Southwest

PARTY SUBMISSION OF SOUTHWEST AIRLINES CO. TO THE NATIONAL TRANSPORTATION SAFETY BOARD

SWA Flight 1380 Investigation
Philadelphia, PA
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DCA18MA142

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I. Introduction

A. Overview of Event

On April 17, 2018, Southwest Airlines (SWA) Flight 1380, a Boeing 737-700, registration number N772SW, experienced a fan blade liberation in a CFM-56-7B engine, Engine Serial Number (ESN) 875134 that resulted in an uncontained engine failure (referred to herein as "Flight 1380 Event"). Fragments from the engine inlet and cowling struck the wing and fuselage, resulting in a rapid depressurization after the loss of one passenger window. The flight crew conducted an emergency descent and diverted to land at Philadelphia (PHL).

A total of 5 crew members and 144 passengers (including a SWA employee occupying the aft jump seat) were on board. One passenger received fatal injuries. All crewmembers and passengers deplaned via air stairs. The airplane sustained substantial damage.

B. Prior Fan Blade Liberation Event in 2016

On August 27, 2016, SWA experienced another fan blade liberation event in a CFM-56-7B engine (ESN 874112) on SWA Flight 3472, a Boeing 737-700, registration number N766SW, which also resulted in an uncontained engine failure and depressurization (referred to herein as "2016 Fan Blade Event"). The flight departed from New Orleans (MSY) en route to Orlando (MCO) and landed safely at Pensacola (PNS). Debris struck the fuselage, causing cabin depressurization. The aircraft diverted course and landed at PNS without incident. There were 99 passengers, 1 lap child, and 5 crewmembers on board the incident flight; no injuries were reported.

II. Flight 1380 Factual Information

A. Operational Information

i. Flight 1380 Event

Flight 1380 had an on-time departure from LGA at 1030[1]. The first officer (FO) was the pilot-flying. The flight crew stated that nothing unusual occurred during the taxi, takeoff, and initial climb toward their cleared cruising altitude of flight level (FL) 380.

At 1103, at about 40.444° north latitude, 76.235° west longitude and shortly after passing through FL 320, Flight 1380 experienced a failure of the left CFM-56-7B engine (Engine 1). A fan blade was liberated from the failed engine and struck the engine inlet and cowling, causing portions of both to strike the wing and fuselage of the aircraft. The inlet cowl damage created by the fan blade fragments, combined with the displacement wave and flight loads on the inlet, caused the inlet lip, forward and aft bulkheads, and inner and outer barrels to depart the airplane. Fragments from the engine inlet and cowling struck the wing and fuselage. A fragment from the

[1] All times are Eastern Daylight Savings Time unless otherwise specified.

inboard fan cowl struck the fuselage and resulted in the loss of one cabin window and rapid depressurization of the aircraft. Pressure altitude at this time was about 32,648 ft. Engine 1 fan and core speeds decreased immediately after the event and Engine 1 vibration levels were elevated. The Engine 1 control recorded a flameout protection recovery mode active at 11:03:35 and remained in this mode until the engine 1 fuel switch position transitioned from Run to Cutoff at 11:04:09.

At the onset of the event, the flight crew noted a loud bang, significant aircraft vibration, and aircraft yaw and bank to the left. The cabin altitude warning light and horn (indicating cabin altitude of more than 10,000 ft) were activated almost immediately after the vibration began. The flight crew donned their oxygen masks. The FO rolled the airplane back to wings-level and began an emergency descent. About one minute later, the aircraft was descending through FL 307.

At 1104, the air traffic controller in communication with the flight (unaware of the situation) issued a clearance direct to VINSE waypoint. The controller reported hearing a response that contained only static. He also stated that he heard an alarm in the background. By 1105, the crew was able to communicate with the air traffic controller and reported an engine fire and that the aircraft was descending. The crew requested that air traffic control provide vectors to the nearest airport. The controller responded by issuing a heading of 250 degrees to the Harrisburg International Airport (MDT), Middletown, Pennsylvania. The crew then requested a destination of PHL. At 1106, after coordination with another controller, the controller in contact with the flight cleared it direct to PHL.

