AAIB
Air Accidents Investigation Branch

AAIB Bulletin 12/2017

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AAIB Field Investigation Reports

A Field Investigation is an independent investigation in which AAIB investigators collect, record and analyse evidence.

The process may include, attending the scene of the accident or serious incident; interviewing witnesses; reviewing documents, procedures and practices; examining aircraft wreckage or components; and analysing recorded data.

The investigation, which can take a number of months to complete, will conclude with a published report.

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A330-323, N276AY	
No & Type of Engines:	2 Pratt & Whitney PW400 turbofan engines	
Year of Manufacture:	2001 (Serial no: 0375)	
Date & Time (UTC):	26 June 2016 at 1115 hrs	
Location:	London Heathrow Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 12	Passengers - 277 Ground staff - 2
Injuries:	Crew - None	Passengers - 1 (Minor)
Nature of Damage:	APU failure	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	61 years	
Commander's Flying Experience:	31,635 hours (of which 1,912 were on type) Last 90 days - 200 hours Last 28 days - 28 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The cabin filled with smoke whilst the aircraft was on stand after boarding. The cabin crew were unsuccessful in making contact with the commander, and one of the flight attendants (FAs) initiated a passenger evacuation.

Several passengers exited using the emergency slides from the two aft doors, but most left using the jetbridge at exit 2L. Passengers opened the two emergency exits situated immediately aft of the wings (exit 3L and exit 3R). Exit 3L had not been armed, so the slides did not deploy and the passengers did not use the exit. Exit 3R was armed and opened by a passenger and the slide deployed, but this exit was not used either.

The commander attempted to halt the evacuation, (because he believed he had isolated the source of the smoke) which caused some confusion until the FAs encouraged all remaining passengers to exit via the jetbridge.

Air Traffic Control (ATC) observed the incident and alerted the emergency services, which reached the scene quickly. Three passengers and several FAs received treatment for the effects of smoke inhalation and one passenger suffered a minor leg injury while using an escape slide.

The source of the smoke was traced to a failure of the Auxiliary Power Unit (APU) load compressor carbon seal that allowed hot oil to enter and pyrolyse in the bleed air supply.

Metallic debris in the shared oil system compromised the load compressor bearing, leading to the failure of the load compressor carbon seal.

The APU manufacturer has taken action to address this type of event, and the relevant section of the Master Minimum Equipment List (MMEL) has been reviewed and amended.

Six Safety Recommendations are made in the areas of interphone design, passenger briefings and the co-ordination of pilot and cabin crew training. A further two Safety Recommendations are made concerning modification to enhance automatic APU shut-down protection in the event of lubrication system contamination.

History of the flight

The crew, comprising three pilots[1] and nine FAs (designated A-FA to H-FA and K-FA), prepared the aircraft for departure from Stand 307 at Heathrow while ground engineers dealt with defects raised by the crew of the inbound flight. Passenger boarding began later than scheduled, with engineers, caterers and cleaners still working on-board. Some of the FAs felt more pressured than usual as a result of having to supervise the passenger boarding during this other cabin activity.

The APU was being used for air conditioning, but external electrical power was connected because the APU generator was unserviceable[2]. The engineers departed one hour after boarding began and all the exit doors were then closed and armed. In preparation for this, the FAs briefed the passengers seated in four '*exit seats*[3]', referring them to their safety instruction cards which contained guidance on opening the adjacent exit. Before the doors were armed passengers occupying these seats were required to agree they were able and willing to open these exits if necessary.

The jetbridge was removed at 1057 hrs but two minutes later the commander requested further engineering assistance because there was an indication of a navigation system defect. All the doors were disarmed, the jetbridge was re-attached at exit 2L (Figure 1), and an engineer went to the flight deck, accompanied by the Gate Operational Co-ordinator (GOC).

The In-flight Entertainment system (IFE) was inoperative so the FAs needed to provide a manual passenger safety demonstration using equipment stored in on-board pouches. Before departure, their duty stations were mostly, but not exclusively, in the vicinity of their jump-seats; the K-FA's duty station for boarding was at 2L. Because there were no pouches stored next to exits 3L and 3R, the F-FA went forward towards exit 2L and the G-FA went aft towards exit 4R, to retrieve pouches stored near these locations. Meanwhile, the K-FA was also looking for a demonstration pouch in the vicinity of the aft galley on the left side of the aircraft.

Footnote

[1] The flight deck crew comprised the commander, the co-pilot and an International Relief Officer (IRO), who was a qualified co-pilot occupying the cockpit jump seat.

[2] See *Dispatch with APU generator inoperative.*

[3] Seats 25A, B, G and H are designated as exit seats because they have direct access to either exit 3L or exit 3R. See *Exit seat*s.

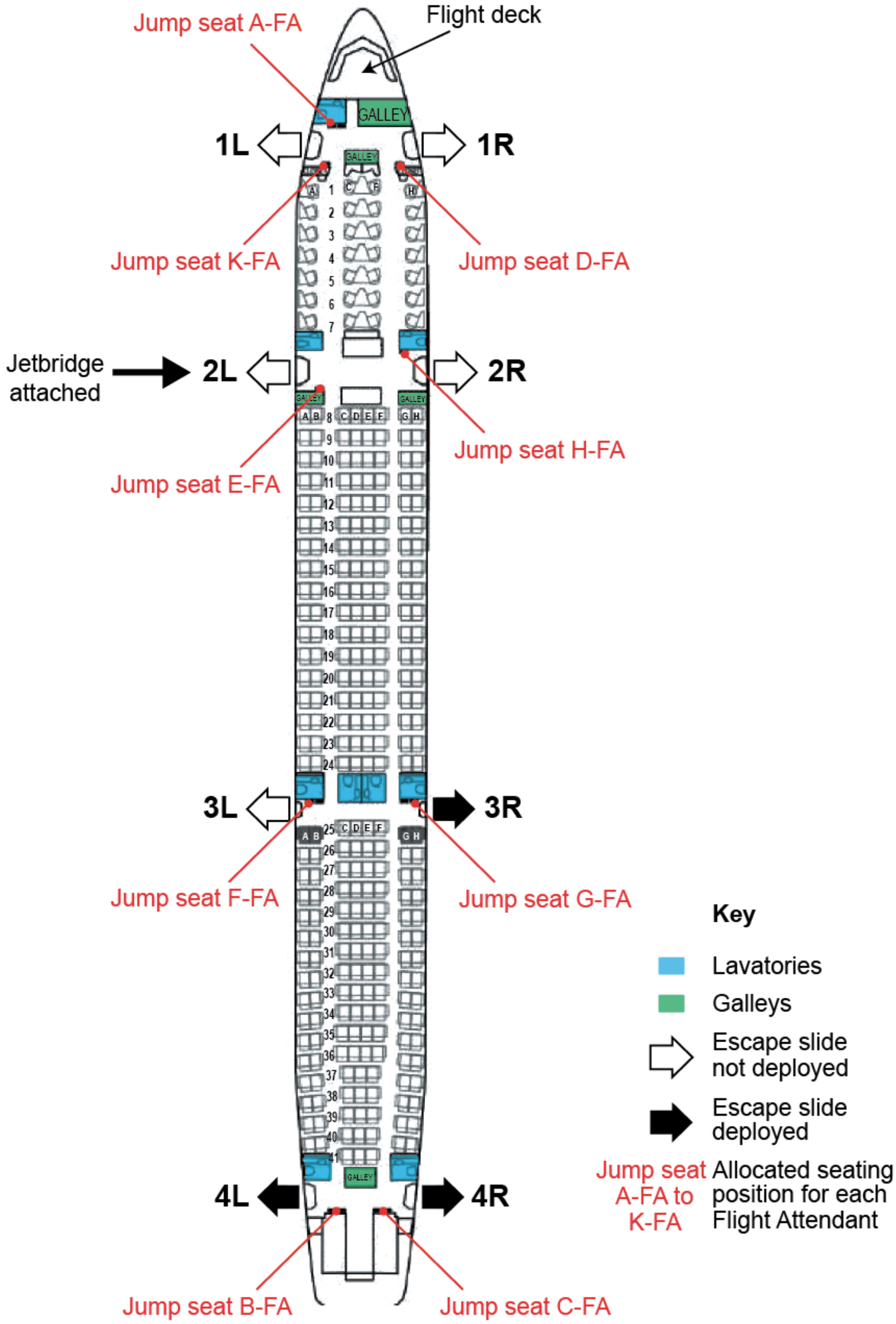

Figure 1

Cabin layout of N276AY showing numbered exits and FA jump seat locations

The engineer was on the flight deck and was talking to the pilots when the commander thought he smelt burning. Assuming it was associated with the engineering activity, the commander asked the engineer what was causing the smell, but the engineer did not know.

The commander recalled that, a few seconds later, smoke appeared behind his seat and the SMOKE LAVATORY SMOKE warning[4] illuminated on the upper display of the Electronic Centralised Aircraft Monitor (ECAM) in the centre of the main instrument panel, accompanied by an aural chime. Over the sound of this, he believed he heard the words "smoke in the cabin" and possibly "evacuate" spoken. He saw the cabin full of smoke and smoke coming from the windshield vents. Aware that the APU was providing conditioned air, he assumed it was causing the smoke and pressed the APU bleed switch to close off the APU air supply.

From the jump seat at the rear of the flight deck, the International Relief Officer (IRO) saw smoke issuing from ventilation ducts. He recalled that the commander and co-pilot actioned the checklist for a SMOKE LAVATORY SMOKE warning, and the co-pilot began to action the '*Smoke/ Avionics Vent Smoke/Fumes'* checklist, with assistance from the IRO. The co-pilot recalled that the SMOKE LAVATORY SMOKE warning illuminated after they had begun to action the '*Smoke/ Avionics Vent Smoke/Fumes'* checklist. Both pilots commented that various chimes, alarms and warnings were operating together and were distracting.

The IRO remembered one of the FAs coming to the flight deck and reporting that an evacuation was underway. At approximately the same time the commander saw, in a reflection from the terminal building, that a rear escape slide had been deployed, and noticed the APU AUTO SHUTDOWN message displayed. He assumed the APU had caused the smoke and that the situation was under control because the APU had shut down so, while the other two pilots actioned the Quick Reference Handbook (QRH), he made a Passenger Announcement (PA) to stop the evacuation in order to prevent unnecessary injuries. He expected this would stop the use of the slides and that disembarkation would continue via the jetbridge.

The commander noticed the interphone light was on, indicating a call from an FA in the cabin, but he had not heard any associated aural alert call. He assumed the sound of the smoke warning had prevented him from hearing the interphone call alert, and cancelled the master warning before trying to return the interphone call. When there was no response, he made a radio call to the aircraft operator to announce the presence of passengers on the ramp. Later he saw the Rescue and Fire Fighting Service (RFFS) arrive, and assumed there was no need for him to notify ATC himself.

Standing towards the back of the flight deck, the GOC heard the evacuation PA and observed the cabin fill with white smoke. She heard the commander first make a PA telling passengers to stop evacuating, then another telling them to continue. She used her portable radio to inform the operator's ground team that an evacuation was underway, then moved through the cabin and onto the jetbridge, helping to usher passengers off as she did so. Initially she directed them to the nearest lounge area but when smoke drifted along the jetbridge into this area they were re-directed to another lounge further from the

Footnote

[4] See *Smoke in the cabin.*

aircraft. The GOC later stated that all passengers and FAs were clear of the aircraft by 1125 hrs and she then went down to the ramp to meet the passengers who had escaped via the rear slides.

The IRO and the co-pilot actioned the evacuation checklist in the QRH because they wanted to "ensure nothing was missed", but the evacuation alarm[5] was not turned on because it was believed passengers were no longer using the slides. They then walked through the cabin as the last passengers were leaving, and with some RFFS personnel already on-board. All the FAs then disembarked and, after the RFFS had checked the aircraft, the pilots remained on-board until approximately 1200 hrs. During this period they liaised with the aircraft operator but did not ensure that power for the Cockpit Voice Recorder (CVR) was disconnected.

Cabin evacuation

Mid-cabin

The door at exit 2L remained open and the jetbridge was attached throughout the incident. The E-FA was in the galley between exits 2L and 2R, near to the F and H-FAs, when the latter drew their attention to smoke at ceiling level. The E-FA looked down the aisle and observed "smoke fill the cabin in less than three seconds". She immediately tried to call the commander using the CAPT button on the interphone[6] but received no answer. She smelt what she thought was an electrical fire and made a PA telling passengers to evacuate. Passengers attempting to retrieve belongings from the overhead bins were instructed to leave them behind. The E-FA reported that she had considered arming exit door 2R to assist the evacuation but decided this might create confusion and break the flow.

As passengers exited, the E-FA heard the commander make a PA to stop the evacuation. She believed he could not perceive the smoke and fumes as she could, so shouted to the passengers to keep moving. She then heard a further PA from the commander to continue the evacuation. Although the commander's instructions caused a short interruption, passengers responded to shouts from the FAs and continued exiting onto the jetbridge.

Aft cabin

There were four FAs in the aft galley area; the G and K-FAs who were collecting demonstration pouches, the B-FA (whose station is at exit 4L) and the C-FA (whose station is at exit 4R). The B-FA heard an "explosive noise", which seemed to come from above the left side of the galley, before smoke appeared suddenly in the cabin, obscuring her view of the other FAs. Her colleagues did not hear the sound but they were all aware of the sudden appearance of dense white smoke, which some described as having a chemical or electrical smell. The K-FA checked the ovens and looked down the left aisle of the economy cabin to establish the source of the smoke. Passengers were becoming agitated and some were standing up.

Footnote

5 See *Evacuation signalling system.*
6 See *Interphone calls to flight deck.*

The G-FA was forward of the aft galley, on the right side, when she saw the smoke. She shouted a warning and tried to contact the commander using the interphone CAPT button; but heard an engaged/busy tone. The B and C-FAs also stated that they tried to call the commander but their calls were not answered. By now an alarm was sounding and, while the B-FA identified this as a smoke alarm, the C-FA believed it was the secondary evacuation signal[7]. The B-FA grabbed a fire extinguisher and her Portable Breathing Equipment (PBE), and heard a PA commanding an evacuation.

The other three FAs nearby could not hear PAs due to the noise from the alarm and from passengers shouting, but had each decided independently that an evacuation was essential and said afterwards that they responded as trained. The G-FA commanded them to re-arm the doors and the K and C-FAs held back passengers while the B and G-FAs armed and then opened exits 4L and 4R. They confirmed slide deployment and checked it was safe outside before working in pairs to instruct passengers to evacuate, using the command "jump and slide".

The first passengers to evacuate were instructed to help at the bottom of the slide. All but two passengers were prevented from taking cabin bags with them.

The B-FA then heard the commander's PA to stop the evacuation and shouted this instruction to her colleagues at exits 4L and 4R. The B-FA said she spoke to the A-FA, who was the senior cabin crew member (SCCM), on the interphone and received confirmation of this instruction[8].

Twenty five passengers (including one baby) used the two aft slides. Remaining passengers were directed forward, with no further PAs heard by any of the FAs in the aft cabin. Some of them said later that there was still a lot of smoke in the aft cabin and, because they were unsure of its source, they believed continuing evacuation using emergency escape slides would have been appropriate.

Forward cabin

The SCCM was in the forward left lavatory (aft of the flight deck) when smoke appeared. She reported that the compartment filled with smoke in approximately four seconds and, as she opened the door, she thought she heard the words "smoke in the cockpit" several times, followed by the sound of "smoke bells". She grabbed a fire extinguisher and a PBE from under her crew seat and, thinking the source of the smoke was in the flight deck, she tried to pass her extinguisher to the pilots. Nobody took it from her and she realised there was smoke throughout the cabin. She then heard a PA from the E-FA saying "Evacuate, come this way".

In response to the PA, the SCCM and D-FA moved aft through the business cabin ushering passengers towards exit 2L. Approaching this exit, the SCCM heard a PA from the commander telling passengers to stop evacuating. Looking around she saw the commander standing

Footnote

[7] See *Evacuation signalling system*.
[8] The A-FA did not recall this exchange.

in the flight deck looking towards her. Realising the cabin still contained thick smoke she told the nearby E and F-FAs to continue evacuating passengers and went forward to tell the commander they should continue the evacuation. He acknowledged this and she heard a further PA to continue evacuating. She estimated that 50 passengers had vacated through exit 2L by this stage and, with some light visible at the aft end of the cabin, believed the doors there were open.

The SCCM moved aft, encouraging passengers to leave their belongings and get off. She noticed that exit 3L was open but its slide was not deployed. A passenger with two children was looking out of the door, so she instructed them to go to exit 2L and placed a safety strap across the open doorway. She saw that exit 3R was also open, with its slide deployed. The G-FA was there speaking to a passenger who said he had been seated a few rows aft of the exit and saw passengers seated there having difficulty trying to open it. He knew the slide would be needed and managed to help arm the door and open it, although nobody evacuated through the exit.

As the last passengers were leaving, personnel from the RFFS arrived and instructed the FAs to evacuate. Once on the jetbridge one FA, who had a pre-existing respiratory issue, was given portable oxygen. Several of the FAs experienced a burning sensation in their nose, throat and eyes after leaving the aircraft.

Aerodrome response

The ATC Ground Controller, who had a direct view of the aft section of the aircraft[9], spotted some smoke and the start of a passenger evacuation. An Aircraft Ground Incident (AGI) was declared at 1116 hrs and the emergency services were alerted while other aircraft were kept clear. No radio transmissions were made from the evacuating aircraft and ATC tried unsuccessfully to make contact on the Delivery frequency.

The first RFFS vehicle reached the scene between 1118 and 1119 hrs and found two evacuation slides deployed on the right side of the aircraft and one on the left. Firefighters reported smoke on the jetbridge and in the aircraft, which they boarded at approximately 1122 hrs, but there were no signs of fire. They were informed by the commander the smoke had come from the APU, and heat detectors were used to ensure there were no residual hot spots. The RFFS log recorded that all passengers and crew, except the pilots, were clear of the aircraft by 1126 hrs.

Airport police reached the stand at 1120 hrs, and attended to the 25 passengers who had evacuated onto the ramp, supervising their subsequent transfer to the terminal building.

Medical information

Crews from the London Ambulance Service responded to the AGI and provided first aid to passengers and crew in the terminal building. Three passengers and several FAs were treated for symptoms of '*minor smoke inhalation*'. One passenger grazed a leg using a

Footnote

9 ATC at Heathrow has a direct view of certain stands but many others are not in line of sight.

slide. All crew members and one passenger were taken to a hospital and, following medical checks, were released later that afternoon.

The FAs were exposed to the thickest smoke for the longest time and some reported minor discomfort, such as headaches and ongoing irritation of their eyes and nasal passages, for 24 hours or more.

Passenger reports

The airport authority distributed AAIB questionnaires inviting passengers to provide details of the incident. Only 26 forms were returned to the AAIB, most handed to the operator by passengers once they reached the USA the following day.

It was evident from the responses that some passengers seated near the aft end of the cabin did not hear any PA instructions, but that they considered the shouted instructions given to them by the FAs nearby were clear. However, 65% of the respondents (mostly seated between row 2 and row 34) indicated the instructions they heard were unclear and 46% referred to conflicting, confusing or contradictory instructions. One respondent seated near exits 3L and R, where no FAs were positioned, stated they heard no announcements and that this caused "panic". Around 23% of the received reports suggested the commands were clear and did not refer to conflicting instructions, but indicated that the commander's intervention caused a few seconds delay.

Passengers in all sections of the cabin reported thick smoke suddenly pouring out of the air vents. The smoke was generally assessed as having a "bad" chemical smell which created a burning sensation in eyes, mouths and throats. Those near the front of the cabin indicated the effect was irritating rather than choking, while those positioned further aft reported the smoke was thicker there but that they were able to see through it.

A respondent seated in row 23 (slightly forward of exits 3L and R), commented that it was possible to see through the smoke but believed that passengers adjacent to these exits felt the smoke was so thick they needed to get air into the cabin. A passenger in row 27 watched someone else open the door at 3L and then discover the escape slide had not deployed. On the other side of the cabin, passengers in the exit row were unable to open exit door 3R but a passenger seated a few rows back assisted. He armed the door before opening it but then a PA was heard which instructed everyone to leave via the main door, and exit 3R was not used.

Recorded data

Flight recorders

No data from the event was recorded by the Flight Data Recorder (FDR) because neither of the main engines had been started. The supply of external electrical power to the aircraft meant that the CVR was operating during the event but overwritten because it remained powered for several hours after the event.

CCTV

On CCTV footage recorded by the airport operator a cloud of white smoke appeared immediately behind the aircraft while it was stationary (Figure 2). This smoke began to dissipate after approximately 30 seconds, at which point the door at exit 3R opened, followed five seconds later by the door at exit 4R. Slides deployed at both exits and the first passenger jumped onto the aft slide one minute after the first smoke appeared. The CCTV footage showed 12 more passengers using this slide over a period of 33 seconds but nobody was seen to evacuate via the slide at exit 3R. The first RFFS vehicle shown on the CCTV footage arrived on the stand 3 minutes 20 seconds after smoke appeared, 2 minutes 20 seconds after slide evacuation commenced. Numerous other response vehicles were visible attending the aircraft over the following few minutes.

Figure 2

Image from CCTV showing white smoke immediately behind the aircraft

Description of Auxiliary Power Unit

The aircraft was fitted with a self-contained APU to supply bleed air for starting engines and for the air conditioning system, and to provide electrical power. The APU generator was inoperative and the aircraft was operating under the provisions of the MMEL.

The APU consists of a gas generator which is used to power the load compressor for bleed air, and the APU generator for electrical power (Figure 3). The APU bleed valve is used to isolate the air supplied by the load compressor from the aircraft pneumatic system. When the APU is running and the bleed valve is closed, the unused air supply from the load compressor is vented into the gas generator exhaust.

The APU is electronically controlled and can be operated from the flight deck. It has several automatic shutdown modes, including low oil pressure, high oil temperature or metallic chips detected in the oil system.

The APU has a single oil system that provides lubrication and cooling to relevant components of the APU and its constituent parts, including the load compressor and the generator. This system includes pressure and scavenge pumps and two oil filters, both of which are fitted with a bypass feature to allow oil circulation to continue should the filter become blocked. Activation of the bypass causes a mechanical tell-tale indicator to extend. A magnetic chip detector is also fitted which sends a signal to the electronic control system should a conductive chip be detected.

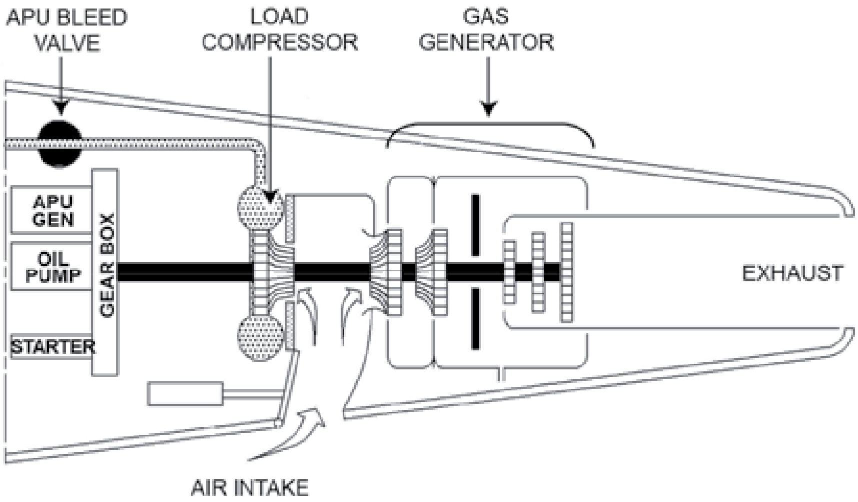

Figure 3
Schematic diagram of APU

Dispatch with APU generator inoperative

The MMEL allows an aircraft to be dispatched with certain defects if other provisions are met to assure safe flight. In this case, Section 24-3 option 2 of the A330 MEL (Figure 4) was being used. The task (24-23-00-040-803) to check the APU generator maintenance condition involved interrogating the aircraft's maintenance computer. This was completed appropriately. Relevant procedures had been carried out and recorded in the aircraft technical records.

