Australian Government
Australian Transport Safety Bureau

Depressurisation and crew incapacitation Boeing 737-376SF, VH-XMO

19 km north of Narrandera Airport, New South Wales on 15 August 2018

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Addendum

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Safety summary

What happened

On the evening of 15 August 2018, a Boeing 737-376 Special Freighter, registered VH-XMO, operated by Express Freighters Australia, was transporting freight from Brisbane Airport, Queensland to Melbourne Airport, Victoria when the master caution and a right wing-body overheat annunciator illuminated.

The non-normal checklist was actioned followed by further troubleshooting in consultation with maintenance personnel. This resulted in a reduction of cabin pressure. The crew donned oxygen masks and the aircraft was entered into an emergency descent. During the initial part of the descent the captain was temporarily incapacitated by a reaction to the increased supply of breathing oxygen from the mask. A MAYDAY was declared by the first officer and the aircraft was diverted to Canberra Airport, Australian Capital Territory. During the diversion, the first officer also experienced incapacitating symptoms. The aircraft landed at Canberra Airport, under the control of the captain, with no further issues.

What the ATSB found

The ATSB found that faults in the right wing-body overheat detection system likely led to intermittent flickering of the master caution light and illumination of the right wing-body overheat annunciator. The operating flight crew conducted the appropriate non-normal checklist, however the overheat indication could not be rectified due to the fault in the wing-body overheat detection system.

An additional fault with an isolation valve in the aircraft pressurisation system prevented isolation of the right wing-body pressure duct. This led the crew to conduct further troubleshooting during which the cabin air supply was reduced. In conjunction with a higher than normal cabin leak rate, the reduced airflow also lessened the cabin pressure.

The flight crew responded to the cabin pressure reduction by donning their oxygen masks and descending the aircraft. During the descent, the captain selected emergency flow on the oxygen mask resulting in an ingestion of gaseous oxygen, causing a temporary incapacitation. After the flight was diverted to Canberra, the first officer experienced symptoms consistent with hyperventilation, leading the captain to declare the first officer incapacitated.

Post-occurrence medical testing and assessments were carried out on the flight crew with no effects from the flight identified. During post flight inspections, Qantas engineers identified a range of serviceability issues with the aircraft fuselage cabin drain valves, fuselage door seal, and the auxiliary power unit duct bellow seal that affected the capacity for the aircraft to hold cabin pressure.

What has been done as a result

The operator advised the ATSB that, following the occurrence, amendments were incorporated into the approved scheduled maintenance program to:

- incorporate a functional check of the cabin drain valves
- specifically verify the integrity of the auxiliary power unit duct bellows seal
- introduce an enhanced aircraft cabin pressurisation system check.

The operator implemented an inspection regime to ensure timely detection and rectification of faults compromising the operation of the wing-body overheat detection system.

The operator also advised that in-flight troubleshooting outside of the non-normal checklist procedures and Flight Crew Operations Manual is now prohibited.

Safety message

This occurrence is a reminder to flight crew of the hazards of dealing with system malfunctions that are not resolved using the approved non-normal checklist procedures. In such circumstances, associated system effects need to be taken into account when electing to conduct further troubleshooting outside of the non-normal procedures, even with the assistance of external maintenance specialists. Configuration changes to an aircraft system may induce other effects due to underlying unserviceable components that may not be immediately apparent.

The ATSB also reminds flight crew to be cognisant that a non-normal situation can lead to a misapplication of emergency equipment in the moment that it is actually needed. In this case the selection of the emergency flow setting on the fixed oxygen system resulted in temporary incapacitation of the captain.

Finally, a sequential series of non-normal events, in conjunction with the use of emergency equipment, can add pressure and workload to the flight crew. Though it would seem unlikely to occur, these pressures may result in hyperventilation, increasing the potential for incapacitation during a critical phase of the flight.

Contents

The occurrence

On 15 August 2018, a Boeing 737-376 Special Freighter (SF), registered VH-XMO, and operated by Express Freighters Australia, was conducting a flight from Brisbane Airport, Queensland to Melbourne Airport, Victoria. The operating flight crew comprised of a captain and first officer. There were no passengers. The aircraft departed Brisbane at 1206 Coordinated Universal Time (UTC)[1] and climbed to a cruising altitude of Flight Level (FL) 260.[2]

At 1300 the flight crew observed a momentary illumination of the master caution[3] light within the flight deck of the aircraft. The master caution then began to flicker with increasing frequency. After about 2 minutes of continuous flickering, the flight crew identified illumination of the right wing-body overheat annunciator, indicating a possible bleed air leak from the ducting of the right wing.

The flight crew consulted the quick reference handbook (QRH)[4] and conducted the non-normal checklist[5] procedure for a right wing-body overheat annunciator alert. This procedure removed bleed air pressure from the right wing bleed air duct by closing the isolation valve, switching off the right air conditioning pack, and turning off the bleed air source from the right engine.

Following completion of the non-normal procedure, the right wing-body overheat annunciator remained illuminated and the master caution light continued to flicker. Additionally, the right wing-body duct pressure gauge in the cockpit displayed a residual pressure of 14 pounds per square inch (psi),[6] indicating to the crew that the duct remained pressurised despite that system being isolated. The flight crew, concerned with the potential for leakage of high temperature bleed air into the right wing, contacted Sydney Line Maintenance Operations by VHF radio for technical assistance.

In consultation with a Sydney Line Maintenance Operations engineer, the flight crew began a process of troubleshooting with the intention of isolating the bleed air duct and extinguishing the right wing-body overheat annunciator light. The flight crew advised of the already completed steps and discussed the non-normal checklist with the engineer. The engineer advised the flight crew to cycle components of the system and monitor the right bleed air duct pressure.

After noting that the residual pressure was lowest when the right pack was switched to AUTO the engineer assessed that the right wing-body overheat annunciator light was likely an erroneous warning. However, the engineer recommended that the right pack remain in AUTO for the remainder of the flight. Following receipt of that advice, contact with the engineer ceased due to the aircraft proceeding out of VHF radio range.

