Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation – AO-2010-089
Preliminary

In-flight uncontained engine failure overhead Batam Island, Indonesia 4 November 2010 VH-OQA Airbus A380-842

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Postal address: PO Box 967. Civic Square ACT 2608
Office location: 62 Northbourne Ave, Canberra City, Australian Capital Territory, 2601
Telephone: 1800 020 616, from overseas +61 2 6257 4150
Accident and incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6247 3117, from overseas +61 2 6247 3117
Email: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

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Prepared By

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Acknowledgements

Figure 2: Google Earth
Figure 6: Rolls-Royce plc
Figure 10: Airbus

Abstract

On 4 November 2010, at 0157 Universal Coordinated Time (UTC), an Airbus A380 aircraft, registered VH-OQA (OQA), being operated as Qantas flight 32, departed from runway 20 centre (20C) at Changi Airport, Singapore for Sydney, New South Wales. On board the aircraft were five flight crew, 24 cabin crew and 440 passengers (a total of 469 persons on board).

Following a normal takeoff, the crew retracted the landing gear and flaps. The crew reported that, while maintaining 250 kts in the climb and passing 7,000 ft above mean sea level, they heard two almost coincident 'loud bangs', followed shortly after by indications of a failure of the No 2 engine.

The crew advised Singapore Air Traffic Control of the situation and were provided with radar vectors to a holding pattern. The crew undertook a series of actions before returning the aircraft to land at Singapore. There were no reported injuries to the crew or passengers on the aircraft. There were reports of minor injuries to two persons on Batam Island, Indonesia.

A subsequent examination of the aircraft indicated that the No 2 engine had sustained an uncontained failure of the Intermediate Pressure (IP) turbine disc. Sections of the liberated disc penetrated the left wing and the left wing-to-fuselage fairing, resulting in structural and systems damage to the aircraft.

As a result of this occurrence, a number of safety actions were immediately undertaken by Qantas, Airbus, Rolls-Royce plc and the European Aviation Safety Agency. On 1 December 2010, the ATSB issued a safety recommendation to Rolls-Royce plc in respect of the Trent 900 series engine high pressure/intermediate pressure bearing structure oil feed stub pipes. In addition, the Civil Aviation Safety Authority issued a Regulation 38 maintenance direction that addressed the immediate safety of flight concerns in respect of Qantas A380 operations with the Trent 900 series engine. On 2 December 2010, Qantas advised that the requirements of Rolls-Royce plc Service Bulletin RB211-72-G595 would take place within the next 24 hours on engines in place on A380 aircraft currently in service, and before further flight on engines on aircraft not yet returned to service.

The investigation is continuing.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Risk level: The ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

Safety action: the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

ABBREVIATIONS

AAIB	Air Accident Investigation Bureau of Singapore
ACARS	Aircraft communications and automatic reporting system
ACMS	Aircraft conditioning monitoring system
ANSU	Aircraft network server unit
ATSB	Australian Transport Safety Bureau
BEA	French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile
CASA	Australian Civil Aviation Safety Authority
CVR	Cockpit voice recorder
ECAM	Electronic centralized aircraft monitor
FDR	Flight data recorder
ICAO	International Civil Aviation Organization
LDPA	Landing distance performance application
NTSC	Indonesian National Transportation Safety Committee
QAR	Quick access recorder
SAR	Smart ACMS recorder
UK AAIB	United Kingdom Air Accidents Investigation Branch
UTC	Universal coordinated time
VDAR	Virtual digital ACMS recorder
WDAR	Wireless digital ACMS recorder

FACTUAL INFORMATION

The information contained in this preliminary report is derived from the initial investigation of the occurrence. Readers are cautioned that there is the possibility that new evidence may become available that alters the circumstances as depicted in the report.

Investigation overview

On 4 November 2010, the Australian Transport Safety Bureau (ATSB) was notified of an engine failure on a Qantas Airbus A380 aircraft over Batam Island, Indonesia and that the aircraft had returned to its departure airport in Singapore (Figure 1).

The investigation of aircraft accidents and incidents is conducted in accordance with Annex 13 to the Convention on International Civil Aviation, *Aircraft Accident and Incident Investigation*. As the engine failure occurred over Indonesian territory, the responsibility for instituting and conducting the investigation rested with Indonesia as the State of Occurrence. However, Annex 13 permits the investigation to be delegated to another State by mutual arrangement. Following discussions between the Indonesian National Transportation Safety Committee (NTSC) and the ATSB, the NTSC delegated the investigation to the ATSB.

The ATSB initiated an investigation under the Australian *Transport Safety Investigation Act 2003* on 4 November 2010 and, in accordance with the provisions of Annex 13, appointed Accredited Representatives from the United Kingdom Air Accidents Investigation Branch (UK AAIB), the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA), the Air Accident Investigation Bureau of Singapore (AAIB) and the Indonesian NTSC. Advisors to the Accredited Representatives were also appointed from the aircraft and engine manufacturers, Airbus and Rolls-Royce plc respectively, and from the European Aviation Safety Agency (EASA). A number of Observers were also appointed from various agencies, including from the Australian Civil Aviation Safety Authority and the Civil Aviation Authority of Singapore.

Figure 1: VH-OQA showing the damaged No 2 engine

History of the flight

On 4 November 2010, at 0157 Universal Coordinated Time (UTC)[1], an Airbus A380 aircraft, registered VH-OQA (OQA), being operated as Qantas flight 32, departed from runway 20 centre (20C) at Changi Airport, Singapore for Sydney, New South Wales. On board the aircraft were five flight crew, 24 cabin crew and 440 passengers (a total of 469 persons on board).

The flight crew was comprised of:

- the aircraft Captain, as pilot in command (PIC)
- the First Officer (FO), acting as copilot
- a Second Officer (SO)
- a second Captain, who was undergoing training as a Check Captain (CC)
- a Supervising Check Captain (SCC), who was overseeing the training of the CC.

The flight included a route check on the PIC by the trainee CC under the supervision of the SCC. The pre-flight briefing included tracking to the east of the active Merapi volcano in Indonesia and the PIC added 2 t of fuel to allow for any manoeuvring around the volcanic area.

[1] The 24-hour clock is used in this report to describe the time of day in Universal Coordinated Time (UTC), as particular events occurred.

The PIC was the handling pilot for the flight and was seated in the forward left seat. The FO was seated in the forward right seat, with the CC seated in the centre observer's seat. The SCC and the SO were seated in the right and left rear observer seats respectively. The following account is primarily based on the flight crew's recollection of the events.

The engine failure

Following a normal takeoff, the crew retracted the landing gear and flaps. The crew reported that, while maintaining 250 kts in the climb and passing 7,000 ft above mean sea level (AMSL), they heard two, almost coincident 'loud bangs'. The PIC immediately selected altitude and heading hold on the autopilot control panel, and the FO started his chronometer. The crew reported a slight yaw and that the aircraft immediately levelled off in accordance with the selection of altitude hold. The PIC expected the autothrust system to reduce power on the engines to maintain 250 kts as the aircraft levelled off; however, it became clear that the autothrust system was no longer active, so the PIC manually retarded the thrust levers to control the aircraft's speed. Both flight directors remained available to the crew.

At the same time, the Electronic Centralised Aircraft Monitor (ECAM)[2] system displayed a message indicating an 'overheat' warning in the No 2 engine turbine. Soon after, multiple ECAM messages started to be displayed. The PIC confirmed with the flight crew that he was maintaining control of the aircraft and called for the commencement of the requisite ECAM actions by the FO in response to those messages.

The associated procedure for the overheat message was to move the affected engine's thrust lever to the IDLE position and to monitor the situation for 30 seconds. During that 30 seconds monitoring period, at 0202, the crew transmitted a PAN[3] radio call to Changi air traffic control (ATC). The FO looked down at the ECAM and saw a warning indicating a fire in the No 2 engine that displayed for about 1 to 2 seconds. The ECAM then reverted back to the overheat warning, which recommenced the 30-second monitoring procedure. The crew elected instead to shut down the No 2 engine and, after they had selected the ENG 2 master switch OFF, the ECAM displayed a message indicating that the No 2 engine had failed.

The aircraft's engine failure procedure required the crew to determine whether serious damage had occurred to the affected engine. The crew reported assessing that there was serious damage and discharged one of the engine's two fire extinguisher bottles into the engine in accordance with the relevant procedure. Contrary to their expectation, the flight crew did not receive confirmation that the fire extinguisher bottle had discharged. They repeated the procedure for discharging the fire extinguisher and again did not receive confirmation that it had discharged.

The flight crew recalled that, after a brief discussion, they followed the procedure for discharging the second fire extinguisher bottle into the No 2 engine. After completing that procedure twice, they did not receive confirmation that the second bottle had discharged. The crew reported that they then elected to continue the

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[2] The ECAM provides information to the crew on the status of the aircraft and its systems.

[3] Radio code indicating uncertainty or alert, in the form of a general broadcast to the widest area but not yet at the level of a Mayday.

engine failure procedure, which included initiating an automated process of fuel transfer from the aircraft's outer wing tanks to the inner tanks.

The crew also noticed that the engine display for the No 2 engine had changed to a failed mode, and that the engine display for Nos 1 and 4 engines had reverted to a degraded mode[4]. The display for the No 3 engine indicated that the engine was operating in an alternate mode as a result of the crew actioning an ECAM procedure. During this time, the ECAM continued to display numerous other warnings and alerts to the crew.

The customer service manager (CSM) reported attempting to contact the flight crew, including through the use of the EMERGENCY contact selection on the cabin interphone system, which activated the flight deck warning horn. However, that selection had no associated ECAM message and the flight crew stated that they associated the emergency contact warning horn with the continuously-sounding warnings from the ECAM system and so cancelled the horn.

The flight crew recalled the following systems warnings on the ECAM after the failure of the No 2 engine:[5]

- engines No 1 and 4 operating in a degraded mode
- GREEN[6] hydraulic system – low system pressure and low fluid level
- YELLOW[7] hydraulic system – engine No 4 pump errors
- failure of the alternating current (AC) electrical No 1 and 2 bus systems[8]
- flight controls operating in alternate law[9]
- wing slats inoperative
- flight controls – ailerons partial control only
- flight controls – reduced spoiler control
- landing gear control and indicator warnings
- multiple brake system messages
- engine anti-ice and air data sensor messages
- multiple fuel system messages, including a fuel jettison fault
- centre of gravity messages
- autothrust and autoland inoperative

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4 Degraded or alternate engine mode indicates that some air data or engine parameters are not available.

5 As recalled by the flight crew. The list may be incomplete, and will be verified against recorded information during the course of the investigation.

6 The GREEN hydraulic system is one of two primary hydraulic systems on the A380. Hydraulic power is supplied by engine-driven pumps on Nos 1 and 2 engines.

7 The YELLOW hydraulic system is the second of two primary hydraulic systems on the A380. Hydraulic power is supplied by engine-driven pumps on Nos 3 and 4 engines.

8 Nos 1 and 2 busses are two of several electrical alternating and direct current electrical systems on the A380.

9 Alternate law reduces some of the flight control protections that are available under normal law.

- No 1 engine generator drive disconnected
- left wing pneumatic bleed leaks
- avionics system overheat.

Flight crew response

The flight crew reported that they discussed the available options for the recovery of the aircraft, including an immediate return to Singapore, climbing or holding and decided that the best approach would be to hold at the present altitude while they processed the ECAM messages and associated procedures.

The flight crew recalled frequently assessing the amount of fuel on board, which they decided was sufficient to hold while they completed the procedures, and that the aircraft was controllable. They contacted ATC and advised that they would need about 30 minutes to process the ECAM messages and associated procedures, and sought an appropriate holding position in order for that to occur.

Singapore ATC initially cleared the flight crew for a holding pattern to the east of Singapore. However, following further discussion, the flight crew advised ATC of the requirement to remain within 30 NM (56 km) of Changi Airport in case they should need to land quickly. ATC acknowledged that requirement and advised of reports of a number of aircraft components being found by residents of the Indonesian island of Batam. ATC vectored the aircraft to a position east of the airport and provided heading information to maintain the aircraft in an approximately 20 NM (37 km) racetrack holding pattern at 7,400 ft.

As the crew continued to action the extensive ECAM messages and associated procedures, the SO was dispatched into the cabin to visually assess the damage to the No 2 engine. As the SO moved through the cabin a passenger, who was also a pilot for the operator, brought the SO's attention to a view of the aircraft from the vertical fin-mounted camera that was displayed on the aircraft's in-flight entertainment system. That display appeared to show some form of fluid leak from the left wing.

