

Level 1 ice protection must be selected for all flights. It includes:

- Probes heating
- Windshield heating

Level 2 ice protection must be selected as soon as, and as long as, atmospheric icing conditions exist.[33] It includes:

- Level 1 items, plus
- Propellers 1 & 2 Heat
- Flight Control horns L & R Heat
- Side Windows L & R Heat
- Engine 1 & 2 air intake de-icing
- Minimum propeller RPM at 86%
- Minimum maneuver/operations icing speed bugged and observed
- ICING AOA light illuminated (automatic upon selection of horns anti-icing)

Level 3 ice protection must be selected at the first visual indication of ice accretion and as long as atmosphere icing conditions exist.[34] It includes:

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[29] NTSB Docket No. SA-533, Exhibit 2-Z (Excerpts from Empire ATR 42 Quick Reference Handbook (QRH)); NTSB Docket No. SA-533, Exhibit 2-AA (Excerpts from ATR 42 Airplane Flight Manual ("AFM")).

[30] *Id.*; Bonetto Test., 344:24-346:10.

[31] Public Hearing Testimony of Bill Tubbs, FAA POI for Empire Airlines ("Tubbs Test."), 188:14-189:3.

[32] Operations Report, § 5.4.

[33] *Id.*; Docket No. SA-533, Exhibit 32 (Excerpts from ATR 42 AFM, § 3.02.01 ("Normal Procedures -- Icing Conditions")).

- Level 2 items, plus
- Airframe de-icing equipment (wings and horizontal stabilizer pneumatic boots) ON
- Continuous Relight (engine ignition)

1.5.7 Crew Resource Management

Crew Resource Management (CRM**)** refers to the ability of crews to manage resources to properly respond to well-known, anticipated situations by applying their experience and training in both technical and non-technical skills. Such situations require thorough knowledge and command of technical skills. These include both theoretical technical topics, such as: aircraft systems; standard operating procedures (SOP); phraseology; weather; aircraft performance; and aircraft limitations. They also include the practical ability to execute essential crew tasks, such as: piloting; navigation; communication. Non-technical skills (NTS) are equally essential to ensure flight safety. They refer to pilots' attitudes and behaviors, and are not directly related to aircraft control, systems management or SOP. There are four categories of NTS:

- **Situational awareness** (of time, external environment and aircraft systems);

- **Cooperation** (team building; consideration and support of others; conflict resolution);

- **Leadership and managerial skills** (proper use of authority; providing and maintaining standards; planning and coordination; workload management);

- **Decision making skills** (problem definition and diagnosis; consideration of options; risk assessment and decision making; outcome review).

2 ANALYSIS

2.1 Flap asymmetry

DFDR data only provides the average position between right and left inboard flaps. Actual flaps positions are not individually recorded. ATR's computerized simulation of the accident flight, however, shows that the DFDR data is consistent with the right flap being at 0° and the left flap being at 10°. This provides clear evidence that the flap asymmetry protection system correctly worked as designed and prevented an asymmetry of greater than 10°.

When taking into consideration the ATR's flap system architecture, the possible causes for the asymmetrical flap extension are: a flap actuator jamming; a mechanical jamming of one flap possibly due to a foreign object interfering with flaps kinematic; or a flap actuator hydraulic line clogged. Thorough analyses of the four flap actuators recovered from the aircraft

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(Footnote continued from previous page)
[34] *Id.*

was performed, as was an analysis of the removed hydraulic lines. No evidence was found of an anomaly that could have caused an asymmetrical extension. Analyses of hydraulic fluid samples were also inconclusive. Moreover, essential parts of right flaps, which remained at 0° position, were destroyed during the post-impact fire, which prevented identification of a potential mechanical interference. Thus, despite extensive analysis, the cause of the flap asymmetry has not been determined.

