BUREAU OF AIRCRAFT SAFETY INVESTIGATION PAKISTAN

FINAL INVESTIGATION REPORT

SERIOUS INCIDENT

IN-FLIGHT ENGINE SHUTDOWN
HPT STAGE 1 BLADE FRACTURE DUE TO SPLCF / CREEP INTERACTION

Aircraft Type	Airbus A321-251NX
Registration	AP-BOD
Operator	Airblue Limited
Flight	ABQ207, Islamabad (OPIS) to Karachi (OPKC)
Date of Occurrence	30 October, 2023
Location	Approx 12 NM west of Islamabad International Airport (OPIS)
Classification	Serious Incident – In-Flight Engine Shutdown (IFSD)
Report Status	Final Investigation Report
Report Reference	HQ BASIP/1000/454/Inv
Date of Report	30 April, 2026
This report is issued pursuant to Pakistan Aircraft Safety Investigation (PASI) Act, 2023, Air Safety Rules 2025 and ICAO Annex 13	

TABLE OF CONTENTS

SCOPE

At Bureau of Aircraft Safety Investigation Pakistan (BASIP), investigations are conducted in accordance with Pakistan Aircraft Safety Investigation (PASI) Act, 2023, Air Safety Rules 2025, and International Civil Aviation Organization (ICAO) Annex-13.

The sole objective of the investigation and its final report is to prevent future accidents, serious incidents, and incidents of similar nature, without apportioning blame or liability. Accordingly, it is inappropriate to use BASIP investigation reports to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for judiciary or administrative purposes.

This report contains facts which are based on information that came to the knowledge of BASIP during the investigation up to the time of publication. Such information is published to inform the aviation industry and the public about the general circumstances of civil aviation serious incidents.

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INTRODUCTION

This serious incident was reported to Bureau of Aircraft Safety Investigation Pakistan (BASIP) by Pakistan Airports Authority (PAA) vide Incident Occurrence and Unserviceability Report (IOU)1. This serious incident was notified2 to International Civil Aviation Organization (ICAO), National Transportation Safety Board (NTSB) USA, Bureau of Enquiry and Analysis (BEA) for Civil Aviation Safety, France in line with Annex-13. The investigation has been conducted by BASIP. All corresponding timings are mentioned in Universal Coordinated Time (UTC).

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SYNOPSIS

On 30 October 2023, Airblue Limited flight ABQ207, an Airbus A321-251NX aircraft, registration AP-BOD, was operating a scheduled revenue passenger flight from Islamabad International Airport (OPIS) to Karachi Jinnah International Airport (OPKC). The aircraft was carrying 240 passengers and 8 crew members (including Captain as Pilot Monitoring (PM), First Officer (FO) as Pilot Flying (PF), and an additional First Officer serving as Safety Pilot — indicating the flight was also a training sector for the FO.

The aircraft departed Runway (R/W) 28L at 12:41:39 UTC. During initial climb, at approximately 8,000 feet (ft) Above Mean Sea Level (AMSL) at 12:45:28 UTC, the crew and cabin crew heard a loud bang, accompanied by abnormal vibrations throughout the aircraft. At 12:45:32 UTC, the Captain announced Engine No. 1 FAIL and assumed the role of PF, with the FO transitioning to Pilot Monitoring (PM). The crew levelled off at 8,000 ft AMSL and requested return to OPIS. A 'PAN PAN' urgency call was declared at 12:46:23 UTC. The aircraft executed an Instrument Landing System (ILS) Z Approach to R/W 28L via ISDUR and landed safely after 13:00:00 UTC. Fire vehicles followed the aircraft to stand 24. All 248 persons on board survived without injury.

Post-landing, small metallic pieces from internal engine components were found at the rear of Engine No. 1. A metallurgical evaluation was conducted on the High-Pressure Turbine (HPT) Stage 1 blades from the event engine (ESN 599-942) and the Equivalent-time Sister Engine (ESN 599-899). The evaluation was the earliest recorded In-Flight Shutdown (IFSD) for the LEAP-1A fleet at the time of occurrence.

The investigation determined that the cause of this serious incident was an In-Flight Shutdown of Engine No. 1 (ESN 599-942) due to creep-induced cracking in the HPT Stage 1 blade airfoil. Fracture initiated at the airfoil mid-span of Blade 17 (S/N GNK07EWD) through Sustained Peak Low-Cycle Fatigue / Creep (SPLCF/creep) interaction, propagating via fatigue and resulting in the liberation of the outer airfoil span. The liberated material overstressed the remaining 41 blades in the HPT Stage 1 set, causing the engine failure. Contributing factors included 100% in-region Severe Engine Operation (SEO), the proximity of the failure to the first scheduled 1,600-cycle service bulletin inspection, and significant post-incident procedural lapses in crew medical testing and evidence preservation.

ABBREVIATIONS

ADF	Automatic Direction Finding
ADIRS	Air Data Inertial Reference System
ADS	Automatic Dependent Surveillance
AMSL	Above Mean Sea Level
ATCOs	Air Traffic Controllers
BASIP	Bureau of Aircraft Safety Investigation Pakistan
BEA	Bureau of Enquiry and Analysis
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
ESN	Equivalent-time Sister Engine
FO	Firt Officer
FOD	Foreign Object Debris
ft	Feet
GPS	Global Positioning System
HF	High Frequency
HFACS	Human Factors Analysis and Classification System
HPT	High Pressure Turbine
ICAO	International Civil Aviation Organization
IFSD	In-Flight Shutdown
ILS	Instrument Landing System
IOU	Incident Occurrence and Unserviceability
KGs	Kilograms
Ltrs	Liters
m	Meters
NM	Nautical Miles
OEM	Original Equipment Manufacturer
OPIS	ICAO code – Islamabad International Airport
OPKC	ICAO code – Karachi Jinnah International Airport
PAA	Pakistan Airports Authority
PASI	Pakistan Air Safety Investigation

PBB	Passenger Boarding Bridge
PCAA	Pakistan Civil Aviation Authority
PF	Pilot Flying
PM	Pilot Monitoring
R/W	Runway
Ras	Radio Altimeters
RFFS	Rescue and Fire Fighting Services
SEO	Severe Engine Operation
SPLCF/creep	Sustained Peak Low-Cycle Fatigue / Creep
UTC	Universal Time Coordinated
VHF	Very High Frequency
VOR	Very High Frequency Omni-Directional Range
UTC	Universal Coordinated Time

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Sr	Description	Appendix
1.	PAA – IOU Report dated 30th October, 2023	**Appendix A**
2.	ICAO – Initial Notification	**Appendix B**

SECTION 1 – FACTUAL INFORMATION

1.1. History of the Flight

1.1.1. On 30 October 2023, Airblue flight ABQ207, Airbus A321-251NX (AP-BOD), was scheduled to operate from Islamabad International Airport (OPIS) to Karachi Jinnah International Airport (OPKC) with 240 passengers and 8 crew members. The flight crew comprised a Captain, FO designated as PF, and an additional FO Safety as Safety Pilot, indicating the sector was also a training flight for the FO.

1.1.2. Boarding and pre-flight checks were completed normally. The aircraft was reported airworthy prior to departure.

1.1.3. Taxi was performed by the Captain. Change of flying controls was carried out at 12:41:20 UTC.

1.1.4. The aircraft departed R/W 28L at 12:41:39 UTC, with the First Officer as PF and the Captain as PM.

1.1.5. At 12:42:07 UTC, simultaneous communication between Captain and FO was observed concerning a delay in raising the landing gear by approximately one minute. The delay was attributed to a braking system MEL item rendering auto-brake deactivated; accordingly, the landing gear was retracted after one minute airborne, at 12:42:39 UTC.

1.1.6. During initial climb, at approximately 8,000 ft AMSL at 12:45:28 UTC, the flight crew and cabin crew heard a loud bang, seemingly from the engine, accompanied by abnormal vibrations throughout the aircraft. The Captain immediately assumed the role of PF, with the FO transitioning to PM.

1.1.7. At 12:45:32 UTC, the Captain announced Engine No. 1 FAIL and decided to level off at 8,000 ft AMSL.

1.1.8. At 12:45:46 UTC, approximately 12 Nautical Miles (NM) west of OPIS, the crew informed Islamabad Approach of levelling off at 8,000 ft and requested to return to OPIS due to engine failure.

1.1.9. At 12:46:23 UTC, 'PAN PAN PAN' urgency call was declared. The aircraft was initially offered a direct routing to ISBAX for R/W 28L, but the crew requested and was approved for the ILS Z approach via ISDUR.

1.1.10. The 'PAN PAN' declaration was repeated at 12:48:43 UTC with confirmation of Engine No. 1 failure.

1.1.11. Cabin crew assessed outside conditions through observation windows, performed physical checks of the cabin and passengers, and reported no smoke, fire, or unusual odour. At 12:50:53 UTC, the Lead Cabin Crew (LCC/Purser) entered the cockpit and was briefed using the NITS protocol: Engine No. 1 had failed; the aircraft was returning

to Islamabad for landing within 8 minutes. The LCC briefed the cabin crew via interphone and secured the cabin. Passengers remained calm with no panic reported.