The SO proceeded to the lower deck on the left side of the aircraft and observed damage to the left wing and fuel leaking from the wing. The SO recalled that the fluid leak appeared to be coming from underneath the left wing, in the vicinity of the No 2 engine and that the fluid trail was about 0.5 m wide. He reported that he could not see the turbine area of the No 2 engine from any location within the cabin. The SO returned to the cockpit and reported his observations to the other members of the flight crew.

The flight crew reported that, during their assessment of subsequent multiple fuel system ECAM messages, they elected not to initiate further fuel transfer in response to a number of those messages, as they were unsure of the integrity of the fuel system. In addition, the crew could not jettison fuel due to the ECAM fuel jettison fault and they were aware that there was fuel leaking from the left wing. The crew also recalled an indication that the aircraft's satellite communications system had failed. They also received an aircraft communications and automatic reporting system (ACARS[10]) message from the aircraft operator that indicated that multiple

[10] ACARS is a system of electronic communication between an operator and an appropriately-equipped aircraft.

failure messages had been received by the operator from the aircraft. At the time, the flight crew were busy managing the ECAM messages and procedures and only found time to acknowledge that ACARS message.

The SCC and PIC made a number of public address (PA) announcements to the passengers indicating that the aircraft had sustained a technical failure, and that the crew were addressing the issues associated with that failure. The passengers were advised that it would take some time to complete those actions and that information updates would be provided as time progressed.

Subsequently, the SCC and SO returned to the cabin on numerous occasions to visually assess the damage on the left side of the aircraft, and to inspect the right side of the aircraft, and to provide feedback to the cabin crew and passengers.

It took about 50 minutes for the flight crew to complete all of the initial procedures associated with the ECAM messages. During that time, the aircraft's autopilot was engaged. They then assessed the aircraft systems to determine those that had been damaged, or that were operating in a degraded mode. They considered that the status of each system had the potential to affect the calculation of the required parameters for the approach and landing. The crew also believed that the failure may have damaged the No 1 engine, and they discussed a number of concerns in relation to the lateral and longitudinal fuel imbalances that had been indicated by the ECAM.

Planning the recovery and landing

The FO and the SCC input the affected aircraft systems into the landing distance performance application (LDPA)[11] to determine the landing distance required for an overweight landing to runway 20C at Changi Airport of about 440 t, which was 50 t above the aircraft's maximum landing weight[12].

Based on the initial inputs to the LDPA by the flight crew, the LDPA did not calculate a landing distance. After discussion, and in the knowledge that the runway at Changi was dry, the crew elected to remove the inputs applicable to a landing on a wet runway and re-ran the calculation. This second calculation indicated that a landing on runway 20C was feasible, with 100 m of runway remaining. The crew elected to proceed on the basis of that calculation and advised ATC to that effect.

The crew also advised ATC that they would require emergency services to meet the aircraft at the upwind end of the runway, and that the aircraft was leaking fluid from the left wing that was likely to include hydraulic fluid and fuel. ATC acknowledged that advice and continued to provide radar vectors to the crew to assist them maintain the holding pattern.

Prior to leaving the holding pattern, the crew discussed the controllability of the aircraft and conducted a number of manual handling checks at the holding speed. The crew decided that the aircraft remained controllable, and advised ATC that they would like radar vectors for a 20 NM (37 km) final approach to runway 20C that commenced at 4,000 ft. ATC fulfilled that request.

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[11] A computer application used to calculate aircraft landing performance.

[12] In an emergency, a landing above the aircraft's maximum landing weight is permitted by flight crew and aircraft maintenance procedures.

The approach and landing

As the crew started to reconfigure the aircraft for the approach by lowering flaps, they conducted further controllability checks at the approach speed and decided that the aircraft remained controllable. As a result of the landing gear-related ECAM messages, the landing gear was lowered using the emergency extension procedure and a further controllability check was conducted.

The landing performance application indicated a required approach speed of 166 kts. The flight crew reported being aware that: reverse thrust was only available from the No 3 engine[13], no leading edge slats were available, there was limited aileron and spoiler control, anti-skid braking was restricted to the body landing gear only, there was limited nosewheel steering and that the nose was likely to pitch up on touchdown. An ECAM message indicated that they could not apply maximum braking until the nosewheel was on the runway. The wing flaps were extended to the No 3 position.

Singapore ATC vectored the aircraft to a position 20 NM (37 km) from the threshold of runway 20C and provided for a progressive descent to 4,000 ft. The PIC was aware that accurate speed control on final would be important to avoid either an aerodynamic stall condition, or a runway overrun. Consequently, the PIC set the thrust levers for Nos 1 and 4 engines to provide symmetric thrust, and controlled the aircraft's speed with the thrust from No 3 engine.

The autopilot disconnected a couple of times during the early part of the approach as the speed reduced to 1 kt below the approach speed. The PIC initially acted to reconnect the autopilot but, when it disconnected again at about 1,000 ft, he elected to leave it disconnected and to fly the aircraft manually for the remainder of the approach. Due to the limited landing margin available, the CC reminded the PIC that the landing would have to be conducted with no flare[14] and that there would be a slightly higher nose attitude on touchdown.

The flight crew briefed the cabin crew to prepare the cabin for a possible runway overrun and evacuation.

The aircraft touched down at 0346, the nosewheel touched down within about 6 seconds, and the PIC commenced maximum braking and selected reverse thrust on the No 3 engine. The flight crew observed that the deceleration appeared to be 'slow' in the initial landing roll, but that with maximum braking and reverse thrust, the aircraft began to slow. The PIC recalled feeling confident that, as the speed approached 60 kts, the aircraft would be able to stop in the remaining runway distance. In consequence, the No 3 engine was gradually moved out of maximum reverse thrust. Manual braking was continued and the aircraft came to a stop about 150 m from the end of the runway. The aircraft was met by emergency services.

The aircraft's departure track from Singapore, the holding point and pattern and approach to Changi Airport are shown at Figure 2.

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[13] In the A380, reverse thrust is only available from the No 2 and No 3 engines.

[14] Final nose-up pitch of landing aircraft to reduce rate of decent to approximately zero at touchdown.

Figure 2: Aircraft's flight path, showing the departure from Singapore, the holding pattern to the east of Singapore and the approach to Changi Airport

Securing and exiting the aircraft

The flight crew commenced to shut down the remaining engines and, when the final engine master switch was selected OFF, the aircraft's electrical system went into a configuration similar to the emergency electrical power mode. That rendered many of the aircraft's cockpit displays inoperative, and meant that there was only one very high frequency (VHF) radio available to the crew.

It was reported that, just before the cockpit displays went blank, a number of the flight crew noticed that the left body landing gear brake temperature was indicating 900 °C, and rising. After some initial confusion about which radio was functioning, the FO contacted the emergency services fire commander, who asked for the No 1 engine to be shut down. The FO responded that they had done so already, but was advised again by the fire commander that the engine continued to run.

The flight crew briefly discussed the still-running No 1 engine and recycled the engine master switch to OFF, but the engine did not shut down. In response, the flight crew decided to use the emergency shutoff and fire extinguisher bottles to shut down the engine. Despite the flight crew's action to complete that procedure, the engine continued to run. At that stage, the fire commander indicated that there appeared to be fuel leaking from the aircraft's left wing. The FO advised the commander of the hot brakes, and requested that fire retardant foam be applied over that fuel. The fire commander complied with that request.

The crew then discussed the options for disembarking the passengers. The PIC made a PA to the cabin crew and passengers to advise them of the situation, and that the emergency services were dealing with a fluid leak from the left side of the aircraft. After accessing the necessary checklists, the crew decided that the fire risk had decreased, and that a precautionary disembarkation via stairs on the right side of the aircraft would be the safest course of action.

The crew elected to use a single door so that the passengers could be accounted for as they left the aircraft and because they wanted the remainder of the right side of the aircraft to be kept clear in case of the need to deploy the escape slides. They also decided to have the other doors remain armed, with crew members in their positions at those doors ready to activate the escape slides if necessary, until all of the passengers were off the aircraft. The crew asked the fire commander to have stairs brought to the right side of the aircraft and to arrange for buses to move the passengers to the terminal. Initially, one set of stairs was provided. Consideration of how to shut down the No 1 engine continued, with some crew members contacting the operator via mobile phone to seek further assistance.

The passengers commenced disembarking from the aircraft via the No 2 main deck forward door about 55 minutes after the aircraft touched down. The last passengers and cabin crew disembarked the aircraft about 1 hour later.

The crew were advised by the fire commander that four of the wheels on the left body landing gear had deflated. The crew continued their attempts to shut down the No 1 engine but without success.

The operator's maintenance personnel advised the flight crew to attempt to shut down the No1 engine by activating a series of circuit breakers in the aircraft's equipment bay. That was not successful. Attempts were then made to reconfigure the transfer valves in the aircraft's external refuelling panel, in an effort to transfer fuel out of the No 1 feed tank, and starve the No 1 engine of fuel. However, due to the lack of electrical power, that was not possible.

Ground engineers also attended the aircraft and attempted a number of methods to shut down the engine, each without success. Finally, the decision was taken to drown the engine with fire-fighting foam from the emergency services fire vehicles. The No 1 engine was reported to have finally been shut down at 0653, about 2 hours and 7 minutes after the aircraft landed.

Injuries to persons

There were no reported injuries to the crew or passengers on the aircraft. There were reports of minor injuries to two persons on Batam Island.

Personnel information

The flight crew's qualifications and aeronautical experience are at Table 1.

Table 1: Flight crew qualifications and experience

Flight crew member	Licence	Total experience (hours)	Total A380 (hours)	Total last 90 days (hours)	Total last 30 days (hours)
PIC	ATPL(A)[15]	15,140.4	570.2	78.1	34.1
FO	ATPL(A)	11,279.5	1,271.0	127.5	35.3
SO	ATPL(A)	8,153.4	1,005.8	151.7	34.7

[15] Airline Transport Pilot (Aeroplane) Licence (ATPL(A)).

Flight crew member	Licence	Total experience (hours)	Total A380 (hours)	Total last 90 days (hours)	Total last 30 days (hours)
CC	ATPL(A)	20,144.8	806.4	133.2	50.2
SCC	ATPL(A)	17,692.8	1,345.9	189.3	59.9

All flight crew held valid class 1 medical certificates at the time of the occurrence.

Aircraft information

The aircraft information is summarised at Table 2.

Table 2: Aircraft information

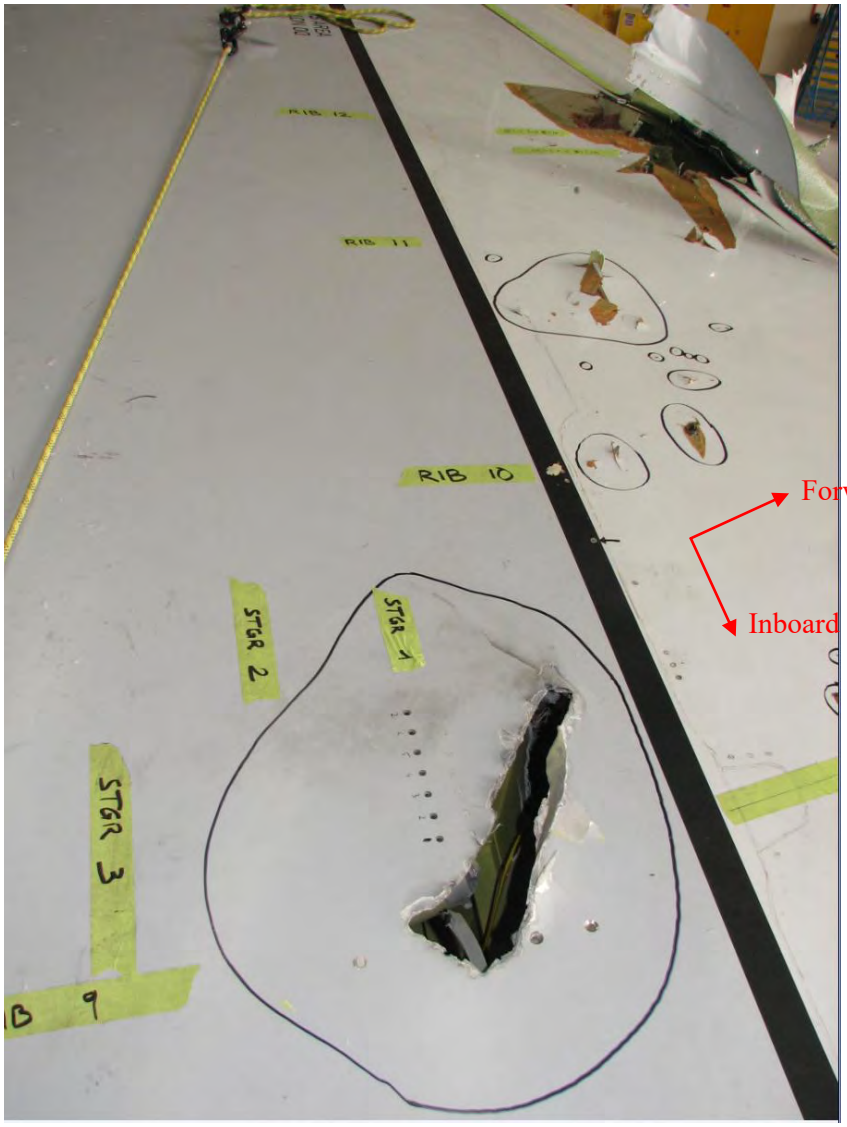
Manufacturer	Airbus
Type	A380-842
Serial number	MSN 0014
Total hours	8,533.02
Total cycles	1,843
Date of manufacture	2008
Certificate of Registration	4 September 2008
Certificate of Airworthiness	18 September 2008