Examination of the APU

An examination of the APU immediately after the event showed signs of oil wetting around the bleed air outlet and from the APU air inlet. The magnetic chip detector in the oil system had collected significant quantities of fine particles of ferrous material but the detector had not been triggered. The mechanical visual differential pressure indicators of both oil filters had activated, indicating the filters had blocked and as a result were bypassing unfiltered oil. Interrogation of the aircraft's maintenance computer showed the APU had shut down automatically due to high oil temperature.

The APU was deactivated and the aircraft was flown back to its maintenance base where the APU was replaced.

The APU was sent to its manufacturer in the USA where it was disassembled under supervision of the United States Federal Aviation Administration (FAA) as directed by the National Transportation Safety Board (NTSB). The load compressor and generator were removed and shipped to their original manufacturers in the Netherlands and the UK, where they were inspected under supervision of the Dutch Safety Board and AAIB respectively.

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A330 Minimum Equipment List

NUMBER INSTALLED / REPAIR CATEGORY / NUMBER REQUIRED FOR DISPATCH / DISPATCH NOTIFICATION REQUIRED / FLIGHT CREW PLACARDING

SYSTEM 24						ELECTRICAL POWER
24-3 AC Auxiliary Generation (APU Generator, GCU, Line Contactor) (MMEL 24-23-01)						
a. Option 1	C	1	0	Y	Y	**(O)(DP)** Except for ER Operations beyond 120 minutes, may be inoperative provided: a) APU is not used, and b) Both IDG's operate normally.

(O) PROCEDURES
A. Do not operate flight on ETOPS flights in excess of 120 minutes.
B. Do not use APU. On overhead panel 215VU ensure APU MASTER p.b. is off.
- No APU bleed air will be available for Main Engine Start (MES) or air conditioning.
- No electrical power will be available from the APU generator.

(DP) PROCEDURES
A. Do not dispatch flight on ETOPS flights in excess of 120 minutes.
B. Verify ground pneumatics and electrical power is available at destination airport and alternate(s).
C. Do not dispatch flight over any Volcanic Ash SIGMET Areas

b. Option 2	C	1	0	Y	N	**(M)(O)(DP)** Except for ER Operations beyond 120 minutes, may be inoperative provided: a) The failure is not mechanically related, b) APU GEN Pb Sw is selected OFF, and c) Both IDG's operate normally.

(M) PROCEDURES
A. Ensure the APU generator has not failed mechanically. Refer to TASK 24-23-00-040-803 Check of the APU-Generator Maintenance Condition.

(O) PROCEDURES
A. Do not operate flight on ETOPS flights in excess of 120 minutes.

(DP) PROCEDURES
A. Do not dispatch flight on ETOPS flights in excess of 120 minutes.

Figure 4

Master Minimum Equipment List extract

The examination of the APU revealed considerable metallic debris in the shared oil system. The quantity of debris overwhelmed the filtering capacity of the system, causing the bypass to operate and allow debris to move into other areas of the oil system such as other bearings and seals. This debris eventually caused a failure of the load compressor carbon seal, allowing hot oil to enter the bleed air supply to the cabin and causing smoke in the cabin. The initiating source of the debris could not be identified positively due to the distribution of debris throughout the whole oil system.

The APU control system had initiated an auto-shutdown due to high oil temperature. This caused the bleed air valve to close, shutting-off the air supply to the cabin. Excess air was directed overboard via the gas generator exhaust, causing the plume of smoke seen by ATC.

Safety actions

APU Manufacturer

The APU manufacturer had experience of similar events where a failure occurred and oil then entered the bleed air system via the load compressor carbon seal. It had already implemented changes and features intended to prevent them.

In July 2003, the APU manufacturer issued Service Bulletin (SB) GTCP331-49-7704 which modified the design of the APU to include a "shoulder" on the load compressor-to-power section quill shaft, to prevent unseating of the carbon seal due to a failure of the load compressor bearing that could allow smoke into the cabin. In addition, software changes were made to perform an auto-shutdown of the APU in the event of a chip detection. This was done in order to allow more time for the detection of chips and activation of an auto-shutdown before an unseating or failure of the load compressor carbon seal. In addition, logic was added to the Electronic Control Box (ECB) to initiate an auto-shutdown in the event of a chip detection under certain conditions. This SB had been implemented on this APU. Based on the evidence gathered during the inspection of the APU, the manufacturer believed that this SB could not have prevented the carbon seal fracturing as found in this case.

In November 2007, the APU manufacturer issued SB GTCP331-49-7936[10] to add an optional APU auto-shutdown system for lubricating oil contamination. The system detects lubrication system contamination by sensing differential pressure across each of the two oil filters. If an impending filter bypass is detected an auto-shutdown of the APU is initiated, preventing further damage and reducing the likelihood of smoke entering the cabin. This optional system was not installed on this aircraft.

Generator manufacturer

The generator manufacturer employs a proactive FRACAS (Failure Reporting and Corrective Action System) process in which a monthly reliability trend review examines product reliability and the associated primary and secondary failure modes. If a trend is detected, internal actions are taken to investigate and resolve the issue. No adverse trends have been identified with the bearings within the generator.

Footnote

[10] Service Bulletin GTCP331-49-7704 is for the -5 APU and GTCP331-49-7738 is for the -4 APU and the ECB is modified by either GTCP331-49-7701 or GTCP331-49-7705 according to model.

Crew stations

The operator is regulated by the FAA and Federal Aviation Regulation (FAR) 121.391 states at paragraph (d):

> *'During takeoff and landing, flight attendants required by this section shall be located as near as practicable to required floor level exits and shall be uniformly distributed throughout the airplane in order to provide the most effective egress of passengers in event of an emergency evacuation. During taxi, flight attendants required by this section must remain at their duty stations with safety belts and shoulder harnesses fastened except to perform duties related to the safety of the airplane and its occupants.'*

FAR 121.394 states at paragraph (c):

> *'If more than one flight attendant is on the airplane during passenger boarding or deplaning, the flight attendants must be evenly distributed throughout the airplane cabin, in the vicinity of the floor-level exits, to provide the most effective assistance in the event of an emergency.'*

It does not specify where FAs should be positioned when the aircraft is stationary on the ground with passengers on-board who are not in the process of boarding or deplaning.

Exit seats

FAR 121.585 designates '*exit seats'* as seats from which passengers '*can proceed directly to the exit without entering an aisle or passing around an obstruction*'. The Regulation requires that passenger information cards include details of who may occupy these seats and what they are required to do in an emergency should no crew member be available to assist. The card must instruct exit seat passengers to identify themselves for reseating if they believe they cannot or do not wish to perform the functions which may be required to operate the exit. Before the aircraft is pushed back or taxis, a crew member is to determine that the passengers in the exit seats appear capable of performing such functions.

In 2003 the FAA issued Advisory Circular (AC) 121-24C regarding oral briefings given by FAs. This guidance material '*strongly encourages air carriers to require crewmembers to provide a preflight personal briefing to each person seated in an exit seat*'. The object of the briefing is to explain clearly what the person should do if the exit has to be used and to refer them to the relevant information provided on an information card.

Operator's procedures

In December 2013 the previous operator of this aircraft, with approximately 30,000 employees, had merged with another operator with approximately 70,000 employees. Over the next 16 months the new organisation's processes and manuals were inspected by the FAA prior to issue of a '*Single Operating Certificate*'. Unification was still underway at the time of this occurrence and a single flight operations system for the entire fleet, which includes 14 different aircraft types and variants, was not adopted until four months later.

The philosophy during the merger was to integrate, stabilise and improve any apparent issues, and the operator considered it was in the improvement phase by the time of the occurrence. The aircraft operator stated that this improvement phase "was part of senior management's long-term effort to capitalize on the synergies associated with the merger, to yield a better overall product." It did not involve changes to safety-related issues but it "was a complicated and lengthy part of the [merger] process, and safe and effective change management was emphasized throughout." It noted that the crew had extensive experience operating this aircraft type, and all were familiar with the on-board equipment.

Exit seats

There were four seats on this A330-323 designated as exit seats, as defined in FAR 121.585; seats 25A and B adjacent to exit 3L, and seats 25G and H adjacent to exit 3R. Figure 5 shows exit 3L and adjacent seats. For a fully laden aircraft the door sill height is a minimum of 5.2 metre above ground level at exits 3L and 3R.

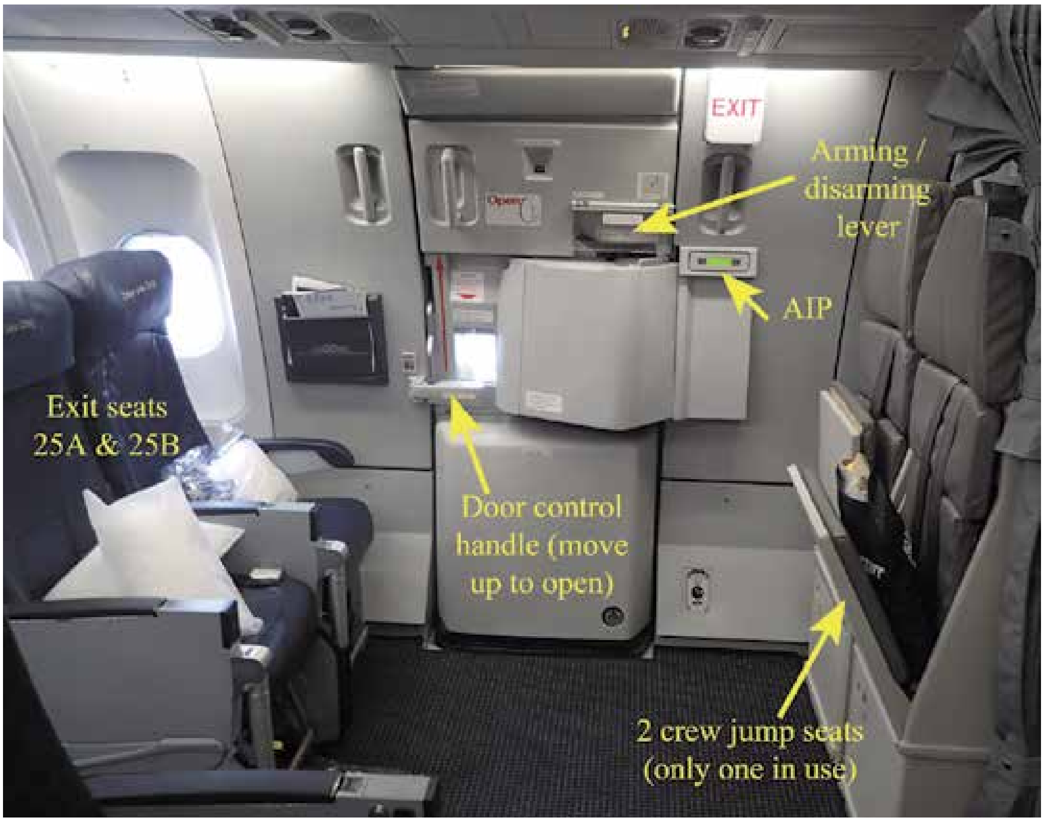

Figure 5

Photograph of Exit 3L and surrounds; the Attendant Indication Panel (AIP) is described in *Crew stations*

In accordance with AC 121-24C the aircraft operator's Flight Service In-flight Manual (FSIM) required that, prior to door closing, the F-FA give individual briefings to the passengers in 25A and B and the G-FA briefs those in 25G and H. Passengers not responding positively that they were willing and able to perform the required functions and obtain a verbal response were to be re-seated before the doors were closed.

Crew stations

A station assignment chart in the FSIM assigned work stations to each FA for various activities. During passenger boarding, the A and D-FAs work stations were at exits 1 L/R, the E and H-FAs at 2 L/R, the F and G-FAs at 3 L/R, the B and C-FAs at 4 L/R and the K-FA at 2L. There was no requirement for FAs to remain at or near their work station when the aircraft was stationary on the ground, with passengers on-board. For taxi, takeoff and landing each FA was allocated a jump seat (Figure 1). They were permitted to leave this seat to perform specific safety-related duties while the aircraft was taxiing.

An Attendant Indication Panel (AIP) (Figure 5 and Figure 6) is installed in the vicinity of each FA jump seat. The AIP displays messages relating to passenger or interphone calls as well as certain warning messages (e.g. SMOKE LAV A, EVACUATION ALERT or EMERGENCY CALL). Each AIP has a two line alphanumeric display screen. A steady green light accompanies a communication message and a flashing red light highlights the display of a warning message.

Figure 6

Example of an AIP, indicating a normal interphone call from the commander

Adjacent to exit 1L there is a Flight Attendant Panel (FAP) which provides the A-FA with detailed information and controls relating to cabin services. There is a switch on the FAP to allow the A-FA to turn on emergency lighting, which provides illumination to aid cabin evacuation, as well as indications and controls for an evacuation signalling system and for lavatory smoke alarms. Smaller versions of the FAP, known as the Additional Attendant Panels (AAP), are located by exits 2L and 4L, and have controls for the evacuation signalling system and lavatory smoke alarms.

Evacuation signalling system

The evacuation signalling system can be switched on from the flight deck or from the FAP or the AAPs, to initiate a continuous and rapidly repeated series of short, high-pitched tones throughout the cabin. When the system is activated an EVACUATION ALERT message and a flashing red light show on each AIP and a red EVAC light flashes on the EVAC control panel situated on the left overhead console in the flight deck. A horn will also sound in the flight deck for three seconds when one of the three cabin switches is used to switch the system on. The flight deck horn can be cancelled using a HORN SHUT OFF push button.

The aircraft operator's A330 Operating Manual (OM) Volume II stated that two signals were used to initiate an evacuation: the primary method being a PA by the commander, the secondary being use of the EVAC COMMAND switch. The FSIM referred to the '*emergency signalling system'* and informed FAs they could activate it from the FAP or from certain AAPs by pressing the EVAC command switch once.

Smoke in the cabin

The nine lavatory compartments on the aircraft were each equipped with a smoke detector. When smoke is detected, an aural smoke alarm sounds through all cabin loudspeakers, creating a Hi/Hi/Lo/Lo chime series which repeats continuously. Simultaneously a red light flashes at each AIP, alongside a message indicating smoke in a specific lavatory. There are also indications on the FAP and the AAPs while reset pushbuttons on these panels allow the alarm to be silenced. If detectors in more than one lavatory activate, the same aural alarm sounds and all activated detectors can be reset together from the FAP and/or from an AAP.

When any of the detectors are activated, the ECAM presents a SMOKE LAVATORY SMOKE message on the upper of two display units in the centre of the main instrument panel in the flight deck. To assist flight crew awareness, the warning is highlighted by flashing red master warning lights on either side of the main instrument panel, accompanied by continuous repetitive chimes from the flight deck loudspeakers. Both the master warning and the chimes can be cancelled by pressing either of the master warning push buttons, thus acknowledging the warning.

The procedures to be followed by the flight crew in response to the SMOKE LAVATORY SMOKE message are also shown on the upper central display panel and appear as 'CKPT/CAB COM…. ESTABLISH'. This is an abbreviated instruction for the flight crew to establish communications between the cockpit (flight deck) and the cabin.

Guidance concerning the FAs response to various emergency scenarios was provided in the FSIM. Some drills were detailed in a section of the manual that was not specific to this type of aircraft. In the event of signs of fire or smoke in the cabin, or '*If an odor is present, but cannot be identified or localized*', it instructed FAs to '*notify flight deck crew immediately using four chimes*'. Elsewhere in the FSIM it was stated that, '*On all aircraft, four chimes is an Emergency Call*', whereas a routine call was announced by '*two chimes*'. This system had been developed for the internal communication equipment on other aircraft types in which there were no priority or emergency call switches.

Interphone calls to the flight deck

There is no common standard concerning the keypad layout on interphone handsets for passenger aircraft, therefore neither the equipment manufacturer nor the aircraft operator have any obligation to consider keypad standardisation between aircraft types. On the Airbus A330-300 each FA station has an interphone handset with a number of buttons (Figure 7). When a handset is lifted from its base station and the button marked CAPT is pressed, a single long buzzer[11] sounds through the flight deck loudspeakers and small push buttons, marked ATT, flash amber on the pilots' Audio Control Panels (ACPs). When a pilot responds by depressing his ATT push button, the interphone system connects to the calling station and the light in the push button changes to green. If no pilot responds to the call within 60 seconds, the lights in the ATT push buttons extinguish. Replacing the handset in its cradle or pressing the reset button returns the handset to its original status.

Footnote

[11] The aircraft manufacturer advises each buzzer tone lasts for approximately one second.

Figure 7

Interphone communication handset showing keypad

If the handset button marked EMER CALL is pressed, the ATT push buttons on the flight deck ACPs flash amber, three long buzzer tones sound from the flight deck loudspeakers and an amber EMER CALL light flashes on a Cabin Call System Panel (CCSP), situated on the left side of the flight deck ceiling. The aircraft manufacturer states that if a pilot does not respond by depressing an ATT push button within 60 seconds, the lights in the ATT push buttons extinguish but the light on the ceiling panel continues to flash until the call is cancelled.

In a section specific to the aircraft type the FSIM stated that when the EMER CALL button is pressed the flight deck will be alerted by '*four buzzers*'. The FSIM gave dialling instructions in a tabulated format. For a normal call the CAPT button was to be pressed twice and for an emergency call the EMER CALL button was to be pressed four times.

Interphone calls from flight deck

The OM Volume II stated that a routine call from the flight deck to an FA position was announced by a single Hi/Lo chime sounding in the cabin and by a green light and a message on the relevant AIP. An EMER CALL from the flight deck to the cabin was initiated by depressing a guarded pushbutton on the CCSP. This sounded a series of three Hi/Lo chimes on all cabin loudspeakers while all AIPs showed an EMERGENCY CALL message and a flashing red light. After depressing the guarded pushbutton pilots could speak on the interphone to any FA who picked up a handset by depressing the ATT push button on their ACP.

Flight deck door indications

The lower of two central display panels on the main instrument panel is termed the System Display (SD). When the aircraft is parked and electrical power is switched on, the SD will, by default, present the DOOR/OXY[12] page which depicts the status of each door and its

Footnote

12 Doors and oxygen page.

associated slide on a diagrammatic representation of the aircraft. A locked and armed door is depicted by a green symbol with the message SLIDE next to it in white letters. An open door is depicted by an amber symbol plus an amber caution message, CABIN. If a door is not armed the message SLIDE is displayed in amber instead of white.

Evacuation procedures

The aircraft operator's OM Volume I stated that the commander normally initiates an evacuation and that pre-planned and unplanned evacuations were to be executed in the same manner. This guidance was reflected in the Flight Manual (FM) Part 1, which stated:

> *'In an emergency evacuation, it is likely that certain passengers and crewmembers will suffer injury. The Captain should consider the relative risks of remaining aboard the aircraft against the risks of evacuation.'*

However, both these manuals and the FSIM indicated that, when an aircraft is stationary and FAs determine that a life-threatening situation exists, they may initiate an evacuation if they are unable to communicate with the commander. The FSIM noted that fire or smoke may indicate a life-threatening situation, and stated that 'if contact with the flightdeck is not possible FAs will make an independent decision regarding evacuation and operate all usable exits'. In the event that one FA initiates an evacuation, all FAs were to initiate evacuation procedures immediately by shouting evacuation commands. The FSIM did not differentiate between pre-planned and unplanned evacuations but stated that the commander had the authority to override their decisions.

The FSIM contained a list of FA '*Evacuation Procedures*'. FAs were trained to follow these procedures without reference to notes. It offered no guidance regarding the PA which an FA should make to initiate an evacuation.

The OM Volume I stated:

> *'Depending on the Emergency, A DOORS ECAM may indicate that the evacuation has started. If an evacuation has commenced, it is usually best not to attempt to stop the evacuation already in progress. If an evacuation has not commenced and it is determined that an evacuation is not needed, make an immediate PA commanding, "This is the captain. Remain seated, remain seated, remain seated".'*

The FSIM indicated that the aircraft commander might make additional PAs in an evacuation situation, including '*Remain seated, remain seated*' to advise that circumstances had changed. It stated that FAs hearing this were to safely stop the evacuation but that:

> *'It is critical for FAs to update the captain if cabin conditions warrant an evacuation. The flightdeck may be unaware of life-threatening situation(s) -e.g., excessive smoke, fire.'*

The flight deck evacuation checklist was presented on the back page of the QRH. It included shutting down the engines and APU and using fire extinguishing agent, if appropriate, instructing the commander to make an evacuation PA and to operate the EVAC COMMAND switch. The OM Volume I stated that when the commander and co-pilot had completed their flight deck duties they should proceed to the cabin, assess the conditions and assist with the evacuation.

Emergency deplaning

The FSIM included a further procedure entitled '*Emergency Deplaning / Evacuation at the Gate*'. It stated that if only a jetbridge was used, the event was considered an '*Emergency Deplaning*' rather than an evacuation. The first step in this procedure was for FAs to advise the flight deck immediately, if possible, of any emergency. The second step was:

> *'Use PA (if possible) to direct passengers to a door equipped with a jetbridge… If PA is used, add the following introduction: "Your attention please, this is your flight attendant, everyone must quickly leave the aircraft"'*

Step three instructed all FAs to remain near their assigned exits, if possible, and to direct passengers by repeating the same instructions. It warned that disarmed doors should not be left unattended while passengers were deplaning. Step four stated:

> *'If, at any time, an evacuation signal is given (e.g., "This is the captain. Evacuate. Evacuate. Evacuate." followed by the signalling system), immediately initiate an evacuation using all useable exits and appropriate evacuation commands. Be prepared to arm and open all usable exits, if necessary.'*

The Emergency Deplaning procedure was not mentioned in the aircraft operator's A330 QRH, the FM Part 1 or in the OM Volume I. However, it is a procedure recognised by the International Air Transport Association (IATA) which refers to '*Rapid Deplaning*' in its Cabin Operations Safety Best Practices Guide, stating:

> *'There are situations when passengers and crew need to deplane immediately and quickly (e.g., in serious situations such a fuelling emergency). A rapid deplaning is when passengers and/or crew rapidly exit the aircraft via the boarding doors and via the jetbridge or stairs, for precautionary measure. A rapid deplaning may be initiated by the pilots or, in their absence, the SCCM.'*

Some UK aircraft operators refer to such a procedure as '*Precautionary Rapid Disembarkation*'.

CVR procedures

The aircraft operator's Safety Policies & Procedures Manual stated that for accidents or incidents that occur outside the United States the Investigator in Charge from the State of Occurrence will have authority over the disposition of the FDR and CVR, and that an '*NTSB or Foreign Government Investigator may request the DFDR or CVR*'.

The FM, which was not specific to this aircraft type, listed the occasions on which commanders must report immediately to the operator's '*Dispatch*' department. Some, including '*Evacuation of an aircraft in which an emergency egress system is used*', required the circuit breaker for the CVR to be pulled after flight.

On this aircraft the CVR circuit breaker was situated in the avionics compartment below the flight deck, and the operator's A330-300 OM Volume I ('*Non-Normal Operations*') stated that for various occurrences, such as after an evacuation, pilots were to contact '*maintenance*' to ensure the CVR circuit breaker was pulled.

EU requirements

Exit seats

The term "exit seats" is not used in EU regulations. European aircraft operators are required to ensure that passengers in seats '*that permit direct access to emergency exits appear to be reasonably fit, strong and able to assist the rapid evacuation of the aircraft in an emergency*.'