Shortly after the emergency descent began, the captain took control of the airplane and the FO assumed the duties of pilot monitoring, per SWA procedures. The FO began executing the *Engine Fire or Engine Severe Damage or Separation* checklist from the SWA B737NG Quick Reference Handbook (QRH). The crew reported that they completed the non-normal *Engine Fire or Engine Severe Damage or Separation* checklist. The pilots stated during their respective interviews that they were very busy controlling the plane and assessing the damage and did not have time to execute two other non-normal checklists, *Cabin Altitude Warning or Rapid Depressurization* (indicated by the cabin altitude warning light and horn), or *Emergency Descent* (required by step 5 of the *Cabin Altitude Warning or Rapid Depressurization* checklist). The pilots also stated that they completed the *Before Landing* checklist prior to landing at PHL.

ii. Flight Crew Experience

The Captain and FO held all required certifications and completed all appropriate training for the Boeing 737-700, including the successful completion of SWA's Federal Aviation Administration (FAA) approved Advanced Qualification Program (AQP).

The Captain had a total flying time of 11,715; total pilot-in-command time of 8,518; total Boeing 737 time of 10,513; and total Boeing 737 pilot-in-command time of 7,118. The Captain had been a pilot at SWA for 24 years; she had flown as a FO on the Boeing 737 until 2000 when she was promoted to Captain. Prior to flying for SWA, the Captain had flown A-7s and F-18s in the Navy, as well as forest fire support.

The FO had a total flying time of 9,508; total pilot-in-command time of 1,468; total second-in-command time of 8,039; including total Boeing 737 second-in-command time of 6,927. The FO had been employed by SWA for 10 years and two months, after having flown T-37, T-1, and E-3 aircraft in the Air Force.

iii. Flight Attendant Response

The three flight attendants on board Flight 1380 were trained at SWA University, which provides a 4-week training program covering a variety of topics, including company orientation, regulatory compliance, normal procedures, and emergency procedures. A non-flight attendant SWA employee was a passenger riding in the aft jump seat.

The three flight attendants and the SWA employee reported that they heard a loud sound and felt severe vibration at the inception of the Flight 1380 Event. At approximately 1103, when the decompression occurred, oxygen masks automatically deployed in the cabin. Two flight attendants (one who was in the forward lavatory and the other who was near row 5 taking drink orders) immediately went to the forward jump seat and sat down. They fastened their four-point restraints and put on the oxygen masks that had deployed from above the jump seat. The third flight attendant put on an oxygen mask near the aft jump seat.

The three flight attendants subsequently donned portable oxygen bottles and moved through the cabin to check on passengers and to assist passengers with their oxygen masks. One flight attendant saw a passenger in row 14 with her torso partially outside the broken window. The flight attendant attempted to pull the passenger back into the aircraft, but was unable to do so. Two male passengers then provided assistance and were able to pull the passenger back inside the aircraft. Two passengers subsequently began CPR on that passenger while one flight attendant went to retrieve the automated external defibrillator (AED). Another flight attendant called the flight crew to alert them of the passenger's condition and request additional medical assistance from qualified passengers.

Due to wind noise caused by the depressurization and the use of oxygen masks, the flight attendants had difficulty communicating with the flight crew and hearing P/A announcements.

For landing, one of the passengers in row 14 (who had been seated where the injured passenger was receiving medical attention) was, for the passenger's safety, moved to one of the two aft jump seats. The off-duty SWA employee was also seated in an aft jump seat and had been seated at the same location since takeoff. A flight attendant who had been assisting the injured passenger in row 14 sat on the floor of the aircraft near row 4 during landing because she did not have time to make it to her assigned forward jump seat. Another flight attendant also sat on the floor during landing. One flight attendant was in her assigned jump seat during landing. During the landing process, all three flight attendants shouted the commands "heads down, stay down."

At approximately 1120, approximately 17 minutes after cabin depressurization, the aircraft landed at PHL. The passengers assisting with medical assistance continued to stay with the injured passenger from row 14, conducting CPR compressions. Emergency response personnel then boarded the airplane and transported the fatally-injured passenger to the hospital.

B. Aircraft and Engine Information

i. Aircraft Information

The aircraft was a Boeing 737-700 (7H4) manufactured in 2000, which carried registration number N772SW and serial number 27880. It had 63,043 hours total flight time. There were no deferred maintenance items listed on the dispatch release for the Flight 1380 Event flight.

ii. Engine Description

The aircraft was equipped with two CFM56-7B engines, which is the engine installed on all Boeing Next Generation 737s (these include 737-600, 737-700, 737-800, 737-900, BBJ, and BBJ2 airplanes). The CFM56-7B, manufactured by CFM International (CFM), is a high bypass, dual-rotor, axial flow turbofan engine. The engine contains 24 solid titanium, wide-chord fan blades. The CFM56-7B engine first entered service in 1997. Since then it has accumulated more than 350 million flight hours. Approximately 14,000 CFM56-7B engines are in operation today.