Damage to the aircraft

Aircraft structure

The failure of the No 2 engine ejected a number of engine components that struck the aircraft or were liberated overboard. Sections of the intermediate pressure (IP) turbine disc penetrated the leading edge of the left wing inboard of the No 2 engine, resulting in damage to the leading edge structure, the front wing spar and the upper surface of the wing (Figure 3). A small section of liberated turbine disc penetrated the left wing-to-fuselage fairing, resulting in damage to numerous system components, the fuselage structure and elements of the aircraft's electrical wiring. Released debris also impacted the left wing's lower surface, resulting in a fuel leak from the Number 2 engine fuel feed tank and left wing inner fuel tank.

Figure 3: Damage to left wing upper surface

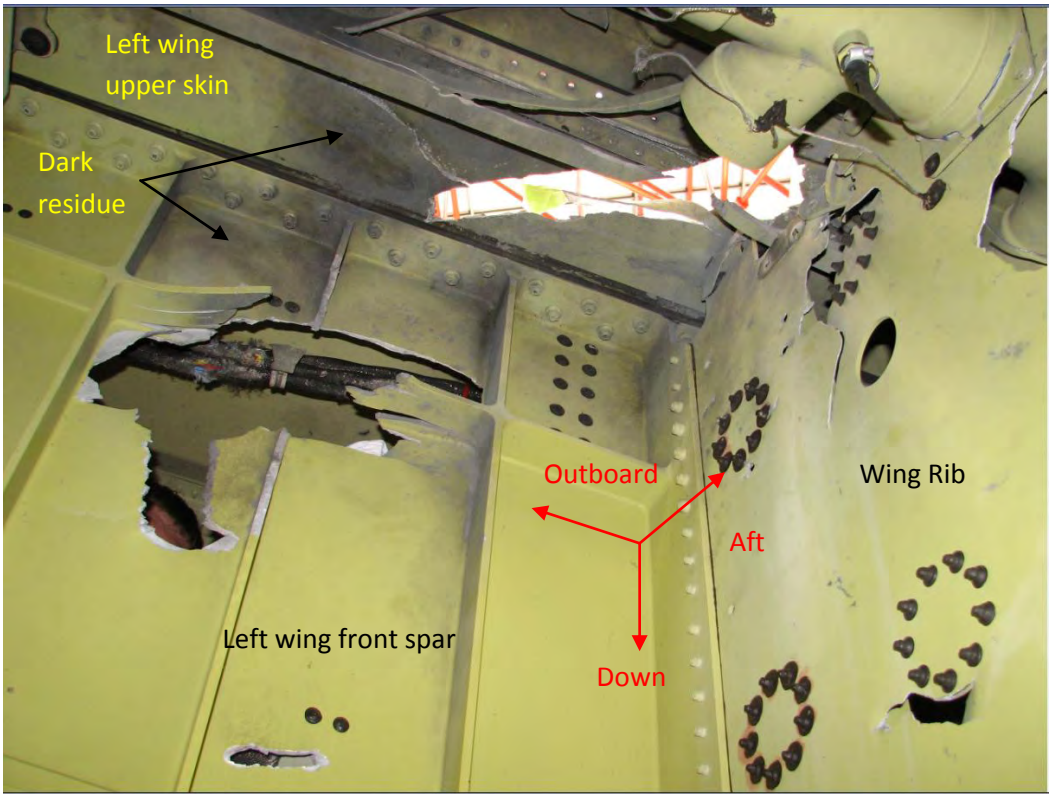


Other impact damage was observed to the No 2 engine support pylon, the No 1 engine, the left fuselage keel beam support splice, and the left wing false spar. A small impact region was also observed on the left side of the aircraft's fuselage.

Fuel tank residue

A dark residue was observed inside the left wing inner fuel tank between ribs 8 to 10 (Figure 4). The residue will be subject to further technical examination.

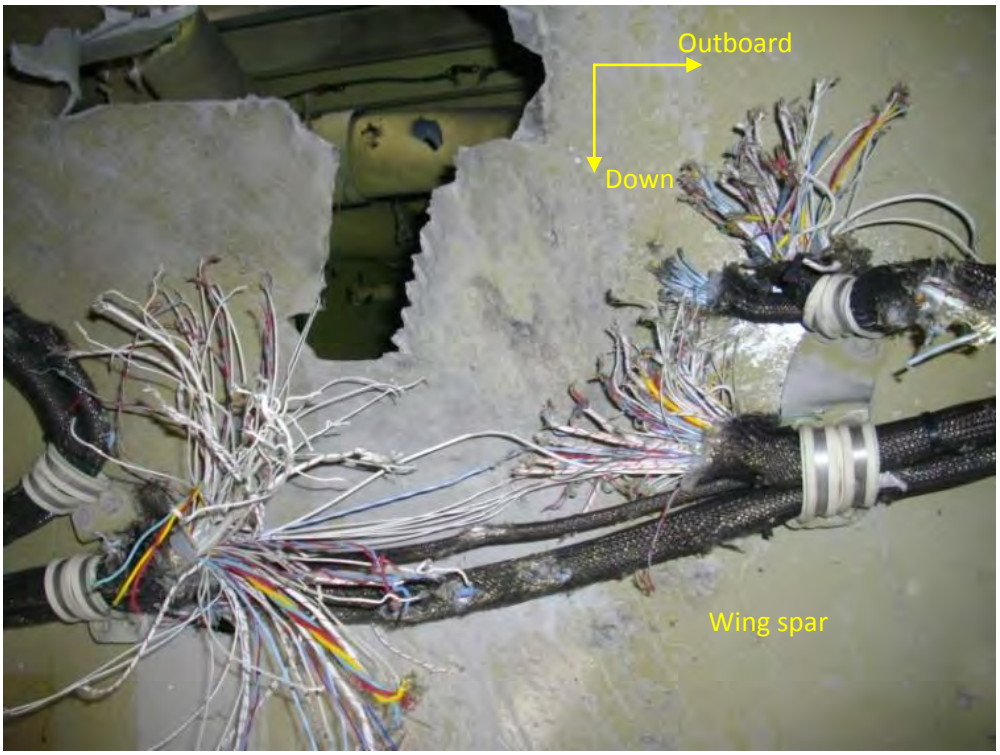
Figure 4: Dark residue observed in the left wing inner fuel tank



Aircraft systems

Impact damage from the liberated engine debris affected a number of aircraft systems. Damage was observed to: elements of the aircraft's electrical wiring that affected the operation of the hydraulic system, landing gear and flight controls; a number of fuel system components; and the leading edge slat system (Figure 5).

Figure 5: Damage to electrical wiring located in the leading edge of the left wing



Engine information

The details of the No 2 engine are summarised at Table 3.

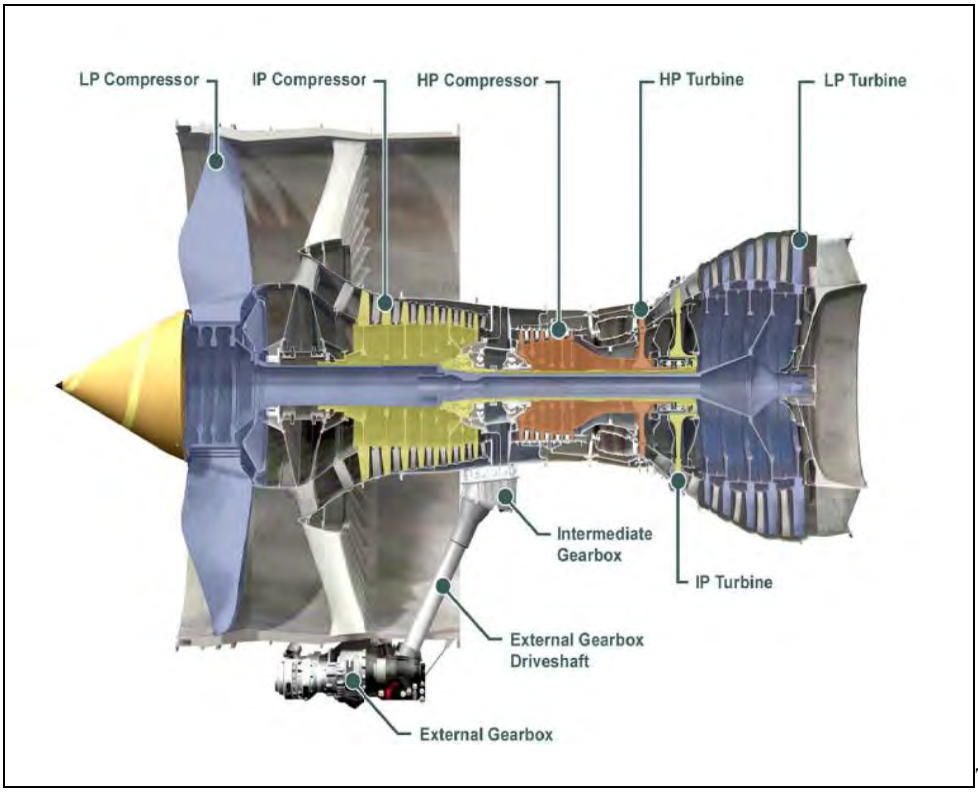
Table 3: Details of the No 2 engine

Manufacturer	Rolls-Royce plc
Type	Trent 972-84
Serial number	SN 91045
Total hours in service	6,314
Total cycles	677
Date of manufacture	2008

Engine description

The Rolls Royce plc Trent 900 engine is a three–shaft, high by-pass ratio turbofan with low pressure (LP), intermediate pressure (IP) and high pressure (HP) compressors that are driven by turbines through co-axial shafts (Figure 6).

Figure 6: Trent 900 engine component layout



The No 2 engine was originally fitted to the aircraft in the No 4 engine position during aircraft manufacture, and was removed from the aircraft on 12 August 2009 due to metal being found on one of the engine's chip detectors.[16] That removal took place after 3,419 flight hours and 416 cycles.

In September 2009, the engine was sent to a workshop in Singapore for examination and repair. That workshop was certified to maintain and repair Rolls-Royce plc engines. Spalling of the top raceway of the low pressure compressor location bearing was identified and the bearing assembly was replaced. The repair was completed in December 2009.

The engine remained in storage until it was refitted to the aircraft as the No 2 engine on 24 February 2010. The engine had completed 2,895 flight hours and 261 cycles since that re-installation.

On 24 June 2010, Rolls-Royce plc Service Bulletin RB211-72-AG329: *IP Shaft Rigid Coupling - borescope inspection of the coupling splines* was carried out on the engine. That inspection was mandated by EASA AD 2010-0008 dated 15 January 2010, which was subsequently revised by EASA as AD 2010-0008R1 on 4 August 2010.

Damage to the No 2 engine

Examination of the failed No 2 engine indicated that it had sustained an uncontained failure of the IP turbine (Figure 7). The turbine disc, blade and nozzle

[16] Device, often a permanent magnet, for gathering metal fragments (chips), usually from lubrication oil.

guide vanes separated into a number of sections, rupturing the surrounding IP turbine casing and damaging the engine's thrust reverser.

Damage was also evident to the engine cold stream duct and outer cowl panels. The No 2 engine thrust links were severed and extensive damage was evident to the LP turbine nozzle guide vanes and stage-1 LP turbine blades.