1.1.12. At 12:56:24 UTC, the aircraft established on the ILS Localizer for R/W 28L and transferred to Tower frequency.

1.1.13. The aircraft landed safely on R/W 28L after 13:00:00 UTC, with surface wind reported at 210° / 3 knots. The aircraft vacated via Taxiway B and taxied via L, K, T and M to Stand 24. Fire vehicles followed the aircraft to parking.

1.1.14. Passengers disembarked normally via the Passenger Boarding Bridge (PBB). The Captain announced the engine failure and safe return. No signs of passenger distress were reported in the post-flight debrief.

1.1.15. A post-landing R/W and taxiway inspection found no Foreign Object Debris (FOD). The aircraft was cordoned off at Stand 24, with ASF personnel deployed. Small metallic pieces from internal engine components were found at the bottom rear of Engine No. 1.

1.1.16. Post-Landing Medical Protocol Lapses

1.1.16.1. The medical team (Doctor, AD Medical Services) was positioned at Stand 24 with equipment and an ambulance prior to aircraft arrival, in accordance with emergency protocols.

1.1.16.2. During passenger disembarkation, the Captain and FO Safety departed the airport via the Passenger Boarding Bridge without informing ground staff and without completing the mandatory immediate post-incident medical assessment required under PCAA ANO-002-XXAM-1.0. There was no communication available for several hours following the incident.

1.1.16.3. The FO Safety subsequently returned and provided blood and urine samples approximately 6 hours 33 minutes after landing (1933 hrs local time). The Captain provided samples approximately 13 hours 28 minutes after landing (0228 hrs on 31 October). Due to the excessive delay in the Captain's case, alternative biological samples (hair and nails) were taken under AAIB supervision at DNA Testing Solution, Lahore.

1.1.16.4. Laboratory reports confirmed both crew members were free of psychoactive substance influence, with no prior history detected. However, no record of a pre-flight alcohol breath analyzer test was received from the Aero Medical Center, PCAA HQs Karachi, in violation of ANO-002-XXAM-1.0 requirements.

1.2. Injuries to Persons

1.2.1. No injury was reported to any person on board the aircraft or on the ground. Details are as follows:

Injuries	Crew	Passengers	Total on Aircraft	Others
Fatal	Nil	Nil	Nil	Nil
Serious	Nil	Nil	Nil	Nil
Minor	Nil	Nil	Nil	Nil
None / Total	**8**	**240**	**248**	**Nil**

Table 1 Injuries Details

1.3. Damage to Aircraft

1.3.1. Engine No. 1 (LEAP-1A, ESN 599-942) experienced an IFSD. Post-landing inspection at Stand 24 revealed small metallic pieces at the bottom rear of the engine, originating from internal engine components.

1.3.2. No signs of bird strike were observed or reported. The rest of the aircraft was in normal condition.

1.4. Other Damage

1.4.1. No damage to third-party property or infrastructure was reported. Post-landing R/W and taxiway inspections confirmed no FOD.

1.5. Personnel Information

1.5.1. Flight Crew

1.5.1.1. Both the Captain and the FO were rated on the Airbus A320/321 family and qualified for their respective roles. Pre-flight breathalyzer records for previous flights were available; however, no record of a pre-flight alcohol breath analyzer test was received for the incident flight, in contravention of ANO-002-XXAM-1.0 requirements.

1.5.1.2. The presence of a third pilot (FO Safety/Safety Pilot) confirms the flight was also serving as a training sector for the FO.

1.5.2. Cabin Crew:

1.5.2.1. All cabin crew members were qualified and followed established procedures during the incident. They held valid medical assessments (Class 2) at the time of the incident. Cabin crew performance during the emergency was effective and professional.

1.5.3. Air Traffic Control:

1.5.3.1. All Air Traffic Controllers (ATCOs) on duty were qualified for their positions and followed standard ATC procedures throughout the incident.

1.6. Aircraft Information

1.6.1. Aircraft and both Engine's details are as follows:

Aircraft Make & Model	Airbus A321-251NX (NEO)
Registration	AP-BOD
Year of Manufacture	2021
Manufacturer Serial No.	9560
Owner	Celestial Aviation Trading 64 Ltd.
Operator	Airblue Limited
Date of Induction	19 November 2021
Max Take-off Weight	93,500 Kgs
Max Landing Weight	79,200 Kgs
Max Fuel Capacity	26,807 Ltrs
Total Aircraft Hours / Cycles prior to event flight	5600:53 / 1524
Total Aircraft Hours / Cycles done in Airblue prior to event flight	5600:53 / 1524
Certificate of Airworthiness (S No, expiry date)	02050, 21-November-2023
Certificate of Maintenance Review prior to event flight (expiry date)	15-November-2023
Last weighing carried out	09-September-2020
Last Daily inspection prior to event flight	29-October-2023
Last Weekly Check prior to event flight	29-October-2023
Last Check A	14-May-2023
Last Major Check	Nil
Total Flight Since Check A	1173 / 282
Last Operated Flight (Prior to event)	PA-171
Auxiliary Power Unit (APU)	P-9071

Table 2 Aircraft Details

Engine No 1	
Engine S No	599942
Manufacturer	CFMI
Engine Type	LEAP-1A32
Date of Installation	19-November-2021
TSN / CSN	5599:08 / 1,524
TSI / TSO	Nil
CSI / CSO	Nil
Engine Trend / Health	Satisfactory
Last Borescope Inspections (BSI)	20-Septermber-2023 (BIRD STRIKE)

Table 3 Engine No 1 Details

Engine No 2	
Engine S No	599899
Manufacturer	CFMI
Engine Type	LEAP-1A32
Date of Installation	19-November-2021
TSN / CSN	5601:03 / 1525
TSI / TSO	Nil
CSI / CSO	Nil
Engine Trend / Health	Satisfactory
Last Borescope Inspections (BSI)	12-August-2023 (BIRD STRIKE)

Table 4 Engine No 2 Details

1.7. Meteorological Information

1.7.1. The meteorological conditions at OPIS at the time of arrival were as follows:

METAR 1200Z	OPIS 1200Z 00000KT 4000 FU NSC 26/17 Q1015 TEMPO 3000
METAR 1230Z	OPIS 1230Z 23004KT 3500 FU NSC 23/17 Q1015 TEMPO 3000
METAR 1300Z	OPIS 1300Z 23004KT 4000 FU NSC 23/19 Q1016 TEMPO 3000

Table 5 METAR details IIAP, Islamabad

1.7.2. Conditions at the time of departure included calm to light winds (up to 4 knots), visibility 3,500–4,000 meters (m) reduced by smoke/haze (FU), no significant cloud (NSC), temperatures 23–26°C, dew points 17–19°C, and altimeter settings Q1015–Q1016. Temporary reductions in visibility to 3,000 meters were forecast.

1.7.3. Meteorological conditions were not a factor in the engine failure.

1.8. Aids to Navigation

1.8.1. Navigational facilities at the Departure / Arrival aerodrome (OPIS) was fully functional during the event flight.

1.8.2. The aircraft was equipped with Navigation Equipment [Air Data Inertial Reference System (ADIRS), Global Positioning System (GPS), Very High Frequency Omni-Directional Range (VOR), Marker Beacon, Instrument Landing System (ILS), Automatic Direction Finding (ADF), Radio Altimeters (RA), Automatic Dependent Surveillance (ADS) etc]. The said systems were serviceable and no technical anomaly / failure was documented before the event flight.

1.8.3. The aircraft was cleared for the ILS Z Approach to R/W 28L via ISDUR. Navigation aids functioned normally; the aircraft established on the localizer without any reported anomaly.

1.9. Communications

1.9.1. **Onboard Communications.** Communication equipment for communication on Very High Frequency (VHF) and High Frequency (HF), in accordance with the aircraft certification requirements. The said systems were serviceable and no technical anomaly / failure was documented before the event flight.

1.9.2. Communication facilities at the departure, enroute and destination were fully functional during the event flight. Communications between the flight crew and ATC were clear and effective throughout the occurrence. Key radio transmissions are summarized as follows:

12:42:48 UTC	ABQ207 contacted Approach; cleared to FL140.
12:45:46 UTC	ABQ207 levelling off at 8,000 ft; requested return to OPIS due to engine failure.
12:46:00 UTC	ABQ207: 'Turn left, proceed direct ISBAX; we have engine failure.'
12:46:23 UTC	'PAN PAN PAN' – ABQ207 declared urgency, engine failure, request land back Islamabad.
12:46:36 UTC	ABQ207 directed: direct ISBAX for immediate return R/W 28L.
12:46:44 UTC	ABQ207: 'We will proceed ISDUR; proceeding direct ISDUR; request descent.'
12:48:43 UTC	'PAN PAN PAN' repeated; Engine No. 1 failure confirmed.
12:56:24 UTC	Transferred to Tower; aircraft established on localizer R/W 28L.
After 13:00	Aircraft landed; taxied to Stand 24.

Table 6 Communication between aircrew and ATC

1.9.3. ATC coordination was timely and effective. Emergency services (RFFS, AMO, DTM, Airworthiness) were alerted promptly. Full emergency procedures were activated

1.10. Aerodrome Information

1.10.1. Islamabad International Airport (OPIS), R/W 28L was in use. The aerodrome is equipped for ILS approaches. Rescue and Fire Fighting Services (RFFS) were deployed as per established SOPs. No abnormality in aerodrome infrastructure was reported.