2.2 Reaction of the Flight Crew to the Flap Anomaly

As stated, in the event of any type of flap anomaly (jam, uncoupling or asymmetry), ATR 42 flight crews are trained to first fly the aircraft and to maintain the minimum safety speed according to the indicated flap position, then to consider initiating a go-around to give the crew time to proceed with applicable checklist items. This includes computation of new arrival and approach speeds and landing distance for the reduced flaps landing. The flight crew need not determine what type of flap anomaly has occurred before implementing these procedures. Identification alone of the fact that the flaps are stuck in position is sufficient cause to follow these procedures. The FAA POI for Empire, who is type rated on the ATR 42, testified that, given the training he received, he would have expected the flight crew in the event of the flap anomaly to complete the QRH, and that had the flight crew performed the published procedures using the QRH, he "would hope" the outcome of the accident would have been different.[35] He also testified that the QRH checklist for a flap anomaly covers flap jam, flap uncoupling and flap asymmetry, and that it is not necessary to know which failure is occurring before applying the checklist. The crew of Flight 8284 did not maintain minimum safety speed for a flaps 0° configuration, did not initiate a go-around and did not apply the QRH checklist, as they were trained to do, and thus did not properly respond to the flap anomaly.

As noted by the Human Performance Specialist's Factual Report, the captain indicated to the first officer that the aircraft was experiencing a flap problem about 90 seconds before the impact. However, "[a]fter the comment was made, no further discussion occur[ed] between crewmembers as to what actions should be taken and no reference was made to the QRH."[36] The Human Factors Specialist's factual report also observed that the ATR instructors from FSI, who were interviewed during the investigation, stated that they do not train crews to troubleshoot a problem by checking the circuit breakers, as the captain of Flight 8284 did, "nor had they observed a crewmember troubleshoot with the circuit breakers."[37]

The CVR did not record the captain commenting on the flap problem for almost 40 seconds after the flaps were deployed. The captain apparently did not confirm that the flaps had reached 15˚ at the time of the deployment, either by looking at the cockpit needle indicator or the flap indicators on the flap fairings under the wings. The captain's recognition of the problem

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35 Tubbs Test., 183:4-11, 183:25-184:8.

36 Human Performance Specialist's Factual Report ("Human Factors Report"), NTSB Docket No. SA-533, Exhibit 14-A, § 2.1.

37 *Id.* at § 2.2.

came 66 seconds before the stall warning disconnected the autopilot, which allowed the flight crew sufficient time to respond by maintaining a safe airspeed and initiating a go-around.

2.3 Flight 8284's Approach to LBB

The captain of Flight 8284 and Empire's Chief Pilot agreed that Flight 8284's approach to LBB did not meet Empire Airline's criteria for a stabilized approach.[38]

2.4 Reaction of the Flight Crew to the Destabilized Approach

Empire pilots were trained to initiate a go-around in the event of a destabilized approach. A stall warning event is a clear indication of a destabilized approach. During Flight 8284's approach, the first stall warning was triggered 8 seconds after the 1000 feet AGL announced by the TAWS, and the second stall warning was triggered at 500 feet AGL. Empire pilots are trained to add power and initiate a go-around in the event of a stall warning on approach. Empire's GOM and training also required pilots to react immediately to a TAWS "pull up" warning by advancing power, pulling up and initiating a go-around. The crew of Flight 8284 did not initiate a go-around, as they were trained to do, and thus did not properly respond to the destabilized approach, stall warning or TAWS warning.

2.5 Reaction of the Flight Crew to the Stall Warning System Activations

The Airplane Performance Study Specialist's Report concluded that the FDR data do not show behavior consistent with an airplane stall, loss of lateral control, or a sudden change in aileron hinge moment. The stall warning triggered at the appropriate local angle-of-attack and airspeed on the FDR and, as a result, provided sufficient stall margin.[39]

Empire pilots were trained to initiate a go-around in the event of stall warning activation during approach. After the first stall warning activation, the first officer suggested a go-around, but the captain rejected her suggestion and decided to continue despite the unstable approach. There was no reaction from the flight crew after the second stall warning activation which was shortly followed by a "pull up" warning.

2.6 Contribution of Power Settings to the Unstable Approach

As also noted by the Airplane Performance Study Specialist's Report, about 30 seconds after the FDR recorded asymmetric flap deployment, the first officer "reduced power from about 58% maximum torque to about 3%, while the autopilot increased the pitch of the airplane to maintain the glide slope. This ultimately resulted in a stall warning, which

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[38] Holberton Test., 71:7-9; Public Hearing Testimony of Cptn. Steve Martini, ATR fleet Chief Pilot at Empire ("Martini Test."), 371:4-9.