EU regulations also specify that passengers with direct access to emergency exits that are not staffed by cabin crew members receive a pre-flight briefing on the operation and use of the exit. According to EASA "Such briefing is not a training; the aim is to provide the necessary basic instructions for a fast egress from the aircraft if a situation dictates so". This briefing is additional to the safety briefing given to all passengers; informing them of the location of emergency exits, where safety briefing cards are stowed and what they contain.

Crew stations

Commission Regulation (EU) No 965/2012 contains the EU requirements for cabin crew to be at their stations. Its Annexe IV, Commercial Air Transport Operations, paragraph CAT.OP.MPA.210 (b) states:

> *'During critical phases of flight, each cabin crew member shall be seated at the assigned station and shall not perform any activities other than those required for the safe operation of the aircraft.'*

The phrase '*critical phases of flight*' is defined as '*the take-off run, the take-off flight path, the final approach, the missed approach, the landing, including the landing roll, and any other phases of flight as determined by the pilot-in-command or commander*'. Further guidance regarding crew stations is offered in the Acceptable Means of Compliance (AMC) to the Regulation, as follows:

'CABIN CREW SEATING POSITIONS

(a) When determining cabin crew seating positions, the operator should ensure that they are:

(1) close to a floor level door/exit;

(2) provided with a good view of the area(s) of the passenger cabin for which the cabin crew member is responsible; and

(3) evenly distributed throughout the cabin, in the above order of priority.'

Thus, EU regulations do not require cabin crew to be evenly distributed throughout the cabin or at specific stations while passengers are boarding or deplaning or when passengers are aboard a parked aircraft.

Annexe III to EU 965/2012 concerns Organisation Requirements for Air Operations. Paragraph ORO.CC.100 details factors that commercial operators should consider when determining the number of cabin crew required on an aircraft. These include the number and type of aircraft doors or exits, their location relative to cabin crew stations and cabin layout, additional actions to be performed by cabin crew with responsibility for a pair of doors or exits and, in the AMC:

'The location of cabin crew stations taking into account direct view requirements and cabin crew duties in an emergency evacuation including:

(i) opening floor level doors/exits and initiating stair or slide deployment;

(ii) assisting passengers to pass through doors/exits; and

(iii) directing passengers away from inoperative doors/exits, crowd control and passenger flow management;'

UK operators' procedures

Some UK aircraft operators provide guidance regarding cabin crew presence at doors or exits on a parked aircraft. One Airbus 330 operator stated that at each pair of doors (including the floor-level exits at 3L and 3R), the left door must be manned by cabin crew at all times when passengers are aboard.

Another operator, with a large fleet of both narrow-bodied and wide-bodied aircraft, indicated that on some types it would be impossible for cabin crew to assist passengers to board or disembark if a cabin crew member always remained next to each pair of floor-level exits. This operator required at least one cabin crew member to '*remain in the vicinity of each pair of floor-level exits*' during boarding. The operator stated that the definition of '*in the vicinity*' was provided because the concept was trained thoroughly. As crew moved further away from an exit they were expected to keep the cabin situation under ever-closer scrutiny and always to be ready to return to the exit area without delay should an emergency arise.

IATA guidance

The IATA Cabin Operations Safety Best Practices Guide (3rd edition) states at paragraph 11.7 that:

> *'During passenger boarding, cabin crew should be evenly distributed throughout the cabin, as close to the exits as practicable to help ensure that they are ready to carry out an evacuation if necessary without warning.'*

Personnel

The crew had rested for more than 24 hours after operating a flight to London the previous day. All the FAs had more than three years' experience on the A330-300 and five had operated this aircraft type for more than 10 years. Each had completed annual recurrent training for this type within the preceding eight months.

This recurrent training required the FAs to prove their knowledge of emergency equipment and procedures using an on-line module before participating in a practical element. This involved type-specific cabin mock-ups in which they had to demonstrate correct operation of the doors while giving appropriate verbal commands to passengers. Sometimes the FAs had simulated calling the flight deck by interphone but each year they were required to demonstrate they could perform an unplanned evacuation of the A330-300 using the cabin mock-up. Their training was intended to ensure they could evacuate aircraft safely in various scenarios, although practise for evacuating a parked aircraft was not required and had not been specifically addressed. There was no evidence of joint evacuation training being undertaken by the FAs and flight deck crew.

The IRO had 11,725 hours experience on this type of aircraft. The commander had 1,912 hours on type (31,635 hours total time) and the co-pilot had 305 hours on type (12,700 hours total time). They had all completed licence proficiency training in the preceding 10 months, in addition to the recurrent human factors training required every 9 months. Their training for evacuation procedures had focussed on rejected takeoffs with fires, leading to a cabin evacuation initiated by the commander. The pilots had practised this in a flight simulator but had not experienced evacuation scenarios involving a parked aircraft because there was no requirement for them to do so.

The operator stated that it aimed to integrate some aspects of flight crew and FA recurrent training but had not provided joint practice of emergency procedures such as cabin evacuation. It acknowledged that when an aircraft is parked at the gate, certain circumstances might warrant an evacuation using only the jetbridge (emergency deplaning), while others might justify the use of all available exits. The operator stated that "its training program emphasized proper assessment of any evacuation situation and the exercise of sound judgment by the cabin crew in accomplishing safe and orderly evacuation".

Crew Resource Management (CRM) training requirements

FAA requirements

The FAA's AC 120-51E concerning CRM training states, '*Communication and coordination problems between cockpit crewmembers and flight attendants continue to challenge air carriers and the FAA.*' It notes that while CRM training is required to be included in recurrent training programmes, '*Joint CRM training for pilots and flight attendants is not required by FAA regulations, but it is encouraged and has been practiced effectively at some air carriers for years*'. The AC recommends that recurrent training includes CRM exercises in which entire crews participate.

The FAA's *Flight Standards Information Management System*[13] document states that its pilot operations inspectors and cabin safety inspectors:

> *'…should ensure that their assigned certificate holders are aware of the desirability of flightcrew and F/As performing emergency evacuation and ditching drills together. Furthermore, they should ensure that when this is not possible, air carriers are aware of the desirability of training programs that include information addressing the roles of other crewmembers during emergency evacuations and ditchings.'*

EU requirements

Annexe III to EU 965/2012 requires flight and cabin crew to undertake certain combined recurrent CRM training. This is specified by AMC1 to ORO.FC.115 paragraph (a) (6) (ii) (A), which states that the combined training should address at least, '*effective communication, co-ordination of tasks and functions of flight crew, cabin crew and technical crew*.' This is repeated in the AMC to ORO.CC.115. Operators are also required by ORO.CC.140 to include evacuation procedures in annual recurrent training for cabin crew (only).

There is no EU requirement for flight crew and cabin crew to receive joint training specifically relating to evacuation procedures. However, some UK operators do routinely include this because, under previous UK regulations which are no longer extant, the Civil Aviation Authority (CAA) had stated (in Civil Aviation Publication 789):

> *'Particular emphasis should be placed on the provision of joint practice in aircraft evacuations and other emergencies so that all who are involved learn of the duties other crew members should perform before, during and after evacuation, thereby appreciating the necessity for effective two-way communications in such emergencies.'*

Footnote

[13] FAA Order 8900.1, Volume 3, paragraph 3-1167 and 3-1792 refer.

Canadian requirements

The Transportation Safety Board (TSB) of Canada studied evacuations of 21 large passenger-carrying aircraft which occurred between 1978 and 1991. Its report[14] found that in three evacuations ineffective crew communications exposed passengers and crew to unnecessary risks. It recommended, among other things, that, '*The Department of Transport require that air carriers implement an approved joint crew emergency training program with emergency simulations for all air crew operating large passenger-carrying aircraft.*' In 1995 Transport Canada introduced new joint CRM training requirements for pilots and FAs, specified in Canadian Aviation Regulations Standard 725.124 paragraph (39), which states that air operators are to provide CRM training that includes:

> *'(b) Annual training in safety and emergency procedures. It shall include, as applicable, joint participation of pilots and flight attendants and cover the following items:*
>
> *(i) relationship of crew members;*
>
> *(ii) review of accidents/incidents of air operators;*
>
> *(iii) presentation and discussion of selected coordinated emergency procedures (practice of CRM skills); and*
>
> *(iv) crew member evacuation drills, including debriefing.'*

IATA training guidance

The IATA Operational Safety Audit (IOSA) Standards Manual sets out standards and recommended practices against which operators are audited by IOSA15. Paragraphs FLT 2.2.9 and CAB 2.2.10 state:

> *'If the Operator conducts passenger flights with cabin crew, the Operator should ensure flight crew members participate in joint training activities or exercises with cabin crew members for the purpose of enhancing onboard coordination and mutual understanding of the human factors involved in addressing emergency situations and security threats.'*

IATA acknowledges such joint training may be difficult to organise, especially when cabin crew outnumber flight crew, so joint training in emergency procedures is not mandated but its inclusion in recurrent training is recommended, at least once every 36 months.

Previous incidents

Evacuation of Boeing 747-436, G-CIVB at Phoenix, Arizona, 11 July 2009

Acrid fumes were noticed when the aircraft was pushed back and the engines started. The engines were shutdown, the doors were disarmed and as the aircraft was towed back on stand several passengers left their seats. Before the door was opened, cabin crew at exits

Footnote

[14] TSB Aviation Safety Study SA9501.
[15] All IATA member airlines are IOSA registered and must remain registered to maintain IATA membership.

3L and 4L, in the worst affected part of the cabin, observed smoke coming from a sidewall and left their stations to use fire extinguishers.

Some passengers became distressed and one person opened the unmanned and un-armed exit 3L. The slide did not deploy and nobody used the exit, although the evacuation alarm was activated. Shortly afterwards the commander instructed that the other doors be re-armed and he then ordered an evacuation using exits on the right side of the aircraft (the terminal was in close proximity on the left side). No slide-related injuries were reported.

After the event the CVR was not preserved because electrical power was applied during maintenance activity. The AAIB made relevant Safety Recommendations to both the operator and the CAA. These were accepted and action was taken to ensure timely preservation of CVR recordings in the event of future reportable occurrences, in accordance with ICAO Annex 6 Part I, 11.6 and EU-OPS 1.160. The AAIB report was published in Bulletin 6/2010.

Evacuation of Boeing 757-28A, G-FCLA at Glasgow Airport, 11 October 2012

Smoke appeared in the cabin and flight deck while passengers were disembarking onto a jetbridge from door 2L. The commander ordered an evacuation, shut down the APU (which he believed was causing the smoke), and alerted ATC. The aft doors 4L and 4R were re-armed and opened by cabin crew, and passengers escaped down slides from these exits and from 3R.

On this aircraft type the exits at 3L and 3R have permanently armed slides and one cabin crew member is stationed adjacent to 3R. The operator of this aircraft requires crew to '*remain in the vicinity*' of exits when passengers are on-board, even when the doors are permanently armed. Door 3L was not opened due to the close proximity to the jetbridge. The crew observed that all the lavatory smoke alarms were activated and this increased the noise level in the cabin. The AAIB report of this occurrence was published in Bulletin 3/2013.

Evacuation of Boeing MD-88, N909DL, at LaGuardia Airport, New York, 5 March 2015

The aircraft was substantially damaged when it departed the runway with five crew members and 127 passengers on-board. The NTSB report of this accident and the subsequent evacuation (NTSB/AAR-16/02) made several Safety Recommendations to the FAA including:

> *'A-16-025 - Require 14 Code of Federal Regulations Part 121 operators to provide (1) guidance that instructs flight attendants to remain at their assigned exits and actively monitor exit availability in all non-normal situations in case an evacuation is necessary and (2) flight attendant training programs that include scenarios requiring crew coordination regarding active monitoring of exit availability and evacuating after a significant event that involves a loss of communications.*

A-16-026 - Develop best practices related to evacuation communication, coordination, and decision-making during emergencies through the establishment of an industry working group and then issue guidance for 14 Code of Federal Regulations Part 121 air carriers to use to improve flight and cabin crew performance during evacuations.'

Regarding Recommendation A-16-025, the FAA is considering revising AC 120-48, which provides guidance on communication between flight crew and FAs. In response to Recommendation A-16-026, the FAA is considering establishing an industry-wide working group *'to examine the issue and make recommendations on additional ways of enhancing communication, coordination and decision-making during emergencies'.*

Previous occurrence involving Airbus A320-214, G-EZWX

During a flight on *28 November 2016*, the crew of G-EZWX had difficulty establishing internal emergency communications due to an undocumented feature of the interphone emergency call function. This confused crew members and delayed the flight deck crew in establishing two-way communications with the cabin crew. Following an AAIB investigation[16], the aircraft manufacturer advised that it would provide additional information to operators on the operation of the emergency interphone system. The aircraft operator intends to provide its crews with appropriate guidance and training once this information is made available.

NTSB Recommendations

A NTSB study of 46 aircraft evacuations which occurred between September 1997 and June 1999[17], found that communication and co-ordination issues continued to exist between flight crew and FAs during evacuations. It noted that joint evacuation exercises had proved effective at resolving these problems and made Recommendation A-00-85 that the FAA should require air carriers to conduct periodic joint evacuation exercises involving flight crews and flight attendants. This Recommendation was rejected by the FAA on the basis that it considered the recommendations in AC-120-51 and in the Air Transportation Operations Inspectors' Handbook[18] to be sufficient.

Following the evacuation of an MD-88 at LaGuardia Airport in March 2015 the NTSB made further recommendations concerning flight and cabin crew performance during evacuations (see *Previous incidents*).

CVR overruns

CVR overruns are well documented in accident and serious incident reports and have prompted a corresponding number of recommendations for the duration of CVRs to be increased. Initially this resulted in the requirement to fit commercial air transport aircraft with a Maximum Certificated Takeoff Mass (MCTOM) greater than 5,700 kg, issued with

Footnote

16 The report of this investigation was published in AAIB Bulletin 9/2017.
17 Safety Study NTSB/SS-00/01 Emergency Evacuation of Commercial Airplanes.
18 Since superseded by the Flight Standards Information Management System document.

an individual C of A (Certificate of Airworthiness) on or after 1 April 1998, with CVRs with a minimum duration of 2 hours. Further changes have now been adopted by the European Commission (Commission Regulation (EU) 2015/2338 amending Regulation (EU) No 965/2012) requiring commercial air transport aircraft with an MCTOM greater than 27,000 kg and first issued with an individual CofA on or after 1 January 2021 to carry a CVR with a minimum duration of 25 hours.

Analysis

The aircraft was operating with an APU generator inoperative and had been dispatched in accordance with the MEL, which included a check of the APU generator condition using the aircraft's maintenance computer. This check did not reveal any anomalies.

Examination of the APU after the event revealed considerable metallic debris in the shared oil system. This debris eventually caused the load compressor carbon seal to fail, allowing hot oil to enter the bleed air supply to the cabin and causing smoke in the cabin. The initiating source of the debris could not be identified positively due to the distribution of debris throughout the oil system.

A feature was available to detect and shut down the APU automatically in the event of lubrication system contamination causing impending oil filter bypass, but was not installed on this aircraft. Had this feature been fitted, it is likely the APU would have shut down automatically prior to the filter bypass condition, thereby preventing the conditions that led to pyrolysed oil entering the cabin. Accordingly, to prevent a similar occurrence, the following Safety Recommendations are made.

Safety Recommendation 2017-022

It is recommended that the Federal Aviation Administration mandate Service Bulletin GTCP331-49-7936 to add a system that shuts down the APU automatically if there is contamination of the lubricating oil.

Safety Recommendation 2017-023

It is recommended that the European Aviation Safety Agency mandate Service Bulletin GTCP331-49-7936 to add a system that shuts down the APU automatically if there is contamination of the lubricating oil.

This event surprised the crew and developed quickly. The pilots were pre-occupied with resolving an unrelated system defect and the flight deck environment was complicated by the presence of an engineer and the GOC. In the cabin, some FAs had found passenger boarding more pressured than normal and preparations were being made for a manual safety briefing when the smoke appeared.

First appearance of smoke

Several FAs attempted to contact the commander, in accordance with the operator's guidance but using the normal interphone call function. None of the pilots noticed the small amber lights on the ACPs or the single buzzer tone which announced a cabin interphone call. The commander suggested afterwards that this might have been due to the noise of the master warning. Aural chimes were not cancelled immediately the SMOKE LAVATORY SMOKE warning was noticed. It is possible the interphone call was not noticed because simultaneously the pilots were asking the engineer about the smoke.

Flight deck reaction to smoke

It took the flight crew a few moments to appreciate that the smoke was not associated with the engineer's work. The commander then assumed it was being emitted by the air conditioning system, fed by the APU, so he pressed the switch to shut off the APU bleed.

The commander's prompt action indicates that he assimilated the problem quickly, but was accomplished without reference to a checklist. His recollection that the SMOKE LAVATORY SMOKE warning was present before he took this action accorded with the IRO's report which stated the commander and the co-pilot then actioned the checklist for SMOKE LAVATORY SMOKE. However, the only action on this checklist was to establish communications with the cabin, and none of the flight crew tried to contact the FAs using the interphone at this stage. Although the A-FA apparently tried to pass an extinguisher into the flight deck, her presence only appears to have been acknowledged by the IRO and no discussion concerning the situation in the cabin appears to have ensued.

Absence of recorded data

The absence of recorded data prevented a more precise understanding of the sequence of events. The co-pilot may have referred to the QRH immediately smoke was seen and, while he was doing this, the commander turned off the APU bleed. If so, the co-pilot and IRO were conducting the '*Smoke/Avionics Vent Smoke/Fumes'* procedure when the SMOKE LAVATORY SMOKE warning illuminated, accompanied by the chimes of the master warning. With the door to the flight deck open the sound of the lavatory alarm from the cabin speakers would have added to the noise level. The flight crew indicated that they were presented with several simultaneous visual and aural inputs, which might account for conflicting recollections of the event sequence.

Emergency call option

The aircraft operator's instructions to FAs for communication with the flight deck in the event of smoke in the cabin was not consistent. Contrary to this guidance, it is necessary to press the EMER CALL button on this aircraft only once to initiate an emergency call.

An emergency call may have been more noticeable to the pilots than a normal call, and prompted them to respond to the FAs. No such guidance was provided by the operator. The FAs were trained to operate on several types of aircraft. Handset keypad layouts are not standardised, such that emergency calls are initiated in different ways on different types. This lack of standardisation may have been a factor in the FAs being unable to initiate an emergency call. Therefore the following Safety Recommendations are made:

Safety Recommendation 2017-024

It is recommended that the Federal Aviation Administration regulate the operation of interphone handsets, including during emergency communications, so that it is standardised irrespective of aircraft type.

And:

Safety Recommendation 2017-025

It is recommended that the European Aviation Safety Agency regulate the operation of interphone handsets, including during emergency communications, so that it is standardised irrespective of aircraft type.

When smoke became apparent in the flight deck, the flight crew responded quickly by taking action they considered appropriate but they did not call the FAs to establish the situation in the cabin. The SMOKE LAVATORY SMOKE checklist requires this to be done and, although an emergency interphone call is not specified, this offers the best means of conferring with all the FAs. The lack of such immediate liaison with the FAs indicates that training to respond to smoke events while on the ground could be improved. The aircraft operator has reported the action it intends to take to address this (see *Aircraft operator's response* in the Safety action section).

Initiation of evacuation

When the E-FA received no response to her interphone call, she decided the situation was life-threatening and made a PA to initiate an evacuation. The alternative '*Emergency Deplaning*' procedure was not mentioned in guidance to flight crew. An appropriate drill has now been introduced (see *Aircraft operator's response* in the Safety action section). The inconsistency might have become apparent to the aircraft operator earlier if the two groups had received regular joint training for evacuation scenarios.

The FA's decision to initiate evacuation was consistent with the aircraft operator's policy that FAs may initiate an evacuation if: the aircraft is stopped, they are unable to communicate with the commander and a threat to life is identified. Having made a PA commanding an evacuation the E-FA did not turn on the evacuation signal, though this is an action the operator expects its FAs to accomplish without reference to notes.

Once an evacuation was commanded, all available exits should have been used, but the exits at 1L, 1R and 2R were not opened and the FAs in the forward portion of the cabin executed an '*Emergency Deplaning*' using only the jetbridge at 2L. Following this event, the aircraft operator's task force has identified the need to prepare new guidance and improve crew training for '*Emergency Deplaning / Evacuation at the Gate*' (see *Aircraft operator's response* in the Safety action section).

Exit seat passengers

The two FAs who might have been in the vicinity of exit 3L or 3R when the evacuation PA was made had both moved away to obtain demonstration pouches. If pouches had been located close to these exits, or if only one of the FAs had gone to obtain one, then a crew member trained to operate the exits would have remained nearby. However, there was no requirement for an FA to remain in the vicinity of these floor-level emergency exits or for the FAs to be evenly distributed throughout the cabin when boarding or deplaning is not taking place and an aircraft is parked.

Passengers in the adjacent seats had received an '*exit seats*' briefing, which effectively placed responsibility on them to operate the exit in an emergency if no crew member was nearby. The safety information card to which they had been referred provided detailed instructions on '*Exit Seat Responsibilities*' as well as diagrams indicating how the exit should be operated.

After hearing the evacuation PA and perceiving the smoke, passengers in the seats adjacent to 3L and 3R opened both exits. Apparently those at 3R decided they needed to do something more than lift the door operating handle and sought help from a passenger seated further aft, who was able to arm the slide before opening the door. CCTV imagery showed that door 3R began to open approximately 30 seconds after smoke was emitted by the APU, and before door 4R opened. It is not known if the passengers checked outside for dangers or hazards before opening door 3R and deploying the slide.

The door at exit 3L was apparently opened in accordance with the safety information card, without the slide being armed. However, the guidance on the card which then shows the manual slide deployment handle being pulled, was not followed and the slide did not deploy. The fall of 5.2m metres from the sill of this door to the ramp below represented a significant hazard to anyone using it.

It is possible that by verbally agreeing to adopt the role of '*exit seat*' passenger, and by accepting detailed instructions, they felt responsible for opening the exits because no FAs were present. Under EU regulations, passengers seated adjacent to unsupervised exits do not receive detailed instructions on '*Exit Seat Responsibilities*' but are given a more basic briefing aimed at allowing them to make a fast egress from the aircraft if necessary. Therefore the following Safety Recommendation is made:

Safety Recommendation 2017-026

It is recommended that the Federal Aviation Administration reconsider the requirements for briefings given to passengers seated at exits, to ensure they offer appropriate guidance on exiting the aircraft rapidly in an emergency without implying undue responsibility for opening the exits.

A review of previous similar events suggests that this scenario is not unique and indicates it is desirable for trained crew members to be available to operate floor-level emergency exits whenever an aircraft is on the ground with passengers on-board. The practice of some UK operators to do so has proved effective, for example during the evacuation of a Boeing 757 at Glasgow in 2012.

IATA advocates cabin crew being evenly distributed throughout the cabin during passenger boarding. This is reflected in FAA regulations which require, when an aircraft has more than one FA, that the FAs be evenly distributed throughout the cabin and in the vicinity of floor-level exits during both boarding and deplaning, to provide the most effective assistance in the event of an emergency. However, the FARs do not require the FAs to be evenly distributed at other times when passengers are on-board a parked aircraft and the EU regulations do not include such a provision. Therefore the following Safety Recommendations are made:

Safety Recommendation 2017-027

It is recommended that the Federal Aviation Administration require cabin crew on aircraft that are parked, and with passengers on-board who are neither boarding nor deplaning, to be evenly distributed throughout the cabin and in the vicinity of floor-level exits in order to provide the most effective assistance in the event of an emergency.

And:

Safety Recommendation 2017-028

It is recommended that the European Aviation Safety Agency require cabin crew on aircraft that are parked and with passengers on-board to be evenly distributed throughout the cabin and in the vicinity of floor-level exits, in order to provide the most effective assistance in the event of an emergency.

