



**PARTY SUBMISSION OF
SOUTHWEST AIRLINES PILOTS ASSOCIATION
TO THE NATIONAL TRANSPORTATION SAFETY BOARD**

**SOUTHWEST FLIGHT 554
KMSY – KENNER, LA
DECEMBER 20, 2023**

DCA24LA330

1.0 Introduction

This Party Submission is provided by the Southwest Airlines Pilots Association (SWAPA) in accordance with 49 CFR §831.11 for the investigation of DCA24LA330. SWAPA represents the line pilot perspective and offers operational, systems, human-performance, and training insights related to the activation of the Load Reduction Device (LRD) on the No. 1 engine and the resulting heavy smoke entering the flight deck, which significantly degraded visibility and increased crew workload during a critical phase of flight.

This submission integrates factual information from the NTSB Operational Factors, Powerplant, Systems, Smoke Toxicity, and Flight Data Recorder Specialist Reports, as well as post-incident guidance from Southwest Airlines and Boeing.

2.0 Flight Information Background

On December 20, 2023, Southwest Airlines Flight 554 departed Louis Armstrong New Orleans International Airport (MSY) at 1413 CST. During initial climb, shortly after liftoff, the aircraft ingested a large bird into the No. 1 CFM LEAP-1B engine. The ingestion caused severe fan damage and triggered activation of the Load Reduction Device (LRD). As designed, the LRD fractured all 23 No. 1 bearing support shear bolts and the No. 2 bearing fuse pins, isolating the damaged fan system.

The fan imbalance and subsequent LRD activation produced immediate secondary effects. Within seconds, the flight deck began filling with acrid white smoke. The crew described the smoke as “very restrictive to visibility” and “smelling like burning oil.” The onset occurred during initial climb at approximately 800–1,000 feet AGL, a critical phase of flight requiring high workload and precise coordination.

The rapid smoke ingress substantially degraded forward visibility and obscured portions of the instrument panel. Crewmembers were forced to rely on verbal cross-checks rather than visual confirmation of switch positions. Communication was strained as checklist steps had to be repeated and clarified under degraded conditions. Workload increased as the crew simultaneously managed the abnormal condition, maintained situational awareness, and ensured continued aircraft control.

Digital Flight Data Recorder (DFDR) data provide the following sequence:

- 14:14:01 – Engine 1 N1 rollback
- 14:14:16 – Engine 1 N2 dropped below 62%, triggering automatic PRSOV closure
- 14:14:16–14:15:46 – Engine oil quantity decreased from >16 quarts to nearly empty within ~90 seconds
- 14:16:56 – Smoke dissipated rapidly following activation of the Engine 1 fire switch

The crew executed memory items and Quick Reference Handbook (QRH) procedures, securing the affected engine. Smoke conditions improved immediately after the Engine 1 fire switch was pulled. The flight crew coordinated with ATC, returned to MSY, and landed safely on Runway 11.



Figure 1: Incident Flight Route of Flight (Source: ADSBExchange.com)

3.0 Systems Group — LRD Activation and Smoke Generation

3.1 Load Reduction Device (LRD) Function and Activation

The LEAP-1B engine incorporates a mechanical Load Reduction Device (LRD) designed to reduce structural loads during severe fan-imbalance events. When activated, the No. 1 bearing support shear bolts fracture and the No. 2 bearing fuse pins shear, allowing the fan rotor to orbit around a new center of gravity and thereby reducing vibratory loads transmitted to the airframe. In this event, LRD activation occurred as designed following catastrophic fan damage.



Figure 2: Fan Blade and Fan Case Damage

3.2 Oil Release Mechanism

LRD activation disrupted the No. 1 bearing housing and associated oil tubes, resulting in a rapid release of engine oil into the core compressor upstream of the pneumatic bleed ports. Powerplant Group findings documented oil leakage within the booster cavity, bent and disconnected oil tubes, and a 15 mm gap between bearing support modules, all of which allowed oil to migrate into the compressor airflow path. This oil was subsequently entrained in the compressor airstream and carried to the bleed ports, where it entered the aircraft's pneumatic system.



