Final Report

A320NEO, B-305J

Smoke in Cabin, Engine fire, Evacuation

10 September 2023

TIB/AAI/CAS.225

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

3 June 2024

<u>The Transport Safety Investigation Bureau of Singapore</u>

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ABBREVIATIONS

ACOD	Approach Coordinator
AGB	Angle gearbox
ANSP	Air Navigation Service Provider
ARFF	Airport Rescue and Fire Fighting Service
ARR	Arrival Controller
AT1	Controller manning the walkie-talkie at the CET
ATC	Air Traffic Control
BSI	Borescope inspection
CET	Changi East Control Tower
CVR	Cockpit voice recorder
DO3	Duty Officer for FS3
ECAM	Electronic Centralised Aircraft Monitor
EHMS	Engine health monitoring system
FDR	Flight data recorder
FMGC	Flight Management Guidance Computer
FS3	Fire Station 3
FL	Flight Level
FO	First Officer
HPC	High Pressure Compressor
ILS	Instrument Landing System
IAPP	Inner Approach Controller
LPC	Lower pressure compressor
LPT	Lower pressure turbine

LSOP	Lube and scavenge oil pump
MGB	Main gearbox
NAPP	North Approach Controller
NM	Nautical Miles
OIC	Officer-in-charge
OC	Operation Commander
PF	Pilot Flying
PIC	Pilot-in-Command
PM	Pilot Monitoring
PO	Third pilot sitting at observer seat
RET	Rapid Exit Taxiway
RNP	Required Navigation Performance
RWC	Runway 20L controller
SATCC	Singapore Air Traffic Control Centre
SOP	Standard Operating Procedures
TCOD	Tower Coordinator
WO	Warrant Officer
WRO	Watch Room Operator

SYNOPSIS

On 10 September 2023, an Air China A320NEO aircraft (registration B-305J) encountered smoke in the cockpit and the cabin. The flight crew declared MAYDAY and requested priority landing at Singapore Changi Airport. The flight crew also received smoke warnings from the avionics compartment, forward cargo compartment and lavatories.

After landing on Runway 20L, the flight crew stopped the aircraft on the runway and initiated an emergency evacuation. All passengers and crew members safely evacuated the aircraft. The Airport Rescue and Fire Fighting Service saw a fire at the left engine tailpipe and extinguished it.

Nine passengers suffered minor injuries during the evacuation.

The Transport Safety Investigation Bureau classified this occurrence as a serious incident.

AIRCRAFT DETAILS

Aircraft type	: AIRBUS A320 NEO
Operator	: Air China
Aircraft registration	: B-305J
Numbers and type of engines	: Two / Pratt & Whitney PW1127G-JM Turbo Fan Engine
Left engine hours/cycles since new	: 8583 Flight Hours/ 3659 Flight Cycles
Right engine hours/cycles since new	: 660 Flight Hours /334 Flight Cycles
Left engine hours/cycles since last shop visit	: 916 Flight Hours/ 446 Flight Cycles
Right engine hours/cycles since last shop visit	: NA
Date and time of incident	: 10 September 2023
Location of occurrence	: Singapore
Type of flight	: Scheduled
Persons on board	: 155 (9 crew and 146 passengers)

1 FACTUAL INFORMATION

All times used in this report are Singapore Local Time (LT) unless otherwise stated. Singapore Local Time is eight hours ahead of Coordinated Universal Time (UTC).

1.1 History of the flight

1.1.1 On 10 September 2023, an Airbus A320NEO was enroute from Tianfu International Airport, Chengdu, China to Changi Airport, Singapore. The Pilot-in-Command (PIC) was the Pilot Flying (PF), and the First Officer (FO) was the Pilot Monitoring (PM). A third pilot[1] (PO), who held the rank of Captain, was occupying the observer seat.

1.1.2 At about 15:49, as the aircraft was descending for landing in Singapore, the flight crew detected an unusual smell in the cockpit. At about the same time, the cabin crew also informed the flight crew via the interphone of an abnormal smell in the cabin. However, as there were no indications on the Electronic Centralised Aircraft Monitor (ECAM)[2] of any abnormalities of the aircraft systems, the flight crew believed that the smell had likely originated from the surrounding air outside the aircraft and did not take any further action regarding the smell. The flight crew informed the cabin crew of their belief but requested the cabin crew to monitor the unusual smell situation in the cabin.

1.1.3 Several minutes later, the flight crew noticed that the smell had intensified and there was smoke in the cockpit. The flight crew described to the investigation team that the smell resembled a burning odour. At around the same time, a cabin crew member informed the flight crew that dense smoke was observed in the cabin. In response, the flight crew promptly put on the oxygen mask.

1.1.4 After the flight crew had donned their oxygen masks and established communication with each other, the PF declared MAYDAY to the Air Traffic Control (ATC) via radio frequency 124.05MHz to the North Approach Controller (NAPP) at the Singapore Air Traffic Control Centre (SATCC) to inform that there was smoke in the cockpit and to request for priority landing due to the emergency.

[1] The PO's responsibilities during the flight included giving feedback to the PF and PM regarding any safety concerns during the flight, assisting the PF and PM in monitoring nearby aircraft activities, and notifying the PF and PM about any operational deviations and missed communication with Air Traffic Control.
[2] The ECAM is a system that monitors aircraft functions and displays the function status to the flight crew. It also produces messages detailing failures and lists remedy procedures to rectify the problem.

1.1.5 At about 16:00, upon receiving the MAYDAY declaration, the NAPP instructed the flight crew to make a left turn to a heading of 180 degrees, directing them towards Changi Airport. The NAPP also announced in the SATCC control room about the MAYDAY declaration and that the aircraft had smoke in the cockpit. The Approach Coordinator (ACOD), who was in the control room, noted the announcement and relayed the information to the Tower Coordinator (TCOD) at the Changi Airport main control tower. The relayed information was received by the TCOD, however, the TCOD said she did not hear the MAYDAY declaration. (More on the ACOD-TCOD communication in paragraph 1.7.1)

1.1.6 The TCOD informed the Watch Room Operator (WRO) of the Airport Rescue and Fire Fighting Service (ARFF) at Fire Station 3 (FS3) of the aircraft on emergency but did not mention the MAYDAY declaration. The WRO informed the Operation Commander (OC) of the situation, and the OC declared Local Standby. Four ARFF vehicles, comprising three foam tenders (callsigns T31, T33 and T34) and a water tender (callsign W41), were put on standby. T31 was commanded by the ARFF Duty Officer for FS3 (hereinafter referred to as the DO3), and T33 was commanded by a Warrant Officer (WO). (More on the standby declaration in paragraph 1.9.1)

1.1.7 Shortly after making the MAYDAY declaration, the flight crew noticed that the Avionics Smoke Indication appeared on the ECAM. The PM, with the help of the PO, then carried out the Avionics Smoke Indication checklist shown on the ECAM. The flight crew also noticed that the Lavatory Smoke Indication appeared on the ECAM. At the same time, a cabin crew member informed the flight crew via the cabin interphone that the Flight Attendant Panel indicated smoke at the rear lavatory[3].