While continuing the flight toward Melbourne, the first officer conducted an instrument scan and identified the cabin pressure differential at 5 psi.[7] The cabin altitude[8] registered 6,000 ft and was increasing at 600 feet per minute. The flight crew discussed the rising cabin altitude, also commenting to each other that they both felt slightly unwell. The first officer recalled that the

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1 Coordinated Universal Time (UTC): Eastern Standard Time (EST) - 10 hours.

2 Flight level: at altitudes above 10,000 ft in Australia, an aircraft's height above mean sea level is referred to as a flight level (FL). FL 260 equates to about 26,000 ft.

3 Master caution: a light used to provide indication to the crew that a malfunction is present within an electrical or electronic system component, it is associated with a relevant system annunciator light. The light remains illuminated as long as the caution condition exists, or until the crew resets the system.

4 Quick Reference Handbook (QRH): an approved document for the flight crew that contains procedures for non-normal and emergency conditions for use in flight.

5 Non-normal checklist: A specific procedure to be carried out in response to a system annunciator light.

6 In Normal flow mode the ducts are pressurised to about 30 psi and in High flow mode up to 60 psi.

7 Cabin differential pressure: the difference in pressure between inside the aircraft cabin and the local external atmosphere. Nominal B737 cabin differential is 7.45 psi at FL 260.

8 Cabin altitude: pressurisation of the cabin is displayed as cabin altitude and is the equivalent to outside pressure at that altitude. e.g. A cabin altitude of 6,000 ft corresponds to an atmospheric pressure of 6,000 ft.

physical symptoms were not consistent with hypoxia[9] and became concerned about the possibility of incapacitation due to fumes within the cockpit. As the cabin altitude continued to climb and anticipating that it would exceed 10,000 ft,[10] the flight crew elected to don the emergency oxygen masks.

At 1325, the captain contacted air traffic control requesting a descent to FL 200. Air traffic control subsequently cleared the aircraft for a descent to FL 250. The captain immediately responded with a PAN PAN[11] call and advised air traffic control that they were descending the aircraft to FL 200.

At the commencement of the descent, the first officer switched the right air conditioning pack from AUTO back to OFF as per the original non-normal checklist instruction. This commanded the left pack into high flow mode, increasing and restoring air flow into the cabin.

During the initial stages of the descent the captain reported that after manipulating the mask settings an ingestion of pressurised oxygen occurred. This resulted in a choking and gagging response from the captain. The first officer, cognisant that they had previously discussed feeling unwell, observed the captain slumped forward, gagging, and gasping for air. The first officer recalled checking on the captain during this episode but not receiving a response.

At 1326, approximately 19 km north of Narrandera Airport, New South Wales, the first officer broadcast a MAYDAY[12] to air traffic control advising that they had issues with the aircraft and had commenced an emergency descent.[13] Air traffic control acknowledged the MAYDAY and advised the first officer that there was no other reported Instrument Flight Rules[14] aircraft traffic for their descent to 10,000 ft.

During the emergency descent, the captain recovered and subsequently removed their oxygen mask. Both the captain and first officer noted that oxygen could be heard continuously flowing from the captain’s mask. Due to their ongoing concern of fumes within the cabin, the first officer elected to remain on oxygen.

Air traffic control contacted the flight crew regarding their intentions to either continue to Melbourne or divert to an alternate airport. The first officer responded with a request for information on the lowest safe altitude for the area, and a heading for an immediate landing at Canberra Airport, Australian Capital Territory. After receiving direction from air traffic control, the captain elected to further descend the aircraft to 8,000 ft and tracked the aircraft toward Canberra.

During the diversion, the oxygen supply from the fixed onboard system depleted. In response, the first officer, who had elected to remain on breathing oxygen, retrieved and connected to the portable oxygen unit that was mounted on the bulkhead at the rear of the flight deck. While transferring to the portable oxygen system, the first officer also attempted to operate an iPad in preparation for the instrument approach to Canberra Airport. The captain recalled being unable to gain the first officer’s attention during that sequence. The first officer eventually responded to the captain, advising they were feeling unwell and had severe back pain.

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9 Hypoxia: a deprivation of oxygen to the body at tissue level.

10 If the cabin altitude exceeds 10,000 ft, an altitude warning horn is activated and the flight crew must don their emergency oxygen masks.

11 PAN PAN: an internationally recognised radio call announcing an urgency condition which concerns the safety of an aircraft or its occupants but where the flight crew does not require immediate assistance.

12 MAYDAY: an internationally recognised radio call announcing a distress condition where an aircraft or its occupants are being threatened by serious and/or imminent danger and the flight crew require immediate assistance.

13 Emergency descent: a manoeuvre for descending as rapidly as possible.

14 Instrument Flight Rules (IFR): a set of regulations that permit the pilot to operate an aircraft in instrument meteorological conditions (IMC), which have much lower weather minimums than visual flight rules (VFR). Procedures and training are significantly more complex as a pilot must demonstrate competency in IMC conditions while controlling the aircraft solely by reference to instruments. IFR-capable aircraft have greater equipment and maintenance requirements.

The captain then instructed the first officer to transition to an observer-pilot role for the remainder of the flight. The captain subsequently declared a PAN PAN radio call to air traffic control informing of the first officer's incapacitation and requested the attendance of emergency services on arrival at Canberra Airport.

At 1404, the flight landed at Canberra Airport and once the aircraft had been shut down, aviation rescue fire fighters entered the aircraft cabin and conducted an air sample test. No fumes were detected. Both the captain and first officer were transported to hospital via ambulance for medical assessment.

Context

Flight data recorder

Following the occurrence, the ATSB retrieved the aircraft's flight data recorder (FDR). A range of parameters were automatically recorded by the FDR including those associated with the cabin warning and aircraft pressurisation systems. ATSB's download of the FDR showed that the total duration of the occurrence flight had been recorded. A plot of the relevant parameters relating to the environmental system is displayed at Figure 1. The following primary events were identified:

At 1259 UTC the master caution proceeded to rapidly flicker on and off for a period of 10 minutes, which correlated with the flight crew's account.

At 1301 UTC the right air conditioning pack (ECS)[15] turned OFF, the left and right packs both signalled a switch to high flow, and the right engine bleed air turned OFF. These events were consistent with the crew actioning the non-normal checklist.