Figure 3: Oil and Sheared No. 1 Bearing Housing Support Bolts in Booster Cavity

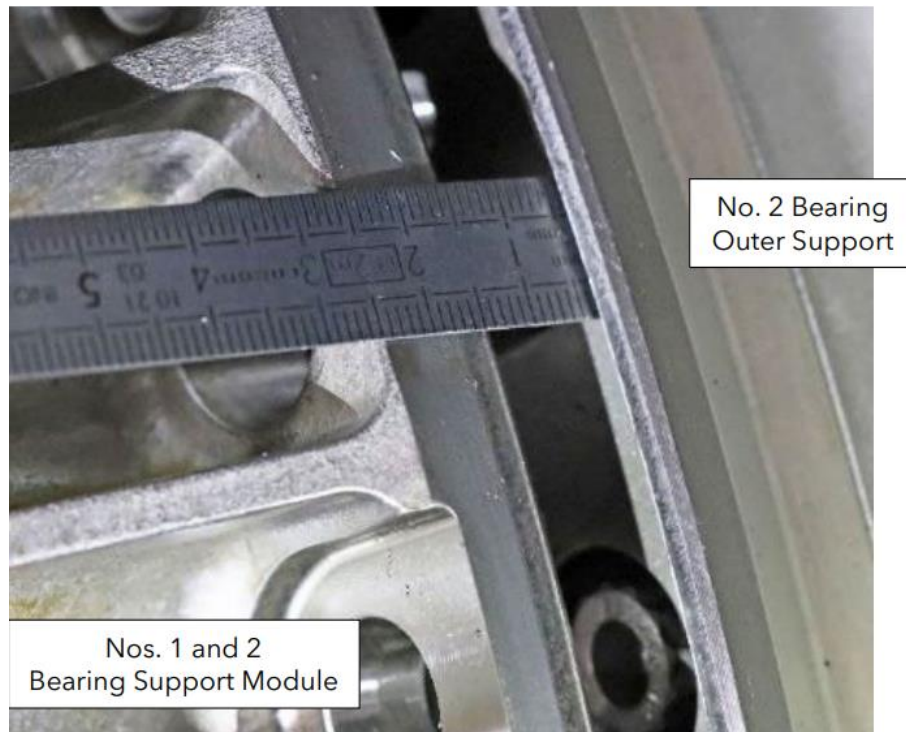


Figure 4: Gap Between Nos. 1 and 2 Bearing Support Module Rear Flange

3.3 Smoke Pathway Into the Flight Deck

Because the left pack supplies the flight deck, contaminated bleed air from the No. 1 engine resulted in the immediate introduction of smoke into the flight deck, producing rapid visibility degradation and contributing to sensory overload during an already high-workload phase of flight. Although the PRSOV closed automatically when N2 decreased below 62 percent, the smoke had already entered the flight deck prior to valve closure.