1.1.8 At about 16:01, the NAPP instructed the flight crew to contact the Inner Approach Controller (IAPP) via radio frequency 126.3MHz. The IAPP instructed the flight crew to descend to FL130 and fly on a heading of 190 degrees and then asked the flight crew if they were able to perform a Required Navigation Performance[4] (RNP) approach for landing on Runway 20L. The flight crew did not respond to the IAPP as regards the RNP approach to Runway 20L, but instead they requested the IAPP for landing on Runway 02R[5]. The IAPP did not accept the flight crew’s request and cleared the aircraft for

[3] A cabin crew member checked the lavatory but did not find any fire nor smoke.
[4] An RNP approach is a type of precision approach that relies on advanced satellite-based navigation systems to guide an aircraft to a specific runway or waypoint with a high level of accuracy.
[5] According to the flight crew, they actually meant to request for landing on Runway 20R.

landing on Runway 20L[6]. The PM, in response, requested for landing on Runway 20R and the IAPP replied *“Stand by”* to the flight crew.

1.1.9 According to the flight crew, reconfiguring the aircraft to land on Runway 20L would mean additional workload[7] which might divert time and attention away from managing the emergency. Therefore, they preferred to land on Runway 20R using an Instrument Landing System[8] (ILS) approach as the aircraft had been configured to land on this runway. However, the Tower Manager, who was the one to decide on the landing runway to be assigned for this emergency aircraft, considered that he needed to abide by the Air Navigation Service Provider’s (ANSP’s) guideline that Runway 20L (4000m) was the preferred runway to Runway 20R (3260m) for emergency landing. Therefore, he required the IAPP to get the flight crew’s confirmation that they could not perform RNP approach for landing on Runway 20L before he would accede to the flight crew’s request to land on Runway 20R.

1.1.10 At about 16:04, the Forward Cargo Smoke Indication appeared on the ECAM. The PM, with the help of the PO, performed the Forward Cargo Smoke Indication checklist, which included discharging a fire extinguisher in the forward cargo compartment.

1.1.11 At about the same time, the IAPP asked the flight crew to confirm if they were unable to accept an RNP approach for landing on Runway 20L. The PF replied “*negative, request….*” and intended to reiterate their request for Runway 20R, but the transmission was truncated. The instructor who was supervising the IAPP then said to the flight crew that she (the instructor) had understood it as the flight crew not being able to accept an RNP approach for landing on Runway 20L. The PF responded that the flight crew were able to accept an RNP approach for landing on Runway 20L[9]. The IAPP then repeated the

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[6] The IAPP could not recall the reason for not accepting the pilot’s request for landing on Runway 02R during the time of the event, but shared with the investigation team that, on hearing the ATC recording again, he believed the flight crew had intended to request for Runway 20R.

[7] According to the flight crew, they needed to take the following steps to reconfigure the aircraft for landing on Runway 20L:

1. Modify the flight plan on the aircraft’s Flight Management Guidance Computer (FMGC) system based on the new approach map using the Multi-Function Control and Display interface.
2. Calculate the landing performance using an application on their tablet.
3. Cross-check the inputs into the FMGC system.

[8] Instrument Landing System is defined as a precision runway approach aid based on two radio beams which together provide pilots with both vertical and horizontal guidance during an approach to land.

[9] The PF explained to the investigation team that he rationalised from IAPP’s transmission that Runway 20R is the main runway for Changi Airport and that it would result in lesser impact to airport operation if the emergency aircraft landed on Runway 20L. Thus, he agreed to land on Runway 20L.

clearance to the aircraft for an RNP approach to land on Runway 20L. At this moment, the aircraft was about 30 nautical miles (NM) from Changi Airport, about 10 minutes to landing.

1.1.12 At about 16:07, the IAPP instructed the flight crew to contact the Arrival Controller (ARR) on frequency 119.3MHz. Subsequently, the ARR asked the flight crew to confirm whether there was any fire in the cockpit or whether it was just an indication problem. The PF told the ARR that the aircraft *“have…forward cargo smoke and… lavatory smoke”*. He did not tell the ARR whether there was fire in the cockpit. Following this, the ARR asked and was told by the PM that there were 155 persons on board but the PM did not reply to the ARR’s query on whether the aircraft was carrying any dangerous goods.

1.1.13 At about 16:09, the flight crew was again cleared for the RNP approach to land on Runway 20L. At about 16:12, the flight crew was instructed to contact the Runway 20L controller (RWC) at the Changi East Control Tower[10] (CET) via radio frequency 131.4MHz. Upon establishing communication with the RWC, the aircraft received clearance to land on Runway 20L. When the aircraft was approximately 3 NM from touchdown, the PM informed the RWC that the flight crew planned to order an emergency evacuation after the aircraft had landed on the runway. In response, the RWC asked the PM if he *“wish to stop on the runway”*. The PM replied the RWC that he would evaluate the situation upon landing and update the RWC of his plan.

1.1.14 The aircraft touched down on Runway 20L at about 16:14. While the aircraft was slowing down, the RWC said to the flight crew *“… if able taxi vacate runway via alpha seven.”*. Instead of responding to the RWC’s instruction, the PM told the RWC that he would be stopping on the runway to conduct further checks. The RWC then asked the flight crew *“can you vacate the runway please”.* At this moment, the flight crew were trying to establish the situation in the cabin to assess if an emergency evacuation was needed and they only responded to the RWC “*we will vacate the runway*”.

1.1.15 After about 10 seconds, the RWC asked the flight crew again whether the flight crew was able to vacate the runway. The flight crew did not respond to RWC as they were busy trying to establish the situation.

[10] CET is the satellite control tower away from the main control tower that is responsible for controlling the aircraft movements near Runway 02R/20L, including take-offs and landings on Runway 02R/20L.

1.1.16 At 16:15:02, the DO3 requested the controller who was manning the walkie-talkie at the CET (hereinafter referred to as the AT1) to check with the flight crew if they needed any assistance from the ARFF.