1.11. Flight Recorders

1.11.1. The aircraft was equipped with a Digital Flight Data Recorder (DFDR) and a Cockpit Voice Recorder (CVR) in accordance with regulatory requirements.

1.11.2. The aircraft was cordoned off post-landing to preserve evidence; however, no specific information on DFDR/CVR data extraction and analysis was provided to BASIP at the time of this report.

1.11.3. BASIP notes that DFDR data analysis (particularly engine parameters, vibration data, and crew inputs preceding the IFSD) is essential for fully characterizing the pre-failure environment and is strongly recommended as an outstanding action

1.12. Wreckage and Impact Information

1.12.1. The aircraft landed safely without impact damage. Post-landing inspection confirmed small metallic debris at the bottom rear of Engine No. 1, consistent with internal component failure. No FOD was found on the R/W.

1.13. Medical and Pathological Information

1.13.1. Both the Captain and the First Officer held valid medical certificates and were reported fit to undertake the flight.

1.13.2. Post-incident medical assessment for psychoactive substances was required as per PCAA ANO-002-XXAM-1.0. The medical team was correctly positioned at Stand 24 prior to aircraft arrival.

1.13.3. The cockpit crew (Captain and FO Safety) departed the airport via the passenger terminal without completing the mandatory immediate medical assessment, in contravention of ANO-002-XXAM-1.0.

1.13.4. The FO Safety returned and provided blood and urine samples approximately 6 hours 33 minutes post-landing. The Captain provided samples approximately 13 hours 28 minutes post-landing. Due to the excessive elapsed time, alternative samples (hair and nails) were taken from the Captain under AAIB supervision at DNA Testing Solution, Lahore.

1.13.5. Laboratory results confirmed both crew members were free of psychoactive drug influence. No pre-flight alcohol breath analyzer record for the incident flight was received from PCAA Aero Medical Center, Karachi, in violation of ANO-002-XXAM-1.0

1.14. Fire

1.14.1. No fire occurred during or after the incident. Cabin crew checks of the cabin and passenger windows confirmed no smoke, fire, or unusual odour throughout the flight.

1.15. Survival Aspects

1.15.1. All 248 persons on board survived without injury. Cabin crew performance during the emergency was exemplary: the cabin was effectively secured, passengers were kept calm, and NITS briefing protocols were correctly applied. Post-flight debrief confirmed no crew or passenger distress.

1.16. Tests and Research

1.16.1. Technical Background – Engine IFSD

1.16.1.1. The aircraft was reported as airworthy prior to departure, as per the Aircraft Information document.

1.16.1.2. The aircraft experienced a failure of LEAP-1A Engine No. 1 (ESN 599-942) at 12:45:28 UTC.

1.16.1.3. Post-landing inspection at stand 24 revealed small metallic pieces at the bottom rear of the engine, apparently from internal components.

1.16.1.4. No signs of bird strike were observed or reported. The rest of the aircraft was in normal condition.

1.16.1.5. The Airblue LEAP-1A engine No 1(ESN 599-942) experienced an In-Flight Shutdown (IFSD) after accumulating 1,522 cycles and 5,597 flight hours since new.

1.16.2. Metallurgical Evaluation of LEAP-1A High-Pressure Turbine (HPT) Stage 1 Blades from Event Engine ESN 599-942 and Sister Engine ESN 599-899

1.16.2.1. A metallurgical evaluation was conducted on the HPT Stage 1 blade set from the event engine (ESN 599-942) and the equivalent-time sister engine (ESN 599-899). The complete set of 60 HPT Stage 1 blades (P/N 2747M92P01) from each engine was examined.

1.16.2.2. A complete set of 60 HPT Stage 1 blades (P/N 2747M92P01) was removed from the event engine (ESN 599-942) and submitted for metallurgical evaluation. Due to the extent of damage observed, blades from the equivalent-time sister engine (ESN 599-899) were also submitted for comparative examination.

1.16.2.3. This was the earliest IFSD recorded for the LEAP-1A fleet at the time, occurring immediately prior to the first scheduled 1,600-cycle service bulletin inspection.

1.16.2.4. The operator reported 100% in-region Severe Engine Operation (SEO).

1.16.2.5. Base alloy specification: C50TF130.

1.16.3. Event Engine ESN 599-942

1.16.3.1. **Blade Material.** N515 nickel-base super alloy substrate; PtAl + Hf bond coat; Electron-Beam Physical Vapor Deposition (EBPVD) Thermal Barrier Coating (TBC).

1.16.3.2. Blade 17 (serial GNK07EWD) was the prime (initiating) blade.

1.16.3.3. Fracture initiated at airfoil mid-span on the internal surfaces.

1.16.3.4. **Initiation Mode.** Sustained Peak Low-Cycle Fatigue / Creep interaction (SPLCF/creep).

1.16.3.5. **Propagation Mode.** Fatigue.

1.16.3.6. Leading-edge external wall exhibited severe oxidation, metal loss, rupture and incipient melting, consuming ~75 % of the cross-sectional area.

1.16.3.7. This overload liberated the outer airfoil span, which then overstressed and damaged the remaining 41 blades in the set.

Figure 1 Blades

1.16.3.7.1. Overall image of the submitted HPT stage 1 blades from 599-942 in the as-received condition. Blade 17 was consistent with being the prime blade that fractured at the mid-span, resulting in the liberation of the airfoil outer span which then overstressed the following 41 blades.

1.16.3.7.2. Detailed Examination – Event Engine 599-942 Prime Blade 17 (GNK07EWD)

1.16.3.7.2.1. Mid-span fracture with ~46 mils radial growth across slots 1–6. Internal planar fractures around: -

1.16.3.7.2.1.1. Cavity 2

1.16.3.7.2.1.2. Bumpers

1.16.3.7.2.1.3. Row 12 cooling hole 7 (with striations)

1.16.3.7.2.2. “Rosette” features (some with striations) at cavities 4, 5, 10 and 11.

1.16.3.7.2.3. Parallel secondary cracks consistent with creep deformation observed on concave, convex and cavity walls.

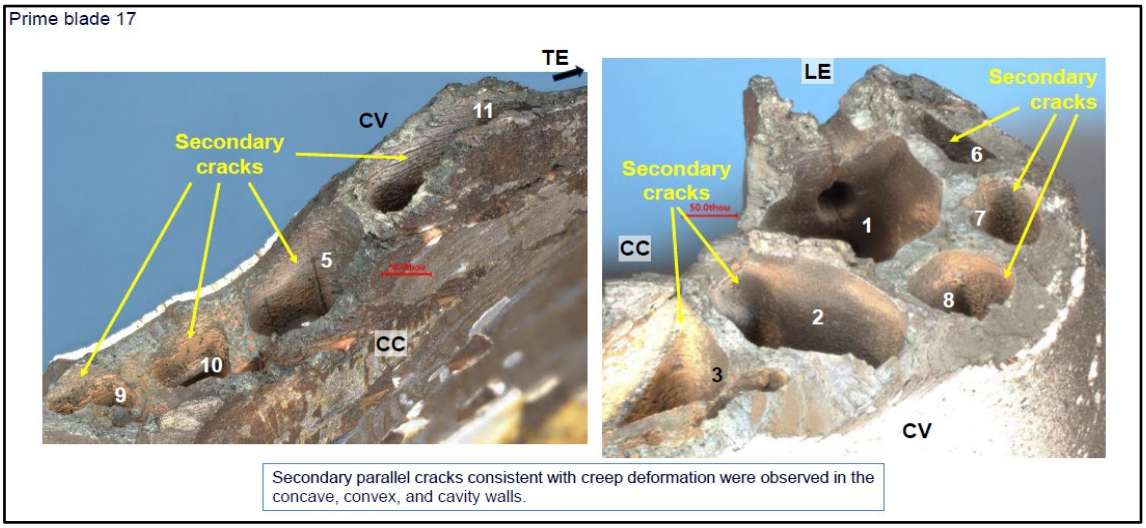

Figure 2 Creep-related parallel secondary cracks on blade walls

1.16.3.7.2.4. Leading-edge wall: heavy oxidation, incipient melting/oxidation, metal loss.

1.16.3.7.2.5. Cross-over hole crack and cooling-hole cracks most pronounced in root and mid-span (up to 77 mils metal loss at Row 12 hole 6).