The FDR data showed that, at 1315 UTC, the right air conditioning (ECS) pack was switched ON and OFF multiple times in a short period. The left pack had switched between high- and low-flow modes. The right pack had also switched between high- and low-flow modes. These events correlated with the troubleshooting period conducted by the flight crew and the engineer at Sydney.

The FDR data recorded that, at 1325 UTC, the right air conditioning pack was turned OFF and the signals for the left and right packs had switched to high flow. The aircraft altitude then reduced rapidly signalling the commencement of the emergency descent.

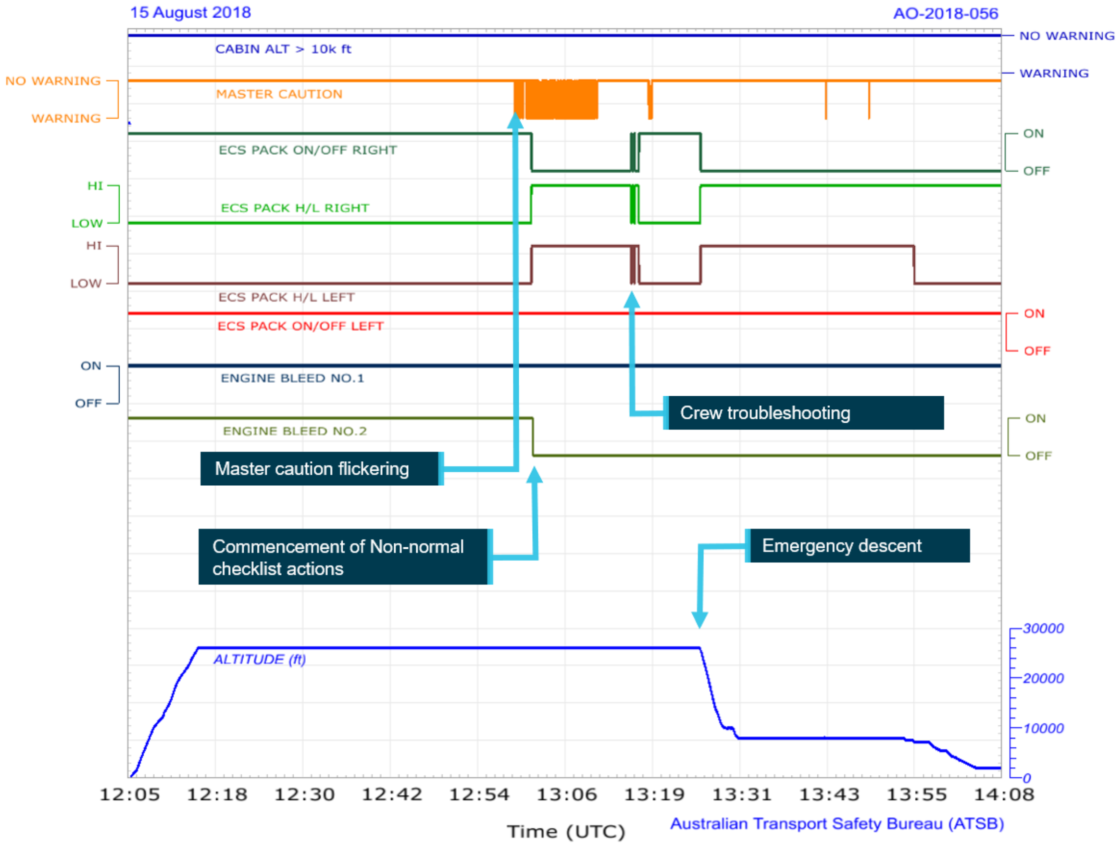
Throughout the flight and reported period of cabin pressurisation problems, the FDR information showed that the cabin altitude did not exceed 10,000 ft.

Cockpit voice recorder

Following arrival to Canberra Airport, the aircraft was powered by engineers to facilitate maintenance action on the bleed air system and the wing-body overheat detection system. The cockpit voice recorder was not isolated during these activities and consequently the audio data was overwritten and not available for this investigation.

[15] Environmental conditioning system pack also known as an 'air conditioning pack'

Figure 1: Recorded data from the occurrence flight.



Displayed is the master caution warning status, air conditioning system status and crew troubleshooting actions during the conduct of the flight through to the emergency descent and landing.
Source: ATSB

Pilot information

Captain

The captain held an Air Transport Pilot (Aeroplane) Licence issued on the 13 September 2012 and a multi-engine command instrument rating. The captain held an Australian Class 1 Aviation Medical Certificate that was valid until 12 November 2018.

The captain had been a company employee for about 8 years, initially as a first officer and then as a captain for the last 3 years. The captain was also a simulator instructor and a 737 ground training instructor with the company. At the time of the occurrence the captain had approximately 4,500 flying hours with 3,400 of those on the 737-aircraft type.

The captain last completed a flight review with the company on 18 February 2018.

First officer

The first officer held an Air Transport (Aeroplane) Pilot Licence issued on the 27 Jun 2014 and a multi-engine command instrument rating. The first officer held an Australian Class 1 Aviation Medical Certificate that was valid until 29 May 2019.

The first officer had been a company pilot since 26 September 2016. At the time of the occurrence, the first officer had approximately 5,000 hours total flying time with 700 of those operating the 737 aircraft-type.

Aircraft information

General

The Boeing 737-376 Special Freighter (SF) was originally manufactured as a passenger aircraft in the United States in 1987, before being converted for air freight operations. At the time of the occurrence the aircraft had accrued a total of 72,255 hours and 44,030 flight cycles. Express Freighters Australia operated four of this aircraft type within their national fleet service under the Express Freighters Australia air operator's certificate.