1.1.17 The AT1 relayed this message to the RWC who posed the question to the flight crew. At 16:15:35, the PM confirmed that they needed the fire service to respond to the aircraft. However, the RWC did not immediately relay this information to the AT1. Instead, he asked the PM again if the aircraft was able to vacate the runway[11]. The PM's response to this query was not clear[12] and the RWC repeated his question. This time, the PM replied, *"we cannot evac… vacate the runway".*

1.1.18 The AT1 waited for the RWC to complete his communication with the PM before checking with the RWC as to whether the flight crew needed the fire service. At 16:16:08, the AT1 received confirmation from the RWC that the PM required the fire service to respond to the aircraft. The RWC also informed the AT1 to grant clearance for the ARFF vehicles to enter the runway.

1.1.19 Just as AT1 was about to give clearance to the ARFF to enter the runway, DO3 also requested clearance to enter the runway as he had heard the radio transmission between the RWC and PM. The AT1 promptly granted the clearance to the ARFF to enter the runway at 16:16:40. By 16:17:51, all the four ARFF vehicles arrived at the aircraft.

1.1.20 In the meantime, the flight crew assessed the situation and determined that the smoke in both the cabin and the cockpit was not dissipating. The PF then instructed the cabin crew to stand by at their respective positions to prepare for evacuation. At 16:16:48, after completing the necessary checklist for evacuation, the PF ordered the cabin crew via the passenger announcement (PA) system to begin the evacuation. Five evacuations slides were deployed. (More details on the deployment of evacuation slides in paragraph 1.10)

1.1.21 At about 16:16, while travelling on the runway to the aircraft, the WO (who was in charge of T33) and the officer-in-charge (OIC) of T34 saw from behind the aircraft what they considered a minor, and localised, fire at the rear of the

[11] The RWC explained to the investigation team that while he knew that the aircraft had an emergency, the aircraft appeared to be operating normally when it landed on the runway. He thought that the aircraft could conduct any troubleshooting on the taxiway after vacating the runway. He was mindful that there were aircraft waiting at the holding point for departure at that time, and he wanted the runway to remain operational for the rest of the traffic.

[12] The PM transmitted "*we are in vacate… we vacating the runway… runway air china four zero three*".

aircraft’s left engine (see **Figure 1**). All the four ARFF vehicles eventually stopped in front of and facing the aircraft. Before this, T33 had travelled on the left side of the aircraft to enable the WO to have a better look at the fire at the rear of the left engine while the other ARFF vehicles travelled on the right side of the aircraft.

Figure 1: Fire at the tailpipe of left engine (Footage from T33’s dashcam)

1.1.22 Having noted that the fire was a small one, the WO prioritised the ARFF operation at guiding the passengers who had evacuated the aircraft away from the left engine fire to a safe area. Meanwhile, the WO continued to monitor the fire situation at the left engine.

1.1.23 All the passengers evacuated the aircraft by 16:18:28. The PIC was the last person to leave the aircraft, at 16:19:15. After that, the ARFF personnel dealt with the left engine fire. Firefighting foam was discharged into the rear of the left engine to put out the fire. The ARFF personnel then inspected the aircraft’s cockpit, cabin, lavatories and cargo compartments to ensure there was no other fire. (More details on the firefighting in paragraph 1.9.2)

1.2 Injuries to persons

1.2.1 Nine passengers suffered minor injuries in the form of abrasion sustained during the evacuation.

1.3 Damage to aircraft

1.3.1 The left engine was inspected after the incident. The results of the inspection are detailed in **Appendix 1**.

1.3.2 The left engine fire was a localised fire within the tailpipe of the engine. There was no sign of damage caused by the fire to any other parts of the aircraft.

1.4 Personnel information

1.4.1 PIC (the PF)

Age	37
Licence type	Airline Transport Pilot License
Issuing authority	Civil Aviation Administration of China
Licence validity date	30 August 2028
Medical certificate	Class 1
Medical certificate validity	24 November 2023
Medical operational proviso	Must wear corrective glasses of lenses and have spare glasses on duty
Last Base Check date	10 June 2023
Last Line Check date	31 May 2023
Total flying hours	10770 hrs 42 mins
Aircraft types flown	A340, A330, A320
Total hours on A320 type	6296 hrs 11 mins
Flying in last 90 days	222 hrs 17 mins
Flying in last 7 days	19 hrs 39 mins
Flying in last 24 hours	0 hrs
Duty time in last 48 hours	0 hrs
Rest period in last 48 hours	48 hrs

1.4.2 FO (the PM)

Age	30
Licence type	Multi-crew Pilot License
Issuing authority	Civil Aviation Administration of China
Licence validity date	17 September 2027
Medical certificate	Class 1
Medical certificate validity	21 December 2023
Medical operational proviso	Nil

Last Base Check date	27 April 2023
Last Line Check date	Nil
Total flying hours	4214 hrs 17 mins
Aircraft types flown	A330, A320
Total hours on type	1156 hrs 20 mins
Flying in last 90 days	237 hrs 32 mins
Flying in last 7 days	10 hrs 20 mins
Flying in last 24 hours	0 hrs
Duty time in last 48 hours	0 hrs
Rest period in last 48 hours	48 hrs

1.4.3 Observer (the PO)

Age	39
Licence type	Airline Transport Pilot License
Issuing authority	Civil Aviation Administration of China
Licence validity date	9 January 2029
Medical certificate	Class 1
Medical certificate validity	16 February 2024
Medical operational proviso	Nil
Last Base Check date	27 August 2023
Last Line Check date	Nil
Total flying hours	11459 hrs 18 mins
Aircraft types flown	A340, A320
Total hours on type	7050 hrs 53 mins
Flying in last 90 days	159 hrs 37 mins
Flying in last 7 days	15 hrs 24 mins
Flying in last 24 hours	0 hrs
Duty time in last 48 hours	0 hrs
Rest period in last 48 hours	48 hrs

1.4.4 Runway 02R/20L Tower Controller (RWC)

Age	67
ATCO licence validity	29 Feb 2024
Ratings	1. Changi Rating – obtained 19 Jan 1980 2. Seletar Rating – obtained 10 April 2015
Total experience (years)	43 years 9 months
Experience in position manned	2 years 11 months

Duty time in last 48 hours	8.5 hrs
Rest period in last 48 hours	39 hrs

1.4.5 Controller manning the mobile walkie-talkie (AT1)

Age	29
ATCO licence validity	30 Nov 2025
Ratings	Changi Rating – obtained on 12 July 2023
Total experience (years)	2 months
Experience in position manned	2 months
Duty time in last 48 hours	9 hrs
Rest period in last 48 hours	39 hrs

1.4.6 Tower Coordinator (TCOD)

Age	37
ATCO licence validity	28 Feb 2027
Ratings	1. Changi Rating – obtained on 20 July 2012 2. Seletar Rating – obtained on 3 May 2016
Total experience (years)	11 years 3months
Experience in position manned	2 years 11 months
Duty time in last 48 hours	0 hrs
Rest period in last 48 hours	48 hrs

1.5 Aircraft's bleed air system[13]

1.5.1 The A320NEO has two engines, each having its own bleed air system. The two bleed air systems are similar. The bleed air system operates by extracting compressed air (bleed air) from the engine's High Pressure Compressor (HPC) and supplying it to various aircraft systems that use bleed air for operation.