The fan blades on the failed aircraft engine, the number one engine, were installed in the engine in September 2012. All 24 fan blades operated as a complete set from the time of first installation on another engine in March 2001. The blades were manufactured as part number (P/N) 340-001-026-0 blades, but were later changed to P/N 340-001-038-0, which had the dovetail profiles modified to prevent premature spalling and wear damage of the copper-nickel-indium alloy coating at the forward and aft ends of the contact faces.

The engine fan blade set on the number one engine had accumulated 32,636 engine cycles[2] since new; 18,088 hours since last shop visit; and 10,712 cycles since last shop visit. The last shop visit for the fan blade set occurred in November 2012 and was performed by Propulsion Technologies International, LLC (PTI), a Safran Aircraft Engines & GE Aviation Joint Company. At that time, the engine had accumulated 48,952 hours and 29,857 cycles.

iii. Aircraft Examination

Upon examination, it was determined that one of the 24 fan blades in Engine 1 on the Flight 1380 aircraft, fan blade No. 13, had fractured at the root of the fan blade and in the middle portion of the airfoil. The dovetail portion of the blade was retained within the fan disk, and the two airfoil pieces were recovered in the engine aft of the fan. The larger (inboard) airfoil piece had a fracture surface at the root-end that mated to the fracture surface on the dovetail piece. The remaining 23 blades showed impact damage resulting from the fractured (liberated) fan blade.

[2] As used herein, the term "cycle" is defined as one takeoff and landing.

The liberated fan blade fractured the engine inlet, and the forward portion of the inlet was missing upon landing at PHL. The lower, aft portion of the inboard fan cowl exhibited evidence of impact damage. The left side of the aircraft fuselage, the left wing leading edges, upper and lower surfaces, and the left side of the horizontal stabilizer exhibited evidence of impact damage. The impact damage consisted of surface scratching, skin gouging and penetrations, and blue and red paint transfer markings. The cowling structure that impacted the fuselage caused a small puncture to the fuselage skin just below the broken passenger window. The entire window (inner and outer panes, as well as the window seal) was missing and not recovered from inside the airplane or during the ground recovery of airplane debris.

C. 2016 Fan Blade Event

On August 2, 2016, at approximately 0922, while en route from MSY to MCO, Flight 3472 experienced an uncontained fan blade failure of the left engine (Engine 1) while at cruising altitude (FL 310) over the Gulf of Mexico, south of Gulfport, MS. The event resulted in a cabin depressurization. The oxygen masks were deployed, the pilots declared an emergency, and an in-flight shutdown of Engine 1 was performed. The airplane was diverted to PNS, where a single engine landing was performed.

The failed aircraft engine was a CFM56-7B series engine. At the time of the fan blade separation, Flight 3472's number one engine had accumulated 60,790 hours since new; 36,329 cycles since new; 30,237 hours since last shop visit, and 17,956 cycles since last shop visit. The last shop visit for the engine was a repair at GE Celma in August 2007. After completion of the engine repair, the engine was shipped back to SWA where it was installed on the Event airplane in engine position No. 1 (left) on October 17, 2007, where it remained until the 2016 Fan Blade Event.

The fan blade set had accumulated 62,851 hours since new; 38,152 cycles since new; 30,237 hours since last shop visit and 17,956 cycles since last shop visit. The event fan blade set was repaired in 2001 and again in 2007, both times at the GKN Aerospace facility in El Cajon, California.

Examination of Engine 1 revealed: (1) a single fan blade had fractured below the platform, and the entire airfoil and shank exited the engine and inlet and were not recovered; (2) the dovetail of the fractured blade remained secure within the fan disk; (3) the remainder of the fan blades remained in place and exhibited varying degrees of impact damage; (4) the fan case exhibited numerous impact marks and gouges, distortion, and loss of the seal material, but the case remained intact and exhibited no through-hole penetrations or uncontainments; and (5) no signs of an undercowl fire were observed.

Metallurgical examination of the event fan blades found that the fractured fan blade, identified as fan blade No. 23, had fractured due to a fatigue crack that initiated on the convex side of the blade root dovetail centered approximately 2.1 inches from the front face and near the outboard edge of the fan blade toward the blade tip. The fractured blade was originally manufactured as P/N 340-001-022-0 and was later modified to P/N 340-001-027-0. The copper-nickel-indium coating on the dovetail was missing and spalled in several locations on the convex side, most notably in an area adjacent to the fracture origin. Optical inspection of the fracture surface revealed several distinct crack arrest lines. No surface or material anomalies were noted during an examination of the fatigue crack origin using scanning electron microscopy and energy-dispersive x-ray spectroscopy.

