Collins Aerospace

Collins Aerospace Systems
Submission to the
National Transportation Safety Board

Southwest 737NG-700 – SWA 1380
Fan Blade Out Engine Failure
April 17, 2018
DCA18MA142

July 19, 2019

Collins Aerospace Systems (Collins) submits this report in support of the National Transportation Safety Board's (NTSB) investigation of the accident involving Southwest Airlines Flight SWA 1380 en route from LaGuardia Airport, Queens, NY, to Dallas Love Field, Dallas, TX, on April 17, 2018.

As established by the NTSB, the subject aircraft experienced a fan blade out engine failure in the left engine that then caused the loss of portions of the engine inlet and fan cowl. A portion of the fan cowl struck the fuselage. Subsequently, a window in proximity of where the fuselage was struck departed, causing a rapid depressurization.[1] The flight crew conducted an emergency descent and diverted into Philadelphia International Airport, Philadelphia, PA. Of the 144 passengers and five crew members onboard, one passenger received fatal injuries and eight passengers received minor injuries.

Collins supplies the engine inlet and fan cowl to The Boeing Company (Boeing) in accordance with Boeing's design specifications. As supplier of the inlet and fan cowl, Collins was named a party to the NTSB's investigation, has supported the NTSB and the other parties throughout the investigation and participated in the NTSB's public hearing on November 14, 2018.

The NTSB, assisted by local and federal law enforcement and the public, was able to recover large parts of the inlet and fan cowl hardware. Collins estimates that approximately 80-90% of the relevant hardware was recovered. Under the NTSB's supervision, Collins reconstructed the hardware in its laboratory at its facility in Chula Vista, CA, to enable the NTSB to conduct a thorough investigation of root cause and develop recommended corrective action(s).

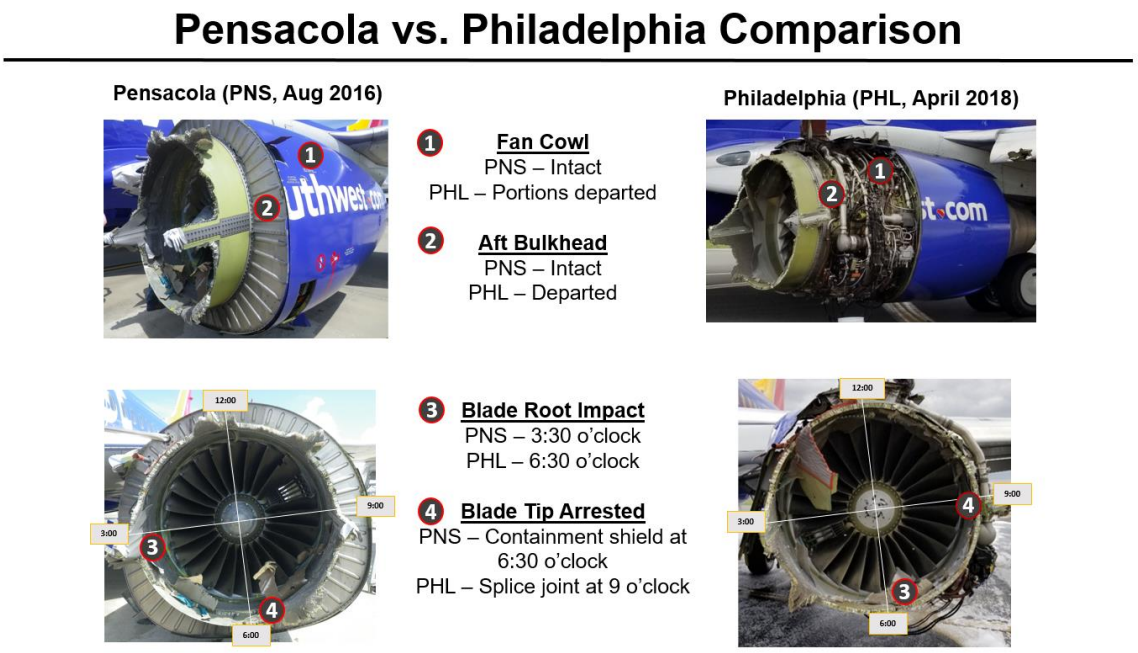
This report summarizes Collins' key findings of the investigation, including probable cause and appropriate recommendations.

[1] Against this background, Collins respectfully submits that the description of the course of events as "*[f]ragments from the cowling and engine inlet struck the fuselage and a window*" (March 27, 2019, Testimony of the NTSB's Chairman before the Senate Committee on Commerce, Science and Transportation [emphasis added]) is inconsistent with the evidence as established by the NTSB.