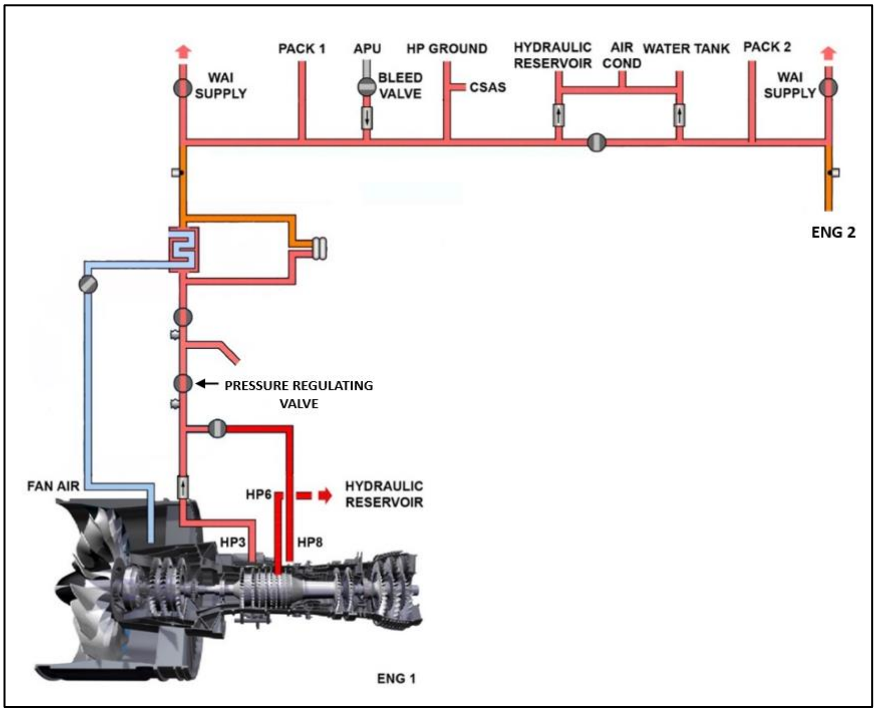
1.5.2 Typically, bleed air is extracted from the third stage (Stage 3) of the HPC during high engine speed (i.e. high power setting).

1.5.3 At low engine speed (e.g. engine at idle power setting during aircraft descent) when the pressure from the Stage 3 is insufficient, the bleed air is tapped from

[13] The term "bleed" refers to the process of diverting a portion of the high-pressure air from the engine.

the eighth stage (Stage 8) of the HPC.

1.5.4 The bleed air passes through a pressure regulating valve that ensures that the bleed air supply matches the requirements of the specific aircraft system. After pressure regulation, the bleed air is distributed through a network of ducts and valves to the different aircraft systems that rely on bleed air for operation (see **Figure 2**), including supplying air to the cabin (for pressurisation and air-conditioning), the cargo compartment (for heating) and the avionics compartment (for cooling).



[Source: Airbus] [Annotation: Airbus and TSIB]

Figure 2: Schematics of the bleed air supply from engine No. 1

1.6 Meteorological information

1.6.1 The aerodrome was experiencing light showers during the incident.

1.7 Communications

1.7.1 ACOD-TCOD communication

1.7.1.1 The ACOD has the responsibility of notifying the TCOD about any emergency situation declared by an aircraft that is landing at Changi Airport. It is the

TCOD's duty to relay this information to the ARFF so that the latter can be aware of the aircraft on emergency.

1.7.1.2 According to ANSP's Standard Operating Procedures (SOP), the information that shall be relayed to the ARFF includes the type of aircraft, the type of emergency (e.g. MAYDAY or PAN PAN declaration), the number of persons on board, where available, and any dangerous goods carried on the aircraft.

1.7.1.3 As mentioned in paragraph 1.1.5, the ACOD relayed to the TCOD the announcement by the NAPP regarding the MAYDAY declaration and that the aircraft had smoke in the cockpit. The ANSP did not require the practice of formal readback among air traffic controllers when announcements were made or messages were passed around. Some form of acknowledgement would suffice.

1.7.1.4 According to the TCOD, she did not hear the ACOD informing her that the flight crew had declared MAYDAY. She told the investigation team that she would have read this back to the ACOD and communicated this to the ARFF had she heard it.

1.8 Flight recorders

1.8.1 The flight recorders that the investigation team recovered from the aircraft were in good conditions and data from both the cockpit voice recorder (CVR) and the flight data recorder (FDR) were downloaded for analysis by the investigation team.

1.8.2 The FDR did not record any fire warning during the entire event.

1.9 Fire

1.9.1 Readiness declaration

1.9.1.1 As mentioned in paragraph 1.7.1.1, the TCOD will inform the ARFF of any aircraft on emergency. Upon receiving the information from the TCOD, the ARFF will assess the situation and determine the appropriate level of readiness and response procedures. The ARFF may declare either of two levels of readiness: Full Emergency or Local Standby[14]. The ARFF will take into consideration whether the aircraft has declared MAYDAY or PAN PAN.

1.9.1.2 During this incident, the ARFF declared Local Standby as the level of readiness. According to the ARFF, a Full Emergency would have been declared if it had known that the aircraft declared MAYDAY.

1.9.2 Firefighting

1.9.2.1 As mentioned in paragraph 1.1.21, the WO in T33 and the OIC in T34 saw fire at the rear of the aircraft's left engine when they were travelling on the runway to the aircraft. The WO told his staff in T33 about the fire, but he did not inform the other ARFF vehicles via the walkie-talkie as he did not wish to interfere with the emergency transmissions.

1.9.2.2 For the OIC of T34, he reported the left engine fire over the walkie-talkie to the WRO who recorded this information in the WRO logbook.

1.9.2.3 Subsequently, the WO informed the OC over the walkie-talkie about the left engine fire. The OC acknowledged the information. The DO and WO followed up to handle the situation.