[39] NTSB Docket No. SA-533, Exh. 13, Airplane Performance Study ("Airplane Performance Report"), p. 5.

disconnected the autopilot just below 1,000 ft AGL, and 125 KIAS."[40] The minimum airspeed to operate the airplane with flaps retracted in icing conditions is 143 kts.[41] The Airplane Performance Study Specialist's Report also states:

> The approach flap setting for the ATR-42 is (a symmetric) 15˚. N902FX had 8˚ to 10˚ deflection on the left flap only. As a result, 'typical' power settings used during the approach would not have applied to the accident approach. This may have contributed to N902FX's apparently unstable approach.[42]

The reduction of power commanded by the first officer was the result of the improper "fly-by-flow" method used by the crew. Rather than performing the "before landing" checklist line-by-line, which is the appropriate methodology, the flight crew performed the checklist items as a block. There was no effort by the crew to acknowledge or verify what the results would be before they started to reduce the speed toward the planned / bugged approach speed, which was incorrect for the configuration.

2.7 Contribution of the Tailwind to the Unstable Approach

As stated, according to the Meteorology Report, wind conditions at LBB were 20°, 11 knots, gust 18 knots. Therefore, the crew intercepted the glide slope with a strong tailwind, which led to a temporary excess of aircraft energy that required monitoring and control by the crew. This situation was not anticipated by the crew during the approach briefing, and does not appear to have been properly managed. This contributed to the unstable approach.

2.8 Aircraft Drag, Lift and Control Force

ATR conducted a computerized simulated analysis of Flight 8284's performance in terms of drag, lift and control forces.[43] The analysis was performed using data from the DFDR and load and trim sheet information from Flight 8284. The aerodynamic data used for this computerized simulation were taken from the test flights of ATR 42-300 Serial Nos. 001 and 002, and verified with the delivery flight of Serial No. 175 (i.e. the accident aircraft). These data were analyzed using drag analysis software, Six Degrees of Freedom software, and hinge moments and control forces engineering software.

Drag and lift analyses were conducted on three flight phases: (1) the first icing encounter at 18,000 feet and down to 14,000 feet; (2) the second icing encounter at approximately 5,000 feet; and (3) from the second icing encounter through final approach.

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40 *Id.* at p. 4.

41 Operations Report, § 13.0; Airplane Performance Report, p. 4, n.3.

42 Airplane Performance Report, p. 4.

43 Cailhol Test., 290:18-300:1; Airplane Performance Report, p. 17; NTSB Docket No. SA-533, Exhibit 13D, ATR Presentation -- ATR Performance Analysis of Empire Flight 8284.

These analyses took into account actual aircraft configuration, including one flap partially extended and the other remaining at zero degrees (flap asymmetry) and gear extended. The analyses showed that, while the icing conditions encountered by Flight 8284 probably degraded the aircraft's performance in terms of drag and lift, in all phases it never exceeded the control authority of the ATR 42-320 and remained within the aircraft's certified flight envelop (Appendix C icing conditions). During Phase 3, the drag increase did not exceed 130 drag counts, and the speed decrease was due to prolonged power reduction to flight idle. (For reference purposes, 130 drag counts represent 8% of engine torque.)

Control forces on the three axis -- roll, yaw and pitch -- were computed and analyzed in four phases of the flight: (1) when the autopilot was engaged and there was no flap asymmetry; (2) when the autopilot was engaged and there was flap asymmetry; (3) when the first officer was flying the aircraft after the autopilot disengaged; and (4) after the captain took over the controls. The maximum control forces computed were in Phase 4, with a roll axis of 29 lbs, a yaw axis of 110 lbs, and a pitch axis of 35 lbs. Each of these forces is within the certification envelop. The wheel control force necessary to counteract the flap asymmetry has been estimated at approximately 13 lbs when aileron trim is not used.[44]

2.9 Reaction of the Flight Crew to Weather Conditions

Flight 8284 encountered icing conditions during cruise and approach. The flight crew did not report any visual cues associated to severe icing conditions. The crew correctly applied the procedures for flight in icing conditions by selecting level 2 and 3 of ice protection system when appropriate. The ice protection system worked correctly. As a result, the airplane's performance stayed within the certificated envelop.