Sections of the IP turbine disc, nozzle guide vanes and thrust reverser sections fell on the Indonesian island of Batam and were recovered with the assistance of the Indonesian National Transportation Safety Committee. The recovered items included one large section of IP turbine disc (see the section titled *Search for engine components*).

The IP turbine disc section and other recovered engine components were sent to the Rolls-Royce plc engine manufacturing facility in Derby in the UK, accompanied by an ATSB investigator. Examination of the disc and other engine components was supervised by investigators from the ATSB and the UK AAIB.

Figure 7: Damage to the No 2 engine

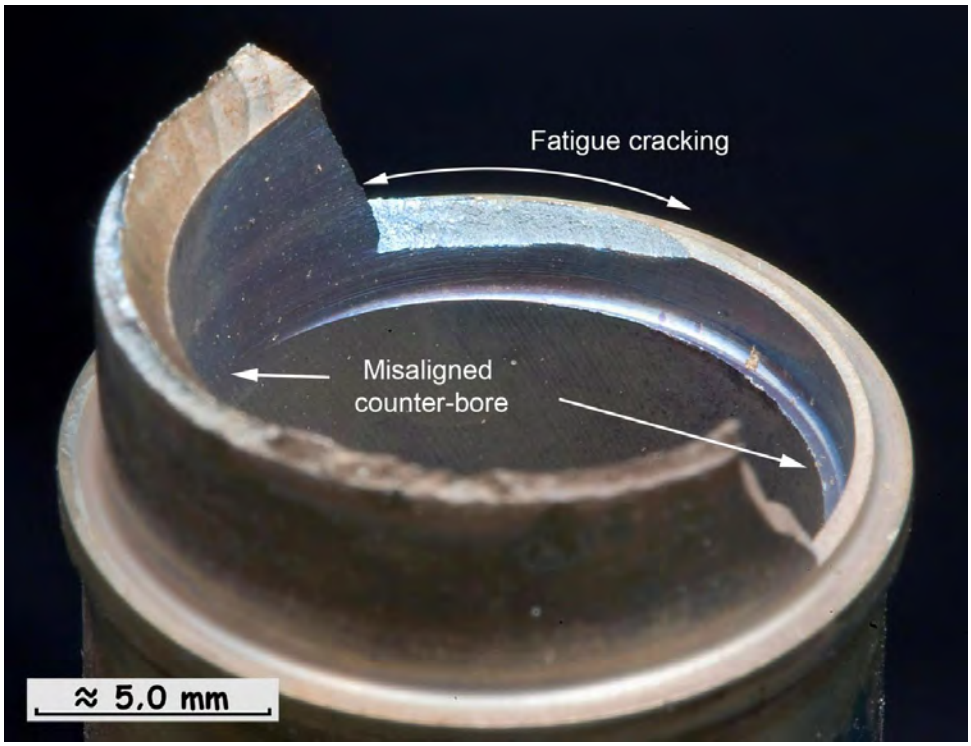
The No 2 engine was removed from the aircraft and taken to a certified Trent 900 engine maintenance, repair and overhaul facility in Singapore. The engine has been examined and disassembled, under the supervision of the ATSB, and relevant components have been forwarded to the Rolls-Royce plc facility in Derby, in the UK for technical examination (Figure 8).

Figure 8: No 2 engine after removal from the aircraft

While the ATSB will continue to direct the examination, the remaining items from the engine are being examined by Rolls-Royce plc at its Derby, UK facility under the supervision of the UK AAIB.

A recent key finding from those examinations was the presence of an area of fatigue cracking within a stub pipe that feeds oil to the HP/IP bearing structure. That cracking was associated with a misaligned region of counter-boring within the stub pipe outlet. The misaligned counter-boring had produced a localised thinning of one side of the pipe wall (Figure 9).

Figure 9: Detail of stub pipe showing misaligned counter-bore

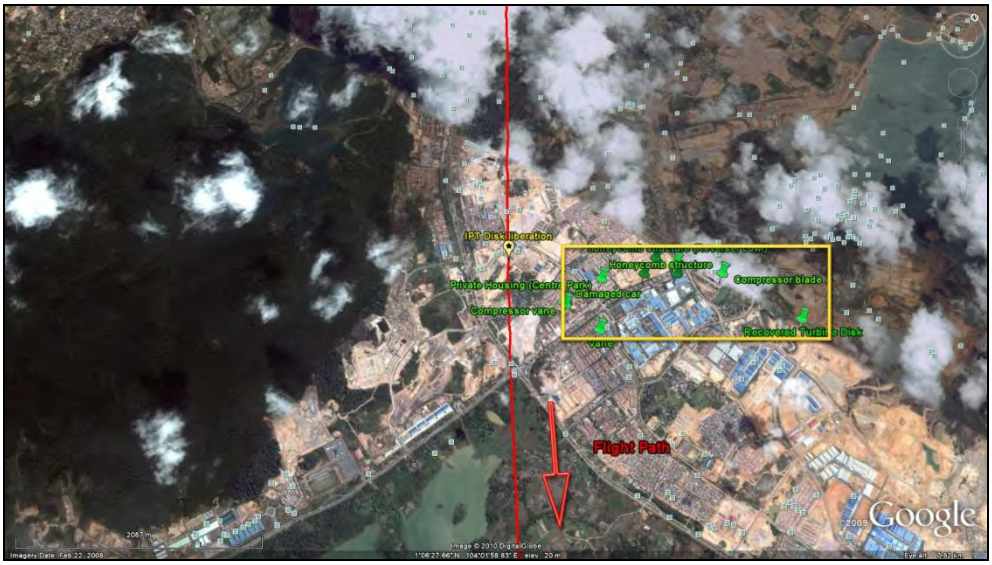


Other damage

Component debris from the failed engine fell over an approximate 1.5 km^2 area on the Indonesian island of Batam. A house was damaged by a large section of the turbine disc and an unknown number of other buildings that include houses and schools received minor damage.

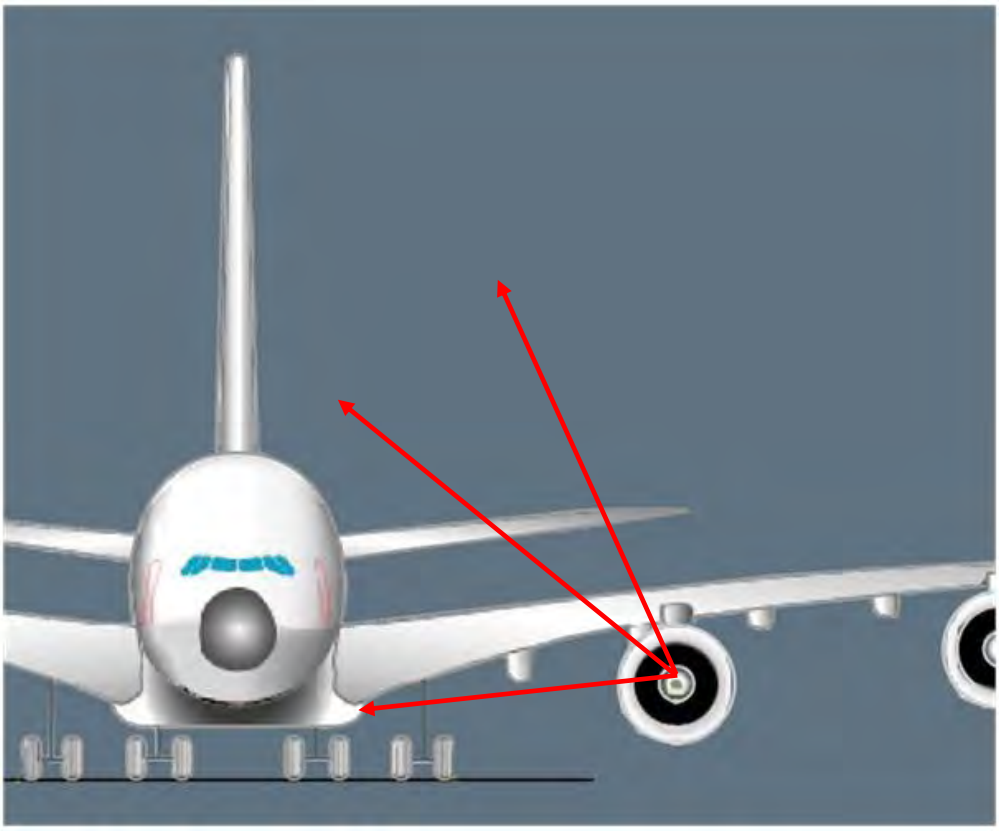
The components that were located on Batam Island were all to the left of the aircraft's flight path. A large segment of IP turbine disc was located about 2.5 km from the aircraft's location at the time of the failure (Figure 10).

Figure 10: Area of recovered components



Damage to the aircraft's left wing and the wing-to-fuselage fairing indicated that several IP turbine disc segments were liberated inboard (Figure 11).

Figure 11: Known direction of travel of some of the liberated engine segments

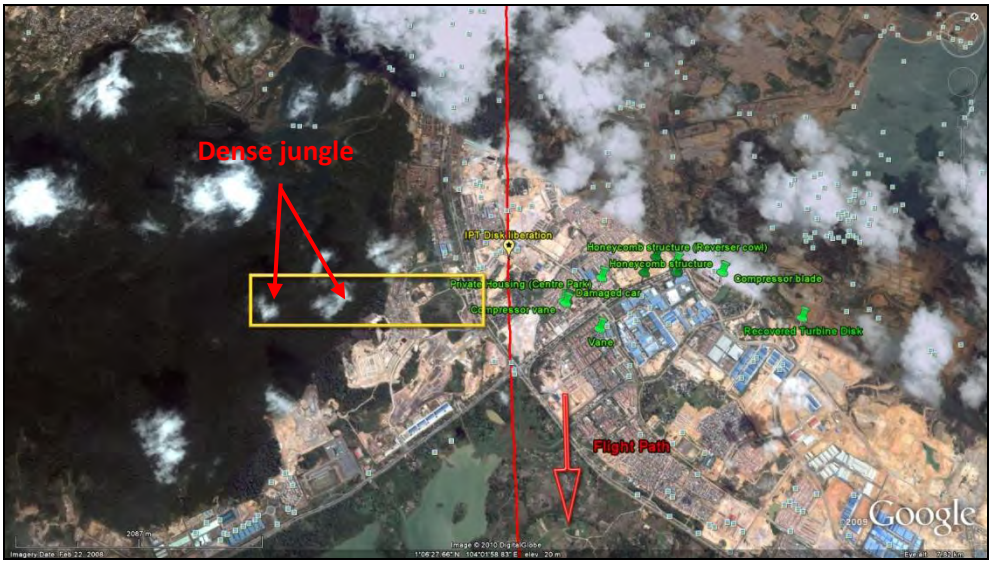


Search for engine components

As only one section of the IP turbine disc was recovered from Batam Island, a search for other turbine parts and engine components was arranged with the assistance of the Indonesian NTSC and Rolls-Royce plc.

Trajectory analysis was undertaken to localise the search area based on a number of aircraft and engine parameters immediately prior to the failure, and on the location of the recovered segment of the IP turbine disc. On that basis, it was estimated that the missing disc segments should be located to the right of the aircraft's flight path, most likely in an area of steep, dense jungle (Figure 12).

Figure 12: Estimated location of the missing disc segments (search area in yellow, including the area of dense jungle)



Although the search was hampered by the local terrain, some small engine components, such as turbine blades and blade attachment points were recovered by local residents and provided to the investigation. However, no other significant turbine disc parts were recovered.

The investigation remains interested in the recovery of the remaining components on Batam Island and anyone finding such items should contact the ATSB on +61 2 6230 4408, or the Indonesian National Transportation Safety Committee in Jakarta on +62 21 3517606 or Batam on +62 85 765033399.

Meteorological information

The following information is taken from the meteorological observations taken every 30 minutes between 0001 and 2000 at Changi Airport:

- no cumulonimbus clouds were reported
- light rain was reported between 0001 and 0130
- visibility was greater than 10 km
- the surface winds were south-south-westerly at 3 and 6 kts
- no wind shear was detected
- no significant weather was observed in the vicinity of the aerodrome during that period.

The winds between 4,000 and 10,000 ft in the area of Batam Island were forecast to be south-westerly to west-north-westerly at 16 to 29 kts.

Landing Forecasts were issued every 30 minutes for Changi Airport. Between 0001 and 2000 on 4 November 2010, those forecasts indicated no significant change from the observed meteorological conditions for that period. As there was no significant weather over the Changi Airport and its north and south approaches between 0001 and 2000 that day, no aerodrome warnings were issued.