1.9.2.4 Once arrived at the aircraft, all the ARFF personnel were focused on facilitating the evacuation of the persons on board the aircraft to a safe area. Meanwhile, the WO proceeded to the rear of the left engine to confirm his assessment of the fire. He continued to monitor the fire while assisting the passenger evacuation.

1.9.2.5 The WO's considerations for not tackling the left engine fire immediately were as follows:

(a) The fire was minor and localised.

(b) In line with ARFF's standard operating procedures, he avoided starting the firefighting while evacuation was still on-going, as it could potentially jeopardise the evacuees' safety. In particular, laying out fire hoses to fight the engine fire could impede the evacuation process as the

[14] Full emergency is declared when an aircraft approaching the airport is known or is suspected to be in imminent danger of an accident. Local standby is declared when an aircraft approaching the airport is known or is suspected to have developed some defect(s), but the problem is not such as would normally involve any serious difficulty in effecting a safe landing.

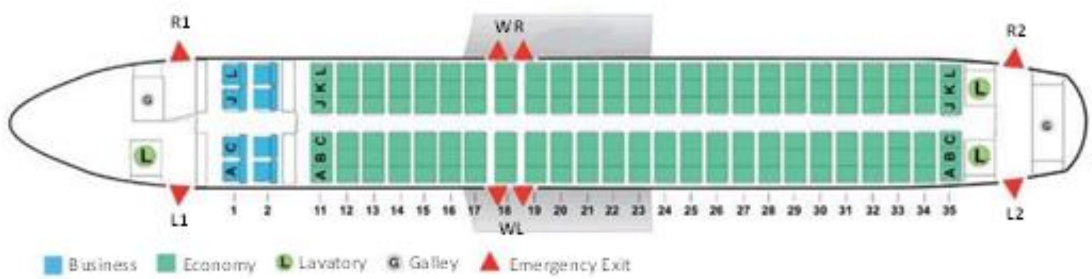
evacuees might trip and fall because of the hoses.

(c) A fire tender would be positioned in front of the left engine to deal with any conflagration of the left engine.

1.9.2.6 According to the WO, after ensuring that all the persons on board the aircraft were guided to a safe area and just as he was about to give the instruction to fight the left engine fire, he saw DO3 and informed DO3 about the fire. The DO3 gave the instruction to fight the left engine fire after a quick assessment.

1.10 Survival aspects

1.10.1 The A320NEO aircraft was equipped with six evacuation slides: one each at the four main passenger exits at the front (L1, R1) and rear (L2, R2) of the aircraft and one each at the left over-wing (WL) and right over-wing (WR) emergency exits (see **Figure 3**).



[Source: Air China] [Annotation: TSIB]

Figure 3: A320NEO emergency exits

1.10.2 For the emergency evacuation, the evacuation slides at the four main exits (L1, R1, L2 and R2) and at the left over-wing (WL) emergency exits were deployed. They were deployed by the five cabin crew members on board, viz. PS1, FS2, SS4, SS5 and SS6, in accordance with the operator's emergency procedures. The seating of these five cabin crew members and the evacuation slides they deployed were as follows:

Cabin Crew	Seated at	Slide deployed
PS1	L1	L1
FS2	L1	R1
SS4	R2	WL
SS5	R2	R2
SS6	L2	L2

1.10.3 The cabin crew members told the investigation team that, as per standard operating procedure, they had checked through the observation window of these exits to verify that the slide deployment areas were safe before deploying the evacuation slides. The cabin crew did not see any fire at the left or right engine.

1.11 Tests and research

1.11.1 The following items from the left engine were sent for testing:

(a) Engine oil samples from:

- Oil tank
- Main filter drain of the oil system

(b) Particles on the magnetic chip collector[15] from:

- Angle gearbox (AGB)
- Main gearbox (MGB)
- No. 3 bearing compartment
- No. 4 bearing compartment
- No. 5 and No. 6 bearing compartment[16]

(c) Particles collected from:

- AGB filter housing
- Pinion gear
- Oil tank strainer
- Lube and scavenge oil pump (LSOP) strainer
- Main oil filter bowl

1.11.2 Traces of iron were found in the engine oil samples collected from the oil tank and the main filter drain of the oil system.

1.11.3 Particles collected in 1.11.1(b) and (c) were extracted and subjected to energy

[15] There are six magnetic chip collectors located at different parts of the engine. The magnetic chip collectors are to attract metal debris in the oil system that might otherwise cause damage or premature wear to the engine parts. There was no particle on the magnetic chip collectors of the fan drive gear.

[16] Oil from No. 5 and 6 bearing compartments flow past a single magnetic chip collector.

dispersive x-ray (EDX) analysis to determine the elemental composition of the particles.

1.11.4 Particles on the magnetic chip collectors of AGB, MGB and No. 4 bearing compartment were found to contain high iron content with trace amounts of metal element.

1.11.5 Particles on the magnetic chip collectors of No. 3, No. 5 and No. 6 bearing compartments were found to contain high amount of carbon.

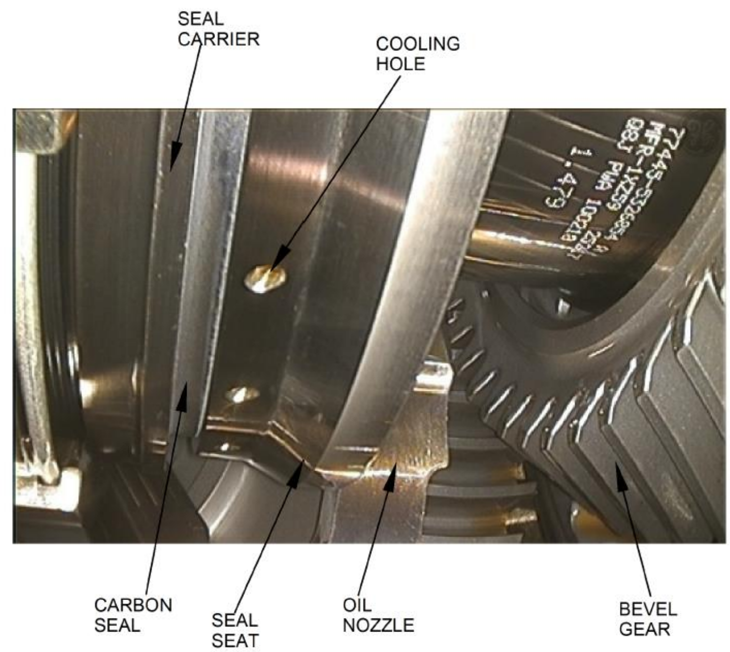
1.11.6 All particles collected in 1.11.1(c) were also found to contain high carbon content. Particles from the AGB filter housing, oil tank strainer and LSOP strainer had traces of metal element while the particles from pinion gear were found with higher amount of iron as compared to the rest of the particle samples.