SUMMARY

Prior to the Philadelphia event, a similar event took place on another SWA B737NG-700. On August 27, 2016, SWA 3472, en route from New Orleans, LA, to Orlando, FL, also experienced a fan blade out event in which the fan cowl stayed intact and the engine inlet's containment shield performed its intended function. The flight crew diverted to Pensacola International Airport, Pensacola, FL (NTSB# DCA16FA217). Similar to the Philadelphia event, the NTSB requested that Collins reconstruct the hardware remaining on the aircraft in its laboratory. Collins' analysis and findings in the Philadelphia event are facilitated and informed by its findings in the Pensacola event.

Importantly, in the Pensacola event, the fan cowl stayed intact. Debris struck the fuselage, causing a slow depressurization. In both Philadelphia and Pensacola events, the engine inlet's containment shield[2] performed its intended function as it was not penetrated in either event.[3] Both fan blade out engine failures occurred at comparable altitude, aircraft speed and engine power setting. The following compares the Philadelphia and Pensacola engine failures.[4]



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2 For an overview of the evolution of Boeing's design requirements for the engine inlet, see UTC Aerospace Systems November 14, 2018 Supporting Material, Ref. 4, p.2-6.

3 In addition, Collins is aware of at least two bird strike events in 2003 and 2009, respectively, where the engine inlet's containment shield performed its intended function.

4 UTC Aerospace Systems November 14, 2018 Supporting Material, Ref. 4, p.9.

The fan blade out engine failure on SWA1380 resulted in physical and kinematic load and other characteristics beyond Boeing's design specifications, causing an uncontained release of engine and nacelle debris. The fan blade out event on SWA1380 imparted more energy into the inlet and fan cowl than Boeing's design specifications. Fan blade fragments entered the engine inlet with quantities, trajectories, velocities and total mass that exceeded Boeing's specifications.

In 1995, Boeing defined specifications that required a containment shield be added to the engine inlet to ensure that a single forward spiraling blade fragment resulting from a fan blade out engine failure would not cause structural damage to the inlet. Specifically, Boeing defined these requirements as (i) one specifically defined (dimensioned) blade fragment (tip) spiraling into the inlet, (ii) having a weight of approximately two pounds, (iii) at a speed of around 600 mph, and (iv) a trajectory (helix) angle of up to 15 degrees.[5]

In the SWA1380 event (Philadelphia),[6] (i) at least four blade fragments spiraled forward, (ii) having a calculated weight of approximately 2.6 pounds, and (iii) with a trajectory greater than 15 degrees (the tip's angle was between 20 and, as determined by Collins, 30 degrees, while the mid fragments' angles were between 19 to 34 degrees).[7] In addition to at least four blade fragments spiraling forward, Collins found evidence that one fan blade platform (weighing approximately 0.7 pounds) also spiraled into the inlet. The fan blade platform (or "spacer") is an insert that is shaped and dimensioned to span the gap between two adjacent fan blades. The platform has not been recovered and Collins recommends further analysis in this regard, as detailed below.

Similarly, the load imparted into the fan cowl through the radial restraint fitting, due to the blade root impact on the fan case at the 6:30 position, and the attendant displacement wave, exceeded Boeing's specifications. In fact, in 1995, when Boeing established the specifications, the phenomenon of the "*displacement wave*" was not yet fully understood and not accounted for in the specifications.[8]

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5 UTC Aerospace Systems November 14, 2018 Supporting Material, Ref. 4, p.4.

6 In the Pensacola fan blade out engine failure, all liberated portions of the fan blade spiraled forward into the inlet, including (i) at least four blade fragments, (ii) having a total calculated weight of approximately 10 pounds, and (iii) with a wide range of trajectories (the tip's angle was between 14 and, as determined by Collins, 30 degrees while the mid and root fragments' angles were between 6 to 37 degrees). As in the Philadelphia event, the fan blade platform was not recovered in the Pensacola event but is believed to have spiraled forward into the engine inlet.

7 Collins did not determine exact fragment speeds but estimates that the fragments' velocity was approximately 600 mph, based on engine RPM at liberation.

8 "*… [A]t that time frame, our analytical capabilities of understanding what the displacement wave was, was not understood from the analysis side*." (November 14, 2018, Testimony of The Boeing Company).

KEY FINDINGS

The following is an overview of Collins' key findings resulting from its support of the NTSB's investigation of the Philadelphia event.

Pertaining to the engine inlet:

- Multiple tip/mid blade fragments spiraled forward into the inlet and caused damage forward of the containment shield, resulting in approximately 180° of inlet inner barrel damage and departure of a portion of the forward section of the inlet (Ref. 5, p.5). The inlet inner barrel is a key component of the inlet required to maintain its structural integrity.
- Blade debris spiraling forward of the engine inlet A-flange exceeded Boeing's design specifications concerning blade fragment quantity, total fragment weight, and trajectory angle as shown by the following table.