The flight crew reported that the weather during the flight had not been a problem.

Aerodrome information

Changi Airport has two main runways that were orientated in a north-north-easterly and the south-south-westerly direction (runways 02 and 20). When landing to the south-south-west (runway 20 direction), the runways are designated runway 20 right (20R) and runway 20 centre (20C). Runway 20C is 60 m wide and 4,000 m long.

The rescue and fire-fighting services at Changi Airport were established at level 10 capacity. That capacity is the highest level of fire-fighting capability required by ICAO Annex 14 – Aerodromes.

Fire

The rear section of the No 2 engine and cowl was damaged by fire (Figure 13). Some components forward of the engine firewall were heat affected.

Figure 13: Number 2 engine showing fire damage

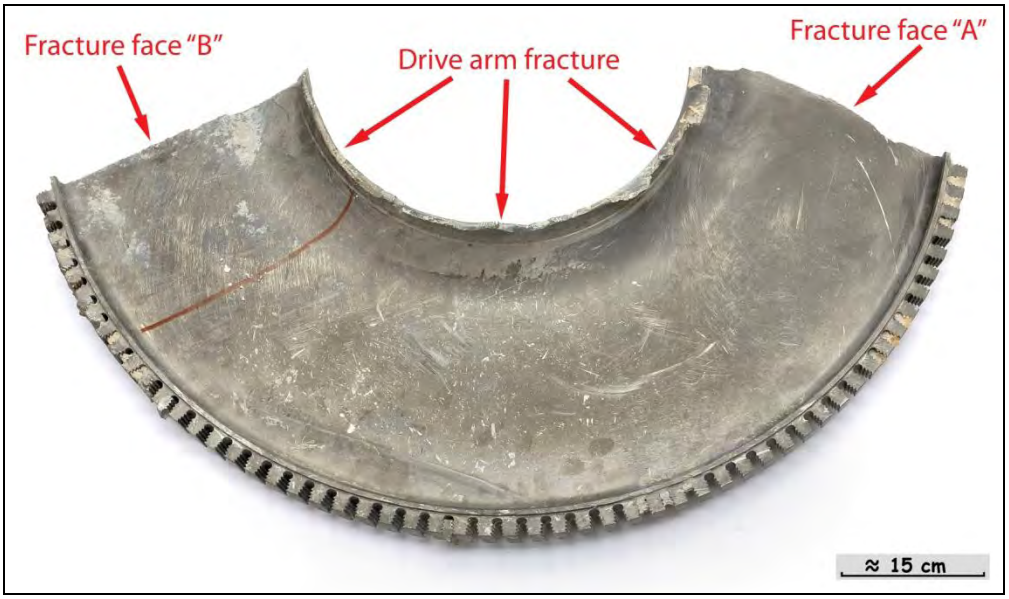
Tests and research

Engine No 2 component examination

The components that were recovered from Batam Island, Indonesia arrived at the Rolls Royce plc facility in Derby, UK at 1500 on Sunday 7 November 2010. Those components included a section of IP turbine disc, segments of low pressure stage-1 nozzle guide vanes (LP1 NGV) segments, and a number of segments of IP turbine blades and outer engine casing.

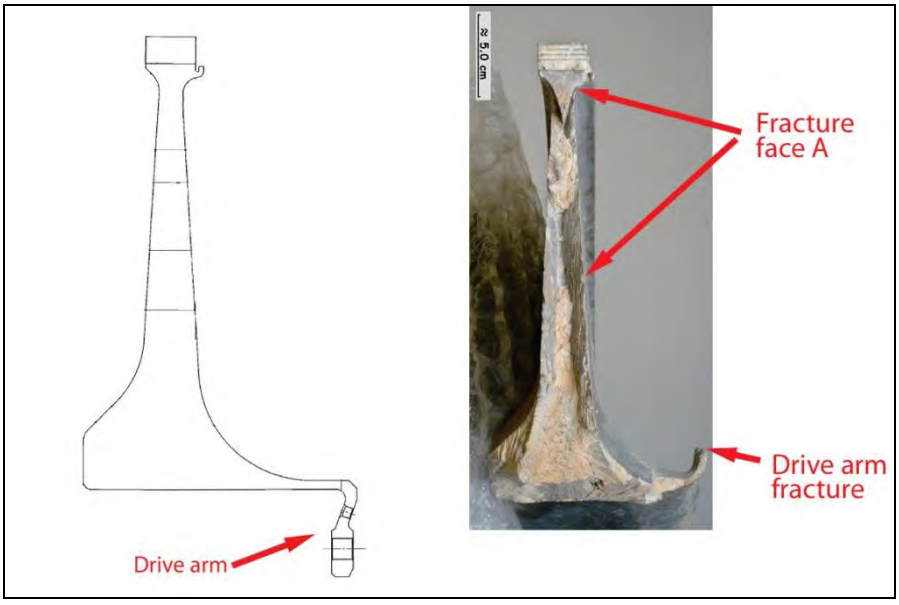
The recovered section of IP turbine disc approximated one-third of the total disc (Figure 14).

Figure 14: Recovered section of IP turbine disc (as viewed from the rear of the engine)



The mass of the recovered IP turbine disc section was almost 70 kg. The section exhibited three distinct fracture faces; two radial fractures from the bore to the external diameter (labelled 'A' and 'B' in Figure 14), and a circumferential fracture face in the region adjacent to the drive arm (the central cylindrical connection to the intermediate pressure spool shaft). The remaining section of the drive arm presented considerable plastic deformation, having bent outward by about 90° (Figure 15). The arm failed at the R850 holes and a section of the drive arm is still missing.

Figure 15: Cross section of the recovered portion of the IP turbine disc



Preliminary work on the IP turbine disc included: visual examination of the two radial fracture faces and the circumferential 'drive arm' fracture face, swabs of the surface to look for contamination, scanning of the components for dimensional

evaluation, and sectioning of the sample to remove some fracture faces for further study.

Visually, the IP turbine disc fractures all appeared to be consistent with a ductile overstress failure mechanism. There was no visible evidence of any pre-existing defects identified during the preliminary examinations.

Three triple segments of the LP1 NGV were received. One of the segments was almost complete, with all three vanes present along with the inner platform and some areas of the outer platform (Figure 16). The remaining two NGV segments retrieved contained the remains of the inner platform only, and the vanes exhibited significant damage.

Figure 16: Portion of LP turbine first stage nozzle guide vanes that was recovered from Batam Island, Indonesia

Evidence of a deposit was observed on the leading (inlet) vane surfaces (as shown in Figure 15). A flaked sample of the deposit was extracted from the vane and the cross section prepared for further examination.

Fifteen IP turbine blade roots were recovered along with a further three blade roots with the platform attached. The components were all identified from the serial number on the forward side.

Analysis of oil samples drawn from the oil circulation system, oil strainer and magnetic chip detector was also carried out at the Rolls-Royce plc facility. Preliminary results of that testing revealed no evidence of contamination, excessive particulate levels or significant thermal stressing.

Recorded information

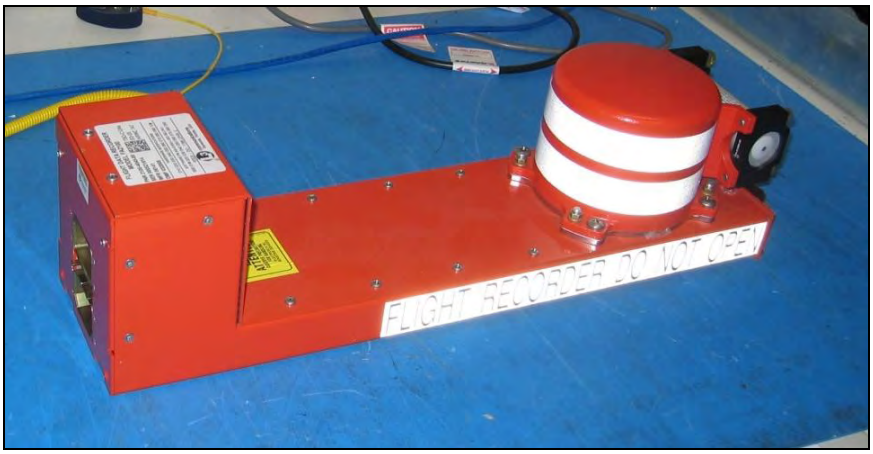
Crash-protected flight recorders

The aircraft was fitted with two crash-protected flight recorders, comprising a flight data recorder (FDR) and a cockpit voice recorder (CVR).

Flight data recorder

The FDR was removed from the aircraft under the supervision of the Air Accident Investigation Bureau of Singapore and transported to the aircraft operator's Sydney base (Figure 17). The ATSB supervised the download of the recorded data on 5 November 2010.

Figure 17: Flight Data Recorder



The FDR contained 77 hours 16 minutes of recorded aircraft operation. The data was of excellent quality and included the accident flight and over five previous flights.

Valuable information was drawn from the data regarding the engine failure (Appendix A).

Cockpit voice recorder

The CVR was returned to the ATSB's technical facilities in Canberra for download and analysis (Figure 18).

Figure 18: Cockpit Voice Recorder

The CVR contained over 2 hours of cockpit audio but, due to the continued running of the No 1 engine in Singapore, the audio at the time of the disc failure was overwritten. The available audio commenced during the landing approach and continued during the subsequent ground operations.

Non-mandatory data recording systems

The operator had incorporated a number of supplementary recorded data sources on board their fleet of A380 aircraft. Those recording systems were fitted to provide the airline with data that enhanced the safety, reliability and efficiency of the in-service operation of the aircraft.

The operator used a number of other devices to store information that was sourced from the aircraft condition monitoring system (ACMS). That information differed to that contained in the mandatory, crash-protected FDR because the ACMS programming was customised to provide enhanced flight and systems monitoring.

Wireless digital ACMS recorder

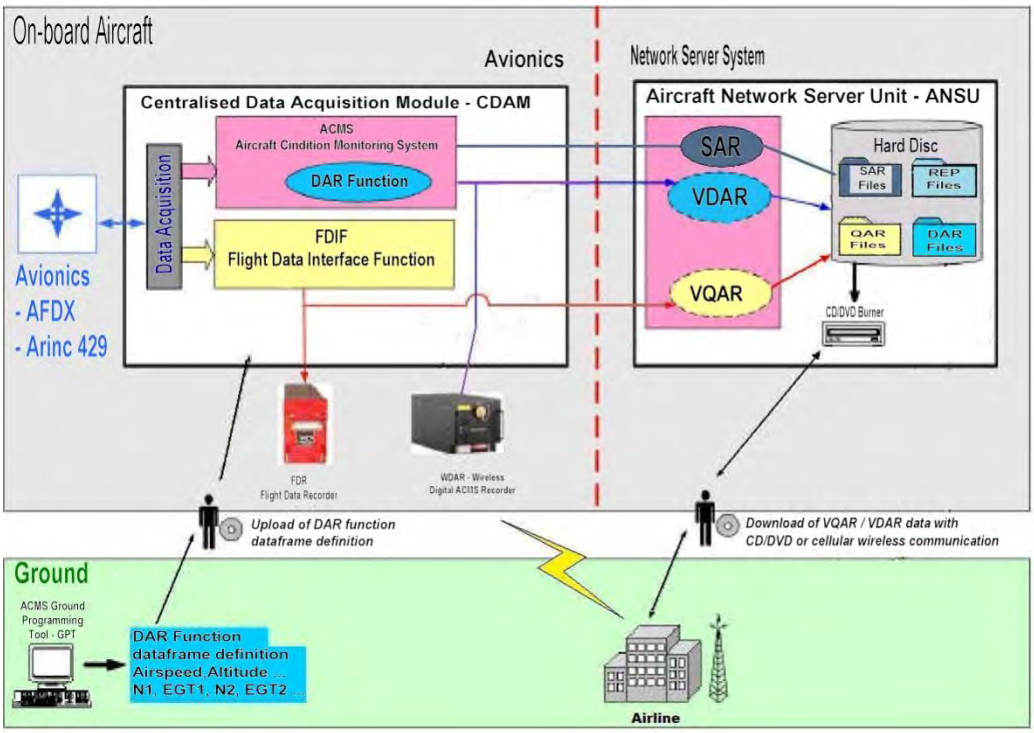
The wireless digital ACMS recorder (WDAR) stored a continuous record of about 1,000 different aircraft and engine system parameters in a custom format that was defined by the operator in conjunction with the aircraft and engine manufacturers. That recorder contained additional engine parameters at a greater resolution and sampling rate than the FDR (Figure 19).