2.10 Minimum Airspeed Required for a No-Flaps Landing in Icing Conditions

As stated, the minimum airspeed to operate the airplane with flaps retracted in icing conditions is 143 KTS. This is where the Red Bug was set. Just as the captain commented on the flap problem and placed the flap control lever in the retracted (or 0˚) position -- at which point the flight crew was on notice that it was required maintain a minimum airspeed of 143 KTS -- the airplane's airspeed began to drop from approximately 160 KIAS to below 130 KIAS when the first stall warning activation occurred. The airspeed then increased again to approximately 160 KIAS, when another stall warning activation occurred due to the large pitch change and high AOA commanded by the captain. The airspeed then dropped again to almost 120 KIAS when yet another stall warning activation occurred.[45] Over the last 25 seconds before the impact the airspeed never increased back to 143 KIAS.

2.11 Aircraft's Capability to Perform a Go-Around

[44] Aircraft Performance Report, p. 5.

[45] *Id.* at Fig. 8.

According to ATR performance analysis, the icing conditions encountered during Flight 8284's approach to LBB degraded the aircraft performance, but these degradations stayed within the certificated envelope.[46] As to the flap asymmetry configuration, the aileron and roll trim authorities were sufficient to enable the pilots to compensate the rolling moment induced by the asymmetry. In this configuration, given the external conditions and available engine power, a go-around could have been conducted at either the first stall warning activation or the second, which was shortly followed by the pull-up warning.

2.12 Crew Resource Management Analysis

The following is a CRM analysis based on excerpts from the CVR transcript:

04:35:03
HOT-2 *what the heck is going on?*

04:35:04
HOT-1 *you know what? we have no flaps.*

04:35:08
HOT-2 *aw #.*

At this point, the captain and first officer are clearly aware of an aircraft system anomaly.

04:35:09
HOT-1 *#*

04:35:22
TAWS *one thousand*

04:35:23
HOT-2 *okay*.

04:35:28
HOT-1 *what the hell?*

04:35:30
HOT *[sound similar to stall warning and stickshaker lasting 1.1 seconds]*

04:35:31
HOT-2 *aw #*

The first officer is made aware of the destabilized approach.

04:35:31
HOT-1 *yeah don't do that*.

04:35:32
CAM *[sound similar to stall warning lasting 0.3 seconds]*

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46 NTSB Docket No. SA-533, Exhibit 13D, ATR Presentation -- ATR performance analysis of Empire flight 8284; Operations Report, § 16.0.

04:35:34
HOT-2 *alright*.

04:35:36
HOT-1 *just keep flying the airplane. okay*.

04:35:40
HOT-2 *should I go around?*

The first officer understands that the cockpit workload has increased and seeks the captain's support for her go-around decision, which was the proper decision based on the circumstances.

04:35:41
HOT-1 *no.*

04:35:43
HOT-1 *keep descending*.

The captain imposes his own opinion of the situation and does not give proper consideration to the flying first officer's initiative in suggesting a go-around.

After identification of the flap anomaly, there was no immediate action taken to control the aircraft. As mentioned in her interview, the first officer stated that she suggested the go-around because they had a flap issue and they needed to figure out their speeds and get themselves situated. She was clearly aware of the flap anomaly and destabilized approach and sought to prioritize tasks so that sufficient crew resources would be retained to try to fly and secure the aircraft.

After the captain's negative response to the go-around suggestion, his leadership becomes autocratic. He essentially destroyed cooperation principles and eliminated the first officer's continued involvement. The conflict remained open for the duration of the flight. In her interview, the first officer stated she felt like he had a good reason why he did not want to go around.[47] Once the captain took control of the aircraft, he was flying solo. The first officer did not make any further suggestions. In her interview, when asked again if she thought she should have suggested going around after he took the controls, the first officer said she did, but she did not verbalize it.[48] The captain's workload increased exponentially after that point, which ultimately contributed to the loss of aircraft control. The last CRM courses attended by the captain were during his initial training.[49]

3. CONCLUSION

3.1 Proposed Findings

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47 Cornell Interview, p. 2.