	Number of Blade Fragments Spiraling Into Inlet	Total Fragment Weight (lbs.)	Trajectory Angle	Speed
Boeing Design Specification	1 (of defined size)	~2.0	15°	~600 mph
PNS (SW 3472)	>4 (including root) + Platform	~10. 0 + Platform: ~0.7	Tip: 14°* -- 30°** Mids*: 6°-37°	Not determined but approximated to be ~600 mph based on engine RPM at liberation
PHL (SW 1380)	4 + Platform	~2.6 + Platform: ~0.7	Tip: 20°* – 30°** Mids*: 19°-34°	

* CFM trajectory assessment (Ref. 6).
** Collins determined that the tip trajectory angles were up to 30 degrees (Ref. 5).

- The containment shield performed its intended function and was not penetrated (Ref. 1, p.27).
- Embedded titanium particles on the damaged surfaces of the inner and outer barrel align with evidence of blade trajectories (Ref. 5, p.9).
- A fan blade platform was released and not recovered. There is evidence it also spiraled forward into the inlet causing additional damage forward of the containment shield (Ref. 5, p.55-61).
- Inlet inner barrel back skin fracture surface exhibited ductile overload characteristics caused by fan blade debris (Ref. 5).

Pertaining to the fan cowl:

- Fan blade root impact at 6:30 was severe enough to cause a large through-crack in the fan case (Ref. 1, p.39).
- In addition, Boeing's design did not account for the attendant displacement wave, as it was not fully understood at the time (Ref. 3, p.13).

RECOMMENDATIONS

Risk assessment pursuant to FAA AC39-8. Collins respectfully recommends that a risk assessment be performed, consistent with FAA AC39-8, Continued Airworthiness Assessments of Powerplants and APU Installations of Transport Category Airplanes, and that effective risk mitigation actions be implemented in coordination with the regulatory agencies for aircraft powered by CFM56-7B engines to prevent future occurrences of engine inlet or fan cowl parts departing the aircraft following a fan blade out event.

Further analysis concerning the departure of the window. Collins respectfully recommends that further analysis be conducted concerning the root cause of the window's departure. The NTSB's investigation did not establish conclusively that any portion of the fan cowl struck the window and directly caused the window's departure. This also contrasts with the Pensacola event, where debris struck the fuselage near a window, yet that window did not depart. At this stage of the investigation, it is unclear why the window departed in the Philadelphia event and therefore, further analysis should be conducted.

Further analysis concerning missing fan blade platform. Collins respectfully recommends that further analysis be conducted concerning the missing fan blade platform in both the Philadelphia and Pensacola events. The platform was not recovered in either case and it is likely that in both events, the platform spiraled forward into the inlet. On the hardware involved in the Philadelphia event, Collins found evidence that a fan blade platform (Ref. 2), weighing approximately 0.7 lbs., and approximately 10" long, 2.5" wide and 2" deep, spiraled forward into the inlet and caused additional damage to the inner barrel and possibly outer barrel (Ref. 5). Collins has found evidence of zinc, a component of 7000 series aluminum (the platform material), in several locations on the fracture surfaces of the inner barrel. (The only other 7000 series aluminum within the inlet is the attach ring, which stayed attached to the fan case and thus could not have been a source of zinc).

REFERENCES

1. Powerplant Group Chairman's Factual Report, NTSB No DCA18MA142, NTSB, November 12, 2018 (DCA18MA142 Docket Item: 8-A Powerplant Group Chairman's Factual Report).

2. Materials Laboratory Factual Report, 18-049, NTSB No DCA18MA142, NTSB, October 25, 2018 (DCA18MA142 Docket Item: 15 - Materials Laboratory Factual Report 18-049).

3. Structures Group Chairman's Factual Report, NTSB No DCA18MA142, NTSB, June 21, 2019 (DCA18MA142 Docket Item: 7 - Structures Report 2 Tech Review Version).

4. NTSB Public Hearing Supporting Material, NTSB No DCA18MA142, Collins, November 14, 2018 (DCA18MA142 Docket Item: 7-C UTAS Supporting Documentation).

5. Fan Blade Fragment Trajectories and Inlet Damage, Collins Aerospace, April 18, 2019 (DCA18MA142 Docket Item: 7 - Report from Party - Collins).

6. CFM presentation Fan blades fragments trajectories and Philadelphia inlet damage assessment, CFM, March 29th, 2019 (DCA18MA142 Docket Item: 7 - Report from Party - CFM).