Evacuation from 4L and 4R

Having been unsuccessful contacting the flight crew by interphone, the four FAs in the aft galley area assessed that the situation merited an emergency evacuation. The lavatory smoke alarm was sounding in the cabin but the C-FA misidentified this as the secondary evacuation signal. The sounds of the two alarms are different and AIP provides a further indication, so this misinterpretation suggests inadequate training or knowledge of the systems. However, even if the alarm had been correctly identified, it is likely that the dense and noxious smoke was sufficient for the FAs in the aft galley to initiate evacuation, with or without a PA instruction being heard.

The FAs reported that they worked in a well-coordinated manner to arm the doors and begin an orderly evacuation, with the first passengers seen using the 4R slide one minute after smoke was first emitted from the APU exhaust.

Commander's instruction to cease evacuation

The occupants of the flight deck did not report noticing amber door indicators presented on the flight deck SD. The pilots' attention may have been focussed on the smoke warning on the display above. Consequently the commander only realised that a slide evacuation was underway when he saw a reflection of the deployed slide from the terminal building. He thought the source of the smoke had been removed, because he had taken action to close off the APU air supply. He knew the APU had shut down, so did not seek assistance from outside the aircraft. He was concerned passengers might be put at more risk by using the slides than by staying on-board.

Had the commander initiated an EMER CALL to speak to the FAs it would have been in accordance with the actions required for the SMOKE LAVATORY SMOKE warning displayed at the time. This would have enabled the commander to agree a course of action with the FAs. Instead he made a PA to stop the evacuation, despite the OM's guidance that it is '*usually best*' not to attempt to halt an evacuation that is underway.

The commander's PA briefly caused confusion in the cabin and although he subsequently reversed this instruction, passenger egress was delayed by a few seconds. However, the commander reported that as soon as he realised slides had been deployed he made his PA to prevent injury; this stopped passengers from using the slide at 3R and ended the controlled slide evacuation from 4L and 4R.

Aerodrome assistance

The rapid response of the emergency services was due to ATC noticing an evacuation was underway and declaring an AGI. A delay could have occurred if the aircraft had been on a stand out of ATC's line of sight, because no appropriate radio call was made. The only radio call the commander made was to alert the aircraft operator to the presence of passengers on the ramp. He did not call ATC because he assessed they already knew what was happening when he saw the RFFS arrive. Almost two minutes elapsed between the commander's PA to end the evacuation and the arrival of the first RFFS vehicle.

Subsequent flight deck actions

The evacuation commenced without the flight crew's knowledge and the evacuation checklist was not actioned immediately. Following the commander's intervention and the subsequent decision to continue evacuating passengers via the jetbridge, the co-pilot and the IRO actioned the evacuation checklist to ensure "nothing was missed". However, the second checklist item, to call ATC, was not carried out. ATC had tried to call the aircraft without response and a direct line of communication between the two parties might have enabled important information to be exchanged.

The evacuation checklist also instructs the evacuation signalling system to be switched on but this was not deemed necessary with passengers now leaving by the jetbridge. A flight crew drill for '*Emergency Deplaning*' might have been more appropriate but did not exist at the time (see *Aircraft operator's response* in Safety action).

The pilots remained aboard after the passengers and FAs had deplaned and the RFFS had declared the aircraft to be safe. The commander and the operator's '*Dispatch*' department communicated but no action was taken to remove power from the CVR in accordance with the FM.

Crew training

The aircraft operator's guidance lacked clarity in places and there were differences between that provided to the flight crew and to the FAs. For example, the OM Volume 1, referred to by the flight crew, divided evacuations into planned and pre-planned events but no such differentiation was made in the FSIM, to which the FAs referred. The crew experienced communication and co-ordination difficulties, and some recommended procedures were not followed. This suggests that training for this scenario could be improved and reflects findings in Safety Study NTSB/SS-00/01 and also in Canada's TSB Aviation Safety Study SA9501.

The EU requires joint recurrent training that must address '*effective communication and co-ordination of tasks and functions*'. IATA recommends that flight and cabin crew participate in joint training to enhance their co-ordination and a mutual understanding of human factors when dealing with emergencies. Whilst the operator involved in this occurrence has proposed action to improve its processes, improvements more generally may require action by the regulator. Accordingly, the following Safety Recommendation is made:

Safety Recommendation 2017-029

It is recommended that the Federal Aviation Administration require that flight and cabin crew participate in joint training to enhance their co-ordination when dealing with emergencies.

Safety action

Aircraft operator's response

The aircraft operator recognised several aspects of this evacuation which it considered well handled by its personnel, allowing the aircraft occupants to move to a place of safety with minimal injury. However, the operator also found its guidance and training for cabin evacuations was orientated towards incidents during takeoff or landing, and its internal Safety Management System (SMS) dictated that certain processes be changed.

Rather than delaying any changes while a detailed internal report was prepared, the operator immediately established an Emergency Deplaning and Evacuation Task Force. Its role was to improve co-ordination and communication between the workforce in the flight deck, the cabin and on the ramp, to mitigate risks to passengers and employees during emergencies. This resulted in several internal safety actions:

- All pilots were informed that an evacuation should only be halted by the commander if he '*has clear information that continuation of the evacuation would cause greater injury*'.
- Studies of the interphone equipment on different aircraft types confirmed a need to refine the communication process on certain types. On the Airbus A319, A320, A321 or A330-300, FAs should now press the EMER CALL button once to contact the flight deck in an emergency. On the Airbus

A330-200 they should press the PRIO CAPT button and on the Embraer E190 the EMER PILOT button.

- A video was produced with the co-operation of the crew involved in this occurrence, to highlight the issues they experienced. This video is being used as an educational tool for all pilots during their recurrent Human Factors (HF) training, for the nine month cycle commencing 1 February 2017. It may also become possible to use this video during FA training.
- A type-specific '*Emergency Deplaning*' drill has been developed for use by pilots on each of the operator's aircraft types and incorporated into the OM and the appropriate QRH. This drill is relevant to parked aircraft that are using a jetbridge or steps. Details were promulgated to all crews and pilots received relevant simulator training.
- As there is no commonality between the cabin interphone handsets on different aircraft types, a physical training aid is being developed for use during initial and recurrent FA training. This is intended to give FAs a better understanding of the differences they will encounter and to help them adapt to any of the 14 aircraft types or variants on which they can be qualified.
- Recurrent HF training for the aircraft operator's 12,000 pilots takes place on a 9 month cycle. The 27,000 FAs are on a 12 month cycle. This makes it difficult to conduct joint evacuation training with entire crews, so the operator is considering having pilot representatives participate in FA training and vice-versa. Future recurrent training for both pilots and FAs will focus on unplanned cabin evacuations when the aircraft is not on the runway.
- The Continuing Qualification training given to all FAs between April 2017 and March 2018 includes a review of an '*Emergency Deplaning*' and it is likely attendees will hear the specific aural alert signals for each aircraft type.
- The operator expects a company safety investigator to contact the commander by telephone as soon as its '*Dispatch*' department has been advised of a serious incident or accident. The safety investigator is now required to remind the commander during this contact that action be taken to ensure the circuit breaker for the CVR is pulled without delay.
- Training procedures were developed for the aircraft operator's ramp personnel, to ensure they know how best to react if a slide evacuation occurs while an aircraft is parked.

Twice a year, US operators, along with some foreign airlines that operate to the US, share experiences at a safety forum. The operator intends to discuss issues raised by this event at such a forum; to raise the industry's awareness of the challenges that can be created by a cabin evacuation from a parked aircraft.

Aircraft manufacturer

The aircraft manufacturer has reviewed and amended the MMEL section 24-23-01, for the dispatch of an aircraft with APU AC auxiliary generation unserviceable and a summary of these changes is as follows:

> ***MMEL item 24-23-01A*** 'APU not used':
>
> No change, as not relevant to the event.
>
> ***MMEL item 24-23-01B*** 'Electrical failure':
>
> To insure a more robust detection of a mechanical failure, a review has been conducted with the APU Generator supplier and the following 4 failure messages will be added to the list from the AMM task 24-23-00-040-803.
>
> GEN APU (8XS)
> GEN APU (8XS) EX FLD / GAPCU (40XG)
> GAPCU (40XG) EX FLD / GEN APU (8XS)
> GEN APU (8XS) EX FLD / GAPCU (40XG)
>
> If any of these messages is present in the PFR when doing the interactive APU test, then the MMEL 24-23-01C must be applied.
>
> ***MMEL item 24-23-01C*** 'AC auxiliary generation deactivated or removed (mechanical failure)':
>
> An update of the related AMM tasks (e.g. 24-23-00-040-801 and -802) has been decided, to prevent oil cross-contamination from the APU Gen to the APU. The AMM TASK 49-91-41-210-802-A "Check of the APU Oil System for APU Generator Debris" has been added at the end of those tasks, and must be carried out prior to aircraft dispatch. This AMM task includes a physical check of the APU oil system (inlet screens of the scavenge-oil, inspection of the magnetic chip detectors and the mechanical differential pressure indicator, check of the lubrication oil supply and generator scavenge filters).

Conclusion

Smoke entered the cabin after the APU load compressor oil seal became compromised, allowing hot oil to enter and pyrolyse in the bleed air supply to the cabin. Examination of the APU after the event revealed considerable metallic debris in its shared oil system. This debris eventually caused the load compressor carbon seal to fail, allowing hot oil to enter the bleed air supply to the cabin and causing smoke in the cabin. The initiating source of the debris could not be identified positively due to the distribution of debris throughout the oil system.

Modifications exist to mitigate these conditions and two Safety Recommendations have been made that an optional SB, to add enhanced APU automatic shut-down protection for lubrication system contamination, be mandated.

The aircraft manufacturer has reviewed and amended the MMEL to provide enhanced mitigation when operating with unserviceable APU AC auxiliary electrical generation.

This emergency situation, involving an evacuation from an aircraft parked at the gate with the jetbridge in place, was unusual for the FAs, who had not practised it as part of the aircraft operator's training programme. Prompt and effective communication between the cabin and the flight deck might have avoided an evacuation, but the pilots and the IRO were distracted by the presence of an engineer, who was attending to a defect. The normal interphone call function used by the cabin crew did not attract their attention. The EMERGENCY call function may have been more conspicuous but guidance provided by the aircraft operator concerning its use may have been confusing.

An evacuation was initiated because FAs did not receive specific instructions from the flight crew and the FAs perceived that the situation was life-threatening. Exits at the front of the aircraft were not used, indicating that the FAs in this part of the aircraft were trying to achieve an '*Emergency Deplaning*' via the jetbridge, even though an evacuation was commanded. This may have been the most appropriate procedure in this situation but it was not a drill familiar to the flight crew and better crew communication was required before using it.

Passengers near exits 3L and 3R had accepted responsibility for exit operation and, with no FAs in the vicinity when the emergency began, opened the doors but did not deploy one of the slides. This created the hazard of an unprotected five metre drop from the doorway to the ground and, even though an FA subsequently placed a security strap across the opening, it was fortunate that nobody used the affected door.

Once the commander had realised an evacuation was underway he instructed it to cease because he believed he had removed the source of the smoke and wanted to prevent injury, but he did not discuss the cabin situation with the FAs before making his PA. This indicated a breakdown in communication and co-operation between flight crew and cabin crew members; an issue which is being addressed by the operator through enhanced guidance and training. Other operators may be susceptible to similar shortcomings in these circumstances until regulations for cabin evacuation training are amended to minimise them.

SERIOUS INCIDENT

Aircraft Type and Registration:	ATR 72-212 A, 500 Version, G-COBO
No & Type of Engines:	2 Pratt & Whitney Canada PW127M turboprop engines
Year of Manufacture:	2009 (Serial no: 0852)
Date & Time (UTC):	21 December 2016 at 1733 hrs
Location:	5 nm north of reporting point ORTAC
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 61
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	6,040 hours (of which 1,401 were on type) Last 90 days - 152 hours Last 28 days - 51 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was on a scheduled flight from Guernsey to Manchester. While climbing to a cruising level of FL170 the aircraft began to accrue airframe icing. The crew were presented with a DEGRADED PERF and an INCREASE SPEED caution. The appropriate checklists were not fully actioned and the correct climb speed was not maintained because the crew focused on climbing the aircraft clear of the cloud and icing conditions. The aircraft experienced an in-flight upset whilst levelling at FL130 (as requested by the pilots) and commencing a turn instructed by ATC. The aircraft was subsequently recovered to controlled flight, after which the crew elected to return to Guernsey. There were no injuries.

The loss of control resulted from airframe icing accrued during the climb and incomplete use of the appropriate checklists, leading to selection of an unsuitable speed followed by the use of the LNAV mode of the flight director to initiate a turn.

The operator and manufacturer took several safety actions, including an amendment to the aircraft's checklist and operating manuals.

History of the flight

The flight crew reported for a four-sector duty period involving flights from Guernsey to Bristol and return, and Guernsey to Manchester and return. The first two sectors were without incident.

During the turnaround at Guernsey, for the flight to Manchester, the crew had noted that a frontal weather system would be encountered during the flight over the English Channel, with associated cloud, precipitation and moderate icing conditions.

The aircraft took off at 1718 hrs with a takeoff mass of 21,937 kg. The co-pilot, who had recently qualified on type, was undergoing line training under the supervision of the commander, who was a line training captain. The commander was PF for this sector with the co-pilot PM.

Soon after takeoff HI[GH] bank[1] was selected, the autopilot engaged and the aircraft was cleared to climb to FL170. As the aircraft climbed at 170 kt on a northerly track it encountered the weather front and began to accrue airframe icing. Anti-icing systems were activated as the aircraft climbed through 5,300 ft, followed by de-icing systems when actual airframe icing was encountered as the aircraft climbed through FL090 (Figure 1). The aircraft was flown at or above the Minimum Icing Speed (this speed, known as the 'red bug' speed was 165 kt for the aircraft mass at the time). The crew conducted a review of the Quick Reference Handbook (QRH) 'SEVERE ICING'[2] procedure's memory items in the checklist (but not the notes on *Detection*) in case it became necessary to perform it later.

As the aircraft passed about FL110, DEGRADED PERF[3][ormance] and INCREASE SPEED[4] caution messages illuminated. Upon switching the external icing light to ON, to check the extent of the ice on the ice evidence probe, the commander commented "…WE'VE GOT A BIT [of icing] HAVEN'T WE". The commander made a reference to the QRH checklist for the caution, but it was not actioned; however, he did initially increase the target IAS to 175 kt (red bug +10 kt), during which the rate of climb reduced from 420 ft/min to about 25 ft/min and the caution extinguished.

The commander noted that the aircraft was "NOT CLIMBING VERY WELL" and acknowledged that the QRH procedure required an increase in speed to red bug +10 kt but he considered that, as the aircraft was at that moment flying level, it was safe to return the target IAS to 165 kt. This resulted in an increase in the aircraft's pitch attitude and a climb to the selected level. As he adjusted the speed he commented "…JUST SEE IF WE CAN GET ABOVE [THE CLOUDS]." The autopilot remained engaged in the IAS and heading capture modes.

About one minute later the INCREASE SPEED caution message illuminated again. At this point the commander commented "WE ARE PICKING UP QUITE A BIT OF ICE ACTUALLY", later adding that it was the first time he had encountered this [deterioration in climb performance]. At this point the aircraft's rate of climb was about 200 ft/min. The target IAS was again increased to 175 kt. To achieve this the aircraft initially descended, achieving a maximum rate of -540 ft min and descending almost to FL120, where the aircraft levelled off momentarily. The target IAS was then reduced back to 165 kt, which initiated a further climb.

Footnote

1 HI bank allows turns with up to 27° angle of bank, while LO[W] bank allows turns with up to 15° angle of bank and is the default setting in HEADING mode unless HI bank is selected.
2 See *Manufacturer's QRH procedures* section below for the 'SEVERE ICING' procedure.
3 A steady amber light with single audio chime and a master caution on the attention getter.
4 An amber flashing light with audio chime and a master caution on the attention getter. See *Manufacturer's QRH procedures* section below for the actions to be taken in the event these cautions illuminate.

As it was apparent that the aircraft had insufficient performance to reach its cruising level of FL170, the crew made a request to ATC to level off at FL130 so the aircraft could accelerate, before resuming the climb. ATC approved this and instructed the crew to proceed direct to reporting point NORRY, a change in heading of about 10°. This was achieved by re-programming of the Multifunction Control Display Unit and selecting LNAV[5]. The aircraft experienced an in-flight upset as it levelled off and turned towards NORRY. The autopilot had been engaged throughout the climb until that moment.

Recorded data[6] showed that at the point of the upset the aircraft initially rolled left to 32° the autopilot disengaged, before rolling right to 38°. It then rolled left again, reaching attitudes of 73° in roll and 16° nose-down in pitch.

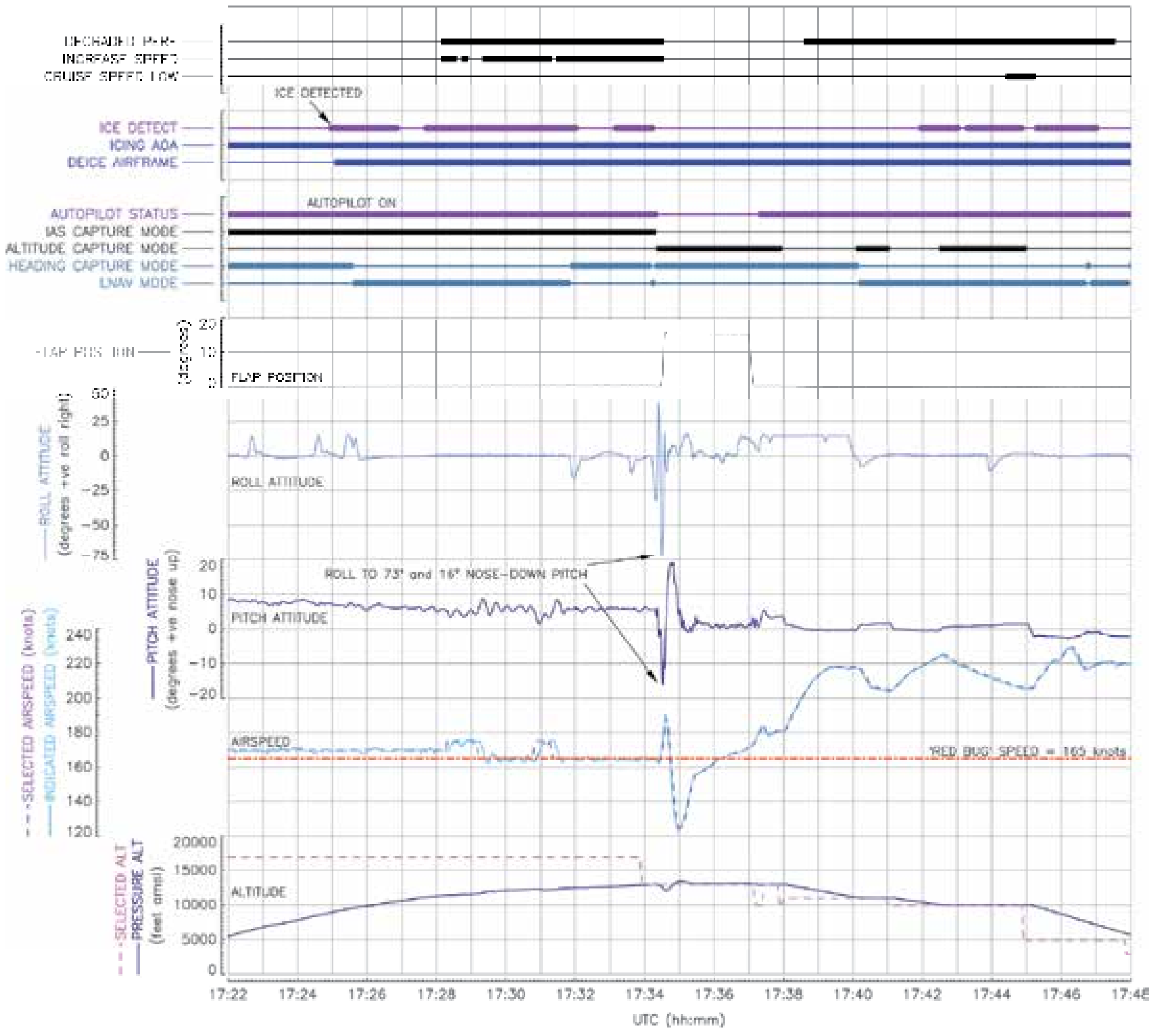

Figure 1

Salient data from the FDR and DAR

Footnote

5 Lateral Navigation. Selecting LNAV from heading mode deactivates the HI bank protection, if it had been selected.

6 Although not recorded on the FDR, the manufacture confirmed that the stick shaker would have activated during the event (resulting in the autopilot disengagement), and also the stick pusher. The crew had no recollection of these inputs, and neither of these was discussed or audible on the CVR.

Upon the commander's instructions the co-pilot actioned the upset recovery items when instructed to do so by the commander. These included extending the flaps to Flap 15[7]. The commander recovered the aircraft to controlled flight at FL130, having descended through about 1,000 ft. During the recovery, pitch increased from nose-down to a nose-up attitude of 19°, before reducing to a normal value. During these pitch and roll oscillations, the IAS varied between 190 kt and 123 kt.

During the manoeuvres the co-pilot transmitted a MAYDAY call and, once control had been regained and the situation assessed, the decision was made to return to Guernsey. The aircraft subsequently landed at Guernsey without further incident and no injuries were reported.

The aircraft was withdrawn from service pending a maintenance check. Functional tests were conducted on the aircraft's ice detection, anti-ice and de-ice systems as well as the Aircraft Performance Monitoring (APM) system. No abnormalities were found, but analysis of the FDR data indicated that, during the recovery manoeuvre, the extended flaps sustained an overspeed of 5 kt. The aircraft was subsequently returned to service.

Meteorological information

The vertical cross section and significant weather forecast charts issued to the crew for the flight to Manchester indicated that moderate icing was expected over the English Channel and southern England from below FL100 to FL190.

A summary of an aftercast produced by the Met Office included the comment that observed data verified there was an active frontal zone affecting southern England and the English Channel at the time of the incident. The aircraft would have flown through thick layers of frontal cloud during the climb, whose tops were at about FL190, which would have been expected to cause moderate icing. There was no evidence of cumulonimbus clouds or other data associated with severe icing.

Prolonged flight in moderate icing conditions could lead to an increasing amount of ice accretion that could result in severe ice accretion.

Aircraft technical information

Minimum manoeuvre speeds

Minimum manoeuvre/operating speeds are determined in order to provide sufficient margin above stall. They vary with icing conditions, mass, configuration and type of manoeuvre (HI or LO bank). They are defined by a minimum ratio to the appropriate stall speed or by V_2 when applicable. The minimum manoeuvre speed in icing conditions with HI bank selected is red bug + I0 kt.

Footnote

7 With the flaps extended, the APM system does not generate data.

Aircraft Performance Monitoring

The aircraft was equipped with a Multi-Purpose Computer (MPC) which incorporated an Aircraft Performance Monitoring (APM) function. This was designed to monitor aircraft drag in icing conditions and alert the crew of a significant degradation of the aircraft performance, potentially associated with severe icing conditions. The APM also checked that the Minimum Severe Icing Speed[8] (MSIS) was respected.

The APM function was active in icing conditions (based on the status of the airframe de-icing system and ice detection, i.e. active when airframe anti icing was switched ON by the pilot or by automatic ice detection by the aircraft). It compared theoretical aircraft drag with actual in-flight drag, and MSIS with actual IAS. A DEGRADED PERF caution (a steady amber light with a single audio chime and a master caution on the attention getter) would illuminate when the actual drag was higher than the theoretical drag and the IAS greater than the MSIS. An INCREASE SPEED caution (an amber flashing light with audio chime and a master caution on the attention getter) would illuminate when actual drag was higher than theoretical one and IAS less than MSIS, within a threshold (Figure 2).