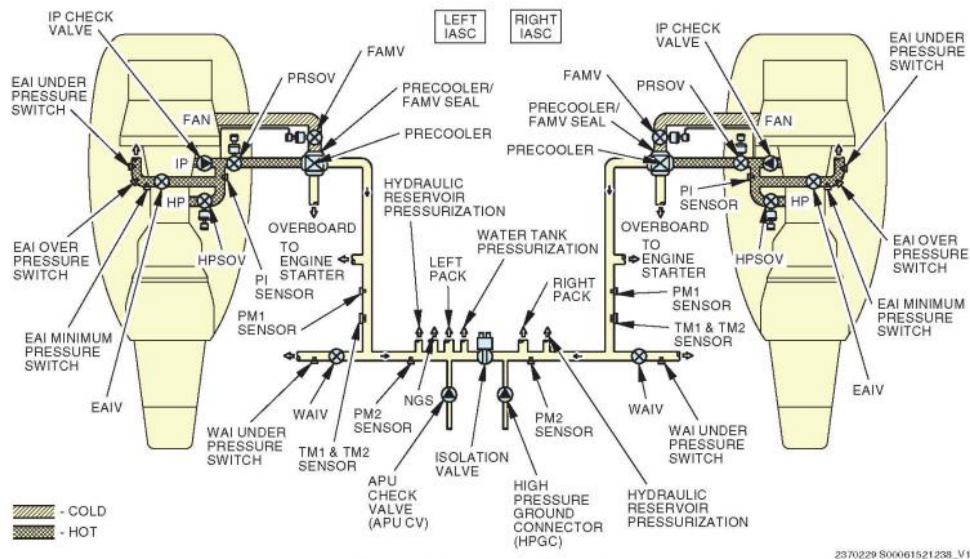


Figure 5: Environmental Control System Schematic

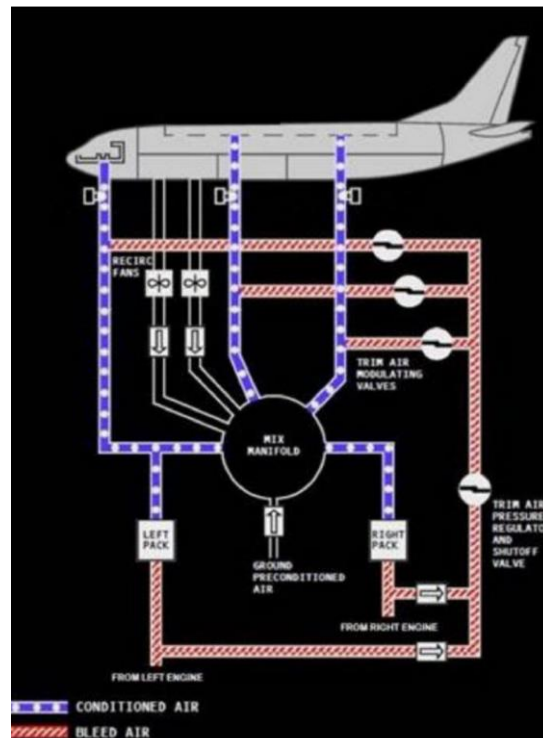


Figure 6: Air Distribution System. (Courtesy of Boeing)

4.0 Human Performance Group — Effects of Heavy Smoke on Crew

4.1 Visibility and Instrument Scan Impairment

Both pilots reported a severe loss of flight deck visibility following the onset of smoke, noting that they were unable to clearly see the primary flight instruments and had significant difficulty reading the Quick Reference Handbook. They also reported difficulty seeing each other, which hindered coordination and nonverbal communication. Due to the obscuration of the instrument panel, aircraft control increasingly depended on the Head-Up Display (HUD). The Captain stated that he “stopped flying off the displays” and relied solely on the HUD because the smoke density rendered the panel-mounted instruments unreadable.

4.2 Mask Donning Under Stress

The First Officer called for oxygen masks as smoke rapidly filled the flight deck, and both pilots donned full-face masks. Once masked, the crew experienced degraded communication, slowed checklist execution, and increased cognitive load. The Smoke Simulation Evaluation further demonstrated that even light-density smoke lenses significantly impair QRH readability, reduce visibility of the PFD and MFD, diminish HUD symbology clarity, and hinder effective crew coordination.

4.3 Physiological Considerations

The Smoke Toxicity Study determined that oil pyrolysis products generated during the event may contain both irritants and toxicants; however, crew exposure duration was limited due to timely PRSOV closure and the rapid donning of oxygen masks. The study found no evidence of acute incapacitation, though one pilot reported a prolonged cough following the incident. Notably, smoke associated with LRD-related events differs from typical fume events because the rapid, high-volume oil release produces a more immediate and concentrated smoke environment.

5.0 Operations Group — Checklist Execution Under Smoke Conditions

5.1 Engine Fire / Severe Damage Checklist Execution

The crew executed the required memory items and QRH procedures; however, the rapid onset of smoke introduced significant time compression and elevated workload, while also reducing their ability to visually confirm switch positions and increasing their reliance on verbal cross-checks. According to the crew, the smoke dissipated “very quickly” after the fire switch was pulled, consistent with PRSOV closure and pack shutdown.

5.2 Risk of Incorrect Engine Shutdown

Boeing and Southwest Airlines post-incident guidance emphasize that the combination of high vibration and smoke should be treated as indicative of severe engine damage, warranting immediate and decisive action. The guidance also underscores the importance of methodical

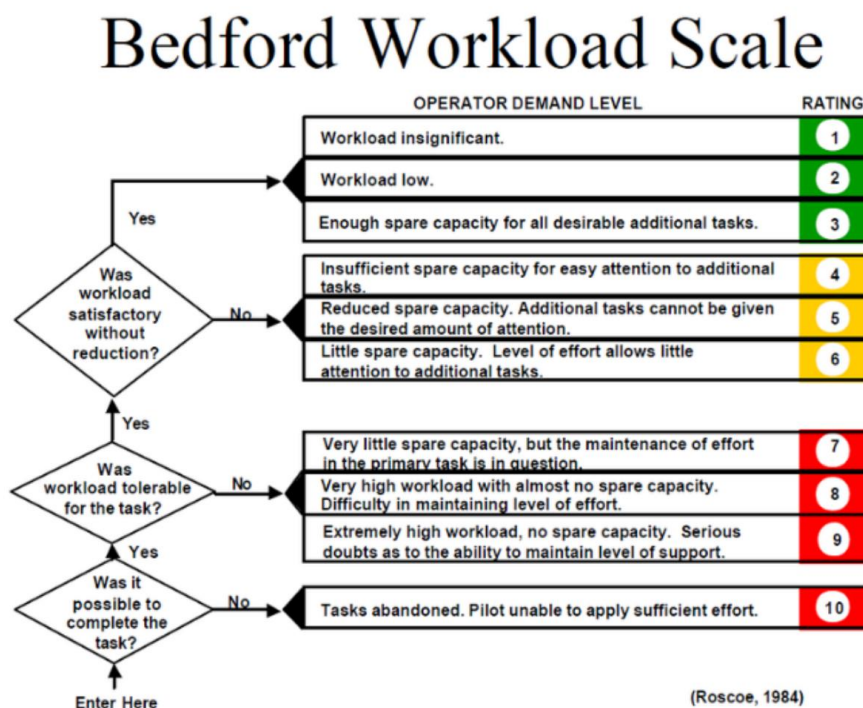
confirmation to prevent inadvertent shutdown of the wrong engine, particularly under time pressure. Additionally, both sources highlight the need for strong crew coordination when visibility is degraded, as effective communication and cross-verification become critical to maintaining situational awareness and executing procedures correctly.