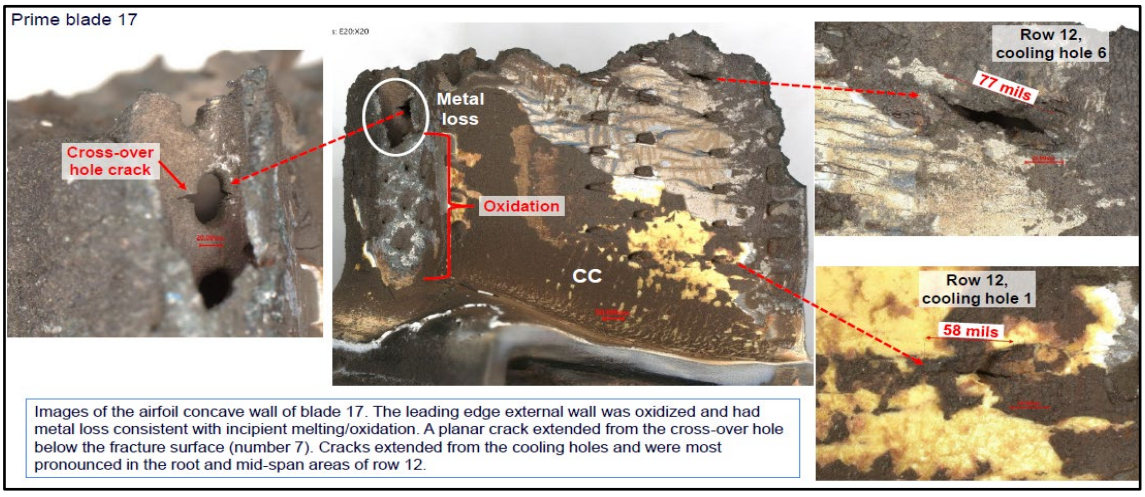

Figure 3 Airfoil Concave Wall of Blade17

1.16.3.7.3. Fracture Surface Summary (Prime Blade 17)

1.16.3.7.3.1. **Yellow: planar/striated fatigue (~15 % area).** Planar, striated areas consistent with fatigue extended from internal ribs, the bumpers, the cross-over hole, and the row 12 cooling hole, consuming approximately 15% of the cross-sectional area.

1.16.3.7.3.2. **Pink: rosette + rougher fatigue (~50 % area).** Rougher areas exhibiting rosettes consuming approximately 50% of the cross-sectional area

1.16.3.7.3.3. **Orange: rupture/incipient melting at leading edge (~35 % area).** The leading edge showed wall thickness loss and missing material, consistent with rupture/incipient melting

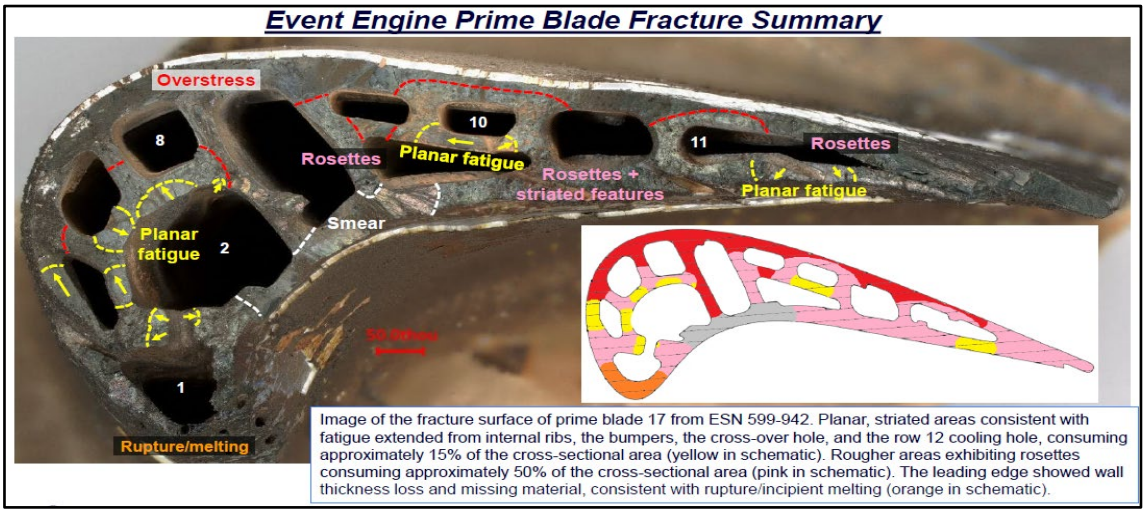

Figure 4 Blade Fracture Summary

1.16.3.7.4. Blade Radial Growth (slots 1–6)

1.16.3.7.4.1. Average for damaged 599-942 blades: 54 mils

1.16.3.7.4.2. Prime blade: up to 73 mils in localized areas

1.16.3.7.4.3. Visual Creep Ranking (0–3 scale) – 599-942 (intact airfoils only)

1.16.3.7.4.4. Level 3+ creep observed on 13 of 20 blades examined. Multiple blades showed 3+ distress with radial growth >60 mils.

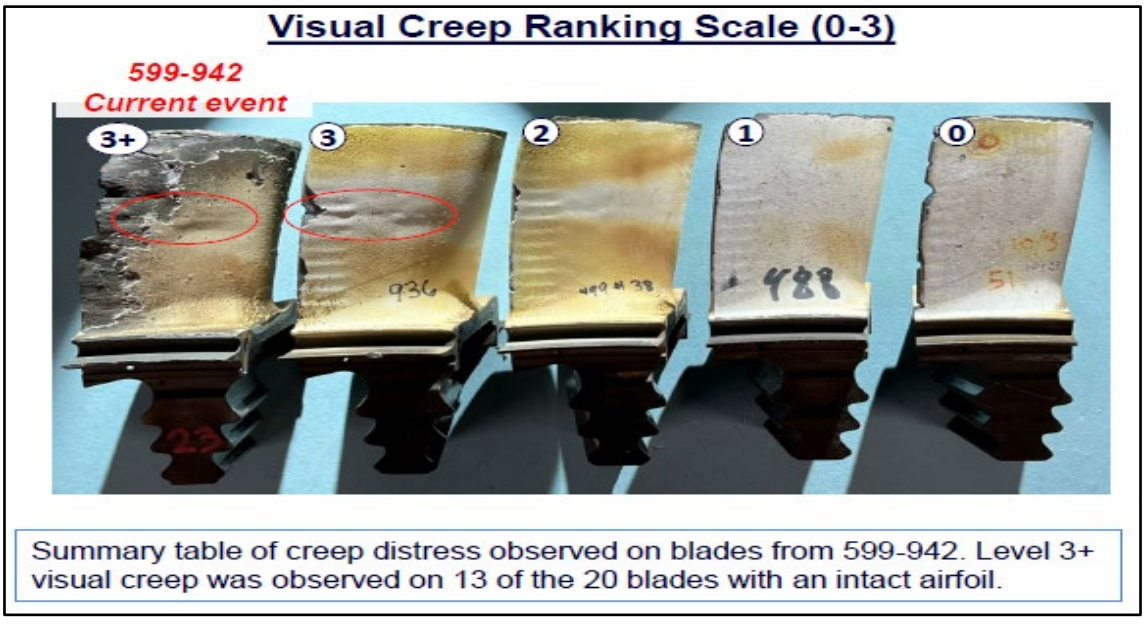

Figure 5 Creep Distress observed on Blades

1.16.3.7.5. Root Cause / Discrepancy Identified of Event Engine ESN 599-942.

The metallurgical examination of the HPT stage 1 blades from 599-942 revealed a fracture of blade 17 extending along the mid-span with leading edge distress connecting with regions consistent with sustained peak, high-alternating stress, low-cycle fatigue (SPLCF)/creep interaction internally. Internal fractures around cavity 2, the bumpers, and row 12 cooling hole 7 were planar and initiated with striated features. The fractures around cavities 4, 5, 10, and 11 initiated from “rosette” features, some with striations. The fractures also occurred in regions of deformation, consistent with, load-controlled SPLCF cracking. The fatigue/creep interaction regions connected with leading edge distress consistent with rupture and incipient melting, consuming approximately 75 percent of the cross-sectional area, which then overstressed the remainder of blade 17 (considered the prime blade based on fatigue area) and overstressed the remaining 41 blades.