Figure 2

APM messages.
(Similar layout on left side of the cockpit)

Previous events

The previous day there had been an 'information' entry in the aircraft's technical log stating that the APM system had been giving spurious information. The system was subsequently checked and found serviceable.

The operator also provided the investigation with four additional reports in which flight crews believed APM cautions were spurious.

Operational ceiling

The extant regulation (CAT.POL.A.315) stated that an aircraft is deemed to have reached its operational ceiling when the rate of climb reduces to 300 ft/min.

Footnote

8 The MSIS is Minimum Icing Speed+10 kt.

Effect of icing on performance

The manufacturer states, in its *Cold Weather Operations* publication, that the main effects of ice accretion are:

- A reduction of lift at a given angle of attack
- A reduction of maximum lift
- A reduction of maximum lift angle of attack
- Greater drag at a given angle of attack
- Greater drag at a given lift
- Best lift/drag ratio at a lower lift coefficient

Manufacturer's QRH

The aircraft manufacturer's QRH procedures for the cautions experienced by the crew were as follows:

DEGRADED PERF and INCREASE SPEED

DEGRADED PERF

Mainly appears in level flight after CRUISE SPEED LOW or in climb, to inform the crew that an abnormal drag increase induces a speed decrease or a loss of rate of climb

The most probable reason is an abnormal ice accretion

AIRFRAME DE-ICING ON .... CHECK
IAS > RED BUG + 10 KT .... MONITOR
AP (if engaged) .... HOLD FIRMLY CONTROL WHEEL and DISENGAGE

■ **If SEVERE ICING conditions confirmed**
– or –
■ **If impossibility to maintain IAS > RED BUG + 10 KT in level flight**
– or –
■ **If abnormal aircraft handling feeling**

SEVERE ICING procedure (1.09) .... APPLY

■ **If not**

SCHEDULED FLIGHT .... CONTINUE
ICING CONDITIONS and SPEED .... MONITOR

INCREASE SPEED

Appears after DEGRADED PERF to inform the crew that the drag is abnormally high and IAS is lower than RED BUG + 10 KT

■ **If abnormal conditions confirmed**

IMMEDIATELY PUSH THE STICK TO INCREASE SPEED
TO RECOVER MINIMUM IAS = RED BUG + 10 KT

SEVERE ICING procedure (1.09) .... APPLY

Of note, the DEGRADED PERF checklist stated:

'The most probable reason is an abnormal ice accretion.'

SEVERE ICING

SEVERE ICING

MINIMUM ICING SPEED...INCREASE by 10 kt
PWR MGT..MCT
CL 1 + 2...MAX RPM
PL 1 + 2...NOTCH
AP (if engaged).......FIRMLY HOLD CONTROL WHEEL and DISENGAGE
SEVERE ICING CONDITIONS..ESCAPE
ATC...NOTIFY

- **If an unusual roll response or uncommanded roll control movement is observed :**

  Push firmly on the control wheel
  FLAPS..EXTEND 15

- **If the flaps are extended, do not retract them until the airframe is clear of ice.**

- **For the approach, If the aircraft is not clear of ice :**

  GPWS .... FLAP OVRD
  STEEP SLOPE APPROACH (≥4.5°) ....PROHIBITED
  APP/LDG CONF ....MAINTAIN FLAPS 15
  APP SPEED......"REDUCED FLAPS 15 LDG icing speeds" + 5 kt
  Multiply landing distance FLAPS 30 by 1.91.

DETECTION

Visual cue identifying severe icing is characterized by ice covering all or a substantial part of the unheated portion of either side window

and / or

Unexpected decrease in speed or rate of climb

and / or

The following secondary indications :
. Water splashing and streaming on the windshield
. Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice
. Accumulation of ice on the lower surface of the wing aft of the protected areas
. Accumulation of ice on propeller spinner farther aft than normally observed

The following weather conditions may be conducive to severe in-flight icing :
. Visible rain at temperatures close to 0°C ambient air temperature (SAT)
. Droplets that splash or splatter on impact at temperatures close to 0°C ambient air temperature (SAT)

Of note, the *Severe Icing* drill stated that:

> *'Unexpected decrease in speed or rate of climb' is one of the indicators of severe icing.'*

Flight crew training

The operator commented that, prior to this event, APM training was not included in the initial aircraft type rating but pilots were briefed on its use during follow-on line training using the manufacturer's *Cold Weather Operations* publication and its APM briefing package. The simulator used principally by the operator was not fitted with an APM, although it had been requested by several operators since 2013.

Other recent events

The Accident Investigation Board Norway (AIBN) investigated a similar event that occurred to an ATR 72-212A, registration OY-JZC, on 14 November 2016 while en route from Bergen to Ålesund in Norway[9]. The findings of this investigation have not been released at the time this AAIB Bulletin was published.

Analysis

The aircraft was climbed into a known area of frontal weather that was forecast to have moderate icing conditions. As the aircraft's altitude increased its performance decreased to a point where it had reached its operational ceiling due to the accretion of airframe icing. Although the DEGRADED PERF caution illuminated, the crew did not action the DEGRADED PERF check list or the SEVERE ICING procedure.

The forecast and aftercast icing conditions, and the visible extent of the icing encountered, were not entirely consistent. However, the poor climb performance was an indication to the crew of the severity of the ice accretion. Had the crew actioned the QRH procedure for the DEGRADED PERF they would have been directed to carry out the SEVERE ICING checklist. The crew had reviewed the memory items in the checklist, but not the notes on detection which listed '*Unexpected decrease in speed or rate of climb*' as being one of the indicators of severe icing.

The DEGRADED PERF checklist and SEVERE ICING memory procedure both required (among other things) that the speed be maintained at or above red bug +10 kt and that the autopilot be disconnected. The crew did not observe these actions, varying the speed instead between 165 kt (red bug) and 175 kt (red bug +10 kt). Consequently departure from controlled flight was more likely because the aircraft was flown slower than required. Also as the autopilot remained engaged, the crew would not have been aware of any handling indications of an imminent departure. With the controls in a dynamic condition, an extreme upset was more likely if the crew were not holding the controls firmly at that time.

The crew were focussed on climbing out of the icing conditions into VMC above the clouds, and in trying to achieve this, they had made speed selections which they knew were below that required by the DEGRADED PERF and SEVERE ICING checklists. An earlier level off or a descent would have been required, but this would have involved the

Footnote

9 A summary on the AIBN's website can be found here: https://www.aibn.no/Aviation/Investigations/16-790

aircraft remaining in icing conditions, contrary to what the crew intended to achieve. High terrain was not a factor, and a descent, with the associated increase in IAS, would have avoided the occurrence.

Eventually, control of the aircraft was lost with extreme roll and pitch as a result of a combination of icing, an inappropriate speed, and a turn that was initiated by a change from HDG mode to LNAV which permitted a HI bank turn. The crew's actions enabled a recovery to normal flight and an uneventful landing at Guernsey.

There was evidence that pilots lacked confidence in the APM system, with technical log reports of spurious warnings including on the incident aircraft from the day before. This may have predisposed the commander to partially disregard the cautions and therefore not carry out the appropriate checklist appropriately. The APM system was subsequently checked and found serviceable.

The occurrence highlights that poor decisions are possible in stressful or otherwise high workload situations. In such circumstances, it may be necessary to abandon the immediate goal and pursue an alternative, safer course of action, even if that course of action is perceived as taking the aircraft further away from the desired state. In this case, the desired state was a climb out of icing conditions and thus a return to more normal performance, but the well-intentioned pursuit of the goal led directly to the upset.

Safety actions

Operator

The operator reviewed its ATR procedures and amended them to improve safeguards against similar occurrences. Flight crews were reminded of the required response to APM cautions, and the operator now replicates this incident, and APM messages, during pilots' flight simulator training. Several internal recommendations were made, addressing non-normal situation handling in general.

The following *FLYING STAFF INSTRUCTION – ATR* was issued on 28 December 2016, with an amendment to the ATR Operations Manual Part B, Section 2.4:

> *'2.4.16.2 Climb Speed*
>
> *Standard Climb Speed is 170 kts IAS or Red Bug + 10 kts, whichever is the higher, achieved using AFCS* [Automatic Flight Control System] *IAS mode.*
>
> *Climb speed may only be reduced below 170 knots if required for terrain clearance or mandatory ATC requirements. Under these circumstances the minimum IAS is White Bug + 10 kts in Normal Conditions and Red Bug + 10 kts in Icing Conditions.*
>
> *…*

> *If during climb at Standard Climb Speed the average rate of climb falls below 500 feet per minute, crews should request to stop climb at the next available level or advise ATC of the reduced climb capability. Speed must not be reduced to maintain a given rate of climb.'*

The following memo was sent to all ATR pilots:

> *'APM / Reduced Performance*
>
> *Crews are also reminded that Severe Icing may be encountered without the presence of the normally associated visual cues, and reduced rate of climb or cruise airspeed are sometimes the only indication of significant ice accretion. Whenever crews encounter or suspect severe icing, the full checklist at QRH page 1.09* [Severe Icing] *must be completed.*
>
> *…'*

Aircraft manufacturer

The aircraft manufacturer stated that it is working to improve the APM to avoid the illumination of cautions that are perceived as spurious.

As a result of this occurrence and that investigated by the AIBN the manufacturer has amended the DEGRADED PERF and SEVERE ICING procedures.

The amended DEGRADED PERF procedure will state that the SEVERE ICING procedure should be actioned if the aircraft is unable to maintain a climb rate greater than 100 ft/min, when climbing at red bug +10 kt. The SEVERE ICING procedure will have fewer memory items and will state that, after IAS and engine power are increased and the autopilot is disconnected, a descent is to be initiated to escape the severe icing conditions.

The amendments, in the appropriate documents, are due to be distributed to all operators in January 2018.

The manufacturer of this aircraft, together with other aircraft manufacturers, has contributed to the update of the *Airplane Upset Prevention and Recovery Training Aid (AUPRTA),* Revision 3, which is available on ICAO website[10]. This update includes information specific to turboprop aircraft.

Footnote

[10] AUPRTA can be found here: https://www.icao.int/safety/LOCI/AUPRTA/index.html

Conclusion

The aircraft suffered an in-flight upset at FL130 after accruing airframe icing during the climb, resulting in the adverse aerodynamic effect of ice build-up on the wings. The crew were presented with a DEGRADED PERF caution but did not action the relevant checklist because they focused on climbing out of the icing conditions. The IAS was not maintained at or above red bug +10 kt and control of the aircraft was lost when a turn was initiated in the LNAV mode of the flight director.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 737-36E Freighter, TF-BBF
No & Type of Engines:	2 CFM International CFM56-3B2 turbofan engines
Year of Manufacture:	1992 (Serial no: 25264)
Date & Time (UTC):	3 February 2017 at 0015 hrs
Location:	East Midlands Airport, Leicestershire
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Overheating of rear equipment bay
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	9,889 hours (of which 8,087 were on type) Last 90 days - 94 hours Last 28 days - 26 hours
Information Source:	AAIB Field Investigation

Synopsis

Shortly prior to engine start the aircraft suffered an APU bleed air duct leak in the rear equipment bay. The leaking bleed air heated corrosion-inhibitor material in the rear equipment bay, resulting in scorching and the release of smoke within the main cargo deck. The flight crew shut the APU down. The cause of the bleed air leak was a failed V-band clamp that had fractured due to stress corrosion cracking. The operator is currently replacing V-band clamps at the failure location on its fleet of 737-300 and 737-400 freighter aircraft.

History of the flight

The aircraft was conducting a scheduled cargo flight from East Midlands Airport to Edinburgh Airport, with the co-pilot as Pilot Flying. At approximately 0015 hrs the flight crew completed their pre-departure checklist and requested pushback, which ATC approved. The crew reported that the aircraft was configured for engine start, with the APU running, both air conditioning packs switches in the OFF position[1], the engine bleed air switches both set to ON and the APU bleed air valve switch in the ON position. The aircraft's exterior doors were closed.

Footnote

1 Boeing's FCOM procedure puts both pack switches to AUTO. Boeing later commented that some operators perform one pack takeoff or pack off takeoff to gain higher thrust.

Shortly before the pushback was due to commence, the fire warning bell sounded. The crew looked at the indications on the fire warning panels, both on the centre console and the P5 overhead panel, but did not see any fire warning lights on either panel. The co-pilot cancelled the fire warning bell and then pressed the master caution recall button, and later stated that he could not recall if any fire warning lights were illuminated. The commander also stated that he did not see any fire or overheat warning lights.

Approximately 10 seconds after the first fire warning bell, the fire bell sounded for a second time, again without the crew recalling observing any smoke or fire warning indications on the fire warning panels. The commander asked the ground crew, via the pushback headset, whether they could see any smoke or fire coming from the aircraft; the ground crew reported that smoke was emanating from the rear of the aircraft. Whilst this message was being received, the crew observed and smelt smoke entering the cockpit, despite the cockpit door being closed.

The commander shut down the APU. The co-pilot walked to the forward galley and found that the smoke was thickening rapidly and was getting hotter, with the source of the smoke beneath the cargo deck floor. He returned to the flight deck and informed the commander, whereupon the commander called ATC requesting the immediate response of the airport fire and rescue service (AFRS). The co-pilot opened the forward left cabin door and signalled to the ground crew to bring steps to the aircraft. He then went to the forward galley and opened the forward right cabin door in order to further expel the smoke. The commander signalled to the ground crew to reconnect the ground power unit and the pilots then departed the aircraft via the steps. The AFRS arrived at the aircraft at 0023 hrs and began investigating the source of the smoke.

Aircraft information

The Boeing 737-300 is equipped with a wing-body overheat detection system, consisting of a number of heat detector elements located in close proximity to the aircraft's bleed air ducts and a monitoring system that detects a drop in electrical resistance of a detector element when that element is subjected to excessive heating. When triggered, the system activates a WING-BODY OVERHEAT light on the air conditioning overhead panel[2] and the MASTER CAUTION warning and AIR COND annunciator lights on the cockpit glareshield, Figure 1. No audio warning is associated with the system. Tests performed by the operator's maintenance personnel following the incident showed that the wing-body overheat detection system was serviceable.

During the flight crew operations manual (FCOM) pre-flight procedures, the co-pilot is required to set the aircraft's bleed air valves and air conditioning packs. The procedure requires that one air conditioning pack switch should be switched from OFF to AUTO or HIGH, whilst the other should be set to OFF. The isolation valve switch should be set to AUTO and the engine bleed air switches set to ON, Figure 2.

Footnote

[2] An overheat detection of the APU bleed air duct will cause the left WING-BODY OVERHEAT caption to illuminate.

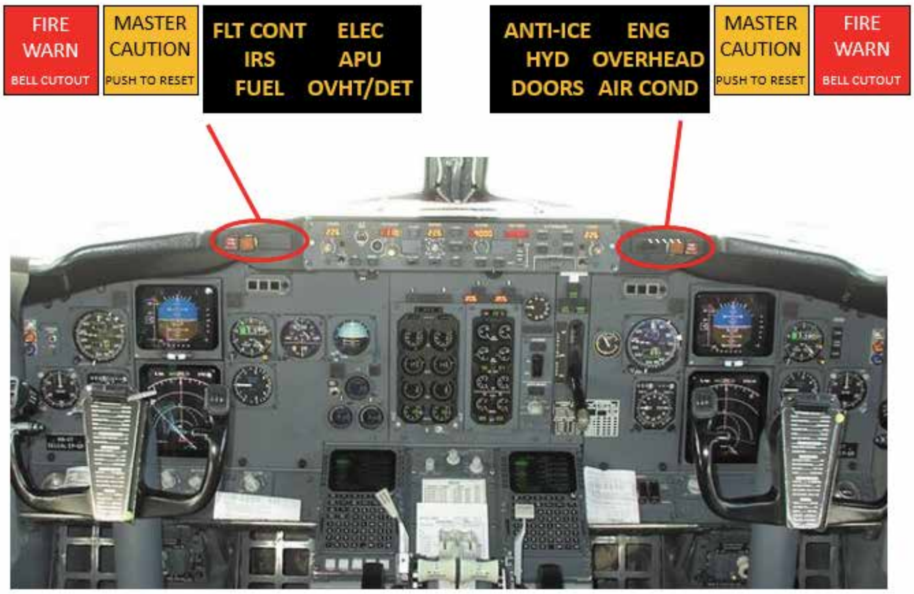

Figure 1

Boeing 737-300 cockpit glareshield fire warning buttons, master caution buttons and system annunciator captions

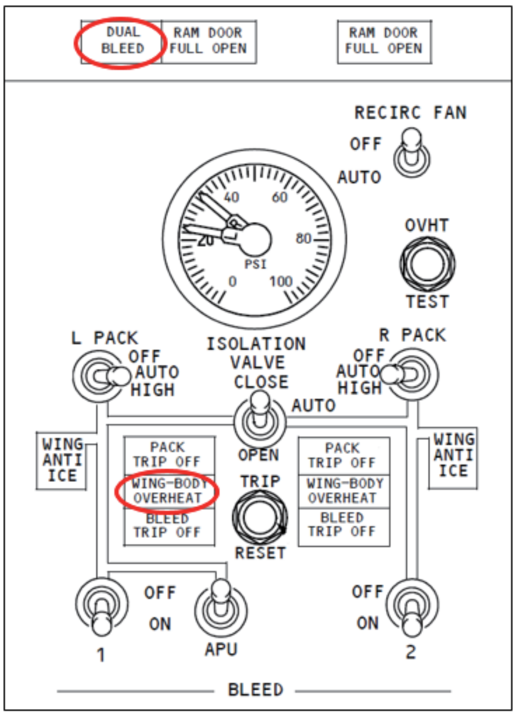

Figure 2

Boeing 737-300 air conditioning control panel, showing positions of the DUAL BLEED and left WING-BODY OVERHEAT captions

Once this has been completed, the APU bleed air switch should be set to ON; this causes the DUAL BLEED warning light to illuminate on the air conditioning overhead panel, accompanied by illumination of the cockpit glareshield MASTER CAUTION warning lights and AIR COND annunciator light, Figure 2. This is a normal part of the pre-flight procedure, as the APU bleed air valve is open at the same time as the left engine bleed air valve, allowing possible back-pressure of the APU if the left engine is operated above idle power whilst the bleed air valves are in this configuration, Figure 3.

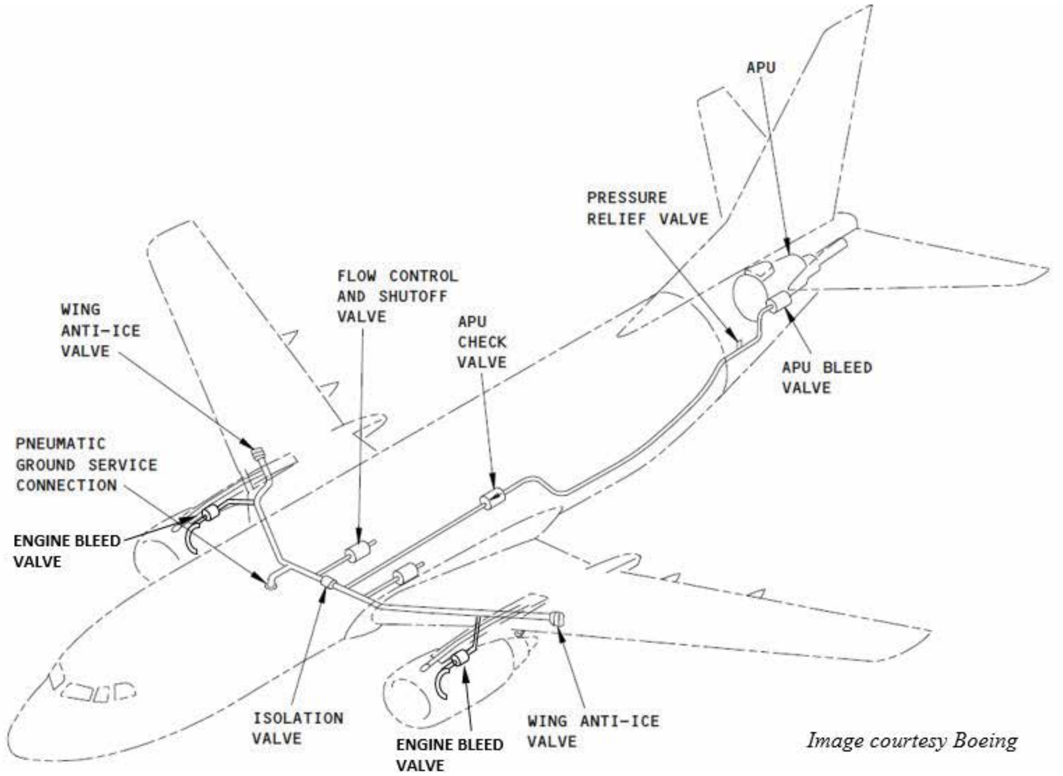

Figure 3

Boeing 737-300 bleed air pneumatic system

The aircraft is equipped with independent smoke detection systems on both the main cargo deck and lower cargo hold. Both systems are integrated with the aircraft's master caution and fire warning systems to alert the crew. The presence of smoke in the main cargo deck will cause the fire bell to sound, the SMOKE warning light to illuminate on the main deck smoke detection system panel, located on the aft overhead P5 panel, and the glareshield MASTER CAUTION and FIRE buttons to illuminate.

The presence of smoke in the lower cargo hold will cause the fire bell to sound, the FIRE warning light to illuminate on the lower hold fire warning system panel, located on the co-pilot's P5 overhead panel, and the glareshield MASTER CAUTION and FIRE buttons to illuminate. Tests on both main cargo hold and lower cargo hold smoke detection systems carried out after the event showed that both systems operated normally and were serviceable.

The aircraft's lower cargo hold is classified as a *'Class D'*[3] hold that is fully sealed in order to passively suppress fires within the compartment through oxygen starvation. The aircraft's rear equipment bay is immediately to the rear of the lower cargo hold, behind a bulkhead, and is immediately beneath the main cargo deck floor. A floor grating in the main cargo deck floor permits the passage of air from the rear equipment bay into the main cargo deck.

As neither of the aircraft's engines were running during the smoke event, neither the FDR nor quick access recorder (QAR) were recording data when the event occurred.

Aircraft examination

Investigation by the operator's engineering personnel revealed that a V-band clamp[4] had separated from a joint on the APU bleed air duct in the rear equipment bay, immediately forward of the aft pressure bulkhead, beneath the main deck cargo floor in the vicinity of fuselage station (STA) 1016, Figure 4.

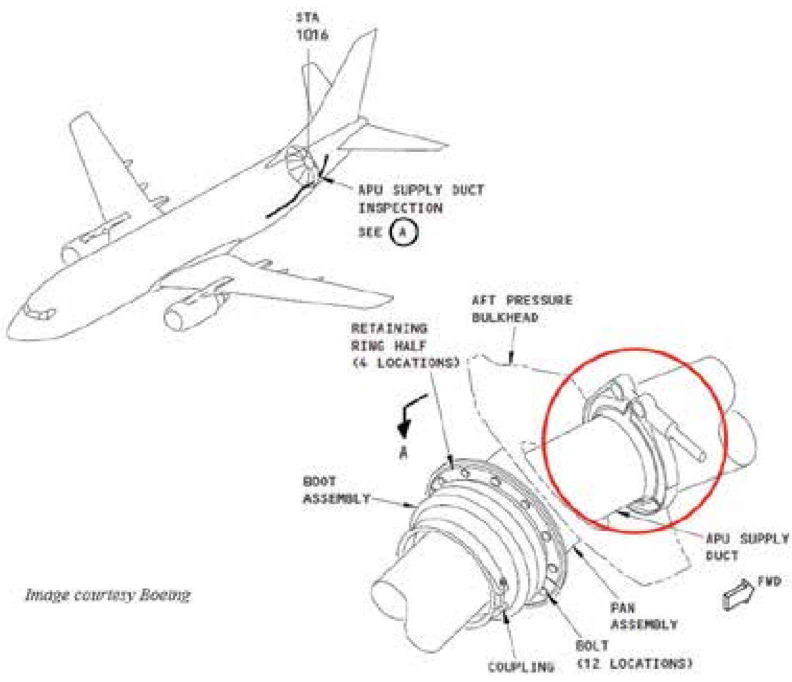

Figure 4

Location of the APU bleed air duct leak and failed V-band clamp

The aft pressure bulkhead adjacent to the leaking APU bleed air duct joint showed evidence of overheating and scorching due to ignition of the Ardrox AV8 corrosion-inhibitor coating on the aircraft's internal structure in this location, Figure 5.