III. SWA Maintenance Program Prior to 2016 Fan Blade Event

Prior to the 2016 Fan Blade Event: (a) fan blade inspection and maintenance was conducted by SWA starting in May 2000 as part of a repetitive blade lube/relube; and (b) fan blades were also inspected and repaired as part of the engine overhauls conducted every 20,000 cycles by the engine manufacturer.

This repetitive blade lube was required by SWA every 3,000 cycles or 5,000 flight hours, whichever occurred first. During the blade lube, a visual inspection of the copper-nickel-indium alloy coating was performed to assess the condition of the blade coating, (including assessing for nicks, dents, scratches, cracks, tears, and tip curl) and the dovetail was inspected for areas of missing coating from the contact face. Fan blade shims were also inspected for cracks, tears, punctures, scratches, nicks, dents, and distortion. The engine manufacturer had not developed any other type of inspection for cracks that could be performed by operators.

During engine overhaul, the fan blades were to be removed and sent to one of two facilities: GKN Aerospace/Chem-Tronics, Inc.'s facility in El Cajon, California; or PTI's facility in Miramar, Florida. The blade overhaul process included: stripping the dovetail coating from the blades, inspecting using fluorescent penetrant inspections (FPI); blending and repairing the airfoil leading edge as needed; shot peening of the entire blade; grit blasting the area of the dovetail to be coated; and recoating the dovetail contact faces with a copper-nickel-indium alloy coating followed by a cured dry-film lubricant. The FPI inspection process is a non-destructive test that utilizes fluorescent dye to reveal surface flaws in non-porous materials. Once applied, the liquid fluorescent dye seeps into small surface defects, which are then revealed under ultraviolet light. FPI techniques are used throughout the aviation industry and have many advantages: large and complex geometry parts can be inspected quickly, it is sensitive to small surface discontinuities, and flaw indications are visible without the need for magnification.

As part of this overhaul process, engine fan blades were sometimes removed from one engine and reinstalled on a different engine. Even though not required by the FAA or the engine manufacturer, on May 11, 2015, SWA proactively began to track fan blades on entry into service for purposes of implementing its fan blade maintenance program.

IV. Service Bulletins Following 2016 Fan Blade Event

The 2016 Fan Blade Event occurred on August 27, 2016. On September 12, 2016, the NTSB released an investigation update that identified the cause of the liberation as a fatigue crack in the fan blade.

Prior to the 2016 Fan Blade Event, the fan blades were inspected for cracks using an ultra-high sensitivity level 4 FPI during overhaul. Following the 2016 Fan Blade Event, CFM developed an eddy current inspection (ECI) procedure and specialized probes to inspect the blade dovetail; this ECI was in addition to the FPI as the FPI covers the entire blade not just the dovetail. ECI is a non-destructive test that utilizes electromagnetic induction to detect surface and subsurface anomalies in metal; this inspection method provides the highest level of sensitivity and is capable of detecting very small flaws in irregularly shaped parts. The ECI developed by CFM was a manual scan of the dovetail on both the concave and convex sides of the dovetail at overhaul and with the Cu-Ni-In coating removed. In November 2016, the ECI procedures were validated and CFM had gone to the various CFM56-7B fan blade overhaul shops to provide them training and tooling to perform the inspection. Also, in November 2016, the ESM TASK 72-01-200-01 Fan Rotor Blade – Inspection was changed to include the ECI inspection.

The NTSB and CFM also determined after the 2016 Fan Blade Event that cracks in the dovetail were masked by the Cu-Ni-In coating, making visual inspection for the presence of a crack ineffective. CFM, therefore, developed an ultrasonic inspection (UTI) technique that, because it could be performed with the coating on the dovetail, could be utilized in the field during fan blade relubes. UTI is a non-destructive test that utilizes high frequency sound waves to detect anomalies in a variety of materials. This inspection method is also capable of detecting very small surface and subsurface flaws. Similar to ECI, UTI involves a manual scan of the dovetail on both the concave and convex sides of the dovetail but the orientation of the scan is slightly different. The UTI scans from the bottom of the blade so that the coating does not interfere whereas the ECI scans at the interface of the root and dovetail and the coating must be removed first.

