June 18, 2025 Aviation Investigation Report AIR-25-03

Mitigations Concerning Load Reduction Device Activation in CFM International LEAP-1B Engines

Introduction

The National Transportation Safety Board (NTSB) is providing the following information to urge the Federal Aviation Administration (FAA), the European Union Aviation Safety Agency (EASA), the Civil Aviation Administration of China (CAAC), CFM International, and Boeing to take action on safety recommendations in this report. These recommendations address the potential for smoke to enter the cockpit or cabin after activation of the load reduction device (LRD) resulting from an engine blade failure or imbalance on CFM LEAP-1B engines and pilot awareness about what to do if this occurs.[1] We identified this issue during our ongoing investigation of an incident involving Southwest Airlines flight 554, a Boeing 737-8, in which smoke filled the cockpit after a bird was ingested into the left (No. 1) engine, a CFM LEAP-1B. The NTSB is issuing an urgent safety recommendation to the FAA. In addition, we are issuing two safety recommendations to the FAA and EASA and one safety recommendation each to Boeing, CFM International, and the CAAC.

Background and Analysis

On December 20, 2023, about 1414 central standard time, Southwest Airlines flight 554, a Boeing 737-8, was departing from Louis Armstrong New Orleans International Airport (MSY), Kenner, Louisiana, when a bird was ingested into the left (No. 1) engine, a CFM International LEAP-1B, during the initial climb (figure 1 shows damage to the engine).[2] The flight crew reported that, after an uneventful takeoff and while climbing through about 1,000 ft, the first officer (FO), who was the pilot monitoring, heard the captain say "bird." This statement was followed immediately by

[1] CFM International is a joint venture between GE Aerospace and Safran Aircraft Engines. The LEAP-1B engine received joint type certification from the FAA and EASA in 2016.

[2] Visit ntsb.gov to find additional information for this NTSB investigation (case number DCA24LA330). Use the CAROL Query to search safety recommendations and investigations.

a “thump” on the left side of the airplane. The flight crew reported that the airplane began to “shake violently with a distinct loss of thrust” in the No. 1 engine.

Figure 1. Close-up photo of damage to the left engine. (Source: Southwest Airlines)

The captain called for the Engine Fire or Engine Severe Damage or Separation checklist in the Quick Reference Card (QRC). After the FO started the checklist, the flight deck filled with “acrid white smoke”; the FO later stated that he could not clearly see the captain. The FO called out “masks” and the pilots donned their masks and resumed the checklist.

The flight crew declared an emergency to air traffic control and asked airport rescue and firefighting to “roll the trucks.” The captain stated that visibility in the cockpit was restricted and that he could see nothing beyond the FO. The captain also stated that his instrument panel was difficult to see, so he thought he might need to fly the airplane solely using the head-up guidance system.[3] However, after the FO

[3] The head-up guidance system is only on the captain’s side of the cockpit but contains all necessary information to fly the airplane. If the cockpit is so full of smoke that the pilot flying cannot see the instrumentation, the head-up guidance system may be the only source of information.

pulled the engine fire switch as directed by the QRC, the smoke began to rapidly dissipate.

The flight crew notified the flight attendants about the emergency and made a public address announcement to passengers that fire trucks would be meeting the airplane. After landing at MSY, the airplane came to a full stop on the arrival runway. After inspecting the airplane, the firefighters found no evidence of a fire. The flight crew was cleared to taxi the airplane to the assigned gate and passengers deplaned normally without further incident. None of the 139 occupants aboard the airplane were injured, and the airplane sustained minor damage. The flight was operating under the provisions of Title 14 *Code of Federal Regulations* Part 121 as a scheduled domestic passenger flight from MSY to Tampa International Airport, Tampa, Florida.

According to the regulations requiring immediate reporting to the NTSB (at Title 49 *Code of Federal Regulations* 830.5, Immediate Notification), Southwest Airlines was not required to report the incident.[4] Once informed by the FAA in November 2024 about its ongoing investigation of the incident, and, in learning of similarities to a March 2023 event in Havana, Cuba, the NTSB began an incident investigation.[5] Preliminary findings from our ongoing investigation indicate that smoke entered the cockpit as a result of the activation of the LRD, an engine system

[4] Among the events requiring immediate NTSB notification is "failure of an internal turbine engine component that results in the escape of debris other than out the exhaust path." Since this incident involved engine oil (which caused smoke) and not debris, it did not meet this notification requirement. Another criterion for reporting is “in-flight fire,” but no fire was involved in this event, only smoke.