Footnote

3 Federal Aviation Regulation 25.857, Cargo Compartment Classification.

4 A V-band clamp consists of a series of profiled segments welded within a tensioned outer strap. They are commonly used to connect the flanged ends of pipe segments together.

Figure 5

Overheating damage to the aircraft's structure adjacent to the APU bleed air duct leak

The aircraft manufacturer stated that, when the aircraft's APU is running, the air within the APU bleed air duct, at the point of rupture, can reach a maximum temperature of 376°C. The material safety data sheet for Ardrox AV8 states that the material has an auto-ignition temperature of 200°C.

The failed V-band clamp was marked with part number *BACC10DU400AB Rev. T* and a date of manufacture of March 1989. The aircraft manufacturer confirmed that it was the correct part number clamp for the application. The clamp is not marked with a serial number and is considered an on-condition part, with its service life not tracked in the aircraft's maintenance programme (AMP). It was unclear how long the clamp had been installed on TF-BBF. The only maintenance inspection for the clamp defined within the AMP, and Boeing documentation, was a zonal inspection[5], performed at 1C and 2C check intervals. This zonal inspection had last been carried out on TF-BBF in July 2015; the inspection contained the following requirement:

> *'Visually check all systems and installations in the aft cargo equipment bay area (Zone 220) for defects/damage, cleanliness, loose and missing fasteners, cracks, corrosion, degradation of protective coatings, condition and security.'*

The aircraft's maintenance planning document defines a visual examination as:

> *'Visual examination of defined internal or external structural areas from a distance considered necessary to carry out an adequate check… Internal applies to obscured structure requiring removal of fillets, fairings, access panels and doors etc. for visibility. Adequate lighting is required and where necessary aids such as mirrors etc., surface cleaning and access procedures may be required to gain proximity.'*

Footnote

[5] Task Card 53-420-21-01.

Metallurgical analysis

The broken clamp was recovered from the rear equipment bay, Figure 6 and subjected to detailed examination.

The clamp's tension band had fractured at the point where the upper folded part of the band is attached to the main lower part of the band by two staggered rows of spot welds, Figure 7.

Figure 6
Broken V-band clamp

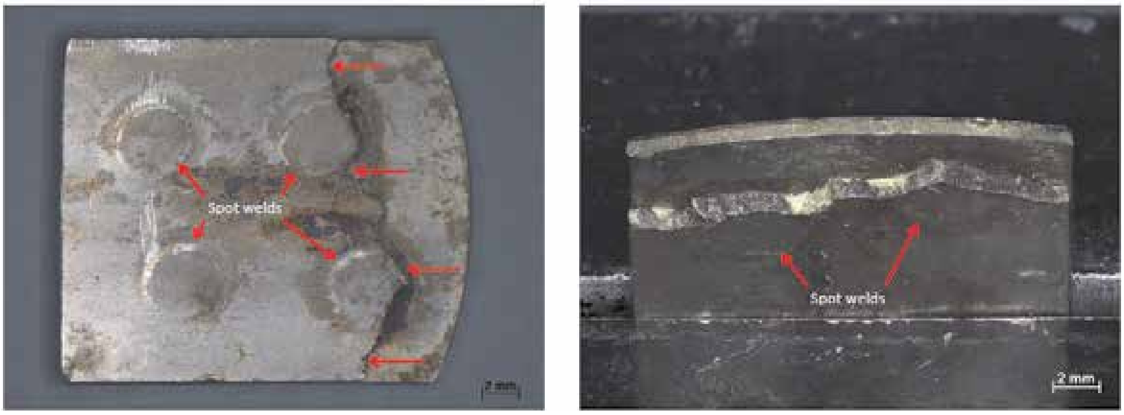

Figure 7
V-band clamp fracture location at spot welds

In addition to the main fracture, three further cracks in the clamp's band were identified, Figure 8. These additional cracks were located at points on the band between where the inner profiled segments were attached, at points where the band bending loads were highest.

Figure 8

Other cracks identified in the V-band clamp band

The clamp band material was specified by the manufacturer as 21-6-9 CRES steel[6], to specification BMS 7-191. The material composition of the clamp was checked by a specialist laboratory and found to be within specification, apart from trace levels of additional sulphur, aluminium and vanadium. The additional sulphur was deemed most likely to be present due to the products of combustion generated during the overheating event.

The fracture surface was heavily corroded, indicating that the crack had been present for a considerable period of time and that the clamp had been exposed to a corrosive environment. After cleaning, scanning electron microscopy analysis of the fracture surface revealed small areas of ductile overload at the outer edges of the crack, and large areas of intergranular cracking, which is consistent with stress corrosion cracking (SCC). SCC is a progressive crack growth mechanism that occurs in certain metals that are subjected to tensile loading in a corrosive environment. The presence of intergranular cracking was further confirmed by a metallographic section of the fracture face, Figure 9, which showed a branching crack path that is typical of SCC. It was not possible to determine exactly when the cracks had formed, and whether they would have been large enough to detect visually when the 1C maintenance inspection was performed in July 2015.

Footnote

6 A corrosion resistant (CRES) stainless steel with major alloying elements chromium, nickel and manganese.

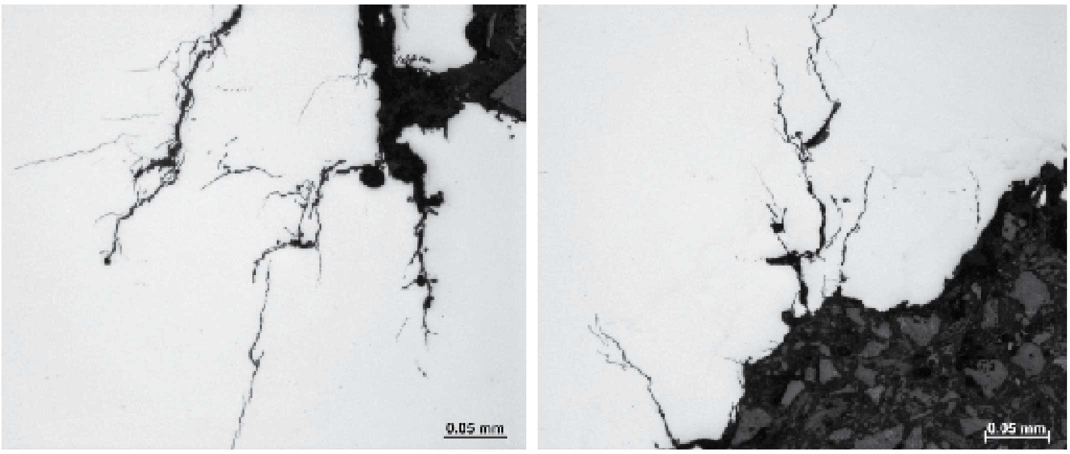

Figure 9

Metallographic section of band fracture face, showing branching crack paths

Analysis

The available evidence suggests that shortly after the APU bleed air valve was opened as part of the engine start procedures, the V-band clamp joining two sections of APU bleed air duct in the rear equipment bay failed, releasing hot bleed air into the rear equipment bay. The bleed air was of sufficiently high temperature to cause auto-ignition of the Ardrox AV8 corrosion inhibitor present on the aircraft's structure in the rear equipment bay. This in turn caused scorching, possibly a localised fire and generation of a significant quantity of smoke. Once the crew was aware of the presence of the smoke emanating from the rear of the aircraft, the action of shutting the APU down removed the source of leaking bleed air.

Human factors

Following the event the crew did not recall observing a WING-BODY OVERHEAT warning light on the air conditioning overhead panel, however when later tested the wing-body overheat detection system was found to be serviceable. One possibility is that the MASTER CAUTION and air cond annunciator light remained lit after the APU bleed air valve was opened, as normal, but when the V-band clamp failed the only indication of an overheat condition was the additional WING-BODY OVERHEAT warning light on the overhead panel. As no aural warning accompanies the WING-BODY OVERHEAT light, and the warning light is in the co-pilot's peripheral vision during engine start, it may not have been observed.

A second possibility is that the first MASTER CAUTION was cancelled but when it recurred, together with the air cond annunciator, the co-pilot looked at the overhead panel and observed the DUAL BLEED warning light, which is what he expected to see, and did not notice the WING-BODY OVERHEAT warning light.

The cause of the fire warning bell to sound was probably due to the presence of smoke in the main cargo deck, entering the cargo deck via the floor grating above the rear equipment bay. As the main cargo deck smoke detection system was found to be serviceable after the event, it is probable that the glareshield FIRE warning buttons and the main cargo deck

SMOKE caption were illuminated, but by this time the crew was aware of the smoke in the rear of the aircraft and were already taking mitigating actions.

Clamp failure

The metallurgical evidence shows that the V-band clamp failed as a result of stress corrosion cracking, and that the crack propagation had taken place over a considerable period of time. The tensile loading in the clamp's outer band, necessary for securing the duct joint, is applied by tightening the clamp's locking nut. Whilst the projection of the clamp's bolt beyond the locking nut as found after the incident did not indicate over-tightening of the clamp, it was not possible to eliminate previous over-tightening of the clamp as a contributory factor in the clamp's eventual failure. The position of the clamp in the rear of the rear equipment bay, in close proximity to the aft pressure bulkhead, renders visual examination for cracking difficult. Furthermore it was not possible to determine exactly when the cracks had formed in the clamp's outer band and it is possible that they were below the size detectable by visual inspection when the aircraft underwent its most recent 1C maintenance inspection.

Safety action

The operator is replacing the V-band clamps at the failure location on TF-BBF across its fleet of 737-300 and 737-400 aircraft. This is being carried out on a rolling programme, as the aircraft undergo scheduled C-check maintenance inspections. The operator is also considering replacement of other V-band clamps on their aircraft where the release of bleed air may create a hazard.

Conclusion

Shortly prior to engine start, a V-band clamp failed on the APU bleed air duct in the rear equipment bay. This led to a leak of hot bleed air which heated corrosion-inhibitor material in the rear equipment bay, resulting in scorching and the release of smoke into the main cargo deck. The flight crew were made aware of the presence of the smoke and shut the APU down. The V-band clamp failed due to stress corrosion cracking and the operator is currently replacing this clamp on its fleet of 737 aircraft during scheduled C-check maintenance inspections.

SERIOUS INCIDENT

Aircraft Type and Registration:	Bombardier BD-700-1A11 (Global 5000), VP-CKM
No & Type of Engines:	2 Rolls-Royce BR700-710A2-20 turbofan engines
Year of Manufacture:	2012
Date & Time (UTC):	15 November 2016 at 0138 hrs
Location:	On approach to Hong Kong International Airport
Type of Flight:	Private
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	6,820 hours (of which 623 were on type) Last 90 days - 58 hours Last 28 days - 22 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was on an approach to Runway 07L at Hong Kong International Airport and descended to 390 ft amsl at a point on the procedure where its cleared altitude was 1,700 ft amsl. Acute fatigue and ineffective crew communication meant that the pilots did not have an accurate mental picture of their situation and did not appreciate they had descended below their cleared altitude. The evidence suggested that the operator did not monitor the professional standards of the crew, or ensure its Standard Operating Procedures (SOPs) were effective and being used consistently, and that this contributed to this serious incident.

History of the flight

Departure, cruise and descent

VP-CKM departed Beijing Capital Airport, China, at 2245 hrs UTC (0645 hrs local) for a private flight to Hong Kong International Airport in China with the commander as Pilot Flying (PF).

During the cruise, the commander commented to the co-pilot on several occasions that he was tired, stating at one point "I NEED TO STRETCH; I AM LOSING IT" before leaving the flightdeck for approximately nine minutes. The co-pilot did not refer to being tired.

While the commander was briefing the co-pilot for the ILS approach to Runway 07L at Hong Kong International Airport, ATC instructed the aircraft to descend to FL 8,400 m[1]. The co-pilot read back 8,300 m, which was corrected by the Air Traffic Control Officer (ATCO), and the correct level was set on the Flight Control Panel (FCP)[2]. The commander then completed his approach briefing.

After approximately 15 minutes, the commander left the flightdeck to fetch a hat because the sun was impairing his visibility. While he was away, ATC instructed the aircraft to descend to FL240 which was the first level to be given in 'feet'. The co-pilot read back the clearance correctly but set 2,400 m on the FCP. He advised the commander in the cabin that they were "heading on down to two four zero" but the commander questioned the cleared level on his return to the flightdeck. The co-pilot said "yes … twenty four hundred metres" as the aircraft descended through FL260. Before reaching FL240 the aircraft was cleared to descend to FL230 which was set correctly on the FCP.

The commander questioned the co-pilot again about the previous level of 2,400 m. The co-pilot replied "it was two thousand four hundred, now it's two thousand three hundred". The commander responded "two thousand three hundred feet, right … you had metres". The co-pilot checked with ATC saying "just want to verify that still flight level two thousand three hundred feet". The ATCO did not answer but instructed the crew to contact Hong Kong Radar. The commander then said "you're in feet … okay".

On contacting Hong Kong Radar, the co-pilot reported the aircraft level as "two thousand three hundred feet", although it was actually at FL230, and this was corrected by the commander. The ATCO cleared the aircraft for the SIERRA 7A Standard Instrument Arrival and, at 0128 hrs (0928 hrs local), transferred the flight to Hong Kong Approach Control.

Standard Instrument Arrival

The weather at the airport was reported as: wind from 310° at 7 kt, 3,800 m visibility, no cloud, a temperature of 15°C and a QNH of 1017 hPa. The commander recalled that the weather was "very bright and very hazy". The aircraft was cleared to descend to 4,000 ft amsl, using a QNH of 1017 hPa, and to proceed direct to LIMES, the first waypoint on the ILS[3] approach to Runway 07L at the airport (Figure 1). The co-pilot read back the altitude correctly but told the commander that the QNH was 1011 hPa. The commander advised the co-pilot he was incorrect but the co-pilot disagreed, reading from the ATIS[4] that the airport QNH had been reported as 1016 hPa. The commander did not respond. Twenty seconds later, the aircraft was cleared to route direct to waypoint LIMES and the co-pilot asked the ATCO to confirm the QNH. On hearing that it was 1017 hPa, he commented to the commander that he (the commander) had been correct. The commander did not respond.

Footnote

1 Flight levels were being given in metres in the Guangzhou Flight Information Region (ZGZU).

2 The pilot can control the aircraft through the FCP by selecting navigation guidance modes and target values for parameters such as heading, airspeed, altitude and rate of climb or descent. The selected altitude on the FCP may be entered in either feet or metres. See later section *Automatic Flight Control System (AFCS).*

3 Instrument Landing System: a precision approach using electronic localiser and glideslope signals to guide the aircraft to the runway laterally and vertically respectively.

4 ATIS: Automatic Terminal Information Service.

At 0132 hrs, the ATCO cleared the aircraft to descend to 3,000 ft amsl and proceed from LIMES to TONIC. Shortly thereafter, he gave the clearance: "FROM TONIC, CLEAR ILS 07L". This was not acknowledged by the co-pilot but, 20 seconds later, the ATCO cleared the aircraft for the ILS approach, which was acknowledged. Having been cleared for the ILS approach, the aircraft was expected to proceed to TONIC, turn right onto a track of 040°M and intercept the localiser signal, which would provide lateral guidance towards the runway (shown in Figure 1 by the black line marked with the localiser course of 073°).

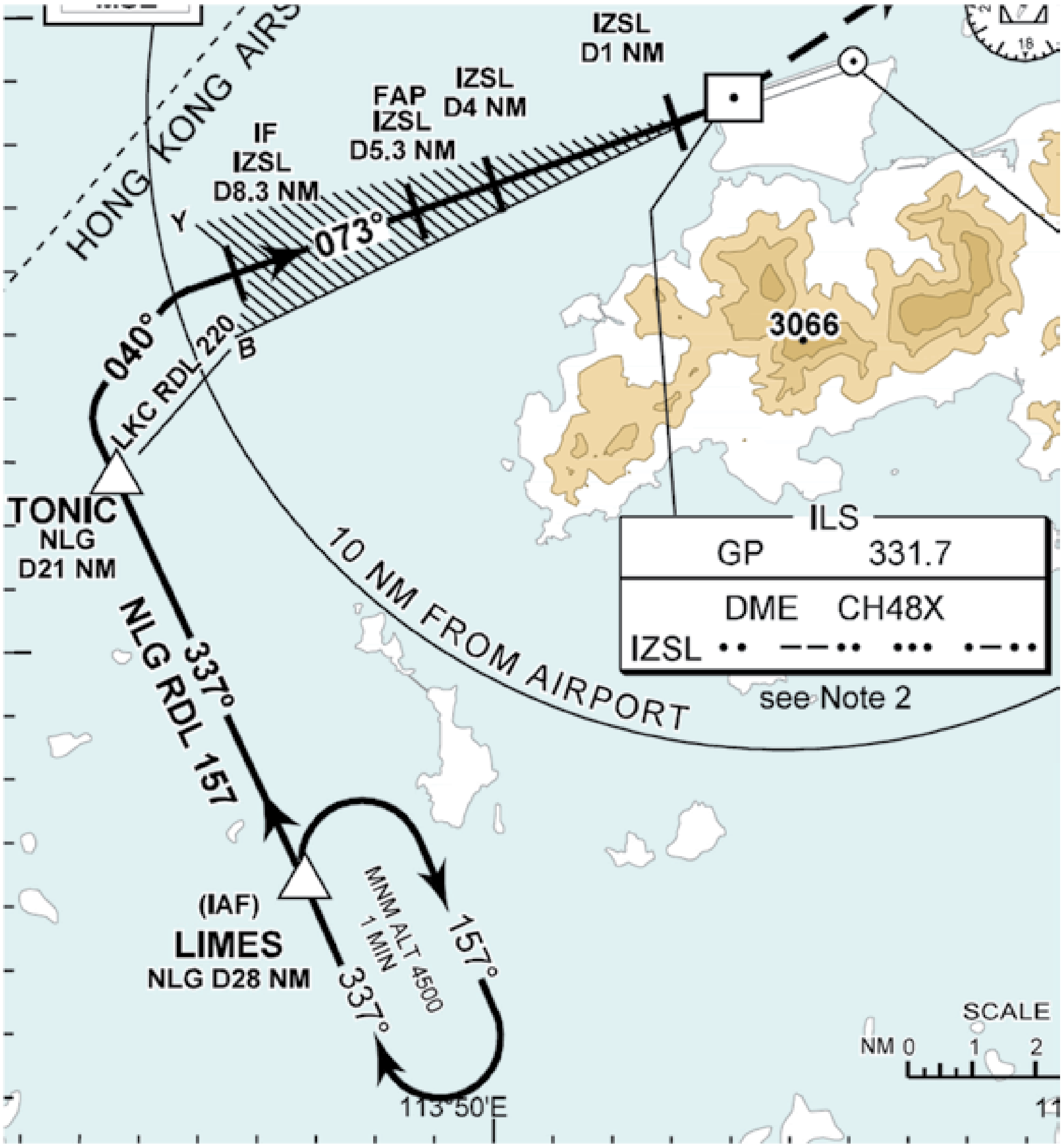

Figure 1

Plan view of the ILS for Runway 07L from the Hong Kong AIP
(valid at the time of the incident)

Figure 2, showing the vertical profile of the ILS 07L approach, indicates that, once cleared for the ILS approach and past LIMES, VP-CKM was permitted to descend to not below 1,700 ft amsl (shown in yellow). The aircraft was then expected to fly not below 1,700 ft amsl until intercepting the glideslope, which would provide vertical guidance towards the runway (shown in Figure 2 by the black line marked '*GP 3.0°*').

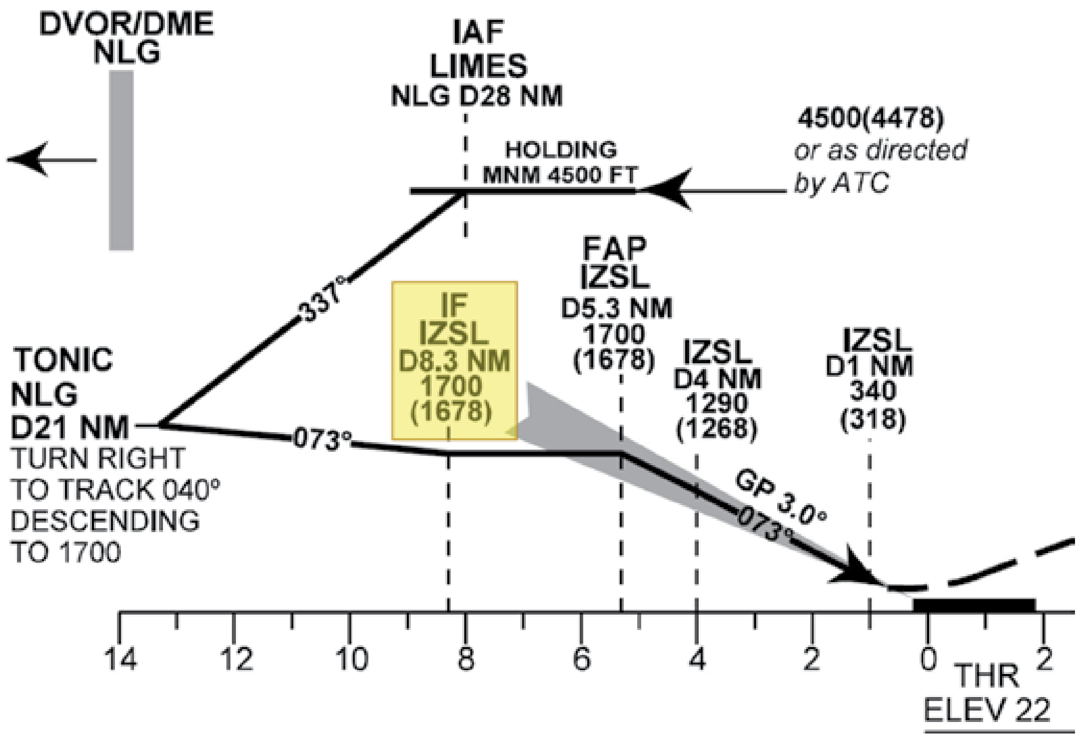

Figure 2

Vertical profile of the ILS for Runway 07L from the Hong Kong AIP

As the aircraft approached TONIC, it was at 3,000 ft amsl with the autopilot engaged in navigation (NAV) and altitude hold (ALT) modes[5] and, after passing the waypoint, the co-pilot displayed the approach chart on his electronic flight display (Figure 3). The approach chart contained information related to both the ILS 07L and LOC[6] 07L approaches (in the lower part of Figure 3, the vertical profile of the ILS approach is shown by a solid line and, for the LOC approach, by a broken line). The co-pilot confirmed that they had been cleared to fly the approach and this was acknowledged by the commander. Approach (APPR) mode was selected on the FCP, thereby arming the localiser and glideslope modes[7]. Shortly thereafter, an altitude of 1,000 ft was selected on the FCP, followed by vertical speed (V/S) mode with a descent rate of 1,100 fpm, and the aircraft began to descend.