Aircraft systems

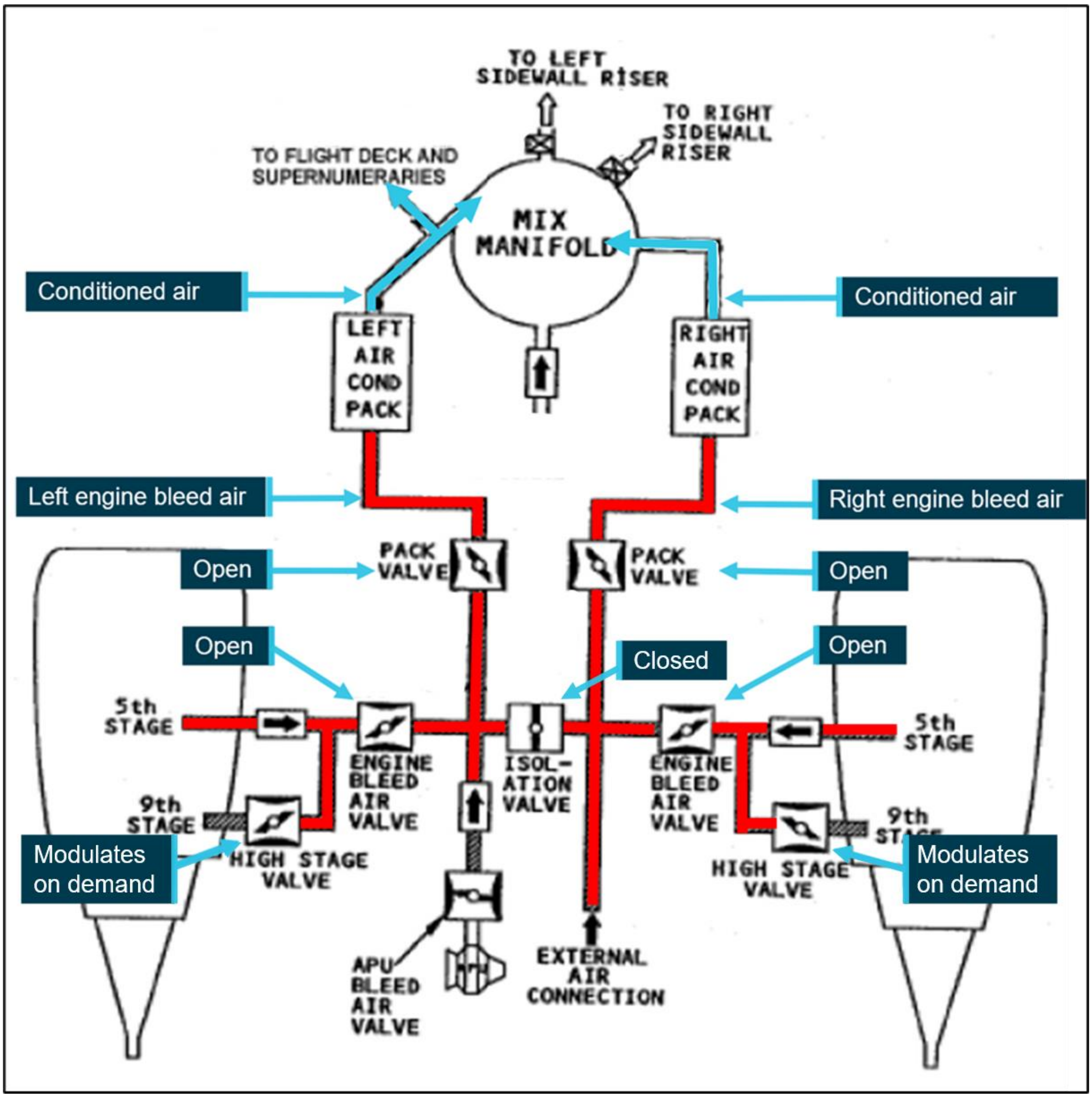
Air conditioning and pressurisation system

The aircraft air conditioning and pressurisation system is designed to keep the flight crew comfortable within the cabin by maintaining adequate air flow, temperature, and pressure. Air temperature is controlled by processing bleed air from the engines in two air conditioning packs.[16] Conditioned air from the left pack flows directly to the flight deck. Excess air from the left pack and air from the right pack is combined in a mix manifold and distributed to the cargo cabin (Figure 2).

During normal operation, the left pack uses bleed air from the left engine and the right pack uses bleed air from the right engine. An isolation valve allows the left and right bleed systems to connect. Engine bleed air is obtained from stage five and nine of the compressor section. When stage-five low pressure bleed air is insufficient for the bleed air system requirement, the stage-nine valve modulates to maintain adequate bleed air pressure.

[16] The air conditioning system is often called the air conditioning package or 'pack'.

Figure 2: Air conditioning schematic for the Boeing 737-300 series aircraft showing the configuration of the system during normal operation



The left air conditioning pack is supplied by stage-five bleed air from the left engine and the right air conditioning pack is supplied by stage-five bleed air from the right engine. The left and right engine stage-nine valves modulate open if stage-five bleed air is insufficient for system requirements.
Source: Express Freighters Australia, annotated by the ATSB.

With both air conditioning pack switches in AUTO and both packs operating, the packs provide ‘normal’ air flow. However, with one pack not operating (OFF position), the other pack automatically switches to ‘high’ air flow to maintain the necessary ventilation rate. To ensure adequate engine power for single-engine operation the automatic switching is inhibited when the aeroplane is on the ground, or in-flight with the flaps extended. With the air conditioning pack switch in HIGH, the pack provides ‘high’ air flow.

A single pack when selected to HIGH flow mode is capable of maintaining cabin pressurisation and acceptable temperatures throughout the aeroplane up to the maximum certified ceiling of 37,000 feet.

A cabin pressurisation controller modulates the cabin pressure via an outflow valve. The cabin pressurisation controller normally controls the cabin altitude rate of climb as well as the cabin altitude. The system has both an aural and visual warning for cabin altitudes above 10,000 ft, a level requiring flight crew to use supplementary oxygen.