[5] On March 5, 2023, Southwest Airlines flight 3923 struck birds, damaging the right engine, shortly after departure from Jose Marti International Airport, Havana, Cuba; the incident is discussed later in this report. The lead investigative authority for this incident is the Instituto de Aeronáutica Civil de Cuba (IACC). In accordance with the provisions of Annex 13 to the International Civil Aviation Organization, the NTSB is participating in the investigation as an accredited representative for the State of Manufacture, Design, Operator and Registry. As of the date of this report, the IACC has not issued a final report for the Havana event.

design feature on CFM International LEAP-1B engines. The LRD minimizes aircraft and engine damage during a fan blade failure or significant fan blade imbalance by reducing the severity of the vibration transmitted from the damaged engine to the airframe (see figure 2). The LRD does this by enabling the fan to be partially mechanically disconnected from the turbomachinery. As a mechanical design feature, the LRD does not require pilot intervention to activate.

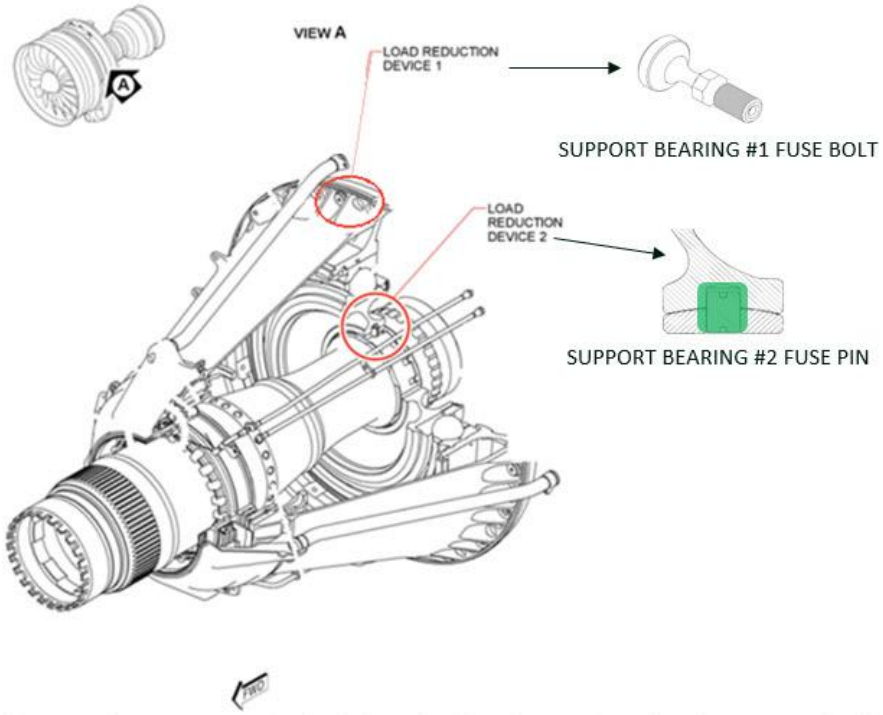

Figure 2. The location of the LRD on the LEAP-1B engine. (Source: CFM)

Activation of the LRD in the MSY event caused tubes supplying oil to the engine sump to become dislodged and the flange from the sump area to open, which allowed oil to enter the core compressor upstream of the pneumatic bleed ports that supply bleed air to the cabin and cockpit.[6] The oil was exposed to high temperatures and resulted in smoke and fumes that were then fed into the cockpit.[7] When the FO pulled the engine fire switch, the smoke quickly dissipated because its

[6] The high-pressure bleed air is bled from the engine to ensure an adequate cabin pressurization level.

[7] Conditioned air (bleed air) from the left air conditioning pack (supplied by the left engine) is normally distributed to the flight deck. Conditioned air from the right air conditioning pack (supplied by the right engine), excess air from the left air conditioning pack, and recirculated air are combined in the mixing manifold and distributed to the cabin. In this incident, smoke entered the cockpit because the left engine of the airplane was damaged. In the Havana incident, smoke entered the cabin because the right engine was damaged.

point of access, the pressure regulating shutoff valve (PRSOV), automatically closed.[8] Each engine has a PRSOV that, when closed, prevents bleed air from entering the airplane (see figure 3).