1.16.3.8. Detailed Examination – Sister Engine 599-899

1.16.3.8.1. All 60 blades displayed Level 2–3 visual creep.

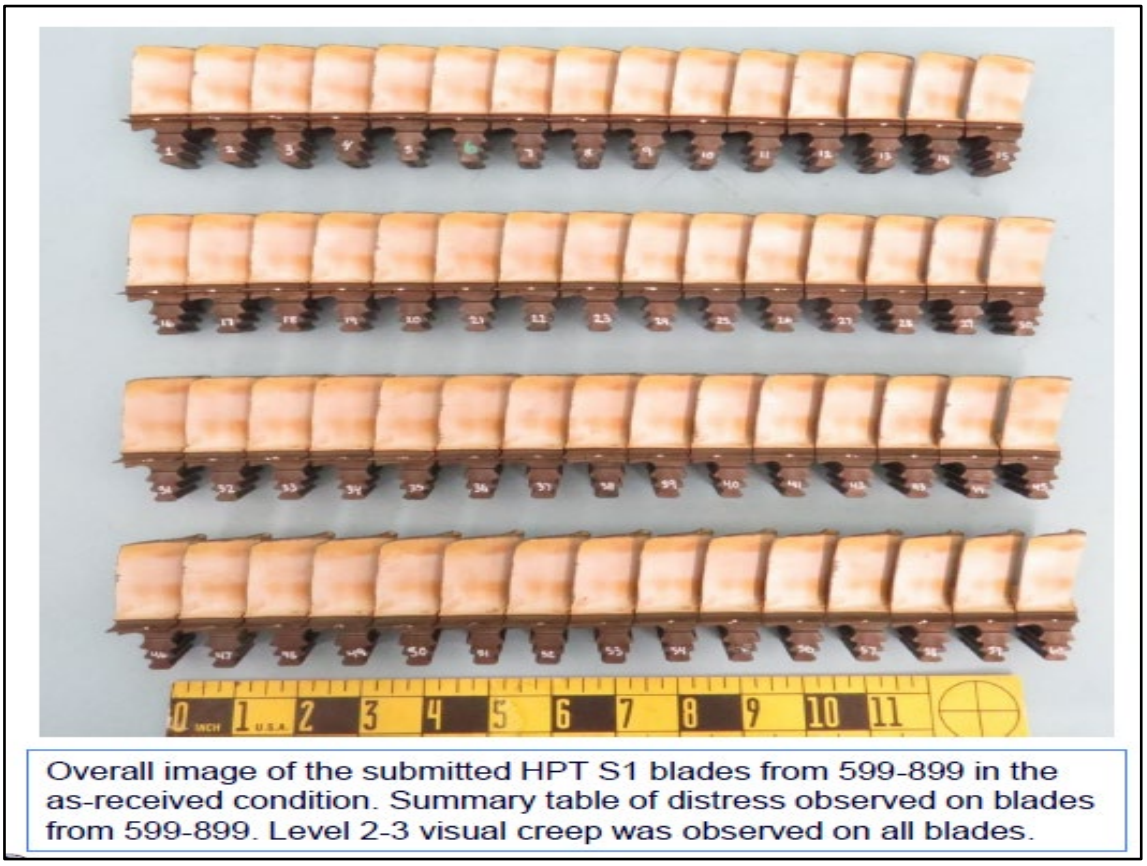

Figure 6 Level 2–3 visual creep distress

1.16.3.8.2. Maximum radial growth: 72.3 mils (blade 30).

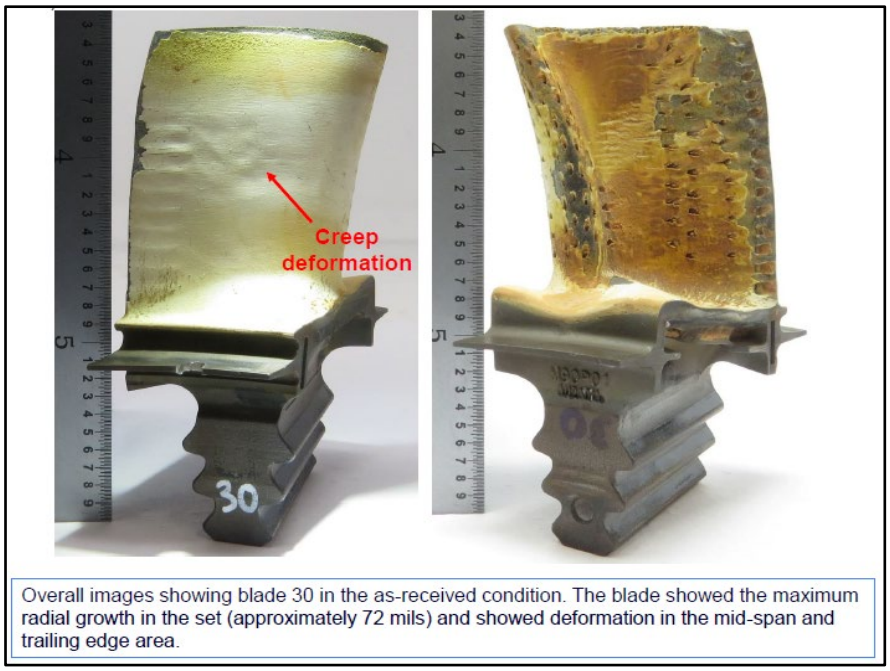

Figure 7 Maximum Radial Growth and Deformation in the mid-span

1.16.3.8.3. Blade 30 exhibited pronounced mid-span and trailing-edge creep deformation, spalled TBC, and heavy oxidation on the leading-edge external wall (most severe at 10 – 50 % span).

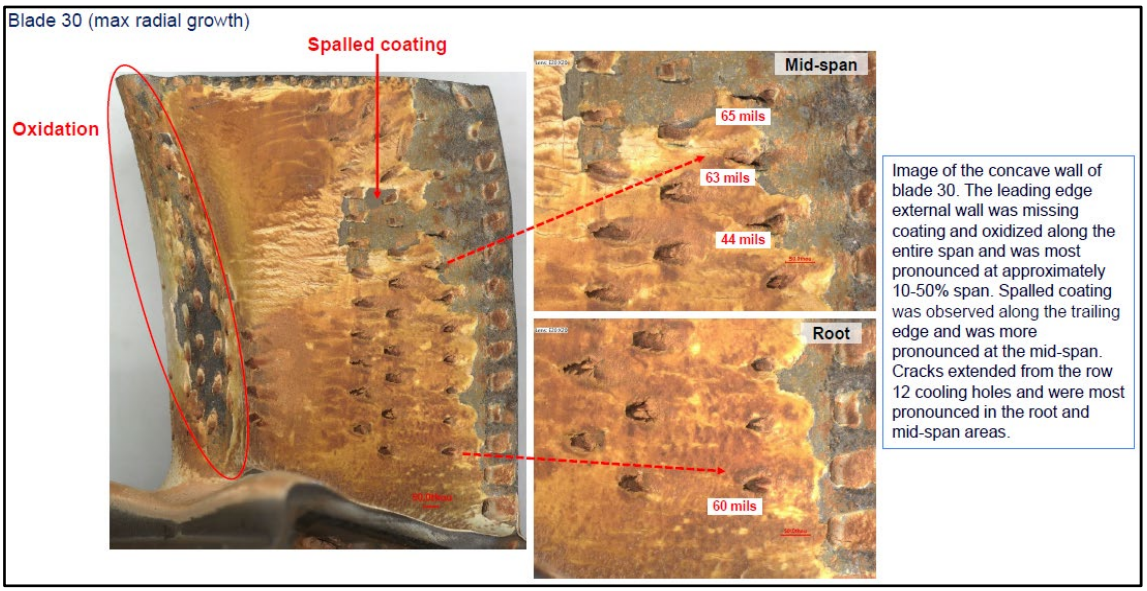

Figure 8 Blade 30: Creep deformation, TBC spallation, severe leading-edge oxidation

1.16.3.8.4. Cooling-hole cracks (Row 12) most pronounced in root and mid-span regions.

1.16.3.8.5. Average radial growth across the full set: ~44 mils.

1.16.3.8.6. Selected Radial Growth Data (Sister Engine – highest values)

1.16.3.8.6.1. Blade 30: 72.3 mils

1.16.3.8.6.2. Blade 57: 62.6 mils

1.16.3.8.6.3. Blade 58: 60.9 mils

1.16.3.8.6.4. Blade 6: 60.5 mils

1.16.3.8.7. **Root Cause / Discrepancy Identified of Sister Engine ESN 599-899.** Examination of the blades from the sister engine 599-899 showed varying extents of creep damage as well. The average radial growth determined from blue light scans was approximately 44 mils (max of 72 mils) and was most pronounced in the mid-span area.

1.16.4. Airblue operated 100% in-region Severe Engine Operation (SEO), consistent with regional airline operations in Pakistan and surrounding high-temperature, high-altitude environments.

1.16.5. The evaluation revealed creep-induced cracking in the airfoil of Blade 17 (S/N GNK07EWD) from the event engine, leading to fracture at mid-span via SPLCF/creep interaction and subsequent fatigue propagation. The sister engine blades showed widespread creep damage with average radial growth of 44 mils (maximum 72.3 mils on Blade 30).

1.17. Organizational and Management Information

1.17.1. The operator is Airblue Limited, a scheduled commercial airline operating under PCAA regulatory oversight.

1.17.2. The Pakistan Civil Aviation Authority (PCAA) oversaw the incident response, including coordination with airport management (APM, AMO, DTM). Emergency response procedures were activated; however, lapses occurred in enforcing post-incident medical protocols and in preventing crew departure before mandatory assessments were completed.

1.17.3. Airport Airside Management failed to contact and retain the cockpit crew in a timely manner post-incident, allowing the crew to depart unescorted before mandatory protocols were completed.

1.18. Additional Information

1.18.1. Not Applicable.

1.19. Use of Effective Investigation Techniques

1.19.1. Standard ICAO Annex 13 compliant investigation procedures and techniques were applied. These included factual data collection, maintenance record analysis, crew interviews, technical system analysis, Airbus consultation, and Human Factors Analysis and Classification System (HFACS) methodology.

1.19.2. Investigation techniques applied in accordance with ICAO Annex 13 included: factual data collection from PCAA/PAA IOU report; ATC communications transcript review; post-landing inspection data; metallurgical evaluation by Original Equipment Manufacturer (OEM) (CFMI / CFM International); HFACS analysis for human factors; and review of regulatory compliance records.

1.19.3. The metallurgical evaluation of both the event engine and sister engine blades provided a comprehensive technical foundation for cause determination.

SECTION 2 – ANALYSIS

2.1. General

2.1.1. This analysis examines the technical mechanism of the HPT Stage 1 blade failure; the role of the severe engine operating environment; the significance of the pre-inspection timing; the post-incident procedural lapses in crew medical testing and evidence management; and the systemic organizational and human factors implications.

2.1.2. The investigation determined that the IFSD was a **technical event caused by material degradation under severe operating conditions, compounded by systemic maintenance programme and regulatory oversight gaps**. The post-incident lapses, while not contributing to the engine failure itself, constitute independent safety failures of significant concern.