Figure 19: Wireless DAR

Aircraft Network Server Unit

The aircraft was fitted with main and backup aircraft network server units (ANSU-OPS1 and ANSU-OPS2). A copy of the FDR information was stored as the virtual quick access recorder (VQAR) within the unit. In addition, a copy of the DAR information was stored as the virtual digital ACMS recorder (VDAR). The Smart ACMS Recorder (SAR) information and the aircraft system reports (REP) were also recorded in ANSU-OPS1 and 2 (Figure 20).

Figure 20: Simplified schematic of the aircraft's data acquisition and recording system



The recorded information in the two ANSU-OPS units was identical when an aircraft completed a normal flight.

The virtual digital ACMS recorder (VDAR) stored the same information as that provided to the WDAR. The SAR stored a snapshot of data relating to pre-defined events (about 2 minutes pre-event). Up to 256 parameters may be recorded. SAR data may be triggered in parallel with a report, providing extensive information relating to an event.

The REP folder contained data that may be sourced from an aircraft system or calculated according to pre-defined logic. Up to 1,000 different reports may be defined, and can be transmitted from the aircraft via the aircraft communication addressing and reporting system (ACARS).

Recovery of the non-mandatory recorded information

The WDAR was downloaded by the operator under ATSB supervision using another of the operator's A380 aircraft. The recording was incomplete, ending about 50 seconds prior to the engine failure. Examination of the WDAR revealed that the recorder operation ceased as a result of disruption to the electrical system during the event.

On 10 November 2010, ANSU-OPS2 was downloaded by the aircraft's and unit's manufacturers, in Singapore. When the data was examined it was found that the recording had also been interrupted and ceased prior to the event; however, a further 14 seconds of DAR information was recovered. SAR files that were recorded on ANSU- OPS 2 were also incomplete due to the power disruption.

The ANSU-OPS1 was downloaded on 12 November 2010. The complete history of the accident flight, including the engine failure was stored in the VDAR, SAR and REP folders. That information was provided to all parties to the investigation.

The engine manufacturer also downloaded data from the No 2 engine's Engine Monitor Unit (EMU) and Electronic Engine Controller (EEC) modules. That data was provided to all relevant parties to the investigation.

Sequence of events drawn from the recorded data

UTC (hhmm:ss)	Event	Comment
0143:24	No 1 engine started	Gross weight 464.8 t
0143:24	No 2 engine started	
0144:36	No 3 engine started	
0144:39	No 4 engine started	
0156:47	Airborne at Changi Airport	Engine thrust 72%
0200:22	No 2 engine oil temperature and pressure values begin to diverge from the recorded values for the other engines	Oil temperature increasing Oil pressure decreasing Altitude 5,330 ft Engine thrust 87% No 2 engine oil temp 179 °C No 2 engine oil pressure 68 psi
0200:59[17]	No 2 N3 vibration[18] increases	Altitude 6,620 ft
	No 2 N3[19] fluctuation	Thrust 88%
0201:00	No 2 engine N1[20] starts to decrease	From 87.5% to 86.9%
	No 2 engine N2 [21]starts to decrease	From 94.5% to 93.2%
	No 2 engine N3 starts to increase	From 94.2% to 98.0%

[17] Timing from FDR data.

[18] N3 vibration is the vibration level of the HP spool comprising the HP compressor and HP turbine. Similarly, N1 vibration is the vibration level of the LP spool, comprising the LP compressor and LP turbine. N2 vibration is the vibration level of the IP spool, comprising the IP compressor and IP turbine (refer Figure 6).

[19] N3 – Engine HP rotor speed – measured as a %rpm of a reference speed (HP reference speed (100%) is 12,200 RPM for an RB211-Trent 972-84 engine).

[20] N1 – Engine low pressure (LP) rotor speed – measured as a % rpm of a reference speed (LP reference speed (100%) is 2,900 RPM for an RB211-Trent 972-84 engine).

[21] N2 – Engine intermediate pressure (IP) rotor speed – measured as a % rpm of a reference speed (IP reference speed (100%) is 8,300 RPM for an RB211-Trent 972-84 engine).

UTC (hhmm:ss)	Event	Comment
0201:07	No 2 engine N3 reaches 98.0% and starts to decrease No 2 engine fuel flow decreases Rapid No 2 engine N1 decrease Rapid No 2 engine N2 decrease Rapid P30 [22]decrease	The No 2 engine fuel flow reduced due to the P30 collapse, which limits the Max allowable fuel flow
0201:08	No 2 engine turbine overheat parameter activates	
0201:09	Master Warning and Master Caution activate	
0201:11	Fault indications commence from multiple systems including: Flight controls - Left mid-aileron, spoiler #4, slats Hydraulics - green Anti-skid Electrical power – AC_2 Bleed Air- pylon and wing overheat	Turbine disc failure Altitude 7,250 ft This list of affected systems is preliminary and not complete.
0336.38	CVR recording begins	
0346:47	Touchdown at Changi Airport	
0349:05	No 3 engine shutdown	
0349:08	No 4 engine shutdown	
0349:15	Attempted shutdown of No 1 engine	
0351:01	First radio contact between QF32 and Singapore Rescue and Fire-fighting Service (RFFS)[23]	

[22] P30 – HP compressor delivery pressure.

[23] The Singapore Changi airport's emergency and RFFS were provided by the Airport Emergency Service Division of the Changi Airport Group.

UTC (hhmm:ss)	Event	Comment
0355:30	RFFS advises QF32 that they are covering leaked fuel with foam	
0357:42	FDR and CVR data has some interruptions from this time onwards	
0440:15	Passenger disembarkation begins	
0540:09	All passengers disembarked	
0602:44	Last FDR data recorded	

Additional recorded information is contained in Appendix A.

SAFETY ACTION

Australian Transport Safety Bureau

Although it is early in the investigation, the Australian Transport Safety Bureau (ATSB) has identified a critical safety issue relating to the engine high pressure/intermediate pressure bearing structure oil feed stub pipes.

Critical safety issue

Misaligned stub pipe counter-boring is understood to be related to the manufacturing process. This condition could lead to an elevated risk of fatigue crack initiation and growth, oil leakage and potential catastrophic engine failure from a resulting oil fire.

Action taken by the ATSB

As a result of the identified critical safety issue, on 1 December 2010, the ATSB issued the following safety recommendation to Rolls-Royce plc.

Safety recommendation AO-2010-089-AR-012

The Australian Transport Safety Bureau recommends that Rolls-Royce plc address this safety issue and take actions necessary to ensure the safety of flight operations in transport aircraft equipped with Rolls-Royce plc Trent 900 series engines.

Action by the Civil Aviation Safety Authority

On 1 December 2010, the Civil Aviation Safety Authority (CASA) issued a maintenance direction to Qantas under Regulation 38 of the *Civil Aviation Regulations 1988.* That direction required that Qantas:

> (a) Comply with Rolls-Royce plc Service bulletin number 72-G595 [see subsequent *Other party safety action – Rolls-Royce plc*] and any amendment or revision of it, within two cycles from the issue of this direction;
>
> (b) In the event abnormal or eccentric counter-boring of the tubes described in the service bulletin is identified, this must be recorded as a major defect of the engine;
>
> (c) Upon completion of compliance with the service bulletin an entry shall be made in the aircraft's maintenance records stating what actions were taken to comply with the service bulletin and this direction;
>
> (d) Upon completion of compliance with the service bulletin a written report shall be furnished to [CASA] stating how the service bulletin and this direction were complied with and the outcome of compliance with the service bulletin.

ATSB assessment of CASA action

The ATSB is satisfied that the action taken by CASA adequately addresses the immediate safety of flight concerns in respect of Qantas operation of A380 aircraft equipped with Trent 900 series engines.

Action taken by Qantas

On 2 December 2010, Qantas advised that:

> ...in response to Service Bulletin RB211-72-G595, and in line with ATSB Safety Recommendation AO-2010-089-SR-012, Qantas will conduct a focused borescope measurement inspection of the HP/IP Turbine bearing support structure oil feed tube for concentricity of the counter-bore and inspection of the related components on its RB211 Trent 900 series engines. The inspection results will be sent to Rolls Royce for evaluation. Rolls Royce will then provide Qantas with formal confirmation as to the serviceability of the engine.
>
> These inspections will take place within the next 24hrs on engines in place on A380 aircraft currently in service, and before further flight on engines on aircraft not yet returned to service.

ATSB assessment of Qantas action

The ATSB is satisfied that the action taken by Qantas adequately addresses the immediate safety of flight concerns in respect of the operation of its A380 aircraft equipped with Trent 900 series engines.

Action by Rolls-Royce plc

On 2 December 2010, Rolls-Royce plc issued revision 1 to NMSB 72-G595 (see subsequent *Other party safety action – Rolls-Royce plc*) incorporating assessment and engine rejection criteria for the measurement of potential counter-bore misalignment, and a tightening of the compliance time frame from 20 to 2 flight cycles.

ATSB assessment of Rolls-Royce plc action

The ATSB is satisfied that the action taken by Rolls-Royce plc adequately addresses the immediate safety of flight concerns in respect of the operation of Trent 900 series engines.

Other party safety action

In addition, the ATSB has been advised of the following safety action by Qantas, Rolls-Royce plc, the European Aviation Safety Agency and Airbus in response to this occurrence. The ATSB is satisfied that the actions taken are consistent with what the investigation has so far established.

Qantas

Qantas has advised of the following safety action in response to this occurrence

> Immediately following the occurrence, the aircraft operator ceased Airbus A380 operations until further information was available as to the likely technical sequence of events leading up to the engine failure. The operator conducted extensive independent investigation and analysis of the event in order to make informed and appropriate decisions with regard to operational safety. This analysis was later reviewed and ratified by the engine manufacturer.
>
> Specific engineering actions included:
>
> 1. Before further flight, and then at repeat intervals of no more than 20 flight cycles, carry out a thorough borescope inspection of each engine in accordance with RR NMSB 72-AG590 and EASA AD 2010-0236-E.
>
> 2. Before further flight, and prior to any flight where the area has been disturbed for maintenance, inspect the air deflector assemblies of each engine to ensure that the deflectors are installed exactly per RR SB 72-G339.
>
> 3. Before further flight, carry out a borescope inspection of the bolted joints of the HP/IP [High Pressure/Intermediate Pressure] Support Structure area of each engine per RR NMSB G592.
>
> 4. As a precaution, only permit operation of HP/IP Support Structures which were manufactured to the RR SB 72-F639 standard or later.
>
> 5. As a further precaution, until further notice, limit the engine thrust usage to a maximum flex temperature of 37 degrees C, unless required for operational reasons.
>
> 6. The operator and engine manufacturer will monitor thrust usage for each engine and the engine manufacturer will nominate engines for removal and refurbishment based on thrust usage history.

On the basis of that safety action, Qantas is progressively reintroducing A380s to its network. The first aircraft returned to service on Saturday, 27 November 2010.

Rolls-Royce plc

On 4 November 2010, Rolls-Royce plc issued non-modification service bulletin (NMSB) 72-G589 that required a series of checks on Trent 900 engines.

On 10 November 2010, Rolls-Royce plc issued alert NMSB 72-AG590, requiring the inspection of Trent 900 series engines for evidence of oil leaks into specific turbine area components.

On 12 November 2010 at 0700 UTC, Rolls-Royce plc advised that:

> Rolls-Royce is now in a position to provide an update on its statement of 8 November concerning the engine failure on the Trent 900 powered A380 Qantas flight QF32 on 4 November 2010.
>
> Immediately following this incident a regime of engine checks was introduced on the Trent 900s to understand the cause and to ensure safe operation. These have been conducted in parallel with a rigorous examination of all available evidence, including data from the damaged engine and its monitoring system, analysis of recovered material and interrogation of the fleet history.

> These investigations have led Rolls-Royce to draw two key conclusions. First, as previously announced, the issue is specific to the Trent 900. Second, the failure was confined to a specific component in the turbine area of the engine. This caused an oil fire, which led to the release of the intermediate pressure turbine disc.
>
> Rolls-Royce continues to work closely with the investigating authorities.
>
> Our process of inspection will continue and will be supplemented by the replacement of the relevant module according to an agreed programme.
>
> These measures, undertaken in collaboration with Airbus, our Trent 900 customers and the regulators have regrettably led to some reduction in aircraft availability. This programme will enable our customers progressively to bring the whole fleet back into service.
>
> Safety continues to be Rolls-Royce's highest priority.