CFM issued two service bulletins, the first, SB 72-1019, on March 24, 2017, and the second, SB 72-1024, on July 28, 2017, calling for inspection of the fan blade root/dovetail pressure faces using UTI. The service bulletins prioritized inspection of fan blades on engines with higher cycles since last shop visit. At the time of the Flight 1380 Event, neither of the service bulletins called for inspection of the fan blades on Flight 1380's number one engine.

CFM56-7B SB 72-1019 called on operators to perform a one-time UTI inspection of fan blade root/dovetail pressure faces for cracks on fan blades with PNs 340-001-022-0, -026-0, -027-0, -028-0, -029-0, -036-0, -037-0, -038-0, and -039-0, installed on CFM56-7B engines. CFM recommended that the SB be performed as soon as possible without effect on revenue service based on engine cycles since last shop visit (CSLSV), in accordance with the following inspection plan:

- For engines that have accumulated more than 15,000 flight cycles (FC) since last shop visit at the issue date of this service bulletin, do this service bulletin not later than 6 months after the issue date of this service bulletin.
- For engines that have accumulated more than 12,000 FC since last shop visit at the issue date of this service bulletin, do this service bulletin not later than 12 months after the issue date of this service bulletin.
- For engines that have accumulated more than 9,000 FC since last shop visit at the issue date of this service bulletin, do this service bulletin not later than 18 months after the issue date of this service bulletin.

On June 20, 2017, CFM issued SB 72-1019 Revision 1, which removed the 12-month and 18-month compliance sections and maintained only the first set of inspections on engines that had accumulated more than 15,000 flight cycles since last shop visit.

On July 28, 2017, CFM issued SB 72-1024. It called for UTI on fan blade PNs 340-001-022-0, -027-0, -029-0, -037-0, and -039-0 (fan blades that were modified from the PN -022-0), installed on CFM56-7B engines as soon as possible and no later than December 31, 2018. The significant difference between SB 72-1019 and 72-1024 are that: (1) SB 1024 does not apply to new production blades introduced by SB 72-0253 or later modified; and (2) unlike SB 72-1019 revision 1, which required inspection of engines within six months based on having more than 15,000 flight cycles since last shop visit, SB 72-1024 required those fan blade PNs listed be inspected within 18 months regardless of FC or CSLSV.

V. Southwest's Role Following 2016 Fan Blade Event

SWA proactively assisted CFM in developing and implementing a program to test and inspect engine fan blades for fatigue cracking. Between September 2016 and November 2016, SWA removed 480 fan blades (20 full sets of engine blades.) All 480 fan blades were sent to GE for ECI testing as part of the off-wing inspection process. As part of this process, GE completed the following: cleaning of blades; removal of coating; ECI inspection; reapplication of coating; and blade returned for use on same engine if determined to be usable by engine manufacturer. This testing/inspection did not identify cracks in any of the 480 inspected fan blades.

On October 26-27, 2016, SWA engaged with GE to prototype on-wing ultrasonic inspection (UTI) procedures on two CFM56-7B engines at MCO (ESN #896240, ESN #875252). The prototype testing did not detect cracks on any of the fan blades. SWA worked throughout December 2016 to assist CFM in developing and implementing training and necessary tooling to conduct future UTI inspections.

SWA began conducting UTI inspections as part of the fan blade lube process in early January 2017, over three months prior to the issuance of SB 72-1019. Specifically, beginning on January 4, 2017 and over the course of the next ten months, through October 12, 2017, SWA inspected the fan blades from 243 engines. SWA worked with CFM to identify an appropriate engine testing population for its inspection program that was based on fan blade manufacture date. Engine fan blades with higher fan blade cycles were identified for initial inspection. The fan blade lube/UTI inspection process was conducted by SWA and consisted of the following: removal of front spinner cone and front fan blades; visual inspection for obvious signs of wear or damage; ultrasonic inspection performed at the blade root prior to lubrication; and, after reinstallation the engine is run to ensure the absence of vibrations. As a result of this inspection process, SWA identified one cracked fan blade, on ESN #892439.

On August 25, 2017, the FAA issued a Notice of Proposed Rulemaking (NPRM) to propose a mandatory inspection of fan blades in accordance with the CFM SBs. Under the NPRM, the FAA proposed an AD that would: (a) direct UTI to be conducted within six months of the issuance of the AD for fan blades with any P/N on engines with more than 15,000 cycles since last shop visit; and (b) direct UTI inspection within the sooner of 18 months of the issuance of the AD or at next fan blade lubrication for fan blades with certain specified P/Ns on engines with fewer than 15,000 cycles.