1.11.7 Carbon seal of the No. 3 bearing compartment

1.11.7.1 The No. 3 bearing of the engine is a ball type bearing for the HPC which holds the front of the HPC shaft radially and axially and is designed to take load in the direction of the HPC shaft axis.

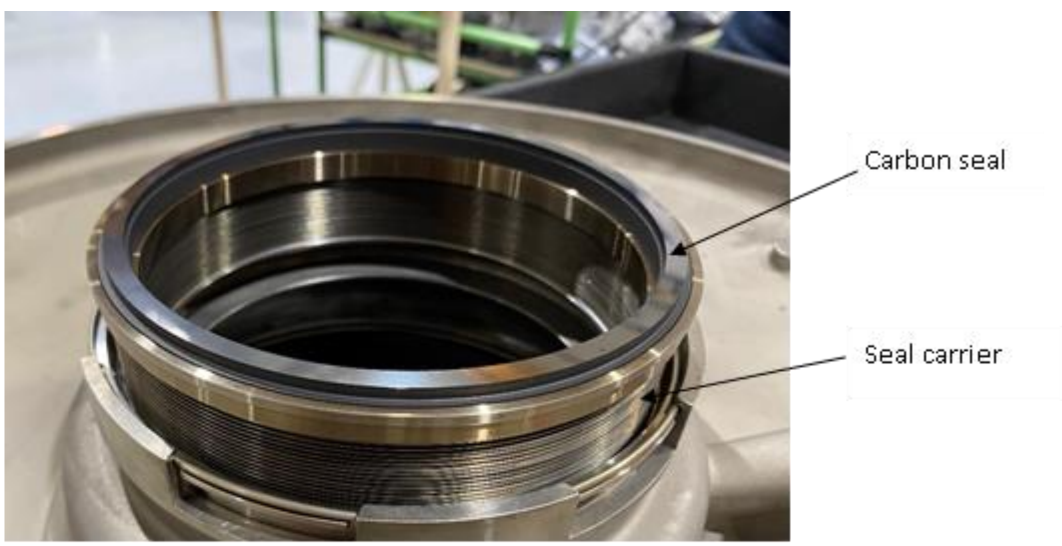
1.11.7.2 Within the No. 3 bearing compartment, a pressurised layer of oil is supplied to the circumference of the bearing assembly to absorb rotor radial vibration. A seal system, one each at the front and rear of the No. 3 bearing compartment, prevents oil and air leakage from the compartment.

1.11.7.3 The seal assembly consists of two components – a seal carrier, and a carbon seal that seats at the rim of the seal carrier (see **Figure 4** and **Figure 5**).



[Source and annotation: Pratt and Whitney]

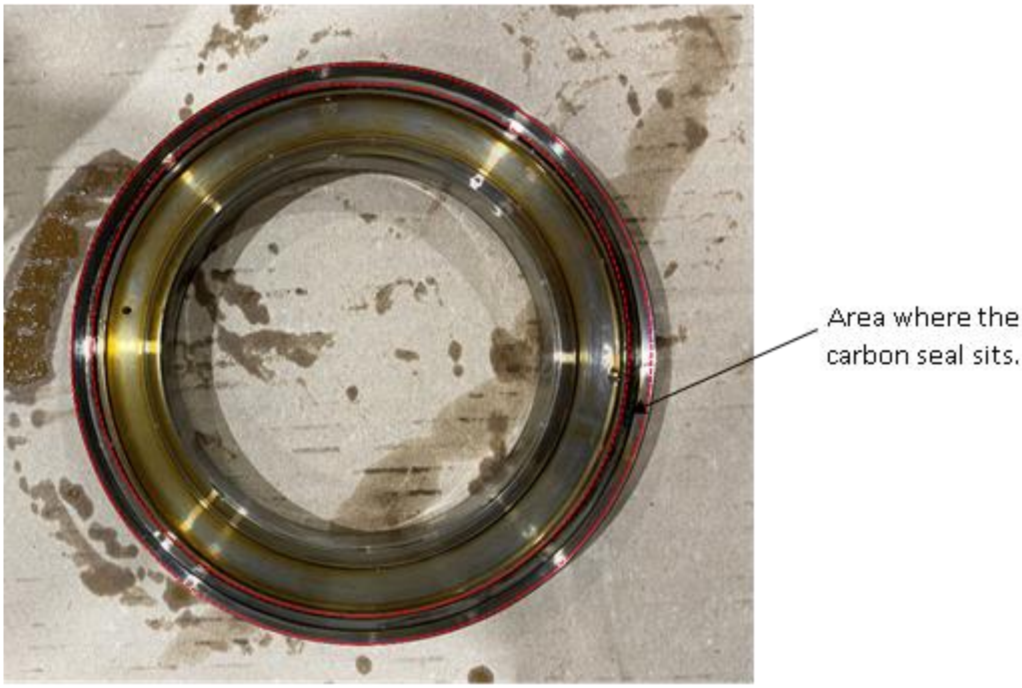
Figure 4: No. 3 Bearing Front Carbon Seal



[Source: Pratt and Whitney] [Annotation: TSIB]

Figure 5: No. 3 Bearing front carbon seal assembly

1.11.7.4 The seal assembly is a stationary component. The carbon seal sits on a seal seat (see **Figure 6**) which rotates with the shaft of the HPC. The face of the carbon seal and the face of the seal seat rub against each other when engine is in operation, creating friction and wear.



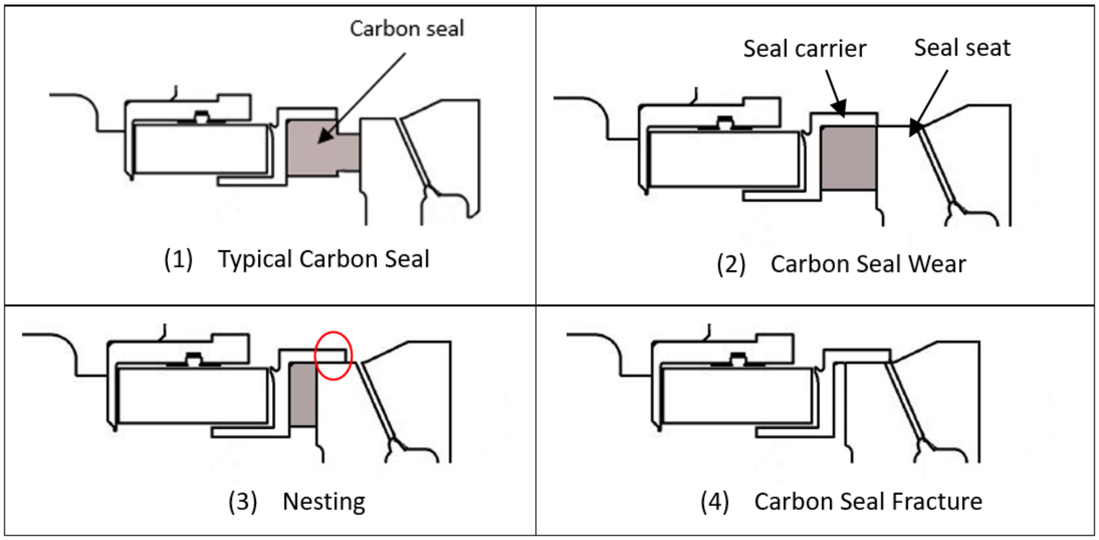
[Source: Pratt and Whitney] [Annotation: TSIB]