6.0 Survival Factors Group — Smoke Toxicity and Exposure

The Smoke Toxicity Group concluded that no direct measurements of the smoke composition were available for this event, though oil pyrolysis products may include irritants and organophosphates. Crew exposure duration was limited due to timely PRSOV closure and the rapid donning of oxygen masks, and no evidence of incapacitation was identified. The group further noted that future events may differ depending on the timing of PRSOV closure and the speed at which flight crews are able to don their masks.

7.0 Training Group — Simulator Smoke Evaluation

The June 16, 2025 Smoke Simulation Evaluation conducted at Southwest Airlines Headquarters, WINGS Building, Simulator 18, demonstrated that even the use of “light” smoke lenses severely degraded flight deck visibility, with pilots reporting workload ratings of 9–10 on the Bedford Workload Scale. Checklist readability was significantly impaired, reaction times were greatly reduced, and HUD usability varied depending on smoke density. These findings underscore the need for enhanced smoke-event training that realistically simulates rapid smoke onset, degraded visibility, mask-on checklist execution, and high-vibration environments.



8.0 SWAPA Summary and Recommendations

SWAPA remains committed to supporting the NTSB's investigation and advancing safety improvements for flight crews and passengers and submits the following safety findings and recommendations:

1 - Current Bleed Air System Design Is Inadequate to Protect the Flight Deck Following LRD Activation

The design of the LEAP-1B engine and 737 bleed air system permits oil contamination of flight deck air before automatic isolation occurs. This is an unacceptable vulnerability. Boeing and CFM International must be required to:

- Eliminate or substantially reduce the potential for oil ingress into bleed ports following bearing support separation
- Implement design changes that prioritize immediate protection of flight deck air quality during severe engine damage
- Demonstrate that no single-engine mechanical failure can result in rapid and uncommanded flight deck smoke

2 - PRSOV Closure Logic Failed to Prevent Hazardous Flight Deck Smoke Exposure.

In this event, the automatic PRSOV closure occurred only after substantial smoke contamination had already entered the flight deck.

This delay is operationally unacceptable. PRSOV logic and thresholds must be re-evaluated and revised to ensure earlier and more decisive isolation of bleed air following indications of severe engine damage, high vibration, or LRD activation.

3 - Full-Face Oxygen Masks should be mandatory safety equipment and must not be degraded or replaced.

This event unequivocally demonstrates that full-face oxygen masks are essential for maintaining vision, breathing, and communication during dense smoke events. Any consideration of two-piece mask and goggle systems represents a regression in safety and should be categorically rejected for transport-category aircraft moving forward.

4 - Current Simulator Training Does Not Adequately Prepare Crews for LRD-Induced Smoke Events

Simulator evaluations confirm that even "light" smoke conditions severely impair instrument visibility, checklist execution, and crew coordination. Training programs must be revised to include high-fidelity, rapid-onset smoke scenarios that replicate:

- Immediate post-takeoff smoke with severe visibility loss
- Mask-on operations from the outset of the event
- Concurrent engine vibration, failure indications, and time-compressed decision-making

Training must reflect the reality that crews may lose effective use of the instrument panel within seconds.

5 - Smoke Toxicity Risks Remain Insufficiently Characterized and Cannot Be Dismissed

Although no acute incapacitation occurred in this event, the composition of oil pyrolysis products introduced into the flight deck remains incompletely understood. SWAPA asserts that absence of measured injury does not equate to acceptable risk. Continued research is required to fully characterize exposure hazards and ensure that protective equipment and procedures are adequate for worst-case conditions.