SWA submitted comments in response to the NPRM in which SWA recommended the following: (a) counting any inspections previously conducted in accordance with SB 72-1019 toward the inspection requirement and not requiring re-inspection; (b) requiring inspections every 3,000 cycles regardless of P/N because operators are not required to track fan blade P/Ns; and (c) allowing 18 months to complete inspections, which would encompass 100% of SWA's fleet and not be limited to only the 22% of SWA's fleet that was subject to the proposed AD or CFM service bulletins.

On December 10, 2017, SWA formally enhanced its existing maintenance program to require recurring UTI at fan blade lubrication, every 3,000 cycles. SWA committed to complete the inspection of all fan blades within the entire SWA fleet, totaling approximately 35,500 fan blades, over the next 18 months, except that any fan blades subject to SB 72-1024 that had not yet been inspected would be inspected no later than December 31, 2018. Between December 10, 2017 and April 17, 2018, SWA completed UTI inspections of 302 engines, identifying no cracking on any inspected fan blades. A total of 44 of the 302 engines that had been previously inspected, were re-inspected as part of the revised inspection program. An additional 130 engines were also inspected with ECI during overhaul. SWA estimates that approximately 17,000 fan blades (on-wing blades and off-wing spares) were inspected between the 2016 event and the Flight 1380 event.

On the Flight 1380 Event engine, the fan blades and shims were lubricated 7 times after the last blade overhaul, which was performed in November 2012. The number of flight cycles between the last 7 fan blade lubrication applications (earliest to latest) were: 1,392 cycles, 1,255 cycles, 1,265 cycles, 1,412 cycles, 98 cycles, 1,385 cycles, and 2,201 cycles. At the time of the Event, the fan blades on the Flight 1380 engine had 1,704 cycles since the last lubrication. The Flight 1380 Event engine fan blades were not subject to or required to be inspected under any SBs or FAA airworthiness directives prior to the date of the Event.

VI. SWA Actions Following Flight 1380 Event

SWA committed under its enhanced inspection program to conduct UTI inspections of engine fan blades every 3,000 cycles. Prior to the Flight 1380 Event, SWA completed a total of 603 CFM56-7B engine blade inspections. SWA identified an additional 502 engines installed on 737-700 aircraft that were scheduled to be inspected under the enhanced inspection program, but were not yet completed, including the Flight 1380 Event engine (ESN #875134). The Flight 1380 Event engine was not recommended or required to be inspected under any of the existing CFM SBs or the FAA's *proposed* AD, which had been proposed in August 2017 but remained unissued at the time of the Flight 1380 Event.

Following the Flight 1380 Event, on April 20, 2018, CFM released SB 72-1033, which, for engines with greater than 30,000 cycles since new, recommended that UTI be performed within 20 days after the issuance of the SB. For engines with fewer than 30,000 cycles since new, the SB recommended: (a) for fan blades with known cycles, UTI is to occur the earlier of no later than 20,000 cycles since new or by August 31, 2018; and (b) for fan blades with unknown cycles, UTI is to occur no later than August 31, 2018. SB 72-1033 further provided that, after initial inspections, recurring inspections were to be performed every 3,000 cycles, which was already included in the SWA inspection program. The SB also recommended that replacement fan blades be inspected before being installed on engines unless the fan blades are known to have less than 20,000 cycles since new or fewer than 3,000 cycles since last inspection.

Also, on April 20, 2018, the FAA issued Emergency Airworthiness Directive (EAD) 2018-09-51, which required one-time UTI inspections for all engines with more than 30,000 cycles since new, to be completed by May 10, 2018, with credit for prior inspections. Unlike SB 72-1033, the EAD did not require recurring inspections or UTI inspections on engines with fewer than 30,000 cycles since new. If any crack indications were found, the EAD required that the affected fan blades be removed from service before further flight.

On April 21, 2018, and in response to the Flight 1380 Event, SWA accelerated its inspection program for the remaining CFM56-7B engines to require that all replacement fan blades be inspected before installation on any engine. This requirement applied to engines undergoing inspections under the enhanced inspection program, as well as inspections that occur in the normal course of service.