Footnote

5 See later section: Automatic Flight Control System (AFCS).
6 A LOC approach is a non-precision approach using the ILS localiser signal but not the glideslope signal.
7 The localiser and glideslope modes change automatically from armed to active when the respective guidance signal is intercepted.

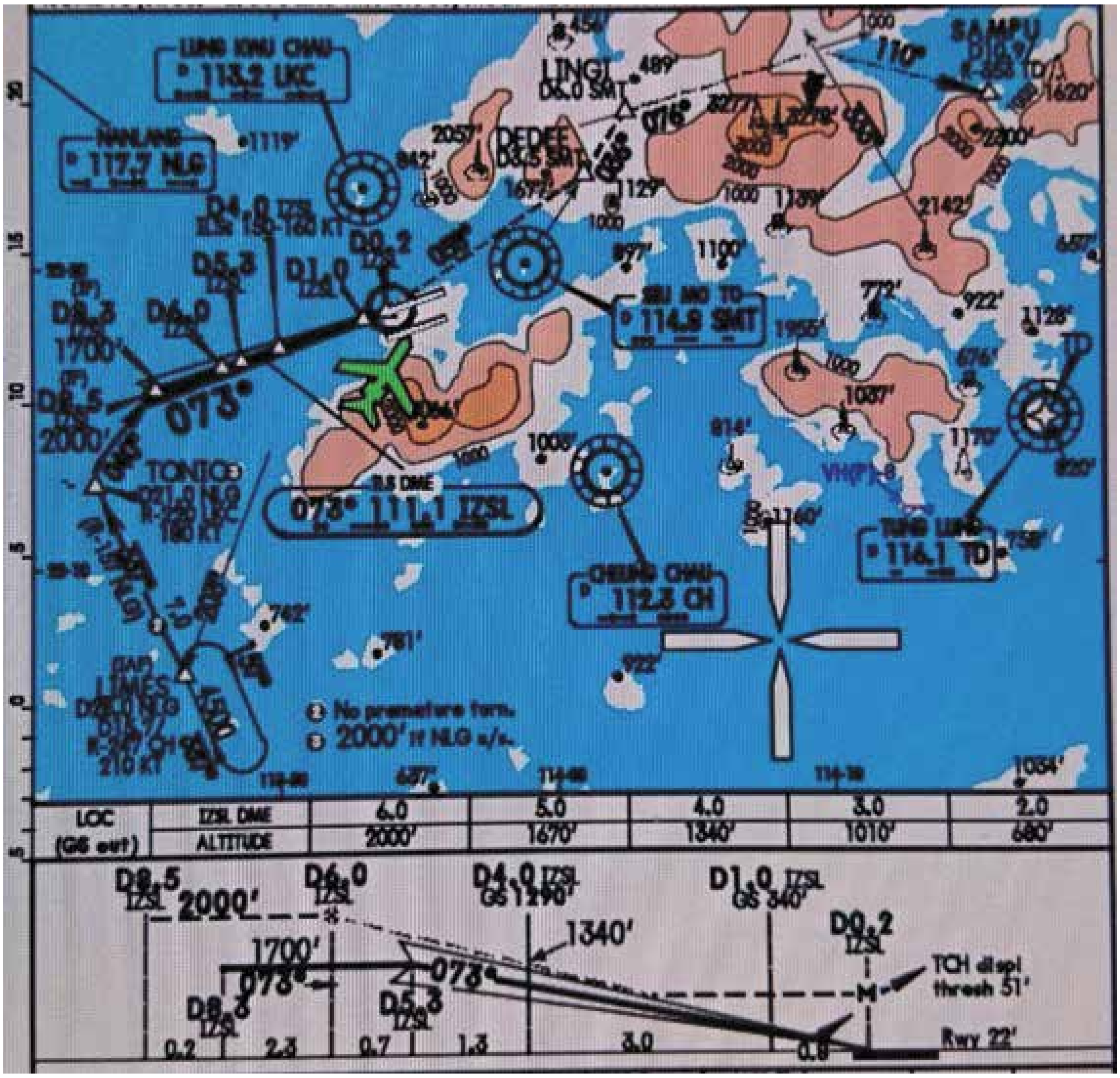

Figure 3

A section of the *ILS or LOC 07L* approach chart shown on the electronic flight display

Final approach

At 0135 hrs, as the aircraft descended through 2,000 ft amsl, a tone was generated in the cockpit indicating that there was 1,000 ft to go before it would reach the altitude selected on the FCP. The navigation system commanded the autopilot to begin a turn to the right in accordance with the procedure and, with the aircraft descending through the minimum cleared altitude of 1,700 ft amsl (Figure 2), the commander asked to what altitude the aircraft could descend. The co-pilot replied that, after TONIC they could descend to 2,000 ft amsl "OR LOWER". The commander queried the altitude and the co-pilot replied: "YOU'RE CLEAR FOR THE APPROACH … IT'S SHOOTING FOR 1,340 WHICH IS 4 DME". During this exchange, as the aircraft descended through 1,550 ft amsl, the commander disconnected the autopilot and selected a heading of 016°M on the FCP, and the co-pilot selected an altitude of 2,000 ft amsl on the FCP.

As the aircraft approached the runway centreline the commander began a right turn to intercept the localiser signal using an angle of bank which reached a maximum of 44°. As the bank angle increased, the pitch attitude decreased to a maximum of 4° nose-down and the rate of descent increased rapidly to 3,600 fpm. At 1,000 ft amsl, the Terrain Awareness Warning System (TAWS) generated a "SINK RATE[8]" aural caution and, shortly afterwards, the aircraft rate of descent reduced to 1,900 fpm. Immediately after this caution, the commander said "OK GIVE ME ... UH … FLAPS 16". The co-pilot acknowledged the command (although he selected FLAP 6) before saying JUST HOLD YOUR ALTITUDE RIGHT THERE. DON'T DESCEND ANY MORE". Two seconds after the "SINK RATE" caution, a configuration "GEAR[9]" aural alert was triggered seven times. Following the seventh alert, the commander asked for the landing gear to be selected DOWN, which the co-pilot did as the aircraft descended through 760 ft amsl.

The co-pilot asked the commander why they were still descending and, although there was no response, the aircraft's pitch attitude was adjusted and the rate of descent reduced. As the aircraft descended past 540 ft amsl, the co-pilot reported to ATC that the aircraft had intercepted the localiser. The ATCO asked the crew to confirm the aircraft's altitude and, at the same moment, with the aircraft at 520 ft amsl, the TAWS "GLIDESLOPE[10]" aural alert was triggered. Fourteen seconds later, the TAWS "TERRAIN; TERRAIN[11]" aural warning was followed by a "PULL UP[12]" aural warning as the aircraft reached a minimum altitude of 390 ft amsl. Six seconds later, the co-pilot said to the commander "GET IT UP TO A THOUSAND … GET UP TO A THOUSAND FEET" and, although the commander did not reply, the aircraft had already begun to climb.

As the aircraft climbed through 1,000 ft amsl, a tone was generated in the cockpit indicating that there was 1,000 ft to go to before it would reach the altitude selected in the FCP (2,000 ft). At 0137 hrs, the co-pilot said: "YOU'RE 5.5 MILES OUT; HOLD YOUR ALTITUDE RIGHT HERE; THIRTEEN HUNDRED". The aircraft continued to climb to 1,640 ft amsl before intercepting the glideslope signal and landing without further incident. During the final approach, and again after landing, the commander said "I'M SO TIRED I CAN'T SEE STRAIGHT".

Information from the pilots

Commander

The commander recalled that the crew arrived at the hotel at approximately 2200 hrs local time the night before the flight. He went to bed at about midnight but did not sleep well and received his crew wake-up call at 0300 hrs.

Footnote

8 A TAWS Mode 1 Caution indicating an excessive descent rate (based on a comparison of radio altitude and descent rate).

9 An aircraft configuration warning indicating that the gear is not down. It is triggered by a comparison of radio altitude, rate of descent, throttle angle and slat/flap control lever position.

10 A TAWS Mode 5 alert triggered when the flightpath is below the glideslope by more than a set margin during an ILS approach. In this case, it was a 'soft alert' indicating glideslope deviation of more than 1.3 dots on the ILS display.

11 A TAWS Mode 2A Caution enabled when a high terrain closure rate is sensed while the flaps are not in position for landing. Initial penetration into the Mode 2A envelope leads to a GND PROX message on the Attitude and Direction Indicator (ADI) and an aural message "TERRAIN TERRAIN".

12 A TAWS Mode 2A Warning indicating continued penetration into the Mode 2A envelope. It generates a PULL UP message on the ADI and a voice warning "PULL UP".

The commander recalled that, after passing TONIC, the aircraft did not appear to be capturing the localiser signal, so he disconnected the autopilot to fly the aircraft manually. Because he was confused by the co-pilot's answer to his question about the cleared descent altitude, he tried to confirm the information from his own chart. He believed that this, combined with fatigue and "hazy" flight conditions meant he did not realise the aircraft was descending below the approach profile. He recalled that he initiated a climb when he heard multiple GPWS[13] warnings including "PULL UP".

The commander stated that he was tired and was distracted by the co-pilot who had missed or misunderstood some radio transmissions during the flight. He was confused about what the co-pilot was doing and this increased his workload. He stated that the arrival was rushed and required multiple changes to the Flight Management System (FMS) "with my pilot monitoring becoming more of a distraction than an assisting crew member, contributing to the deterioration of crew resource management and situational awareness".

Co-pilot

The co-pilot reported that the commander had indicated that he was tired before leaving the hotel but had rejected the co-pilot's suggestion that he (the co-pilot) should operate the flight as PF. The commander did not recall this conversation.

The co-pilot expected the autopilot to remain engaged until just before the landing because the FMS had been programmed to fly the arrival and approach. He was surprised when the autopilot was disconnected and commented that this, along with the commander's "non-standard SOPs", increased his workload. He believed that he was distracted from his monitoring role by ATC and checklist requirements, leading him to miss the fact that the aircraft was descending below the approach profile.

While he was instructing the commander to climb the aircraft, he was also holding the flight controls and considering taking control. However, he felt some resistance from the PF through the controls and did not want to compound the situation by forcibly taking control at such a critical time, especially since he considered the commander to have "a very aggressive attitude". He stated that he found the commander difficult to fly with and "it causes problems if [I] do not do things [his] way".

Information from Hong Kong Airport ATC

To comply with the published ILS RWY 07L Approach procedure, an aircraft that has been cleared for the approach is not permitted to descend below an altitude of 1,700 ft until established on the glideslope. In this case, clearance for the approach was given by ATC when the aircraft was maintaining 3,000 ft and the controller expected the aircraft to descend as per the procedure. When the co-pilot reported that the aircraft was established on the localiser, the controller noticed that the aircraft was low and requested the crew to confirm the aircraft's altitude. The crew responded that they were "visual" and "correcting". Because the aircraft was significantly below the published altitude, the controller asked

Footnote

13 GPWS: Ground Proximity Warning System, which is a TAWS.

the crew to state the aircraft's altitude in order to verify that the altitude displayed on the surveillance system was within tolerance. After receiving the crew's response that the aircraft was at 400 ft, the controller gave position information to the crew immediately in order to assist them in building their situational awareness. The aircraft was subsequently observed climbing and the crew reported that they were established on the glideslope.

Pilot information

Commander

The commander had an FAA-issued Air Transport Pilot's Licence, with a type rating on the Global 5000 aircraft valid until 30 September 2017, and a First Class medical certificate, valid until 20 November 2017. He reported that he had a total of 6,820 hours of flying, including 623 hours on the Global 5000 of which 590 hours were in command.

Co-pilot

The co-pilot had an FAA-issued Air Transport Pilot's Licence, with a type rating on the Global 5000 valid until 3 October 2017, and a First Class medical certificate valid until 12 July 2017. He reported that he had a total of 6,500 hours of flying, including 580 hours on the Global 5000 of which 500 hours were in command.

Recorded information

A complete record of the accident flight was available from the aircraft's FDR including the status of the Automatic Flight Control System (AFCS), and cautions and warnings generated by the TAWS. The 120-minute duration CVR recording started when the aircraft was in the cruise, 520 nm to the north of Hong Kong, and ended when the aircraft was shut down after landing.

Selected data from the FDR are presented in Figure 4.

Note: the aircraft's altitude was derived by correcting the recorded pressure altitude for a QNH of 1017 hPa[14], and the aircraft's height above the surface of the sea was derived from radio altimeter data.

Information obtained from the recorded data and CVR was included in the earlier section *History of the flight*.

Recorded data showed that, during the approach, the commander's Head-up Display (HUD) was deployed and the Enhanced Vision System (EVS) was enabled. The Synthetic Vision System (SVS) was not enabled on the HUD or on either of the PFDs[15].

Footnote

[14] The recorded altitude values were based on the standard pressure datum of 1013 hPa.
[15] See later section for an explanation of EVS and SVS.

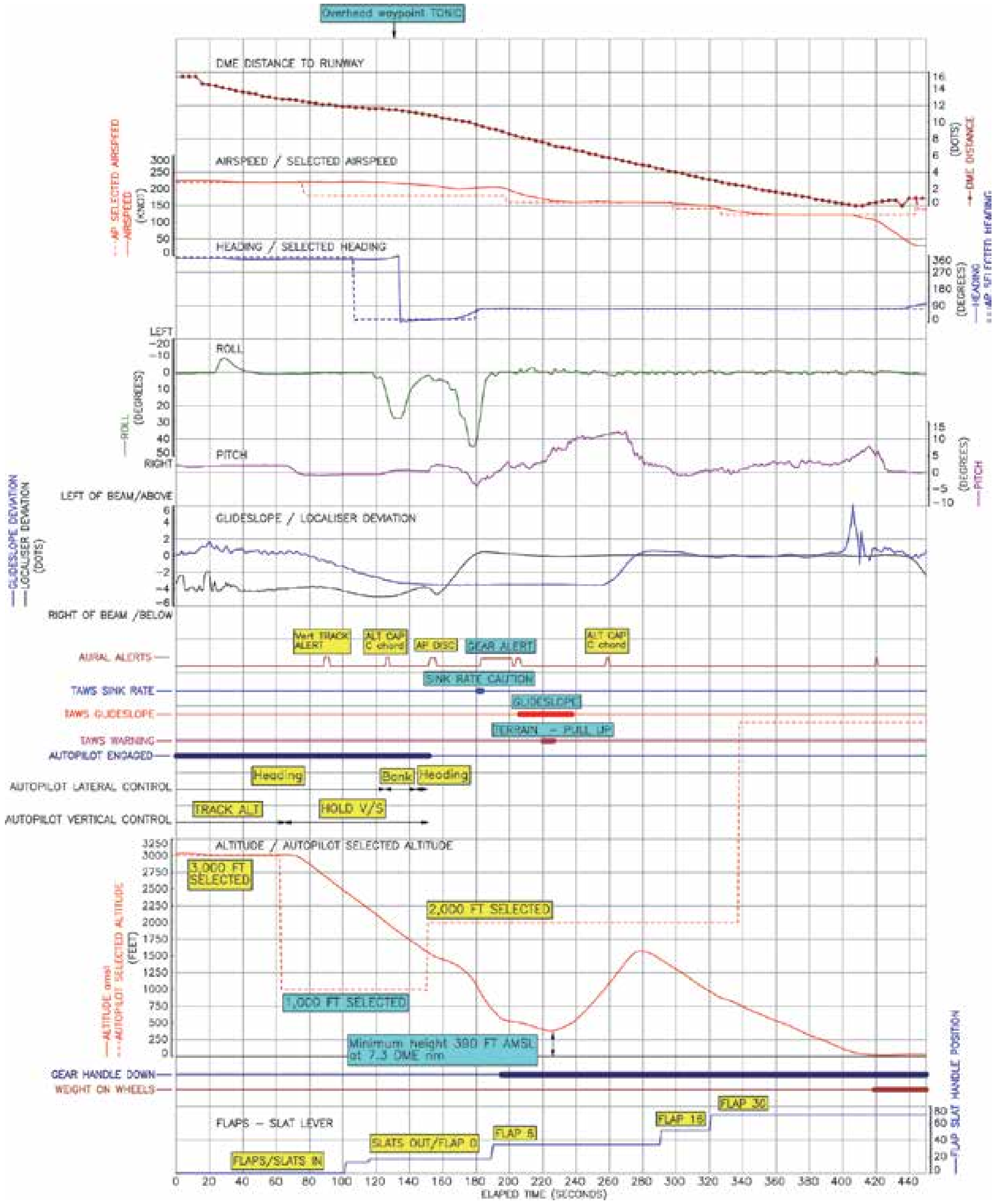

Figure 4

FDR data during the approach to Hong Kong Airport – Runway 07L

Automatic Flight Control System (AFCS)

The Bombardier Global 5000 is fitted with a dual-channel AFCS, which is integrated with the Flight Director (FD), dual-axis autopilot, automatic pitch trim and yaw damper. Flight guidance is computed by the AFCS and can be displayed on one or both Primary Flight Displays (PFDs). Guidance functions are grouped into either 'selected' or 'managed' modes. 'Selected' guidance is based on pilot-selected references, or targets, on the FCP, and 'managed' guidance is associated with lateral and vertical flight commands provided by the FMS. The FCP is located at the top of the instrument panel and is the pilots' primary interface with the AFCS (Figure 5).

Figure 5

Flight Control Panel
(taken from the Flight Crew Operating Manual)

AFCS indications are provided on each PFD and include the FD cue, flight path vector symbol and flight mode annunciations (FMA) (Figure 6). The FMA display, located at the top of the PFD, is divided into columns of text, separated by vertical lines. The display indicates the status of the autothrottle, the lateral and vertical modes, FD coupling and autopilot status. Active modes are shown in green at the top of their respective column, while armed modes are shown directly below them in white.

The FD function computes roll and pitch commands based on data from several systems and sensors, including attitude, heading, air data, radio altimeter, navigation and pilot reference inputs. A green flight path vector (FPV) provides vertical and lateral indications of the aircraft flightpath and a FD cue, which is magenta in colour, provides vertical and lateral steering commands.

Aircraft heading may be controlled manually by selecting heading select mode (HDG) on the FCP and setting the desired heading manually using the HDG knob. HDG is also a transition mode which, once engaged, remains active should either NAV or APPR mode be selected with the aircraft outside the respective mode's capture parameters. In such circumstances, the FD remains in HDG mode, providing heading guidance as selected by the pilot, until the aircraft arrives at a point where mode capture can occur.

The Approach mode provides for the automatic intercept, capture and tracking of the localiser and glideslope signals. The ILS is automatically tuned by the FMS when the aircraft is within 30 nm of the airfield. To prevent premature descent, the GS mode is not permitted to become active until the LOC mode is active.

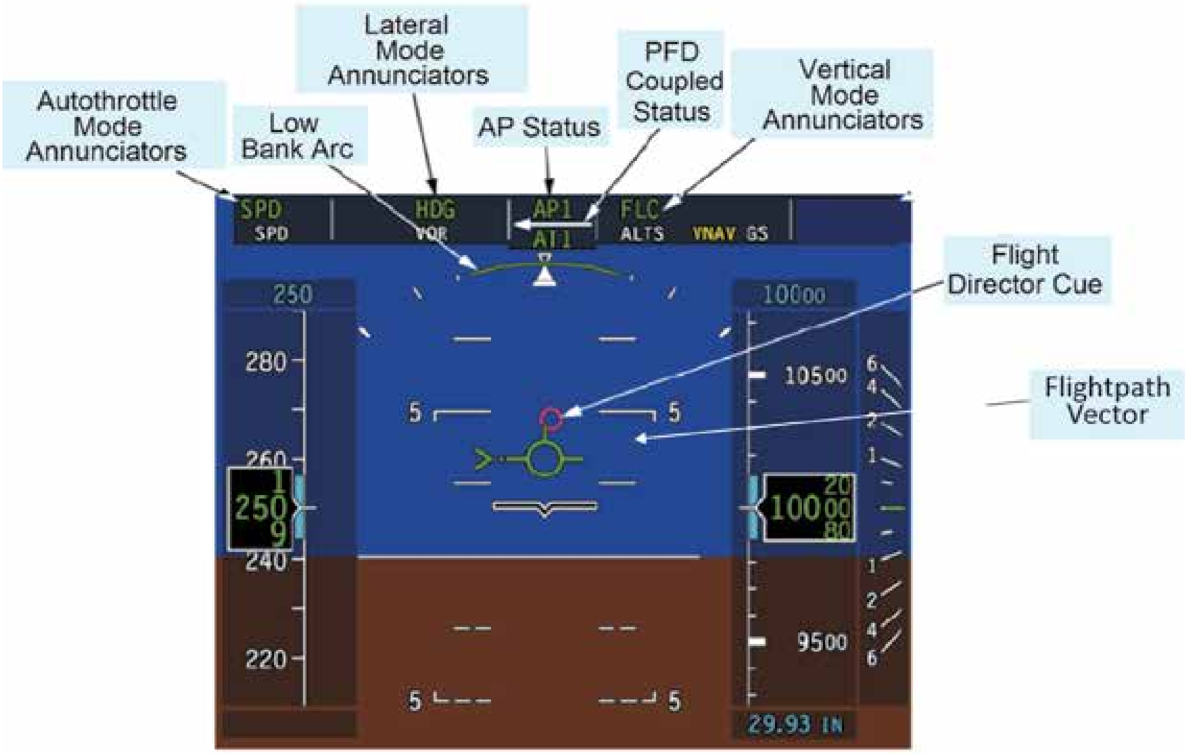

Figure 6

Primary Flight Display
(taken from the Flight Crew Operating Manual)

Enhanced Vision System (EVS) and Synthetic Vision System (SVS)

The EVS uses an infrared sensor to provide a thermal image of the external world ahead of the aircraft within a 30° field of view and is intended to aid situational awareness in conditions of poor visibility. It was displayed on the HUD during this event.

The SVS provides a computer-generated representation of the external environment, including terrain, obstacles, airports and runways. It can be displayed on the HUD and PFDs, although it was not in this event. The manufacturer commented that, had the SVS been selected on the PFDs, the crew might have noticed the flightpath vector symbol intercepting the surface before the runway symbology, indicating that the aircraft would hit the surface before reaching the runway.

Operational oversight of the operator

VP-CKM is registered in the Cayman Islands and oversight responsibility rests with the Civil Aviation Authority of the Cayman Islands (CAACI). The CAACI may issue a Private Flight Operations Approval (PFOA) to the operator of a private turbojet aircraft, such as VP-CKM, under Part 134 of the Air Navigation (Overseas Territories) Order. The requirements to operate such aircraft registered in the Overseas Territories are specified in the Overseas Territories Aviation Requirements (OTARs[16]). The Part 134 Approval may be obtained by an OTAR Compliance Assessment by the CAACI or, alternatively, through the completion of an International Standard for Business Aircraft Operations (IS-BAO)[17] Registration assessment conducted by the International Business Aviation Council (IBAC).

At the time of the incident the operator of VP-CKM had a PFOA valid until 31 January 2017. The operator submitted to an IS-BAO audit between 25 and 27 January 2017 which recommended a further one year IS-BAO registration, after which the PFOA was also renewed for a further year.