48 *Id.*

49 Holberton Interview Summary, p. 4.

ATR proposes that the NTSB adopt the following findings:

1. The ATR 42-320 aircraft, FAA Registration N902FX, was properly certified and in compliance with all applicable FARs.

2. Flight 8284 experienced flap asymmetry on the final approach to LBB after the flight crew selected 15˚ flaps.

3. The flap asymmetry detection and protection system worked as designed and certified.

4. The cause of the flap asymmetry is not known despite intensive examination of the four flap actuators and associated hydraulic lines and fluid

5. The only other known flap asymmetry event on an ATR 42 aircraft occurred for unknown reasons on an ATR 42-500, which has a comparable flap system.

6. The pilots in that one prior event were able to safely land the aircraft without any reported difficulty after following correct procedures.

7. On the ATR 42 airplane, there is no unsafe flight condition when the flap asymmetry is limited to 8˚ to 10˚, even in adverse lateral wind conditions.

8. There was no certification requirement for the accident aircraft to have a specific indicator of flap asymmetry, as no unsafe condition exists when the asymmetry is limited to 8˚ to 10˚.

9. The flap indicator needle will stop when asymmetry is detected and the flaps locked, and, when the autopilot is engaged, a "RETRIM ROLL R(L) WING DOWN" message on the ADU will advise the flight crew of presence of loads on aileron control and the need to trim the aircraft.

10. The average flap position is indicated on the flap indicator and the actual flaps positions can be checked on each wing's flap fairing, which are illuminated at night.

11. The captain, as the non-flying pilot, failed to confirm via the indicator needle or the external markings on the flap fairings the position reached by the flaps after 15˚ selection.

12. The captain told the first officer, who was the flying pilot, that they had a problem with the flaps approximately 40 seconds after the first officer called for 15˚ flaps on approach to LBB.

13. After recognizing the flap problem the captain checked the circuit breakers with a flashlight.

14. The flight crew did not maintain minimum safety speed for 0° flaps in icing conditions and did not perform the reduced flap landing procedure.

15. ATR 42 flight crews are not trained to troubleshoot a flap problem by checking circuit breakers.

16. When a flap anomaly occurs on final approach, ATR flight crews are trained to maintain minimum safety speed and to consider initiating a go-around in order to give them time to proceed with applicable checklists and compute new arrival and approach speeds and new landing distance, for a reduced flaps landing.

17. It is not necessary for the flight crew to determine what type of flap anomaly has occurred (jam, uncouple or asymmetry) before implementing the associated procedure; it is the same whether the problem is a flap jam, flap uncoupling or flap asymmetry.

18. The flight crew had sufficient indications of a flap extension failure, and had sufficient time to follow proper procedures and consider initiating a go around.

19. The crew of Flight 8284 did not maintain minimum safety speed, did not initiate a go-around and did not apply the procedure for a no flap landing, as they were trained to do, and thus did not properly respond to the flap anomaly.

20. The accident aircraft was equipped with a stall protection warning system that included stall warning (stick shaker and aural cricket sound) and stick pusher devices for the flight crew.

21. Empire’s stabilized approach criteria required Flight 8284’s approach to LBB to be stabilized by 1,000 feet AGL.

22. Empire’s flight crews are trained to go-around if an approach is not stabilized.

23. A stall warning indicates a destabilized approach and calls for a go-around.

24. Empire’s operating procedures requires flight crews to react immediately to a TAWS “pull up” alert by advancing power, and its pilots are trained to initiate a go-around.

25. About 104 seconds after the flap deployment, and approximately 66 seconds after the captain informed the first officer about the flap problem, after passing 1,000 feet AGL, the first of several stall warnings occurred, and the autopilot disengaged.

26. After the captain took over the controls, at 500 feet, the stall warning activated again and the TAWS system issued a "pull up" warning.

27. The stall warning activated a last time, approximately 9 seconds before the impact, and did not stop until the airplane impacted the ground about 300 feet short of Runway 17R.

28. Flight 8284's approach to LBB did not meet Empire's criteria for a stabilized approach.

29. The crew of Flight 8284 did not initiate a go-around, as they were trained to do, and thus did not properly respond to the destabilized approach, stall warning and TAWS warning.

30. The aircraft's stall warning triggered at the appropriate local angle-of-attack and airspeed and provided the flight crew with sufficient stall margin.