Figure 6: Seal seat

1.11.8 Engine Health monitoring system for detecting wearing of carbon seal

1.11.8.1 Since November 2019, the engine manufacturer had included in its engine health monitoring system (EHMS) an algorithm to detect carbon seal "nesting"[17] in the engine (see **Figure 7**). Under the EHMS, participating airlines will arrange for operating data of their engines to be transmitted to the engine manufacturer.

[17] "nesting" refers to an undesirable state of the carbon seal assembly where the seal seat is positioned inside the seal carrier as a result of the carbon seal wear (see Figure7(3)).



[Source: Pratt and Whitney with modification by TSIB]

Figure 7: Carbon seal wear progression

1.11.8.2 The algorithm examines the historical data of the engine's main oil filter differential pressure and oil debris count to identify a pattern on their data plots that is indicative of a carbon seal "nesting" event. When such a pattern is observed through the data collected by the engine manufacturer, a notification will be sent to the airline concerned to suggest an engine borescope inspection (BSI) with a view to determining whether a carbon seal replacement is needed.

1.11.8.3 According to the engine manufacturer, the EHMS showed that there had been no significant increase in the oil filter differential pressure and the oil debris count had been within limits on the left engine for the flights leading up to the incident flight.

1.11.8.4 Following the incident, the engine manufacturer shared that the EHMS showed that the aircraft had experienced significantly higher oil filter differential pressure during the incident flight, and that the oil quantity had remained steady throughout the flight until the descent phase where there was a drop in the oil quantity. However, these changes were not sufficient to trigger an in-flight alert to the flight crew. The flight crew did not notice any abnormalities in the engine performance.

2 ANALYSIS

The investigation looked into the following:

(a) Cause of the cabin smoke and engine fire

(b) Engine health monitoring system

(c) ATC communication to ARFF

(d) Landing runway assignment

(e) Communication between flight crew and ATC for ARFF assistance

2.1 Cause of cabin smoke and engine fire

2.1.1 Post-incident examination of the left engine revealed that a carbon seal in the No. 3 bearing compartment had fractured and no remnants of the carbon element was found on the carbon seal carrier. This suggests that the undesirable state of No. 3 bearing front carbon seal fracture had occurred. However, the investigation team could not determine at which moment of the flight the fracture happened.

2.1.2 The No. 3 bearing front seal fracture resulted in oil leaking from the front of the No. 3 bearing compartment towards to the rear of the LPC, the HPC, and the turbine exhaust case. These areas were characterised by high temperatures, which caused the leaked oil to vaporise and generate oil fumes/smoke.

2.1.3 The oil fumes/smoke generated were extracted from the HPC together with the bleed air. The contaminated bleed air flowed through the aircraft bleed air system resulting in smoke in the cabin, cargo compartment and avionics compartment.

2.1.4 The leaked oil also travelled through the bore of the HPC shaft and through the Low Pressure Turbine (LPT) shaft to the LPT area. The fire observed at the rear of the engine had likely resulted from the contact between the leaked oil and the high temperature LPT.

2.1.5 The WO assessed that the fire was minor and localised. Post-incident examinations of the engine also confirmed that there were no signs of fire beyond the engine core.

2.2 Engine health monitoring system

2.2.1 As mentioned in paragraph 1.11.8, the engine manufacturer has an EHMS programme aiming at preventing carbon seal "nesting" from progressing to carbon seal fracture.

2.2.2 Prior to the event flight, the main oil filter differential pressure in the left engine and the oil debris count appeared to have been normal. However, this incident suggests that the database of patterns used as reference for detecting the deteriorated state of the carbon seal had not been sufficient. The investigation team noted that the engine manufacturer has since the incident included additional patterns in the algorithm to enhance the algorithm's detection capability.

2.3 ACOD-TCOD communication

2.3.1 As mentioned in paragraph 1.1.5, the ACOD relayed to the TCOD the announcement by the NAPP regarding the MAYDAY declaration and that the aircraft had smoke in the cockpit. According to the TCOD, she heard the ACOD mentioning about the "smoke in cockpit" emergency but she did not hear the mentioning of the MAYDAY declaration. She acknowledged the ACOD by mentioning only the "smoke in cockpit" emergency.

2.3.2 The ANSP did not require the practice of formal readback among air traffic controllers when announcements were made or when messages were passed around. Some form of acknowledgement would suffice. Thus, when the TCOD acknowledged receipt of the "smoke in cockpit" message, the ACOD took this as the TCOD's acknowledgement that her message had reached the TCOD and presumed that the full content of the message had also reached the TCOD.

2.3.3 It would be desirable for the ANSP to develop a message acknowledgment system for use among its personnel and sub-units to ensure that information passed among them is received in its totality.

2.4 Landing runway assignment

2.4.1 The flight crew were informed by the NAPP at about 15:53 that their landing runway would be Runway 20R and they configured their aircraft accordingly. Following their MAYDAY declaration at about 15:59, the flight crew were asked twice by the IAPP if they could use Runway 20L (see paragraph 1.1.9).

2.4.2 The ATC recording showed that the flight crew had clearly requested for Runway 20R. However, IAPP needed to check with the Tower Manager and told the flight crew to stand by. The Tower Manager again required the IAPP to seek confirmation from the flight crew that they could not perform an RNP approach for landing on Runway 20L. The IAPP queried the flight crew accordingly. The flight crew relented and decided to focus on the emergency rather than prolonging the communications. Nevertheless, had the flight crew insisted on Runway 20R, it is probable that ATC would accede to their request for landing on Runway 20R.