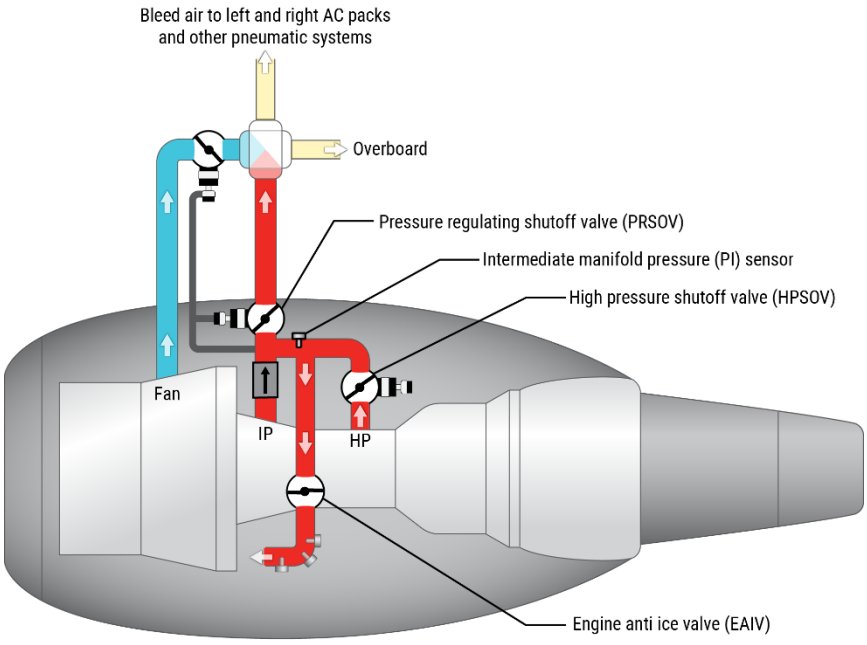

Figure 3. Simplified engine bleed air diagram with PRSOV depicted. (Image Copyright © Boeing. Reprinted with permission.)

Boeing released a flight crew operations manual (FCOM) bulletin on February 9, 2024, that described the results of the bird ingestion in the MSY incident and the actions a flight crew should take if they experience a similar incident. Boeing also updated the system description in the Boeing 737-8 FCOM on November 15, 2024, and the quick reference handbook (QRH) on November 30, 2024, to include engine failure with smoke or fumes in the flight deck or cabin as a condition to trigger reference to the Engine Fire or Engine Severe Damage or Separation QRC.

In addition, on February 14, 2024, Southwest Airlines issued a Read Before Fly brief to its pilots describing the event and incorporating Boeing's updates from its FCOM bulletin. The brief indicated that section 5.5.4 Engine Failure or Shutdown in the aircraft operating manual would be updated to indicate that if smoke enters the flight deck or cabin, flight crews should accomplish the Engine Fire or Engine Severe Damage or Separation steps of the QRC.[9]

[8] The PRSOV is normally open but closes automatically under any of the following conditions: if the engine running relay is de-energized (spools down below 62% minimum N2), the engine start switch lever is moved to cutoff, or the engine fire switch is pulled.

[9] This update was completed March 28, 2024.

Southwest's brief also described the similar event in Havana, Cuba, involving Southwest Airlines flight 3923. Shortly after its departure, birds struck the airplane's right LEAP-1B engine, resulting in activation of the LRD and vapor fog entering the passenger cabin. The flight crew declared an emergency and returned to the airport, where they landed without further incident.

The NTSB is aware that CFM International, in collaboration with Boeing, has begun work on an engine software design update that they anticipate completing in the first quarter of 2026. The update will mitigate the presence of smoke or fumes in the cockpit or airplane cabin by closing the PRSOV when the LRD activates. This update will be entirely software-based and made available through a service bulletin upon FAA certification.

The NTSB is also aware the FAA convened a corrective action review board in November 2024 to evaluate the potential for smoke in the cockpit and cabin resulting from LRD activation; the corrective action review board determined the issue did not warrant immediate action and that any corrective action would be taken through the usual regulatory process.[10]

The NTSB appreciates the plan to prevent or mitigate the potential effects of LRD activation in LEAP-1B engines and understands that such a fix takes time. However, we also note that, although the events discussed in this report involved bird strike or ingestion, LRD activation can occur for many other reasons, including foreign object debris ingestion, the loss of a fan blade or sufficiently large portion of a blade tip to cause an imbalance, or the failure of the fan. Therefore, we remain concerned that smoke intrusion into the cockpit as a result of LRD activation could reduce flight crews' visibility (making access to the QRH or relevant QRC more difficult), which would quickly worsen an already high-workload situation.

The NTSB concludes that even though pilot action can mitigate the amount of smoke released into the cockpit or cabin after LRD activation on CFM LEAP-1B engines, CFM and Boeing's planned software modification, once incorporated, would likely close the PRSOV more quickly, thus minimizing the quantity of smoke and reducing the flight crew's workload. Therefore, the NTSB recommends that CFM International and Boeing work together to complete the development and certification for a software modification for CFM LEAP-1B engines that will prevent or limit the amount of smoke released into the cockpit or cabin after LRD activation.