2.2. Technical Analysis – HPT Stage 1 Blade Failure Mechanism

2.2.1. LEAP-1A HPT Stage 1 Blade Design and Operating Environment

2.2.1.1. The CFM International LEAP-1A engine's High-Pressure Turbine (HPT) Stage 1 blades (P/N 2747M92P01) operate in the most thermally aggressive environment within the engine – immediately downstream of the combustor, exposed to gas temperatures significantly exceeding the blade alloy's inherent capability. Blade survival depends on: an N515 nickel-base superalloy substrate; a Platinum Aluminide with Hafnium (PtAl+Hf) bond coat; and an Electron-Beam Physical Vapor Deposition (EBPVD) Thermal Barrier Coating (TBC) applied to reduce metal temperature.

2.2.1.2. Internal cooling circuits – including cooling holes at Row 12, cavity passages, and cross-over holes – channel compressor bleed air to maintain blade metal temperatures within design limits. Any reduction in cooling effectiveness, TBC degradation, or increase in gas path temperature accelerates creep and oxidation damage.

2.2.1.3. Severe Engine Operation (SEO) conditions – characterised by high ambient temperatures, high-altitude airport operations, extended hot-and-high segments, and aggressive engine power settings – place HPT Stage 1 blades under sustained elevated thermal and mechanical loading, directly accelerating creep deformation and oxidation

2.2.2. Failure Mechanism – Event Engine ESN 599-942, Prime Blade 17

2.2.2.1. Blade 17 (S/N GNK07EWD) was identified as the prime (initiating) blade of the failure sequence. The following damage sequence was established:

2.2.2.1.1. Initiation – SPLCF/Creep Interaction: Fracture initiated at the airfoil mid-span, at internal surfaces. The initiation mode was identified as Sustained Peak Low-Cycle Fatigue / Creep interaction (SPLCF/creep). This mechanism arises when sustained high temperatures cause creep deformation of the blade substrate, while cyclic loading (from

engine power changes and vibratory stresses) drives fatigue crack initiation and early propagation.

2.2.2.1.2. Fracture Surface Composition: Analysis of the prime blade fracture surface identified as Planar/striated fatigue features, Rosette formations with rougher fatigue features & rupture and incipient melting at the leading edge, indicating severe thermal exposure with metal loss.

2.2.2.1.3. Leading-Edge Thermal Damage: The leading-edge external wall of Blade 17 exhibited severe oxidation, heavy metal loss, incipient melting, and rupture, consuming approximately 75% of the cross-sectional area. This catastrophic thermal damage was the proximate cause of the overload rupture that liberated the outer airfoil span.

2.2.2.1.4. Radial Growth: Localized radial growth in the prime blade reached up to 73 mils, with an average of 54 mils across the 599-942 damaged blades. Radial growth is a direct metric of creep deformation severity.

2.2.2.1.5. Creep Ranking: Visual creep ranking (0–3 scale) of the intact airfoils from ESN 599-942 revealed Level 3+ creep on 13 of 20 blades examined, with multiple blades showing >60 mils radial growth. This is consistent with advanced creep degradation across the HPT Stage 1 disc.

2.2.3. Propagation and Secondary Damage

2.2.3.1. The SPLCF/creep cracks propagated via fatigue, driven by cyclic thermal and mechanical loading. Once the leading-edge wall had been sufficiently reduced by oxidation and melting to approximately 25% of its original cross-section, the remaining load-bearing area could no longer sustain the centrifugal and aerodynamic forces at operating rotational speeds.

2.2.3.2. Overload fracture released the outer airfoil span of Blade 17. The liberated material immediately impacted adjacent and downstream blades within the HPT Stage 1 disc, overstressing the remaining 41 blades. This cascade of mechanical impacts and resulting stress overloads constitutes the primary mechanism for the engine failure.

2.2.3.3. The released blade fragment(s) exited through the engine exhaust, consistent with the small metallic pieces found at the bottom rear of the engine post-landing

2.3. Sister Engine Analysis – ESN 599-899

2.3.1. The sister engine (ESN 599-899), at equivalent accumulated cycles and hours to the event engine, was examined to establish whether the creep damage was a fleet-wide condition or isolated to the event engine.

2.3.2. Findings on sister engine ESN 599-899 blades:

2.3.2.1. The investigation determined that the maintenance team working on No. 1 pack on 28 September 2024 performed a deficient leak check.

2.3.2.2. All 60 blades exhibited Level 2–3 visual creep distress on the 0–3 scale.

2.3.2.3. Average radial growth across the full set: approximately 44 mils.

2.3.2.4. Maximum radial growth: 72.3 mils on Blade 30.

2.3.2.5. Growth was most pronounced in the mid-span region, consistent with the failure location of the event engine's prime blade.

2.3.2.6. Selected highest radial growth values: Blade 30 (72.3 mils), Blade 57 (62.6 mils), Blade 58 (60.9 mils), Blade 6 (60.5 mils).

2.3.2.7. Blade 30 exhibited pronounced mid-span and trailing-edge creep deformation, spalled TBC, and heavy oxidation on the leading-edge external wall, most severe between 10–50% span.

2.3.2.8. Cooling-hole cracks (Row 12) were most pronounced in root and mid-span regions, consistent with the event engine pattern.

2.3.3. Significance: The widespread and severe creep damage on all 60 sister engine blades – at an equivalent operating cycle count – confirms unambiguously that the Airblue LEAP-1A fleet had collectively entered a creep-limited operating regime under the SEO environment. The event engine's IFSD was not an isolated, anomalous event but rather the leading edge of a fleet-wide progressive degradation trajectory. Had the sister engine continued to operate without intervention, a similar IFSD event would have been probable.

2.4. Role of Severe Engine Operation (SEO)

2.4.1. Airblue operated 100% in-region Severe Engine Operation (SEO), as reported by the operator and consistent with operations in the high-temperature, high-altitude environments of Pakistan and the broader region (Arabian Peninsula, South Asia, Middle East).

2.4.2. SEO conditions accelerate HPT blade degradation through multiple mechanisms:

2.4.2.1. Higher ambient temperatures reduce the available cooling margin for HPT blades, increasing metal temperature.

2.4.2.2. High-altitude airport operations (such as Islamabad, Peshawar) require elevated engine thrust settings, increasing turbine entry temperature.

2.4.2.3. Sustained high power settings during extended climb phases increase creep damage accumulation per cycle.

2.4.2.4. Thermal cycling during repeated engine start-stop cycles at high ambient temperatures accelerates thermal fatigue interactions with creep.

2.4.3. The OEM (CFMI) SEO classification system acknowledges that HPT blades in SEO environments accumulate creep damage at rates that may differ significantly from standard cycle-counting models. **SEO-specific inspection intervals and enhanced monitoring are intended to compensate for this acceleration**. The 1,600-cycle service bulletin inspection interval was the first scheduled opportunity to assess HPT blade condition.

2.4.4. The IFSD occurred immediately prior to this inspection (at 1,522 cycles), indicating that the creep damage had already exceeded safe operating limits before the first scheduled assessment. **This raises a fundamental question regarding whether the 1,600-cycle interval is appropriate for operators with 100% SEO exposure**.

2.5. Pre-Inspection Timing and Service Bulletin Significance

2.5.1. The event engine accumulated 1,522 cycles at the time of the IFSD, with the first HPT Stage 1 blade inspection mandated by the applicable service bulletin scheduled at 1,600 cycles. The failure occurred 78 cycles (approximately 4.9%) before the first scheduled assessment.

2.5.2. The sister engine examination confirms that severe creep damage was already present across the full HPT Stage 1 blade set at equivalent cycles. This means the engine was operating in a degraded state that would have been partially detectable had an inspection occurred before 1,522 cycles.

2.5.3. The analysis supports the conclusion that the 1,600-cycle inspection interval, while potentially appropriate for standard operating environments, is inadequate for operators with 100% SEO exposure. **An earlier inspection interval for SEO operators would have provided an opportunity to detect advanced creep damage and prevent the IFSD**.

2.6. Flight Crew and Operational Analysis

2.6.1. The nature of this flight as a training sector (with an FO Safety pilot present) introduced additional factors that require consideration:

2.6.1.1. Immediate level-off at 8,000 ft AMSL preserved a safe energy state.

2.6.1.2. Prompt ATC notification and PAN PAN declaration were appropriate.

2.6.1.3. Request for preferred approach routing (ILS Z via ISDUR vs. direct ISBAX) demonstrated crew initiative and situational awareness.

2.6.1.4. NITS briefing to LCC via proper cockpit protocol was correctly executed.

2.6.1.5. Single-engine ILS approach and landing were safely executed.

2.6.2. Crew performance during the in-flight emergency was not a contributing factor to the occurrence.

2.6.3. However, the post-landing departure from the aircraft without completing mandatory medical protocols represents a serious procedural violation that compromised the investigation's integrity.

2.7. Post-Incident Protocol Failure Analysis

2.7.1. The failure of the Captain and FO Safety to comply with PCAA ANO-002-XXAM-1.0 post-incident medical requirements is a significant safety failure independent of the engine failure mechanism. The key failures were:

2.7.1.1. The crew departed the airport via the Passenger Boarding Bridge without notifying ground staff, Airside Management, or the waiting medical team.