2.4.3 The investigation team opined that the communication between the ATC and flight crew could have been shortened if either party had made their perspective clear from the beginning (e.g. stating clearly the "preferred runway" to the flight crew on the part of the ATC, "heavy workload" on the part of the flight crew).

2.5 Communication between flight crew and ATC for ARFF assistance

2.5.1 After the aircraft landed and came to a stop on the runway, the flight crew informed the RWC that they needed the fire service. The RWC was aware that the aircraft had an emergency. He observed that the aircraft appeared to be operating normally when it landed on the runway and gathered that the aircraft could conduct any troubleshooting on the taxiway after vacating the runway. He was also mindful that there were aircraft waiting at the holding point for departure at that time. In view of these, the RWC asked the flight crew if they were able to taxi out of the runway. The reply from the PM was "*we are in vacate… we vacating the runway… runway air china four zero three*". This response from the flight crew was unclear to the RWC on whether they were able to vacate the runway and the RWC repeated his query to the flight crew. This time, the PM replied, *"we cannot evac… vacate the runway"* and this was understood by the RWC that the flight crew could not vacate the runway. The RWC then cleared the ARFF vehicles to enter the runway, about one minute after the request was made by the flight crew. The delay did not impact the situation as the fire was minor, not growing and contained in the left engine's tailpipe.

2.5.2 The ANSP recognises that requests of flight crew of an aircraft in a MAYDAY emergency should be acceded to as fully as possible. It was reasonable for the RWC to check if the aircraft could vacate the runway based on his observation. Nevertheless, it would be desirable for the ANSP to remind its personnel that clearances for ARFF to respond to an aircraft emergency at the behest of the flight crew should be accomplished with minimum delay.

2.5.3 As described in paragraph 2.5.1, in replying to the RWC's initial query, the response from the flight crew, based on inter-cockpit communications, was meant to inform ATC of their intention to conduct an emergency evacuation on the runway. However, the message was unclear. It would be desirable for the flight crew to convey their intention and constraint to the ATC clearly.

3 CONCLUSIONS

From the information gathered, the following findings are made. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

3.1 The smoke in cabin and the left engine fire was caused by the front carbon seal fracture of the No. 3 bearing. This resulted in oil leaking from the bearing compartment to the hot zones of the engine, which led to smoke/fumes being formed, with a twofold consequence: smoke/fumes travelling to the aircraft cabin and cargo compartment through the bleed system, and a localised fire at the engine tailpipe.

3.2 The engine manufacturer's engine health monitoring system had failed to detect the carbon seal "nesting" before it deteriorated to an undesirable "nesting" state and eventual carbon seal fracture.

3.3 The TCOD missed copying the MAYDAY declaration of the aircraft from the ACOD and did not relay the information to the ARFF. The ANSP did not require its controllers to acknowledge messages among colleagues with a full read back.

3.4 The flight crew accepted to land on the ANSP's preferred runway probably to avoid prolonging the communication with the ATC.

3.5 There was delay of about one minute in the activation of the ARFF as the RWC was establishing whether the flight crew could vacate the runway and the communication from flight crew was unclear.

4 SAFETY ACTIONS

Arising from discussions with the investigation team, the organisation(s) has taken the following safety action.

4.1 The engine manufacturer has since November 2023 adjusted their database of patterns for the EHMS to better detect a deteriorated state of the No. 3 bearing carbon seal.

4.2 The engine manufacturer has also indicated to the investigation team that it planned to improve the design of the No. 3 bearing carbon seals to prevent "nesting" from deteriorating into the undesirable seal fracture state.

4.3 The aircraft operator has, following the incident, conducted a fleet-wide inspection of the engines and developed an inspection regime to monitor the status of the carbon bearing seals to complement the engine manufacturer's EHMS.

4.4 The aircraft operator has strengthened its flight crew training by focusing on the use of brief and decisive statements to clearly express their needs to ATC during emergency. All flight crew operating international flights have completed the training.

4.5 The ANSP has included in its procedure to prefix distress message with "MAYDAY" or "PAN PAN" when relaying such information through voice communications between operations units. The receiving controller shall read back on the information received, including the message prefix to ensure accuracy and completion of the information delivered and received.

4.6 The ANSP has reminded its controllers that during all emergency situations:

(a) ATC should be precise, concise, and clear when communicating to aircraft declaring emergency on the preferred assigned runway for landing. Should the flight crew of the distressed aircraft request for a runway that is different from the assigned runway, ATC will facilitate the request unless it has been assessed that doing so would pose a safety issue.

(b) ATC should facilitate ARFF in attending to emergency aircraft as soon as the flight crew have requested so. This has also been incorporated in the ANSP's procedures.

(c) ATC should avoid prolonged communications with the flight crew during an emergency where possible, given the flight crew’s high workload during an emergency.

5 SAFETY RECOMMENDATIONS

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

In view of the safety actions taken by the engine manufacturer, the aircraft operator and the Air Navigation Service Provider, no safety recommendation is proposed.

APPENDIX 1

Post-incident inspection of the left engine

1. Oil quantity

1.1. The oil tank capacity is about 40 quarts and typically there is another about 1-5 quarts of oil in the main gearbox. After the occurrence, 42.25 quarts of oil was drained from the left engine's main gearbox and the oil tank.

2. Borescope inspection

2.1. A borescope inspection (BSI) of the engine was conducted by the airline's technical support team after the occurrence. The BSI found that:

(a) The carbon seal located at the front of No. 3 bearing of the engine had been worn off (more on No. 3 bearing in paragraph 1.11.7).

(b) There were oil stains at first and second stages of the high-pressure compressor (HPC) vanes and blades.

(c) There were soot and oil stains at the first and second stages of the high-pressure turbine (HPT) vanes and blades.

3. Engine disassembly

3.1. The following was observed during the disassembly of the engine:

(a) Presence of oil streaks and oil pooling at the Low Pressure Compressor (LPC) rear module

(b) Presence of oil sludge all around the LPC hub

(c) Oil Sludge and pooling in HPC Rotor Shaft Inner Diameter

(d) Oil pooling and oil stain at the turbine intermediate case

(e) Oil wetness and coking around the Air Cooling Hole on the Low Pressure Turbine (LPT) 2nd stage Bore

(f) No remaining carbon element at the No. 3 bearing front seal (see **Figure A1**)

(g) Wear resulting in a trench at the No. 3 bearing front seal seat

(h) Debris observed at the Lube and Scavage Oil Pump Strainer and Angle Gearbox LR30 port

[Source and annotation: Pratt and Whitney]

Figure A1: Seal face on event engine with missing carbon seal (left) compared to typical seal face with intact carbon seal (right)