On 18 November 2010, Rolls-Royce plc issued a further NMSB 72-AG590 Revision 2, detailing further Trent 900 engine inspections, including for defects in a number of turbine area oil and air feed pipes.

On 1 December 2010, Rolls-Royce plc issued NMSB 72-G595 that required the specialised examination, measurement and reporting of the HP/IP bearing structure stub pipe counter-bore geometry. A 20-flight cycle compliance limitation was specified for the examination.

European Aviation Safety Agency

On 10 November 2010 (European time), the European Aviation Safety Agency (EASA) issued emergency airworthiness directive EASA AD No: 2010-0236-E in respect of the operation of the Rolls-Royce plc RB211 Trent 900 series engines. The airworthiness directive required the periodic inspection of the high pressure/intermediate pressure engine structure for any abnormal oil leakage. If any discrepancy was identified, the further operation of that engine was prohibited.

That action by EASA was based on a preliminary analysis of the circumstances of the engine failure by Rolls-Royce plc, which indicated that an oil fire in a cavity within the HP/LP structure may have caused the failure of the intermediate pressure turbine disc.

A full copy of EASA AD: 2010-0236-E is available at:

http://ad.easa.europa.eu/ad/2010-0236-E

The EASA emergency AD was superseded on 22 November 2010 by a later AD that incorporated the contents of NMSB 72-AG590 Revision 2 that was issued by Rolls-Royce plc on 18 November 2010. The superseding AD: 2010-0242-E is available at:

http://ad.easa.europa.eu/ad/2010-0242-E

EASA also advised that:

> The reason for superseding AD 2010-0236-E with AD 2010-0242-E was that since issuance of AD 2010-0236-E, the investigation has progressed and inspection data from in-service engines has been gathered and analysed. The results of this analysis show the need to amend the inspection procedure, retaining the inspection

> of the air buffer cavity and focusing on the oil service tubes within the HP/IP structure.
>
> EASA is monitoring the progress of the investigation with Rolls-Royce and will continue to take timely appropriate actions when deemed necessary.

On 2 December 2010, EASA issued Major Change Approval 10032805 that approved a Rolls-Royce plc change to the engine electronic control system software. That change incorporated an additional defence against engine intermediate pressure turbine disc overspeed events.

Airbus

Airbus advised that, in response to this occurrence, an All-Operators Telex, 72A8002 was issued on 5 November 2010 that required operators to comply with the requirements of the Rolls-Royce NMSB that was issued on 4 November 2010.

Airbus also issued a number of Accident Information Telexes (AITs) to all of its A380 customers informing them of the investigation progress, and of the details of the aircraft's recovery, and confirming its ongoing participation and assistance to the investigation.

Civil Aviation Safety Authority

The Civil Aviation Safety Authority (CASA) advised that:

> Qantas provided CASA with extensive documentation to support the planned return to service as well as a number of briefings by key personnel. Qantas' plans as presented and analysed by CASA's technical experts detailed a conservative approach and called for the implementation of additional safety mitigation strategies above the requirements of the engine manufacturer.
>
> CASA is satisfied that Qantas' decision is appropriate.

ONGOING INVESTIGATION ACTIVITIES

It is early in what is a very complex investigation, and it is possible that the scope of the continuing investigation as outlined below may change as the investigation progresses.

The ATSB acknowledges the safety actions already taken, which are consistent with what has already been established through the investigation. It is nevertheless likely that further investigation will highlight additional lessons from the occurrence.

The continuing investigation will include the detailed examination of the:

- mechanism/s of the engine failure
- aircraft's response to the observed damage
- flight and cabin crew responses to the emergency, including anything that facilitated the recovery of the aircraft
- emergency services response
- recorded information
- aircraft and engine maintenance documentation
- the engine type service history
- fracture faces on the intermediate power (IP) turbine disc
- scan results to further assess expansion and deformation of the recovered IP turbine disc segment
- IP turbine disc blade root connections
- left fuel tank residue
- composition of the layered deposit on the No 1 low pressure nozzle guide vane
- metal spatter on the IP turbine blade platform
- additional components recovered from the disassembly of the No 2 engine and forwarded to Rolls-Royce plc in Derby, United Kingdom
- monitoring of any other reported issues with similar engine types.

Those, and any other issues identified during the progress of the investigation will be addressed in the final report.

The Australian Transport Safety Bureau plans to complete its investigation within 1 year of the occurrence. Should any further critical safety issues emerge during that time, the ATSB will immediately bring those issues to the attention of the relevant authorities or organisations and publish them as required.

APPENDIX A: FLIGHT RECORDER INFORMATION

Figure A-1: Graphical representation of selected parameters for entire accident flight