On April 23, 2018, and only three days after the EAD was issued, SWA completed inspections of all fan blades requiring inspection by EAD 2018-09-51. In addition, as part of its enhanced inspection program, SWA planned to complete the inspection of all fan blades within its entire fleet by mid-2019, except any fan blades subject to SB 72-1024 that had not yet been inspected would be inspected no later than December 31, 2018.

On May 2, 2018, the FAA issued AD 2018-09-10 for all CFM model CFM56-7B engines. AD 2018-09-10 required initial and repetitive inspections of the concave and convex sides of the fan blade dovetail to detect cracking and replacement of any blades found cracked. The AD was superseded by AD 2018-10-11, which was issued by the FAA on May 17, 2018 to require a UTI or ECI of the concave and convex sides of the fan blade dovetail as follows: (i) within 30 days of June 1, 2018, perform an initial inspection of the fan blades identified using paragraph 1.C.2.(a), 1.C.2.(b), or 1.C.2.(c), of CFM SB CFM56-7B S/B 72-1033, Revision 01, dated May 9, 2018; (ii) for all other fan blades not required to be inspected within the 30 day requirement, perform an initial inspection prior to accumulating 20,000 cycles on the fan blade or within 90 days of June 1, 2018, whichever occurs later; and (iii) thereafter, repeat this inspection no later than 3,000 cycles since the last inspection.

By May 17, 2018, SWA completed inspections of all fan blades within its entire fleet. CFM subsequently communicated to SWA that it intended to revise SB 72-1033 to reduce the repetitive UTI inspection interval from 3000 cycles to 1600 cycles. In response to that information, on June 4, 2018, SWA proactively accelerated recurrent fan blade lubes/UTI inspections to reduce the UTI inspection interval to 1600 cycles.

Seven weeks later, on July 27, 2018, CFM issued SB 72-1033 Rev. 2, recommending a UTI of engine fan blades every 1600 cycles. Subsequently, on October 2, 2018, the FAA issued AD 2018-18-01 formalizing the requirement that airlines conduct a UTI of engine fan blades every 1600 cycles.

Less than one week after CFM issued SB 72-1033 Rev. 2, and two months before AD 2018-18-01 was issued by the FAA, SWA completed the UTI inspection of all SWA fan blades within 1600 cycles on August 2, 2018. SWA continues to implement this 1600-cycle fan blade inspection program.

VII. Analysis

A. SWA Actions Following the 2016 Fan Blade Event were Proactive and Appropriate

The proactive inspection programs implemented by SWA following the 2016 Fan Blade Event exceeded the requirements of CFM's SBs and the FAA's ADs:

- Between September 2016 and November 2016, SWA submitted 480 fan blades to the engine manufacturer for ECI in lieu of FPI in order to employ testing using the highest available level of sensitivity and to detect any potential fatigue cracking. Such activities were not required under any applicable SB or AD in place at the time.

- As part of its enhanced inspection program, SWA inspected 243 engines using UTI between January and October 12, 2017. Such inspections were initiated over three months before CFM issued its first SB on this issue, SB 72-1019. The inspections resulted in the removal of 22 fan blades, and the identification of one cracked fan blade. The inspections were not recommended or required under any applicable SB or AD in place at the time.

- On December 10, 2017, SWA enhanced its maintenance program to require recurring UTI at fan blade lubrication events, regardless of SB or AD applicability, at least every 3,000 cycles for its entire fleet (approximately 35,500 fan blades). This commitment was broader than the inspections recommended under SB 72-1024, which targeted only specific P/Ns. This commitment also encompassed fan blades that were identified for inspection in the FAA's proposed AD, which was never issued.

- SWA committed over the next 18 months to complete the inspection of all fan blades within the entire SWA fleet, totaling approximately 35,500 fan blades, except that any fan blades subject to SB 72-1024 that had not yet been inspected would be inspected no later than December 31, 2018. Between December 10, 2017 and April 17, 2018, SWA completed UTI inspections of 302 engines, identifying no cracking on any inspected fan blades. A total of 44 of the 302 engines had been previously inspected, but were re-inspected as part of the revised inspection program. SWA estimates that approximately 17,000 fan blades (on-wing blades and off-wing spares) were inspected between the 2016 event and the Flight 1380 event.

- None of the fan blades on the failed Flight 1380 engine were recommended or required to be inspected under the SBs in effect at the time or by the FAA's proposed AD. At the visual inspection during the last lubrication event (on June 21, 2017), the crack would not have been detectable by visual inspection.