2.7.1.2. No pre-flight alcohol breath analyzer record exists for the incident flight, indicating the pre-flight testing requirement was either not performed or not documented prior to departure.

2.7.1.3. Sample collection delays (6h 33min for FO Safety; 13h 28min for Captain) exceeded scientifically reliable detection windows for several psychoactive substances. While alternative samples confirmed no influence, the reliability of delayed biological samples for regulatory purposes is significantly reduced compared to immediate testing.

2.7.2. Systemic failures enabling the protocol breach:

2.7.2.1. Airline Coordination Failure: Airblue ground staff and airline management did not have effective mechanisms to retain the crew at the aircraft or escort them to the medical team.

2.7.2.2. Airport Authority Failure: The Airside Manager failed to contact and hold the cockpit crew in a timely manner, enabling their unescorted departure.

2.7.2.3. Absence of Mandatory Escorts: No regulatory or operational requirement for mandatory physical escorts of crew from aircraft to medical facilities was in place and enforced.

2.7.2.4. ASF Deployment Gap: While ASF personnel were deployed to cordon off the aircraft, no protocol was in place to ensure crew retention simultaneously.

2.7.3. The post-incident protocol failures reflect a systemic gap in Pakistan's aviation emergency management framework regarding crew retention and immediate biological sampling after serious incidents. While the final test results were negative, the procedural failures represent a systemic vulnerability that, in a future incident with different circumstances, could compromise evidence critical to a safety investigation or regulatory enforcement action.

2.8. Human Factors Analysis – HFACS Framework

2.8.1. Level 1 – Unsafe Acts

2.8.1.1. **Post-Incident Violation (Crew):** Departure from the aircraft and airport without completing mandatory medical assessments, in **direct violation** of ANO-002-XXAM-1.0. This was an intentional act, whether motivated by unawareness of obligations, discomfort with the testing process, or other factors not established.

2.8.1.2. **Omission (Pre-flight):** No record of pre-flight alcohol breath analyzer testing for either crew member was retained, indicating either non-performance or non-documentation of a mandatory safety check.

2.8.2. Level 2 – Preconditions for Unsafe Acts

2.8.2.1. **Inadequate Crew Awareness:** The crew's post-incident departure behaviour suggests inadequate training or internalization of post-incident legal and procedural obligations.

2.8.2.2. **Psychological State Post-Emergency:** The stress and adrenaline of managing a serious engine failure may have impaired crew judgment regarding post-landing procedural requirements.

2.8.3. Level 3 – Unsafe Supervision

2.8.3.1. Failure by Airblue ground staff, Airside Management, and airline management to intercept and retain the crew before departure.

2.8.3.2. No effective supervisory chain was activated to enforce post-incident crew retention protocols.

2.8.4. Level 4 – Organizational Influences

2.8.4.1. **Regulatory Gap:** Absence of a mandatory, operationally enforceable crew escort and retention procedure from aircraft to medical facilities after serious incidents.

2.8.4.2. **Training Gap:** Insufficient crew training on post-incident regulatory requirements and consequences of non-compliance.

2.8.4.3. **Engine Maintenance Programme Gap:** The 1,600-cycle inspection interval, as applied to 100% SEO operators, did not provide adequate protection against accelerated HPT blade creep degradation

2.9. Systemic Analysis

2.9.1. The occurrence highlights two distinct but related systemic concerns:

2.9.1.1. **Technical/Airworthiness:** The LEAP-1A HPT Stage 1 blade life management system, as currently structured, may not adequately account for the cumulative creep acceleration effect of 100% SEO operation. **The fleet-wide nature of the creep damage (confirmed by sister engine examination) indicates a systemic - not isolated - airworthiness risk.**

2.9.2. **Safety Management / Regulatory:** Pakistan's post-incident crew testing and retention framework lacks operationally enforceable mechanisms. The multiple systemic failures that enabled the crew's departure without medical testing expose a gap that must be addressed to ensure the integrity of future investigations.

2.9.3. Both systemic issues require coordinated action by Airblue, CFMI/OEM, and PCAA to prevent recurrence.

SECTION 3 – CONCLUSIONS

3.1. Findings

3.1.1. The following findings are presented in accordance with ICAO Annex 13 requirements and reflect facts and safety-relevant conditions established during the investigation.

3.1.2. Flight and Occurrence Facts

3.1.2.1. On 30 October 2023, Airblue flight ABQ207 (AP-BOD) departed OPIS R/W 28L at 12:41:39 UTC with 248 persons on board (240 passengers, 8 crew including Captain, FO (PF), and FO Safety).

3.1.2.2. At 12:45:28 UTC, during initial climb at approximately 8,000 ft AMSL (~12 NM west of OPIS), a loud bang and abnormal vibrations were experienced. At 12:45:32 UTC, Engine No. 1 IFSD was declared.

3.1.2.3. The crew levelled off at 8,000 ft, declared 'PAN PAN' at 12:46:23 UTC, and executed an ILS Z approach to R/W 28L. The aircraft landed safely after 13:00:00 UTC with no injuries.

3.1.2.4. Post-landing inspection at Stand 24 revealed small metallic pieces from internal engine components at the rear of Engine No. 1. No bird strike evidence was found.

3.1.3. Technical / Metallurgical Findings

3.1.3.1. The IFSD was caused by fracture and liberation of the outer span of HPT Stage 1 Blade 17 (S/N GNK07EWD) from Engine No. 1 (ESN 599-942).

3.1.3.2. The failure initiation mode was Sustained Peak Low-Cycle Fatigue / Creep interaction (SPLCF/creep), with subsequent propagation via fatigue.

3.1.3.3. The leading-edge external wall of Blade 17 exhibited severe oxidation, metal loss, incipient melting, and rupture consuming approximately 75% of the cross-sectional area – constituting the direct trigger for overload fracture.

3.1.3.4. Internal damage in Blade 17 included. mid-span fracture with ~46 mils radial growth; planar fractures at Cavity 2, bumpers, and Row 12 hole 7 (with fatigue striations); rosette formations at cavities 4, 5, 10, and 11; parallel creep cracks; and up to 77 mils metal loss at Row 12 hole 6.

3.1.3.5. The fracture surface comprised. ~15% planar/striated fatigue; ~50% rosette/rougher fatigue (creep-driven); ~35% leading-edge rupture/incipient melt.

3.1.3.6. Radial growth in Blade 17 reached 73 mils locally; average for 599-942 damaged blades was 54 mils.

3.1.3.7. Visual creep ranking confirmed Level 3+ on 13 of 20 intact blades examined from ESN 599-942.

3.1.3.8. The liberated outer span of Blade 17 overstressed the remaining 41 HPT Stage 1 blades, completing the engine failure.

3.1.4. Sister Engine Findings

3.1.4.1. All 60 HPT Stage 1 blades from sister engine ESN 599-899 exhibited Level 2–3 visual creep distress.

3.1.4.2. Average radial growth of sister engine blades. approximately 44 mils. Maximum: 72.3 mils (Blade 30).

3.1.4.3. The widespread creep damage across all sister engine blades confirms that the Airblue LEAP-1A fleet entered a creep-limited regime under its SEO operating environment, and that the IFSD was not an isolated event.

3.1.5. Operational and SEO Findings

3.1.5.1. The operator reported 100% in-region Severe Engine Operation (SEO), which accelerates HPT Stage 1 blade creep damage compared to standard operating environments.

3.1.5.2. The IFSD occurred at 1,522 cycles — 78 cycles (4.9%) before the first scheduled 1,600-cycle HPT Stage 1 service bulletin inspection. This is the earliest recorded IFSD for the LEAP-1A fleet.

3.1.5.3. The failure occurred prior to the first scheduled inspection opportunity, indicating that the current inspection interval is insufficient to detect advanced creep damage before it reaches critical levels in 100% SEO operators.

3.1.6. Post-Incident Protocol Findings

3.1.6.1. The Captain and FO Safety departed the airport without completing mandatory immediate post-incident medical assessments, in violation of PCAA ANO-002-XXAM-1.0.

3.1.6.2. No pre-flight alcohol breath analyzer record for the incident flight was provided by PCAA Aero Medical Center, Karachi, constituting a violation of ANO-002-XXAM-1.0.

3.1.6.3. Biological sample collection was delayed. 6h 33min for FO Safety; 13h 28min for Captain. Alternative samples (hair/nails) were required for the Captain.

3.1.6.4. Laboratory analysis confirmed both crew members were free of psychoactive substances. However, the reliability and regulatory validity of delayed samples are significantly reduced compared to immediate testing.

3.1.6.5. Multiple systemic failures enabled the crew departure. Airblue ground staff coordination failure; Airside Management failure to retain crew; absence of mandatory escort protocols; and no dedicated crew retention procedure post-incident.

3.1.7. Crew Performance Findings

3.1.7.1. The flight crew's in-flight emergency response was timely, effective, and in accordance with applicable procedures. Their actions directly ensured the safe outcome with no injuries.

3.1.7.2. ATC coordination was effective, with no traffic conflicts and timely activation of emergency services.

3.1.7.3. Cabin crew performance was in line with the standard procedures; the cabin was secured, NITS protocols were correctly applied, and passengers remained calm.