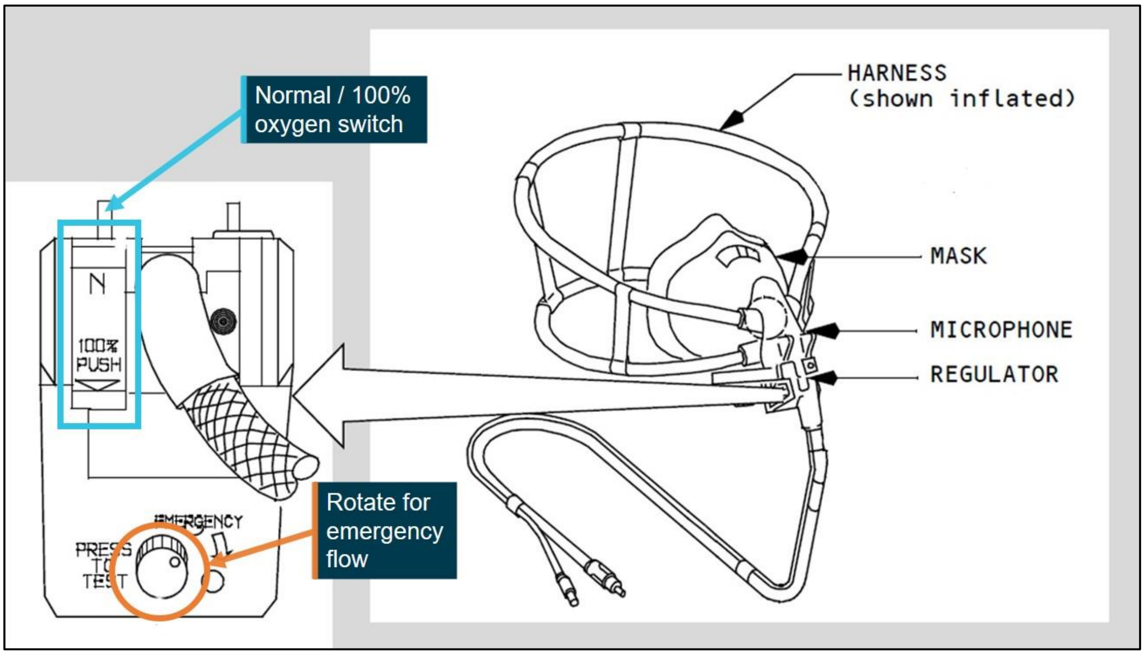
Oxygen system

The B737-300SF is fitted with a fixed oxygen system designed to provide oxygen to the flight crew in the event of high cabin altitude (such as an aircraft depressurisation) or compromised air within the cockpit due to fumes and/or smoke. The B737-300SF is equipped with a 76 cubic foot oxygen cylinder (approximately 2,152 litres) for flight crew supply. Oxygen pressure is displayed on the indicator located on the rear overhead panel and the flow level is controlled through a pressure-reducing regulator, to reduce supply to a breathable pressure.

Each crew position is fitted with an oxygen mask that is stowed in a box immediately adjacent to each crew seat. The mask has selectable features that permit the crew to select either 100 per cent oxygen when contamination of the flight deck air exists or a NORMAL position which provides an air/oxygen mixture (Figure 3). The mask regulator also provides an EMERGENCY setting which is used when needed to supply positive pressure in the masks and goggles to remove contaminants.

The aircraft is also fitted with a flight crew portable oxygen bottle. This is a self-contained oxygen system, offering both demand and constant flow capabilities. The portable oxygen cylinder is installed behind, and adjacent to, the first officer’s seat.

Figure 3: Oxygen mask and regulator fitted to the Boeing 737-300 series aircraft



A push button switch activates the pilot oxygen system for normal use. A rotary dial is used to enable the emergency flow mode.
Source: Express Freighters Australia, annotated by the ATSB.

Post-flight aircraft maintenance

Following the occurrence the aircraft was examined and tested by Qantas engineers at Canberra Airport with the following defects identified:

Aircraft pressurisation

An engine ground run was conducted to simulate the conditions encountered during the flight. That test identified that the aircraft was unable to maintain cabin pressure. Minor leakage of bleed air was discovered on the right-wing leading-edge ducting. The leak was rectified on tightening of the duct clamp.

It was also identified that the isolation valve between the left and right systems was not completely closing, resulting in leakage and the right bleed air duct to remain partially pressurised (Figure 2).

Finally, during single-pack operation in NORMAL flow, the aircraft was unable to maintain differential cabin pressure. The Qantas engineers identified that this was due to:

- leakage of multiple cabin drain valves
- minor door seal leaks
- damage to the auxiliary power unit bleed air duct bellows and clamp.

Those defects created a cabin air escape route through the pressure bulkhead.

Overheat detector

A resistance check of the right wing-body overheat detector elements was completed in Canberra. The engineers identified that the centre wing-body overheat detector element was found out of tolerance and unserviceable. The overheat detector element along with an associated electrical connector was subsequently replaced. No additional faults were found with that system.

Oxygen system and fumes detection

Air sampling from the flight deck was conducted during extended engine operations. No evidence of fumes or odour was detected. The air quality testing showed no abnormal issues associated with carbon dioxide, carbon monoxide or particulate concentrations. The oxygen masks for the captain and first officer were inspected and tested. During replenishment of the aircraft oxygen system, the engineers reported that the captain’s mask had been set to emergency flow. No defects were identified with the oxygen masks.

Operational information

Flight crew operations manual

The Flight Crew Operations Manual (FCOM) was the primary flight crew reference for the operation of the aircraft along with the relevant checklists for normal, non-normal, and emergency conditions.

Non-normal checklists

Non-normal checklists were used by the flight crew to manage unexpected events that affect the normal operating procedures of the aircraft. Illumination of the master caution and system annunciator lights indicate a non-normal condition and are the cues to select and carry out the associated checklist.

Non-normal checklists begin with steps to correct the situation and, if needed, information for planning the rest of the flight. In all instances, the operator’s procedures require the captain to assess the situation to determine the safest course of action. The operator also noted that if further troubleshooting is determined to be the safest course of action, taking steps beyond published non-normal checklist steps may cause further loss of system function or a system failure. Consequently, the operator’s guidance to their pilot’s was that troubleshooting should only be considered when completion of the published non-normal checklist results in an unacceptable situation.

Non-normal checklists also have a list of assumptions. Assumptions relevant to this occurrence were listed within the FCOM:

- If the master caution and system annunciator lights illuminate, all related amber lights are reviewed to assist in recognising the cause(s) of the alert. Aural alerts are silenced and the master caution system is reset by the flight crew as soon as the cause of the alert is recognised.
- The EMERGENCY position of the oxygen regulator is used when needed to supply positive pressure in the masks and goggles to remove contaminants. The 100% position of the oxygen regulator is used when positive pressure is not needed but contamination of the flight deck air exists. The Normal position of the oxygen regulator is used if prolonged use is needed and the situation allows. Normal boom microphone operation is restored when oxygen is no longer in use.