B. <u>Post-Flight 1380 Event Actions were Proactive and Appropriate</u>

The proactive inspection programs implemented by SWA following the Flight 1380 Event exceeded CFM SBs and FAA ADs, as follows:

- The Flight 1380 Event engine was scheduled to be inspected as part of SWA's enhanced inspection program, but was not required to be inspected prior to the time of the Event under any SB or AD.

- Immediately following the Event, on April 21, 2018, SWA accelerated its inspection program for the remaining CFM56-7B engines and, by May 1, 2018, two weeks after the Flight 1380 Event, completed the inspection of an additional 502 CFM56-7B engines.

- On June 4, 2018, SWA accelerated recurrent fan blade lubes/inspections to reduce the UTI inspection interval to 1600 cycles, well before the requirement was implemented by SB 72-1033 Rev. 2 and AD 2018-18-01.

- SWA completed inspection of all fan blades with 1600 cycles on August 2, 2018, just after SB 72-1033 Rev. 2 was issued and two months before AD 2018-18-01 was issued by the FAA.

C. <u>Actions of the Flight 1380 Flight Attendants were Appropriate</u>

The flight attendants acted appropriately during the emergency landing of Flight 1380. Immediately upon cabin depressurization, the flight attendants donned oxygen masks that had fallen automatically to provide for their own receipt of oxygen and ability to assist passengers. The flight attendants exchanged their oxygen masks for portable oxygen bottles that allowed them to get up, walk through the cabin, and assess and assist passengers.

Two complicating factors then arose, to which the flight attendants responded appropriately. First, due to the cabin depressurization and damaged fuselage, the flight attendants had extreme difficulty communicating with each other, passengers, and the pilots due to wind noise, vibration and the use of portable oxygen bottles. Second, a passenger in row 14, while seated with her lapbelt secured, was pulled partially out of the aircraft window. The passenger presented a medical emergency that required extensive attention for the duration of the flight, not only to attend to the injured passenger, but to also calm and attend to the other surrounding passengers.

A flight attendant attempted to pull the passenger back into the aircraft, but was unable to do so. Two male passengers then provided assistance and were able to pull the passenger back inside the aircraft. While passengers began to provide the injured passenger with medical assistance (CPR), one flight attendant went to secure the AED and another flight attendant notified the pilot to seek additional medical assistance from qualified passengers. From this time onward, for the duration of the flight, row 14 could not be used to accommodate passengers.

The pilots issued a P/A announcement to alert the passengers and flight attendants to the intended emergency landing at PHL. The flight attendants verified that each passenger was seated and secured in a lapbelt, as available and/or appropriate. In performing these emergency duties, two flight attendants did not make it to their assigned jump seat for landing. Both sat on the floor, one braced with the help of passengers. Under the emergency conditions faced by the flight attendants, their choice of seat during landing was appropriate to protect the safety of passengers, especially given the fact that first responders were available to attend to passengers upon landing.

VIII. Findings and Conclusions

1. A fatigue crack in a fan blade of the CFM56-7B engine of the Event aircraft resulted in the liberation of that blade, causing an uncontained engine failure.
2. The engine fan blade was liberated from the failed engine and struck the engine inlet and cowling, causing portions of both to strike the wing and fuselage of the aircraft.
3. The inlet cowl damage created by the fan blade fragments, combined with the displacement wave and flight loads on the inlet, caused the inlet lip, forward and aft bulkheads, and inner and outer barrels to depart the airplane.
4. Fragments from the engine inlet and cowling struck the wing and fuselage.
5. A fragment from the inboard fan cowl struck the fuselage and resulted in the loss of one cabin window and rapid depressurization of the aircraft.
6. Prior to the Flight 1380 Event, SWA had implemented an extensive and rigorous inspection protocol to inspect all CFM56 fan blades in its entire fleet.
7. Prior to the Event, the fan blades on the subject CFM56-7B engine had been inspected in accordance with SWA's FAA-approved maintenance program.
8. No additional fan blade inspections were required to be performed under SWA's maintenance program, CFM's SBs, or any issued or proposed FAA ADs on the subject CFM56-7B.
9. Based on the inspections conducted on the Flight 1380 engine fan blades, no information existed from those inspections to call into question the condition of the liberated fan blade prior to the date of the Event.
10. SWA was proactive in addressing fan blade maintenance and inspections both before and after the Flight 1380 Event.
11. The flight attendants acted appropriately in an emergency situation to provide medical attention and attend to the other passengers.
12. Given the emergency situation, two flight attendants did not make it to their assigned jump seats but assumed a brace position for their own safety.