[10] On April 16, 2025, the US Department of Transportation Office of Inspector General (OIG) issued a memorandum to the FAA indicating that the OIG will conduct an audit to "assess FAA's actions in response to recent incidents of toxic smoke and fumes entering aircrafts' cockpit or cabin when load reduction devices are activated." Review of FAA Actions to Address Risks From Load Reduction Devices Activating in LEAP-1B Engines

The NTSB also recommends that the FAA and EASA, once CFM International and Boeing complete the development and certification process for software modifications to the CFM LEAP-1B engines, require all operators of airplanes equipped with CFM LEAP-1B engines to incorporate the software modification developed in response to Safety Recommendations A-25-13 and A-25-14 to prevent or limit the amount of smoke released into the cockpit or cabin after LRD activation.

The NTSB is aware, based on conversations we have had with several pilots who fly Boeing 737 airplanes equipped with CFM LEAP-1B engines, that some pilots may not be fully aware of the MSY and Havana incidents despite Boeing's QRH and FCOM updates. Because of this and given the projected timeframe for completion of CFM's and Boeing's planned modification and the time it will take to incorporate it, the NTSB concludes that it is critical to ensure that pilots who fly airplanes equipped with CFM LEAP-1B engines are fully aware of the potential for smoke in the cockpit if the LRD is activated during a critical phase of flight (takeoff or landing). Therefore, the NTSB recommends that the FAA ensure operators inform flight crews of airplanes equipped with CFM LEAP-1B engines of the circumstances described in this report, emphasizing Boeing's changes to the QRH and FCOM so pilots are aware of actions to take if they encounter smoke in the cockpit or cabin after LRD activation.

The NTSB is aware that LRDs are also part of LEAP-1A engines, which are installed on Airbus A320neo airplanes, and LEAP-1C engines, which are installed on Commercial Aircraft Corporation of China (COMAC) C919 airplanes.[11] We are also aware that the FAA, EASA, Airbus, and CFM are in the process of comparing and assessing these and other LRD-equipped engine/airframe combinations to determine if they are susceptible to smoke in the cockpit or cabin as a result of LRD activation.

The NTSB concludes that potential unintended effects of LRD activation on other CFM LEAP engine models require comprehensive evaluation and, if needed, remediation. Therefore, the NTSB recommends that the FAA, EASA, and CAAC work with CFM International, Airbus, and COMAC to determine if CFM LEAP-1A or -1C engines are at risk of smoke in the cockpit or cabin as a result of LRD activation and require affected operators to incorporate any modification that results.

[11] No COMAC C919 airplanes are operated in the United States.

Conclusions

Findings

1. Even though pilot action can mitigate the amount of smoke released into the cockpit or cabin after load reduction device activation on CFM International LEAP-1B engines, CFM International and Boeing's planned software modification, once incorporated, would likely close the pressure regulating shutoff valve more quickly, thus minimizing the quantity of smoke and reducing the flight crew's workload.

2. It is critical to ensure that pilots who fly airplanes equipped with CFM International LEAP-1B engines are fully aware of the potential for smoke in the cockpit if the load reduction device is activated during a critical phase of flight (takeoff or landing).

3. Potential unintended effects of load reduction device activation on other CFM International LEAP engine models require comprehensive evaluation and, if needed, remediation.

Recommendations

New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations.

To the Federal Aviation Administration:

Ensure operators inform flight crews of airplanes equipped with CFM International LEAP-1B engines of the circumstances described in National Transportation Safety Board Aviation Investigation Report AIR-25-03, emphasizing Boeing's changes to the quick reference handbook and flight crew operations manual so pilots are aware of actions to take if they encounter smoke in the cockpit or cabin after load reduction device activation. (A-25-10) Urgent

To the Federal Aviation Administration and the European Union Aviation Safety Agency:

Once CFM International and Boeing complete the development and certification process for software modifications to the CFM International LEAP-1B engines, require all operators of airplanes equipped with CFM International LEAP-1B engines to incorporate the software modification developed in response to Safety Recommendations A-25-13 and A-25-14 to prevent or limit the amount of smoke released into the cockpit or cabin after load reduction device activation. (A-25-11)

To the Federal Aviation Administration, the European Union Aviation Safety Agency, and the Civil Aviation Administration of China:

Work with CFM International, Airbus, and the Commercial Aircraft Corporation of China to determine if CFM International LEAP-1A or -1C engines are at risk of smoke in the cockpit or cabin as a result of load reduction device activation and require affected operators to incorporate any modification that results. (A-25-12)

To Boeing:

Work with CFM International to complete the development and certification process for a software modification for CFM International LEAP-1B engines that will prevent or limit the amount of smoke released into the cockpit or cabin after load reduction device activation. (A-25-13)

To CFM International:

Work with Boeing to complete the development and certification process for a software modification for CFM International LEAP-1B engines that will prevent or limit the amount of smoke released into the cockpit or cabin after load reduction device activation. (A-25-14)

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