3.2. Cause / Contributory Factors

3.2.1. Cause

3.2.1.1. The cause of this serious incident was an In-Flight Shutdown (IFSD) of Engine No. 1 (LEAP-1A, ESN 599-942) **resulting from fracture of the HPT Stage 1 Blade No. 17** (S/N GNK07EWD). Fracture initiated at the airfoil mid-span via Sustained Peak Low-Cycle Fatigue / Creep (SPLCF/creep) interaction, driven by creep-accelerated damage in a Severe Engine Operation (SEO) environment. The leading-edge external wall sustained approximately 75% cross-sectional area reduction through oxidation, metal loss, and incipient melting, causing overload rupture and liberation of the outer airfoil span. The liberated blade material overstressed the remaining 41 HPT Stage 1 blades, resulting in the engine failure.

3.2.2. Contributory Factors

3.2.2.1. Technical / Operational Contributing Factors

3.2.2.1.1. **100% In-Region Severe Engine Operation (SEO) – Primary Technical Contributing Factor:** The operator's exclusively SEO operational profile continuously exposed HPT Stage 1 blades to elevated thermal and mechanical loading, directly accelerating creep deformation, oxidation, and SPLCF/creep crack initiation beyond the rates anticipated by standard cycle-based life management models.

3.2.2.1.2. **Insufficient HPT Stage 1 Inspection Interval for SEO Operators:** The current first scheduled HPT Stage 1 service bulletin inspection at 1,600 cycles proved inadequate for an operator with 100% SEO exposure. The failure occurred at 1,522 cycles – before the first inspection – when advanced creep damage was already present and detectable in the sister engine at equivalent cycles.

3.2.2.1.3. **Fleet-Wide Creep Degradation:** The sister engine examination confirmed that all 60 HPT Stage 1 blades had entered an advanced creep regime, demonstrating that the technical risk was fleet-wide and not limited to the event engine.

3.2.2.2. Post-Incident Investigation Integrity Contributing Factors

3.2.2.2.1. **Crew Non-Compliance with Post-Incident Medical Protocols (ANO-002-XXAM-1.0):** The departure of the Captain and FO Safety without medical testing compromised the integrity of the post-incident investigation and the validity of the biological sampling.

3.2.2.2.2. **Absence of Pre-Flight Alcohol Breath Analyzer Records:** Non-retention or non-performance of pre-flight alcohol testing for the incident flight crew constitutes a regulatory violation and a gap in the pre-flight safety record.

3.2.2.2.3. **Coordination Failures by Airblue and Airport Authorities:** The absence of effective crew retention mechanisms (mandatory escorts, designated liaison, physical barriers) allowed the crew to depart unescorted, enabling the protocol violations described above.

SECTION 4 – SAFETY RECOMMENDATIONS

4.1. Safety Recommendations

4.1.1. The following safety recommendations are issued in accordance with ICAO Annex 13. All recommendations are aimed at preventing recurrence of similar occurrences and strengthening aviation safety in Pakistan.

4.1.1.1. Enhanced HPT Stage 1 Inspection Interval for SEO Operators	
Addressed To	**CFM International (CFMI) / PCAA (Airworthiness Oversight)**
Recommendation	CFMI should evaluate and issue revised service guidance establishing an earlier HPT Stage 1 blade inspection interval for LEAP-1A operators with 100% SEO classification. The interval should be based on creep life modelling calibrated to SEO profiles. PCAA should mandate compliance for all Pakistani LEAP-1A operators.
Safety Rationale	The IFSD occurred at 1,522 cycles - 78 cycles before the first scheduled 1,600-cycle inspection. Sister engine (ESN 599-899) showed advanced creep damage across all 60 blades at equivalent cycles, confirming the current interval is insufficient for 100% SEO operators. An earlier inspection would provide opportunity to detect and act on pre-failure creep degradation.

4.1.1.2. Mandatory Fleet-Wide HPT Stage 1 Blade Inspection (LEAP-1A SEO Operators)	
Addressed To	**Airblue Limited / PCAA (Airworthiness) / CFM International**
Recommendation	Airblue should immediately submit all LEAP-1A engines for HPT Stage 1 blade creep assessment. PCAA should issue a mandatory instruction requiring all Pakistani LEAP-1A operators to conduct HPT Stage 1 blade inspections prior to further operation or within a defined inspection campaign. CFMI to provide technical inspection guidance.
Safety Rationale	Sister engine ESN 599-899 at equivalent cycles showed Level 2–3 creep on all 60 blades with radial growth up to 72.3 mils, confirming fleet-wide risk. Continued operation without inspection poses unacceptable IFSD risk across the fleet.

4.1.1.3. Mandatory Crew Escort Protocol for Post-Incident Medical Assessment	
Addressed To	**PCAA / Airblue Limited / Pakistan Airports Authority (PAA)**
Recommendation	PCAA should amend regulations to establish a mandatory, enforceable crew escort and retention protocol procedures for serious incidents and accidents. The procedures must designate responsible officers, require physical escort to medical facilities, authorize crew retention at the stand, and mandate BASIP notification if crew depart before assessment. Airblue must update SOPs and train crew on post-incident legal obligations. PCAA and PAA should clearly define regulation in this regard to avoid such recurrences.
Safety Rationale	The Captain and FO Safety departed without completing mandatory medical assessments, enabled by multiple systemic failures (no liaison, no escort, no retention authority). These failures compromised investigation integrity. Without immediate correction, future incidents risk non-detection of psychoactive substance influence — a direct safety risk.

4.1.1.4. Enforcement of Pre- and Post-Flight Alcohol Breath Analyzer Requirements	
Addressed To	**PCAA (Aero Medical / Flight Standards) / Airblue Limited**
Recommendation	PCAA should establish an audit programme for ANO-002-XXAM-1.0 breath analyzer compliance, including mandatory record retention, random audits, and defined sanctions. Airblue should implement internal QA verification for breath analyzer performance and recording for every flight crew departure.
Safety Rationale	No pre-flight breath analyzer record was available for the incident flight, indicating non-performance or non-documentation of a mandatory safety requirement. Systematic non-compliance represents a fundamental gap in crew fitness-for-duty assurance.

4.1.1.5. Rapid On-Site Biological Sampling Capability at Major Pakistani Airports	
Addressed To	**PCAA (Aero Medical) / Pakistan Airports Authority (PAA)**
Recommendation	PCAA and PAA should establish rapid on-site biological sampling capability at major airports, including pre-positioned Aero Medical teams, mobile sampling units for immediate apron-side deployment, and defined maximum sampling windows. Regulatory consequences should apply for breaches of sampling windows.
Safety Rationale	Sample collection delays of 6h 33min (FO Safety) and 13h 28min (Captain) fundamentally compromised biological sampling validity. On-site rapid capability eliminates dependence on crew cooperation with delayed transport and ensures scientifically reliable samples are obtained immediately.

4.1.1.6. SEO-Specific Engine Health Monitoring and Trend Analysis Programme	
Addressed To	**Airblue Limited / PCAA (Airworthiness) / CFM International**
Recommendation	Airblue and CFMI should implement an enhanced Engine Health Monitoring (EHM) programme calibrated for SEO, including EGT margin monitoring with SEO-adjusted thresholds, vibration trend analysis, duty cycle monitoring, and integration with maintenance planning. PCAA should require SEO-specific EHM documentation for all Pakistani LEAP-1A operators.
Safety Rationale	Advanced creep damage on sister engine blades confirms pre-failure degradation was progressive over many cycles. EHM trend data provides advance warning of HPT blade degradation before it reaches critical levels. Without proactive EHM, SEO operators have no early-warning mechanism for accelerated blade life consumption.

4.1.1.7. Crew Training on Post-Incident Legal and Procedural Obligations	
Addressed To	**All Operators / PCAA (Flight Standards)**
Recommendation	All Operators must incorporate mandatory training on post-incident obligations (PASI Act 2023, Air Safety Rules 2025 & ANO-002-XXAM-1.0) into initial and recurrent training, covering: post-incident medical testing requirements; prohibition on departure without Investigation Authority clearance; consequences of non-compliance; and post-incident crew action checklists. PCAA should verify all operators include this in approved training programmes.
Safety Rationale	The crew's departure without mandatory medical testing suggests inadequate awareness of post-incident obligations. Mandatory targeted training directly addresses this gap and ensures crew understand and comply with their legal duties following a serious incident.

4.2. Summary of Safety Recommendations

4.1.2. The following table summarizes all safety recommendations issued in this report:

Para.	Subject	Addressed To	Status
4.1.1	Enhanced HPT Stage 1 Inspection Interval for SEO Operators	CFMI / PCAA	OPEN
4.1.2	Mandatory Fleet-Wide HPT Stage 1 Blade Inspection	Airblue / PCAA / CFMI	OPEN
4.1.3	Mandatory Crew Escort Protocol – Post-Incident Medical Assessment	PCAA / PAA / Airblue	OPEN
4.1.4	Enforcement of Pre/Post-Flight Alcohol Breath Analyzer Requirements	PCAA / Airblue	OPEN
4.1.5	Rapid On-Site Biological Sampling at Major Airports	PCAA / PAA	OPEN
4.1.6	SEO-Specific Engine Health Monitoring programme	Airblue / PCAA / CFMI	OPEN
4.1.7	Crew Training on Post-Incident Legal Obligations	Airblue / PCAA	OPEN

END OF REPORT

Bureau of Aircraft Safety Investigation Pakistan (BASIP)
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