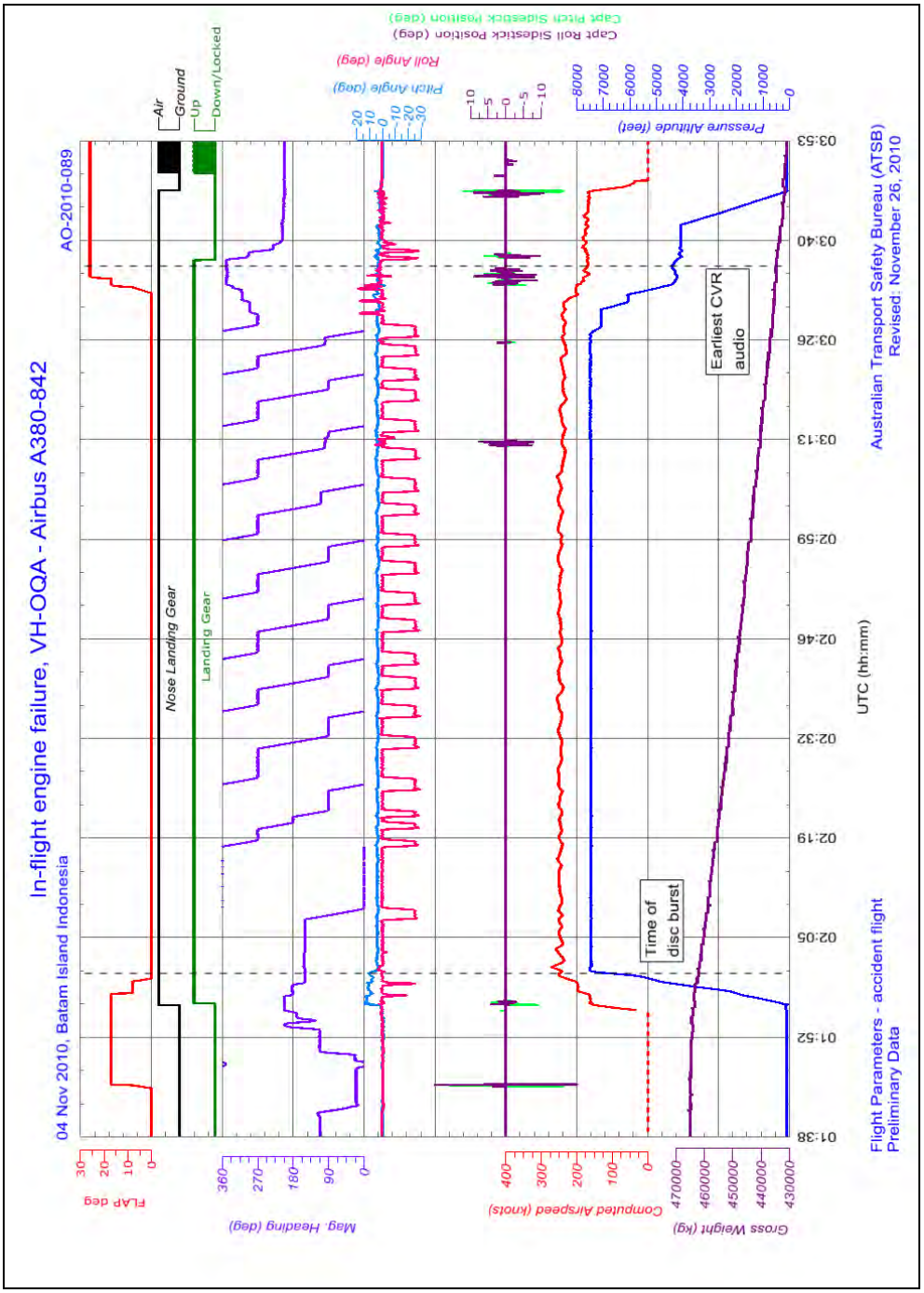


Figure A-2: Graphical representation of engine parameters around time of event

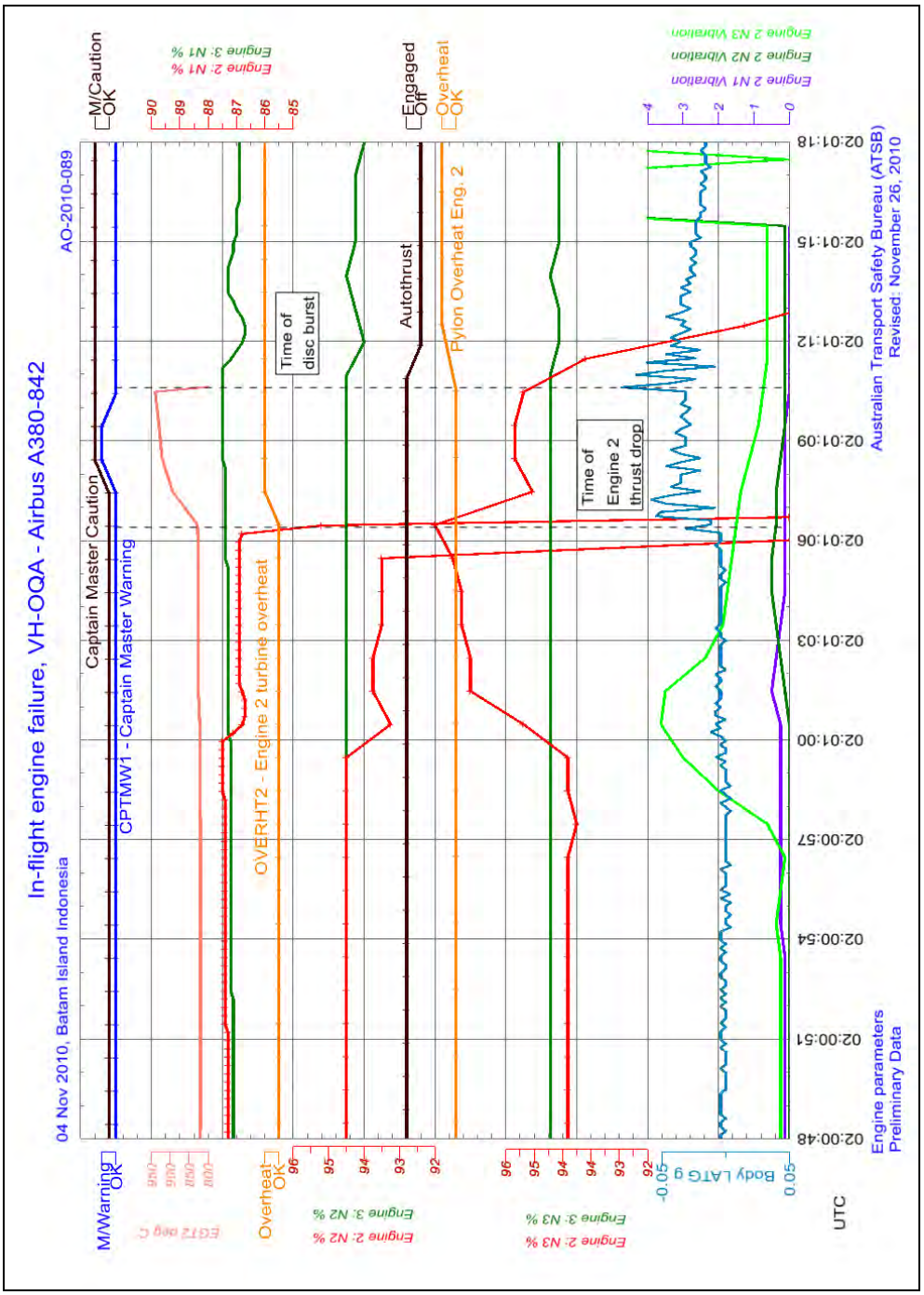


Figure A-3: Graphical representation of engine oil parameters prior to event

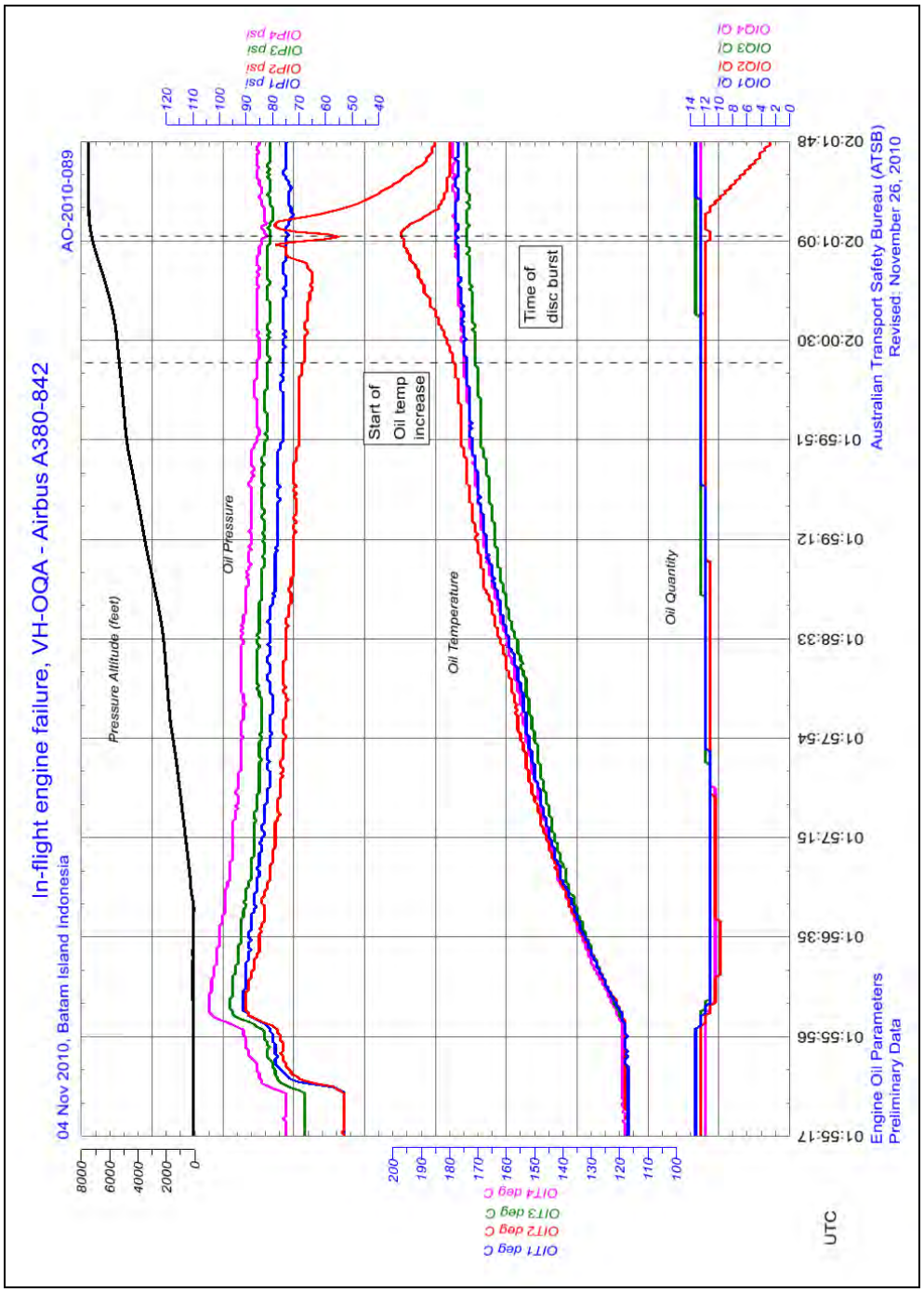


Figure A-4: Graphical representation of fault indications around time of event

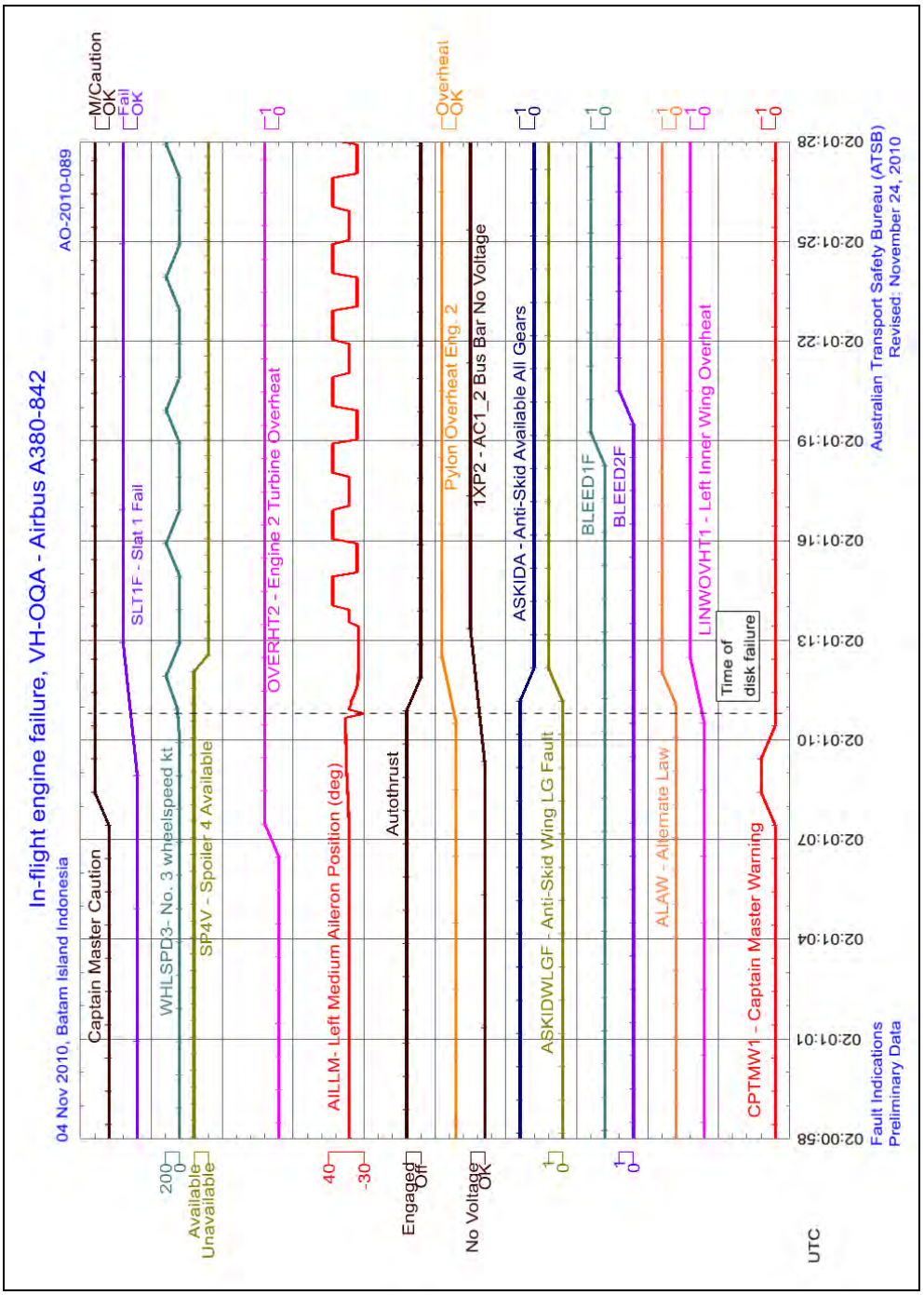
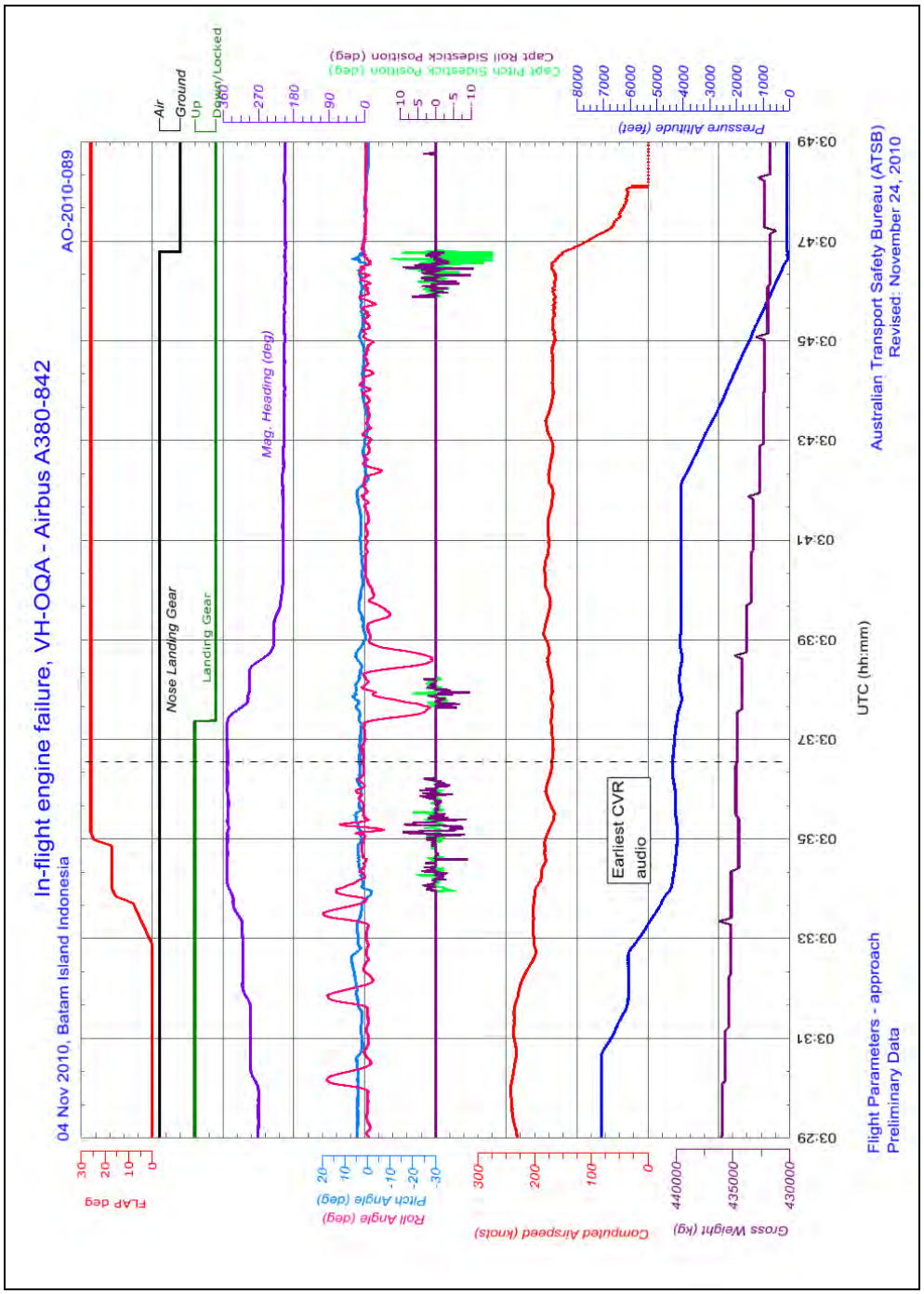


Figure A-5: Graphical representation of selected aircraft parameters during approach and landing



APPENDIX B: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation to date include:

- the operator of VH-OQA (OQA)
- the flight and cabin crew of OQA
- witness reports from a number of passengers and the public in Singapore and Batam Island, Indonesia
- a number of personnel from the Changi Airport Group
- a number of the operator's personnel
- the flight data and cockpit voice recorders
- Airbus
- Rolls-Royce plc
- Changi Airport air traffic control recorded data
- Meteorological Services, National Environment Agency, Singapore.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to Airbus, Rolls-Royce plc, the aircraft operator, the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA), UK Air Accident Investigation Branch (AAIB), Air Accident Investigation Bureau (AAIB) Singapore, Indonesian National Transportation Committee (NTSC), European Aviation Safety Agency (EASA), the Australian Civil Aviation Safety Authority, the flight crew and the customer service manager.

Submissions were received from Airbus, Rolls-Royce plc, the aircraft operator, the French BEA, UK AAIB, AAIB Singapore, Indonesian NTSC, EASA and the flight crew. The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

In-flight uncontained engine failure overhead Batam Island, Indonesia,
4 November 2010
VH-OQA, Airbus A380-842