Flight administration manual

The Express Freighters Australia Flight Administration Manual (FAM) was for the use of crew members and guidance for other personnel in dealing with matters associated with the operation of company aircraft. The FAM defined the policies, standards and procedures to be adhered to under all circumstances.

System failures and in-flight troubleshooting

The FAM stated that a component or system failure in flight should be dealt with according to established procedures, including completion of any associated checklist. Crew troubleshooting of system problems should not normally be attempted in flight unless there is an overriding operational requirement to do so, or where it may assist subsequent rectification. Before attempting any troubleshooting, flight crew were to attempt to contact Maintenance Watch for further guidance.

Medical information

Post occurrence, both flight crew were transported to hospital. Assessments and blood tests were carried out with no markers or indicators of a fumes event detected. The first officer recalled still feeling 'dizzy' and 'foggy' with a dry throat and lips during this time. The flight crew were subsequently released from hospital with no ongoing effects from the occurrence.

The flight crew were individually interviewed and medically assessed by their company doctor. It was reported to the ATSB that the first officer's symptoms of tingling in the fingers and lips, along with the muscle tension were consistent with hyperventilation, although the symptoms can be confused with hypoxia or fume inhalation. An additional assessment of the symptoms was provided to the ATSB by an aviation medicine specialist, who similarly concluded that the first officer had developed hyperventilation as a response to the severity of the emergency.

Hyperventilation

Hyperventilation can be induced from rapid or deep breathing resulting from anxiety or panic. It occurs when the rate or tidal volume of breathing eliminates more carbon dioxide than the body can produce. The symptoms can be lingering and include dizziness, tingling in the lips, hands or feet, headache, weakness, fainting and seizures.

Nias (1998) explains that over-breathing can occur as part of the classic 'fight-or-flight' response as the body involuntarily prepares for action. Gradwell (2006) explains that even moderate hyperventilation has the potential to significantly impair motor skills, which, for a pilot, may lead to a reduced capacity to perform the necessary complex actions associated with the operation of an aircraft. Hyperventilation for aircrew can occur under certain conditions:

- exposure to low-frequency vibration
- during positive-pressure breathing
- the mental stress of a sudden in-flight emergency
- anxiety, apprehension, and fear.

Related occurrences

The ATSB research publication AR-2015-096 reviewed occurrences reported to the ATSB from 2010 to 2014. The publication identified 113 cases of pilot incapacitation with 86 of those in multi-crew, high-capacity transport operations. Almost half of the incapacitation events for those pilots was due to gastrointestinal illnesses, such as food poisoning or gastroenteritis. There were no reported instances involving incapacitation due to hyperventilation.

The review indicated that most incapacitation occurrences do not involve a chronic or pre-existing medical condition and are largely unforeseeable events. Many are not in themselves life threatening but are capable of impairing pilot performance to the extent that safe operation of the aircraft may be adversely affected.

In most of the occurrences, the incapacitation was severe enough for the pilot to be removed from duty for the remainder of the flight. The ATSB found that approximately 10 per cent of the incapacitating events resulted in a return to the departure airport or a diversion to another airport.

ATSB investigation report AO-2013-120 describes the response to smoke in the cockpit by the flight crew of a Bombardier DHC-8-315. The crew found that communication became difficult once their oxygen masks had been donned. As a result, the crew removed their oxygen masks for the remainder of the flight to improve communication. However, that action increased the risk of crew impairment or incapacitation as there was still smoke in the cockpit.

The stress associated with the smoke resulted in a high workload for the crew and adversely affected their performance, leading to errors in aircraft management and checklist completion. This occurrence also highlighted the importance of flight crew familiarising themselves with the operation of the onboard emergency equipment.

Safety analysis

Introduction

The following analysis details the technical and operational issues encountered by the crew of a freight flight that led to pilot incapacitation during an emergency descent and diversion to Canberra Airport.

Aircraft depressurisation

While cruising at Flight Level 260, the flight crew observed the illumination and rapid flickering of the master caution light. Approximately 2 minutes later, the first officer identified the annunciator light for the right wing-body overheat was also illuminated. The concern from such an alert for the flight crew was the potential leakage of hot bleed air gases within the wing cavity damaging wiring and the internal structure of the wing. While various recommended actions were attempted to extinguish the warnings, the flight crew efforts were unsuccessful, and the flickering continued for approximately 10 minutes.

Though the flickering master caution and overheat annunciator light eventually extinguished, it is likely that these alerts were due to an electrical fault with the aircraft detection system rather than the result of elevated temperature within the wing body. After landing, maintenance engineers established that the centre conductor from a sensor within the overheat detection system was out of specification, leading to the observed erroneous system behaviour.