31. The power settings selected by the crew contributed to the unstable approach.

32. The tailwind, which the crew failed to anticipate, contributed to the unstable approach.

33. The aircraft was equipped with an anti-icing advisory system consisting of an electronic ice detector and various cockpit lights and chimes that alerted the flight crew of the icing conditions and the need to implement proper ice protection procedures.

34. Despite ATR's recommendation, the accident aircraft was not equipped with an IEP.

35. Despite ATR's recommendation, the accident aircraft was not equipped with an APM system.

36. Flight 8284 probably encountered moderate icing conditions while flying at 18,000 feet and again after it descended below 6,000 feet.

37. The flight crew correctly activated the electric anti-icing equipment on the accident aircraft, which protected the windshields, probes, side windows,

flight control horns (ailerons, elevators, rudder) and inner leading edge of propeller blades (the outer parts are de-iced by centrifugal forces).

38. The flight crew correctly activated the pneumatic boot de-icing equipment on the aircraft, which protected the critical areas of the airframe, including the wing and horizontal tail leading edges and the engine air intakes and engine gas paths.

39. The flight crew was also able to visually detect ice accretion on the aircraft's propeller spinners.

40. The flight crew did not report visual cues associated to severe icing conditions.

41. The icing conditions encountered by Flight 8284 degraded the aircraft's performance in terms of drag and lift, but the aircraft's ice protection system prevented the icing from degrading the aircraft performances beyond the certified flight envelop.

42. During final approach, the drag increase did not exceed 130 drag counts (i.e. 8% of engine torque) and the speed decrease was due to prolonged power reduction to flight idle.

43. Control forces on the roll, yaw and pitch axis remained within the certification envelop during the final approach to LBB.

44. The icing conditions encountered by Flight 8284 are not a contributing factor to the accident.

45. The flight crew allowed the aircraft's airspeed to drop below the minimum required for a no flaps approach in icing conditions.

46. During the last 25 seconds before the impact, the airspeed remained below the minimum safety speed for flight with flaps 0° in icing conditions.

47. Aircraft flap asymmetry configuration and degraded aircraft performance due to icing would not have prevented the flight crew from initiating a go-around.

48. The reduction of power commanded by the first officer when the flaps had not extended to 15° as planned was the result of the "fly-by-flow" method used by the crew.

49. Empire's operating procedures require non-flying pilots during an ILS approach, such as Flight 8284's approach to LBB, to call out any

deviations from normal altitude, airspeed, or descent rates and to keep the flying pilot advised of any deviations in altitude, airspeed, and course.

50. At no time during the approach did the non-flying pilot call out localizer, glide scope, speed or vertical speed deviations.

51. After the first stall warning and autopilot disengagement the first officer asked the captain if she should go-around, and he said no and told her to keep descending.

52. When the first officer was aware of the flap anomaly and of destabilized approach, she correctly prioritized tasks to try to retain sufficient resources to fly and secure the aircraft.

53. After the captain answered her go-around suggestion in the negative, the captain's leadership became autocratic, which destroyed cooperation in the cockpit and eliminated the first officer's continued involvement. This conflict remained open for the duration of the flight.

54. When the captain took control of the aircraft, he was flying solo. The first officer did not make any further suggestion. As a result, the captain's workload increased exponentially.

3.2 Proposed Probable Cause

ATR proposes that the NTSB adopt the following statement of probable cause:

The National Transportation Safety Board determines that the probable cause of the accident was the flight crew's failure to maintain minimum safety speed for an approach with flaps 0° in icing conditions and flight crew's failure to properly respond to activation of the stall warning and to the TAWS "pull up" alert. The flight crew's allowing of the airspeed to fall below the minimum required for the aircraft's configuration in icing conditions led to an aerodynamic stall from which the airplane did not recover.

Contributing to the accident was the flaps failure to extend symmetrically, the flight crew's failure to stabilize the approach, its failure to adequately monitor airspeed, including the failure of the non-flying pilot to call out the inadequate airspeed. Poor crew resource management, including the failure of the flight crew to effectively cooperate and communicate during the unstable approach, largely contributed to the flight crew losing situational awareness and the decision by the captain not to initiate a go-around despite the first officer's suggestion.