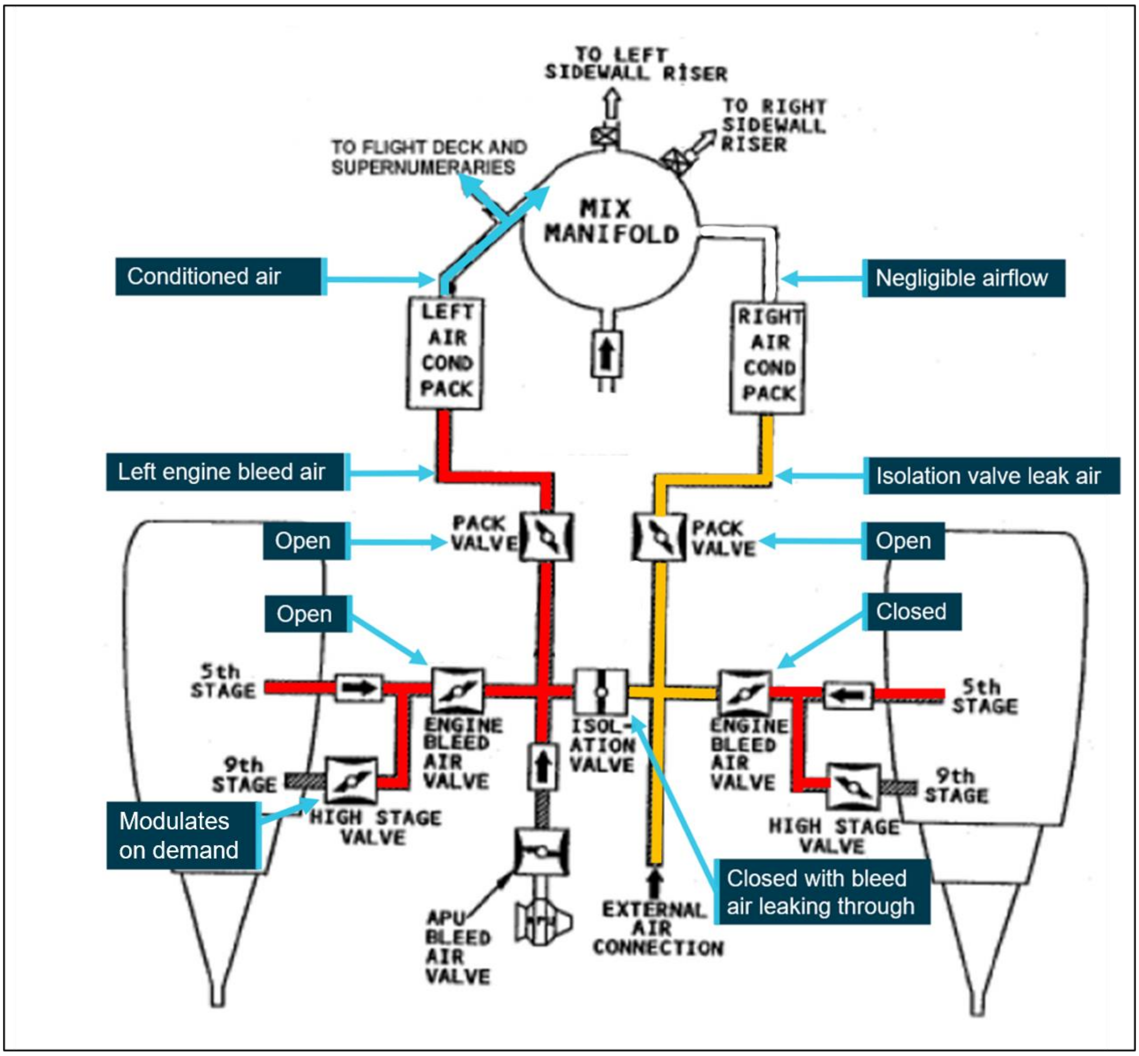
Actioning the non-normal checklist associated with the right wing-body overheat annunciator alert required isolating the bleed air systems from the right engine. Those actions were intended to remove high temperature bleed air, from the right wing-body duct and shut down that part of the air conditioning system.

However, following completion of the checklist the flight crew observed that the right duct remained partially pressurised, indicating that it was not isolated. Technical examination following the occurrence identified that a faulty isolation valve prevented complete closure of the duct.

The residual pressure after completion of the non-normal checklist operations led to the flight crew conducting further troubleshooting activities outside of that checklist in consultation with the Sydney Line Maintenance engineer. This resulted in the right air conditioning pack switch being selected to AUTO from OFF, which then transitioned the left (operating) pack from high flow to low flow, leading to a significant reduction of air available to pressurise the aircraft (Figure 4).

As the right air conditioning system remained partially pressurised, the captain’s decision to conduct further troubleshooting outside the non-normal checklist instructions was appropriate and completed in conjunction with assistance from Sydney Line Maintenance. Despite the attempts to extinguish the overheat alert by isolating the right bleed ducting, the effects of those actions unknowingly contributed toward a gradual depressurisation of the aircraft.

Figure 4: Air conditioning schematic for the Boeing 737-300 series aircraft showing the final configuration of the system post troubleshooting by the flight crew prior to the descent.



The right air conditioning system had been selected by the flight crew to AUTO mode which commanded the left air conditioning package from high flow to low flow. This reduced the conditioned air (highlighted blue) that was directed into the flight deck. The right engine bleed valve had been selected closed by the flight crew as part of their troubleshooting actions. The isolation valve had also been selected closed by the flight crew. A fault with the isolation valve allowed the right duct to become partially pressurised (highlighted yellow).
Source: Express Freighters Australia, modified by the ATSB.

Following the occurrence, the aircraft was found to have significant air leaks from the auxiliary power unit duct bellows, cabin drain valves that were found stuck open and minor leaks from the aircraft door seals. In combination, these leaks were significant however, when the aircraft was operating with both the left and right air conditioning packs operating, cabin pressure was still able to be maintained.

Single pack operation was configured as a result of the completion of the non-normal checklist. The additional troubleshooting actions by the flight crew reduced the air supply into the aircraft cabin. This, in combination with the excessive leakage pathways, resulted in a gradual depressurisation of the aircraft. That, in turn, resulted in the flight crew electing to don oxygen and conduct an emergency descent.

Pilot incapacitation

While wearing an oxygen mask during the descent, the captain selected the emergency purge setting on the oxygen mask resulting in the inhalation of pressurised 100 per cent oxygen. The flight crew operations manual stated that the emergency position of the oxygen regulator was to be used to supply positive pressure within the mask to remove contaminants such as fumes or particles from within the mask. Selection of the emergency position on this occasion produced a gagging reflex and led to the captain becoming temporarily incapacitated.

In response, the first officer declared a MAYDAY and continued the descent to 10,000 ft. While there was no enduring effect from the captain’s temporary incapacitation, had the system remained in normal operation mode administering an on-demand supply setting of regulated oxygen, it is unlikely to have occurred.

After landing at Canberra Airport, the flight crew were transported to hospital for medical assessment. Blood tests showed no markers or indicators that the crew were exposed to disabling or hazardous fumes generated from within the aircraft. This was supported by emergency services not detecting any hazardous gases during their post-landing check of the aircraft flight deck. Additionally, no medical problems were identified.

Despite that, the first officer recalled feeling ‘dizzy’ and ‘foggy’ with a dry throat and lips. They also reported feeling unwell and having severe pain during the descent. On balance, the ATSB concluded that the accumulation of stressors associated with the:

- troubleshooting activities
- use of the oxygen masks
- temporary incapacitation of the captain
- concern for hazardous fumes
- emergency decent and subsequent diversion

probably led the first officer to a heightened state of anxiety, hyperventilation, and the development of further incapacitating symptoms.

ATSB research into pilot incapacitation occurrences showed that the majority of cases were due to gastrointestinal illnesses, such as food poisoning or gastroenteritis. There were no reported instances involving incapacitation due to hyperventilation. The report noted that once declared incapacitated, the pilot was often removed from active flying duty and the flight was sometimes diverted, such as occurred in this instance.

Findings

> ATSB investigation report findings focus on safety factors (that is, events and conditions that increase risk). Safety factors include 'contributing factors' and 'other factors that increased risk' (that is, factors that did not meet the definition of a contributing factor for this occurrence but were still considered important to include in the report for the purpose of increasing awareness and enhancing safety). In addition 'other findings' may be included to provide important information about topics other than safety factors.
>
> These findings should not be read as apportioning blame or liability to any particular organisation or individual.

From the evidence available, the following findings are made with respect to the depressurisation and crew incapacitation that occurred near Narrandera New South Wales, on 15 August 2018 involving a Boeing 737-376SF, VH-XMO.

Contributing factors

- Faults with the right wing-body overheat detection system likely led to intermittent illumination of the master caution and wing-body overheat annunciator.
- The crew were unable to isolate the right wing-body duct due to a faulty isolation valve.
- In consultation with Sydney Line Maintenance Operations, the flight crew conducted troubleshooting activities that resulted in the right air conditioning pack being selected to AUTO. This resulted in a reduction of cabin airflow.
- Due to the reduction in cabin airflow, along with a higher than normal cabin leak rate, the aircraft was unable to maintain required cabin altitude. This resulted in the flight crew electing to conduct an emergency descent.
- During the descent, the captain selected the emergency setting on the oxygen mask resulting in an inhalation of pressurised oxygen. This caused a gagging reflex leading to a temporary incapacitation.
- Throughout the diversion and landing the first officer experienced incapacitating symptoms consistent with hyperventilation from a heightened state of anxiety, leading the captain to declare the first officer incapacitated.

Other findings

- Post-occurrence medical testing and assessments were carried out on the flight crew with no lasting effects from the flight identified.

Safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. All of the directly involved parties are invited to provide submissions to this draft report. As part of that process, each organisation is asked to communicate what safety actions, if any, they have carried out to reduce the risk associated with this type of occurrences in the future. The ATSB has so far been advised of the following proactive safety action in response to this occurrence.

Safety action by Express Freighters Australia

Following this occurrence Express Freighters Australia advised that the three other B737-300SF aircraft within the Express Freighters fleet were inspected, and that:

- the auxiliary duct bellow seal from one other aircraft was similarly damaged
- non-functioning fuselage drain valves were also identified in those other aircraft.

The ATSB was also advised that safety action implemented by Express Freighters as a result of those aircraft inspections included:

- the implementation of an enhanced inspection regime to ensure timely detection and rectification of faults compromising the operation of the wing-body overheat detection system
- an amended maintenance program to incorporate an enhanced pressurisation system check and scheduled functional checks of the fuselage drain valves
- a specific task during scheduled maintenance of the aircraft to verify the integrity of the auxiliary power unit duct bellows seal.

Express Freighters Australia have also amended their policy for system failures and in-flight troubleshooting, advising the ATSB that the following amendment has been incorporated into their Flight Administration Manual:

- A component or system failure inflight should be dealt with according to established procedures, including completion of any associated checklist. Systems troubleshooting by crew is prohibited, except in accordance with the FCOM/QRH. Actions contrary to the FCOM/QRH cannot be authorised by Maintenance Watch.

General details

Occurrence details

Date and time:	15 August 2018 – 1326 UTC	
Occurrence category:	Serious Incident	
Primary occurrence type:	Depressurisation	
Location:	19 km north of Narrandera Airport, New South Wales	
	Latitude: 34° 32.2980' S	Longitude: 146° 33.0720' E

Aircraft details

Manufacturer and model:	The Boeing Company 737-376SF	
Registration:	VH-XMO	
Operator:	Express Freighters Australia	
Serial number:	23488	
Type of operation:	Air Transport High Capacity - Freight	
Activity:	Freight	
Departure:	Brisbane, Queensland	
Planned Destination:	Melbourne, Victoria	
Actual Destination:	Canberra, Australian Capital Territory	
Persons on board:	Crew – 2	Passengers – 0
Injuries:	Crew – 0	Passengers – 0
Aircraft damage:	Nil	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- Flight crew of VH-XMO
- Express Freighters Australia
- Qantas medical services

References

David J. Rainford & David P. Gradwell 2006, *Ernsting's Aviation Medicine*, Hodder Arnold, fourth edition, London UK

David K B Nias 1998, 'Addressing the causes of hyperventilation' Practitioner, London

Submissions

Under section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. That section 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 the following directly involved parties:

- Flight crew
- Express Freighters Australia
- Civil Aviation Safety Authority.

Submissions were received from:

- Flight crew (Captain)
- Express Freighters Australia

The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. It is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB's purpose is to improve the safety of, and public confidence in, aviation, rail and marine transport through:

- 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, as well as participating in overseas investigations involving Australian-registered aircraft and ships. It prioritises investigations that have the potential to deliver the greatest public benefit through improvements to transport safety.

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

Purpose of safety investigations

The objective of a safety investigation is to enhance transport safety. This is done through:

- identifying safety issues and facilitating safety action to address those issues
- providing information about occurrences and their associated safety factors to facilitate learning within the transport industry.

It is not a function of the ATSB to apportion blame or provide a means for determining 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. The ATSB does not investigate for the purpose of taking administrative, regulatory or criminal action.

Terminology

An explanation of terminology used in ATSB investigation reports is available on the ATSB website. This includes terms such as occurrence, contributing factor, other factor that increased risk, and safety issue.