Operating Procedures - general

International Standard for Business Aircraft Operations

The IS-BAO encourages the use of best operating practices for business aircraft using Standards and Recommended Practices (SARPS) derived from ICAO[18] SARPS. Operators may implement requirements relevant to their operation and set aside those not relevant. Section 6.1 of IS-BAO discusses SOPs and states:

> *'SOPs are the foundation of effective crew coordination and a key component of crew resource management and threat and error management. Accordingly, operators of aircraft with two or more crew shall establish and maintain an SOP … that enables the crew members to operate the aircraft effectively. An operator that has established SOPs … shall ensure that …they are used by the crew.'*

IS-BAO Section 10, *Company Operations Manual* states:

> *'For non-commercial operations, the operations manual shall contain the SOPs and a fatigue management system.'*

National Business Aviation Association (NBAA)

The NBAA, which manages the IS-BAO registration process on behalf of the International Business Aviation Council (IBAC), publishes a Best Practices Manual which contains a section on SOPs. It states:

> *'Crew coordination is the effective delegation of responsibility and division of workload [and] is essential for the safe operation of aircraft. SOPs … create a standardised system whereby pilots become immediately aware of any departure from the normal sequence of events. The PF and PNF shall coordinate with each other prior to initiating the following:*

Footnote

[16] OTARs can be found here: http://www.airsafety.aero/Requirements-and-Policy/OTARs.aspx
[17] See next section for more information on IS-BAO.
[18] ICAO: International Civil Aviation Organisation.

> - *A change in aircraft configuration*
> - *A transferring of aircraft control*
> - *Selection or change of navigation equipment settings or frequencies*
> - *Checklist initiation and completion*
> - *A change in altitude.'*

Operator's Flight Operations Manual

Standard Operating Procedures

Shortly after this incident, on 21 November 2016, the operator issued a non-type specific *SOP Quick Reference Sheet* stating that, among other things:

a. Mode changes on the FCP were to be called out.
b. Changes in altitude were to be cross-checked.
c. A call was to be made when the aircraft was 1,000 ft from the assigned altitude.

Chief Pilot

The Operator's Flight Operations Manual (FOM) detailed the responsibilities of a Chief Pilot which included monitoring the professional standards of flight crew, the development of SOPs and ensuring crew scheduling complied with flight time limitations (FTL). The FOM required crews to follow type specific SOPs from the Airplane Flight Manual (AFM) and stated that:

> *'Standardisation/observation flights, and an internal audit program ensure that all personnel adhere to* [the] *SOPs.'*

The operator did not have a Chief Pilot at the time of the incident. On 5 December 2016, the operator appointed a Chief Pilot with responsibilities which included: "*Comply* [with] *the applicable relevant responsibilities for Chief Pilot listed in* [the operator's] *Flight Operations Manual".*

Fatigue management

According to the aircraft flight log, during the 17-day period from 28 October 2016 until the day before the incident, the crew flew the aircraft on four separate days. The maximum duty time was seven hours and the rest periods between flights were between two and four days.

The crew declared that, on the day before the incident, they were on duty from approximately 1510 hrs to 2010 hrs local time. They arrived at the hotel at approximately 2200 hrs local time and departed at 0400 hrs the following morning. Following the incident flight, the crew were off duty at approximately 1010 hrs.

The FOM stated that pilots were to observe the FTLs and not work when fatigued. The FOM defined a 'local night' as '*a period of eight consecutive hours falling between the period of 2200 and 0800 local time'.* The FTL table within the FOM required the crew to have 10 continuous hours off duty in any 24 hours.

Investigating fatigue

A paper by Clockwork Research[19] gives a methodology, adopted in this report, for analysing the effect of fatigue on an occurrence. The methodology considers whether an individual was suffering from fatigue, whether fatigue had an impact on performance, and whether fatigue may have been a contributory or causal factor to the occurrence.

For fatigue to have contributed to the occurrence, two conditions must be met:

a. At the time of the incident the individual was fatigued.

b. A change in performance consistent with fatigue contributed to the incident.

In determining whether an individual might have been suffering from fatigue, the methodology considers the opportunity for sleep, the sleep quality and quantity, other reasons for fatigue and/or sleep loss, and physical signs of fatigue.

In determining whether there was a change in performance consistent with fatigue, the methodology considers whether the following behaviours or characteristics were observed:

a. Reduced alertness, increased response times and impaired situational awareness.

b. Inefficient or ineffective communication.

c. Failure to react appropriately (or at all) to external stimuli.

In determining whether fatigue might have been a contributory or causal factor, the methodology considers whether the changes in performance had an impact on the sequence of events.

Analysis

Flightpath

The aircraft was cleared for the ILS approach to Runway 07L while approaching TONIC and was expected to follow the lateral path shown in Figure 1, and descend not below 1,700 ft amsl until intercepting the glideslope as shown in Figure 2. The autopilot was engaged and the flightpath was being controlled laterally by the FMS, which was in navigation (NAV) mode. The aircraft was flying level at 3,000 ft amsl in altitude hold (ALT) mode. In this configuration, the aircraft would have automatically followed the lateral path of the procedure and remained at 3,000 ft amsl.

Footnote

[19] Available from: http://www.clockworkresearch.com/publications/

When the commander selected APPR mode it armed the localiser and glideslope modes (LOC and GS). In this configuration, the aircraft would have turned onto 040°M after passing TONIC until it captured the localiser signal, when it would have turned onto the final approach course. It would subsequently have descended when it captured the glideslope signal. Instead, an altitude of 1,000 ft was selected on the FCP, vertical speed (V/S) mode was engaged and the aircraft began to descend. There was no announcement that the selected altitude had been changed to 1,000 ft.

As the aircraft descended through 1,700 ft amsl, the commander asked the co-pilot to confirm the cleared altitude. The co-pilot replied that they could descend to 2,000 ft amsl but then said "OR LOWER", which confused the commander. The co-pilot added that "IT'S SHOOTING FOR 1,340 WHICH IS 4 DME". The altitudes to which he was referring (2,000 ft and 1,340 ft) are shown on the lower portion of Figure 3 and relate to the localiser approach (LOC 07L), not the approach for which they were cleared (ILS 07L). Altitudes relating to both approaches were shown on the co-pilot's electronic approach chart. At approximately the same time as this verbal exchange, the co-pilot set 2,000 ft on the FCP and the commander disconnected the autopilot. The co-pilot did not announce that he had changed the selected altitude or why he had chosen 2,000 ft (although it corresponded with the minimum cleared altitude on the LOC 07L approach before descending with the procedure). However, because 2,000 ft was above the aircraft's altitude at the time, it meant the aircraft was descending in vertical speed mode without a target altitude below it. In this configuration, with the aircraft already below the glideslope, the FD cue, if followed, would have continued to command a descent until the aircraft struck the surface of the sea.

Operating procedures

The NBAA Best Practices Manual states that crews are to coordinate changes in aircraft configuration, altitude and navigation equipment settings. In this occurrence, the use of such coordination was sporadic and did not appear to follow a consistent, verbal format. Flight Level, altitude and other clearances were misheard or misunderstood and, although there was an approach briefing, the co-pilot appeared to have been referring to altitudes on his chart which related to the wrong approach. The commander felt that the co-pilot was becoming a distraction, the co-pilot found the commander difficult to fly with and, in the latter stages of the incident, warnings from the co-pilot and aircraft systems that the aircraft was too low and descending too quickly were not acknowledged verbally by the commander. It was concluded that the crew did not exchange sufficient information on altitude selections and aircraft control modes for them to share an accurate mental model of their situation. Consequently, they were not aware that they had descended below their cleared altitude with the aircraft navigation equipment set to command a descent into the sea.

The autopilot was disconnected despite the FMS having been set correctly to fly the approach automatically, and the hand-flown turn onto the localiser used a maximum angle of bank of 44° which led directly to the high rate of descent. It is likely that disconnecting the autopilot increased the workload for both pilots making it less likely that they would exchange sufficient information to keep the situation under control.

Fatigue

The following analysis follows the methodology discussed in the section, *Investigating fatigue.*

The crew arrived at the hotel at 2200 hrs local time and the wake-up call was at 0300 hrs but the commander stated he did not get to sleep until close to midnight and did not sleep well. The FOM classified a local night as eight hours between 2200 hrs and 0800 hrs. It was concluded that the crew did not have adequate opportunity to obtain a local night's sleep, and the sleep actually obtained was inadequate.

The co-pilot reported that, before the flight, he offered to operate the flight as PF in response to the commander indicating that he was tired (although the commander did not recall this conversation). During the cruise, the commander left the flight deck to stretch because, as he said, "I AM LOSING IT". Later in the flight, the commander said twice that "I'M SO TIRED I CAN'T SEE STRAIGHT", and during interview he stated that he had been tired. Despite the different recollections of the conversation before the flight, it was considered likely that the commander was suffering from acute fatigue. However, based on the amount of time the crew had free of duty between 28 October 2017 and this incident, it was unlikely they were suffering from cumulative fatigue.

The earlier discussion on operating procedures supports a conclusion that communication between the pilots could be classified as inefficient or ineffective. The section *History of the flight* shows that the commander did not respond to the co-pilot on a number of occasions as the aircraft descended, although it is possible that this was partly because he was finding the co-pilot to be a distraction. It was concluded earlier that the pilots were not aware that they had descended below their cleared altitude, and it was likely that their understanding of that cleared altitude was, itself, incorrect ie the co-pilot appeared to be using altitudes relating to the incorrect approach. Finally, the commander did not acknowledge or react decisively to system alerts or co-pilot warnings about the low altitude and high rate of descent. It was likely, therefore, that the commander's performance was impaired due to fatigue. It was also considered likely that the impaired performance contributed to the sequence of events.

Operational oversight

IS-BAO considers that SOPs enhance crew coordination and error management and expects operators to ensure they are used. The operator's FOM stated that standardisation flights and an internal audit program would ensure crews adhered to SOPs, and the Chief Pilot would monitor professional standards, develop SOPs and ensure crew scheduling complied with FTL. In this incident, ineffective use of SOPs contributed to the sequence of events, and scheduling did not comply with FTL because the crew did not have the opportunity for a local night's rest. It was not clear whether the operator carried out standardisation flights and/or audits, because it did not respond to requests for relevant information. However, there was no Chief Pilot and it was likely that professional standards and the proper use of SOPs were not being monitored effectively. After this event, the company appointed a Chief Pilot and, subsequently, renewed its registration with IS-BAO.

Conclusion

The aircraft's FMS was set correctly to fly the approach and the autopilot was engaged when a descent was initiated towards 1,000 ft amsl in vertical speed mode. At 1,550 ft amsl, the commander disconnected the autopilot at approximately the same time that the co-pilot selected the target altitude to 2,000 ft amsl. The aircraft was then being flown manually with the FMS set such that, if the FD was followed without further intervention, it would have commanded a descent until the aircraft struck the surface of the sea.

It was concluded that the crew did not exchange sufficient information to share an accurate mental model of their situation and, consequently, were not aware that they had descended below their cleared altitude. Disconnecting the autopilot increased their workload, making it less likely they would regain an awareness of the situation, and made it necessary to fly the turn onto the localiser manually, which led directly to a high rate of descent and to TAWS cautions and warnings. Shortly after the first TAWS warning, the co-pilot told the commander not to descend any further. However, the commander did not respond decisively to the co-pilot's warnings or system alerts until the aircraft was below 500 ft above the surface. Acute fatigue and a breakdown of SOPs within the flight deck led to the ineffective communication between the pilots. It was likely that the operator was not effectively monitoring the professional standards of its crews, or their use of SOPs, because it had no Chief Pilot and this made the ineffective communication more likely.

BULLETIN CORRECTION

When originally published the report stated incorrectly that the aircraft involved in the serious incident was a Bombardier Global Express BD700. The aircraft was a **Bombardier BD-700-1A11 (Global 5000)**.

The online version of the report was amended on 22 December 2017.

AAIB Correspondence Reports

These are reports on accidents and incidents which were not subject to a Field Investigation.

They are wholly, or largely, based on information provided by the aircraft commander in an Aircraft Accident Report Form (AARF) and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

INCIDENT

Aircraft Type and Registration:	Agusta AW139, G-CIPW
No & Type of Engines:	2 Pratt & Whitney Canada PT6C-67C turboshaft engines
Year of Manufacture:	2013 (Serial no: 41344)
Date & Time (UTC):	9 June 2017 at 1625 hrs
Location:	Viscount Platform, North Sea
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	13,840 hours (of which 444 were on type) Last 90 days - 70 hours Last 28 days - 24 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot plus operator's internal investigation and subsequent AAIB enquiries

Synopsis

The crew approached and landed on what they mistakenly believed to be the correct offshore platform. However, the crew had not appreciated that the planned destination had been changed and, in part, this happened because certain platforms can be referred to using different identifiers. When the crew realised they had landed on the wrong, unmanned platform, they lifted off and continued to the correct platform without further incident.

An internal investigation by the helicopter operator recommended several actions which may be implemented to prevent such an incident recurring. This AAIB report also provides information concerning activities being undertaken across the offshore helicopter industry, by a trade association, to prevent Wrong Deck Landings (WDLs).

History of the flight

On the evening before the flight, the crew were e-mailed a schedule for the following day; to depart Norwich Airport at 1500 hrs for a charter flight to the Kelvin platform, LOGGS[1], the Viscount platform, then back to LOGGS before returning to Norwich. During the evening

Footnote

[1] LOGGS is the name for a complex of five interlinked platforms which are central to the Lincolnshire Offshore Gas Gathering System.

this route was input to the crew Flight Planning Software (FPS) by operations staff as '*NWI-KELVIN-LOGGS-VISCOUNT-LOGGS-NWI*', where NWI is the IATA code for Norwich Airport.

When the crew reported for work the next day, at 1200 hrs, the co-pilot was passed a paper '*Route Strip*' from the flight operations department which showed the details of the charter, including the expected payload for each sector. On this strip the routing appeared as '*NWI-KELVIN-LOGGS-OD-LOGGS-NWI*' but in the FPS the name '*VISCOUNT*' was still shown, rather than the helicopter operator coded identifier '*OD*'.

The co-pilot knew that the chartering company, which also operated the platforms, used different identifiers for certain platforms but he was not fully familiar with all of them and he assumed that '*OD*' was an alternative identifier for the Viscount platform. He therefore planned the flight on this basis and when he and the commander later discussed the task they referred to the routing in the FPS, which still showed '*VISCOUNT*' as one of their destinations. They were not informed that, after the chartering company first specified the Viscount platform (using its own identifying code of '*VO*') to the helicopter operator, it subsequently asked for this be changed to the Vampire platform, which it identified using the code '*OD*'.

The commander overlooked the paper strip and referred only to the route in the FPS, which was as he expected; including the sector to the Normally Unmanned Installation (NUI) known as Viscount, to pick up a group of workers who had been dropped off there earlier in the day by another helicopter crew. During their flight preparation, the pilots focussed attention on a forecast of thunderstorms, electing to carry extra fuel because of this.

After departing NWI, the pilots flew uneventfully to Kelvin and then to LOGGS with the commander as Pilot Flying (PF) while the co-pilot, acting as Pilot Monitoring (PM), was responsible for inputting the route into the Flight Management System (FMS). They departed LOGGS without any payload, so there was no need for them to be handed a manifest which would have noted the destination for any passengers or cargo. They informed the radio operator on LOGGS that they were lifting to go to Viscount but he did not identify the variance from the routing he was expecting, which was for them to go to the Vampire platform.

Inbound to Viscount, the PM radioed the Helicopter Landing Operator (HLO) who formed part of the team of workers waiting to be picked-up at Vampire. Because the HLO was using a portable radio, the pilots were not surprised that the received signal strength was weak and, despite asking the HLO to repeat his message, they were unable to hear the name of the platform. All they could distinguish was "…deck is available".

After completing their landing checks the crew confirmed the name painted on the platform was 'VISCOUNT' and then landed normally (Figure 1). Once on the helideck they realised there were no passengers for them and consequently they discovered they should have flown to the Vampire platform. They subsequently lifted from Viscount flew to Vampire and then completed the remainder of their task without further incident.

Figure 1

The Normally Unmanned Installation (NUI) known as Viscount

Commander's comments

Following the incident, the commander observed that on the '*Route Strips*', handed to pilots before a flight, some platforms tend to be referred to by the platform operator's identifier while some are referred to using an abbreviation of their name. This system has developed over a number of years and consequently Viscount appears on the strips as '*VISC*' but Vampire appears as '*OD*'. While the commander was conversant with this system, it occurred to him that his local knowledge was probably better than that of his co-pilot, who had only been based at NWI for a few months. The commander observed that this was the first time he had experienced a discrepancy between the strip supplied by flight operations and the FPS.

Despite the difficulty created by the different naming conventions, the commander stated that sufficient time was available for flight planning and he could have cross-checked the route shown on the strip against the route in the FPS. He also noted that he had been partially distracted by the forecast for thunderstorm activity and highlighted other contributory factors, which were later included in the helicopter operator's incident report. The co-pilot, in his role as PM, entered the route into the FMS, and this was the route the commander was expecting to see, so he readily accepted it.

Helicopter operator's investigation

Following an internal investigation the helicopter operator produced a report with a number of recommended safety actions which are being considered:

- The helicopter operator should liaise with the charterer (the platform operator) and agree an identification system for the various platforms. It was noted that the two platforms involved in this incident are in the process of being de-activated as the gas field in which they are located is expected to shut down in 2018.

- The helicopter operator should ensure that, before each takeoff, the charterer passes the crew a manifest for the next leg to be flown, even when no passengers or cargo are carried.

- The helicopter operator should eradicate the use of paper '*Route Strips*', by altering the practices used in its flight operations department and ensuring that updated route information received from the charterer is input directly to the FPS.

- The helicopter operator should liaise with the charterer to train HLOs so they only use agreed terminology and do not state a helideck is available until they believe the helicopter that has called them on the radio is making its final approach. It is appreciated that this may not be practical in poor weather, when a helicopter's on-board radar is used for approach guidance.

- An overview of the lessons learnt from this incident will be shared amongst all the helicopter operator's pilots.

CAA comment

The CAA noted that helicopters operating across the North Sea carry a paper '*Rig Map*' and at the time of the incident this showed the identifier '*VO*' as relating to the Viscount platform and '*OD*' to the Vampire. Use of this chart might have alerted the crew to the conflicting information they were given.

WDL prevention

Following several WDLs[2], one offshore helicopter operator commissioned a detailed study by a company with specialist knowledge of human performance in aviation. The study was later adopted by HeliOffshore, a global trade association for the offshore helicopter industry with over 100 member organisations[3], and the resulting report, dated 11 December 2015, identified 71 causal factors of WDLs and made 19 recommendations aimed at resolving the issue. This WDL report can be viewed by following a link from HeliOffshore's '*Resources*' web page.

Some of the WDL report's recommendations are relevant to this incident. Recommendation 4 suggests a focus on WDL risks during Crew Resource Management (CRM) training, while Recommendation 7 advocates the introduction of improved Threat and Error

Footnote

2 The AAIB has investigated some of the WDLs recorded in UK waters in recent years. For example PH-EUJ in AAIB Bulletin 9/2017, G-VINB in AAIB Bulletin 7/2017, G-VINL and G-CHBY both in AAIB Bulletin 6/2016.

3 HeliOffshore's website can be found at http://helioffshore.org/

Management (TEM) procedures, to help crews cope with the threat of mis-identifying their intended landing platform. Recommendation 9 advocates that routes allocated to crew be downloaded directly to the helicopter's FMS by the operator, thus eliminating the possibility of crews inputting an incorrect destination.

To help crews ensure they are making their final approach to the correct platform, Recommendations 13 and 14 suggest that, when possible, there should be a radio exchange with the HLO (or equivalent) who should, in most instances, be able to see there is a helicopter close to the platform before indicating the helideck is available. The most relevant recommendation to this incident (and also to the one involving PH-EUJ mentioned at Footnote 2), is for the industry and its regulators to introduce an agreed protocol for offshore platform identifying codes.

In May 2016, in response to the WDL report, HeliOffshore, in collaboration with the International Association of Oil and Gas Producers (IOGP) wrote to regulators, original equipment manufacturers, operators, industry associations and providers of navigational databases and asked for action to be taken by specific organisations to tackle particular recommendations. HeliOffshore's '*Operational Effectiveness Workstream*' is currently liaising with these industry partners to progress the actions recommended.

While work continues to try to implement each of the WDL report's recommendations, HeliOffshore has recently published a guide aimed at formalising industry best practice for offshore approaches[4]. Incorporated within some of the guide's concepts are procedures associated with the WDL report's recommendations.

Conclusion

The crew of this helicopter proceeded to the wrong offshore platform because the operator's flight planning system had not been updated to reflect a change of destination and because different platform identifiers were used by the operator and the chartering company.

Safety Actions by the helicopter operator are aimed at preventing a similar incident from occurring, while the trade organisation HeliOffshore is promoting a global system of identifying codes for offshore platforms. This move by HeliOffshore is one of many safety initiatives it is taking and the publication of this AAIB report provides the industry with an insight to efforts being made to prevent Wrong Deck Landings.

Bulletin Correction

The printed December Bulletin incorrectly states that this **Incident** was classified as a Serious Incident. A Bulletin Correction will be circulated at the earliest opportunity.

Footnote

4 The guide can be downloaded at http://helioffshore.org/wp-content/uploads/2016/07/Approach-Management-Guidelines-v2.pdf

ACCIDENT

Aircraft Type and Registration:	Airbus A320-214, G-EZTV
No & Type of Engines:	2 CFM CFM56-5B4/3 turbofan engines
Year of Manufacture:	2010 (Serial no: 4234)
Date & Time (UTC):	3 March 2017 at 1825 hrs
Location:	Stand 1, Manchester Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 172
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to forward lower fuselage and nose landing gear assembly
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	37 years
Commander's Flying Experience:	7,729 hours (of which 7,510 were on type) Last 90 days - 194 hours Last 28 days - 74 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and reports from: the ground handling company, the airfield operator, the aircraft operator and the manufacturer

Synopsis

During pushback the shear pins[1] on the towbar fractured. The ground crew heard a noise and checked the towbar, but did not discover the broken shear pins, so the pushback continued and the left engine was started.

As the aircraft was subsequently pulled forward, it gained momentum and began to deviate to the right of the direction in which the tug was moving. The tug driver assumed the towbar had separated and tried to move away but a retaining pin, that was subsequently found intact, had prevented tow bar separation, and the aircraft was pulled towards the tug. Before the aircraft could be halted by the pilot the tug collided with the lower left fuselage. The engines were shut down and the passengers disembarked from the rear of the aircraft without injury.

Investigations by the ground handling company, the airport operator and the aircraft operator highlighted maintenance and training issues and a range of safety actions have been taken.

Footnote

[1] Shear pins act as weak links to prevent damage to the aircraft or the ground equipment if a pre-determined force is exceeded.

Description of the accident

During the pushback from Stand 1 at Manchester Airport, in dark and wet conditions, the flight deck crew felt a fore and aft jolt and heard a mechanical "clunk". The commander informed the headset operator who conferred with the tug driver, and then visually checked the towbar and its attachment to the tug and to the aircraft. The ground crew saw nothing abnormal and they assumed the clunk was due to the tow hitch shifting[2], which is a familiar occurrence. The headset operator informed the commander that all was well, and the pushback continued. In response to a request from the commander, the headset operator indicated the left engine could be started, although the aircraft had not reached the designated engine start positon for that stand.

As the aircraft was halted, in preparation for being pulled forward to the release point, the headset operator approved a request from the flight deck crew to start the right engine. The commander was conscious of the aircraft beginning to move gently forward, while he was concentrating on starting the right engine. Both the tug and the headset operator were concealed from his field of view and he was not surprised when the aircraft's nose turned first to the right and then to the left, as if it was being lined-up on the taxiway centreline. He then heard an urgent instruction from the headset operator for the brakes to be applied, so he responded by pressing on the toe brakes before setting the park brake. The headset operator then informed him that the tug and aircraft had collided, but that nobody was injured. Both engines were then shut down.

Ground crew from adjacent stands came to assist and found the towbar was still connected to both the tug and to the aircraft. The nose gear leg was rotated approximately 90º to the left and the tow bar was bent around the front corner of the tug (Figure 1). The shear pins on the towbar had fractured (Figure 2), and pieces were later found within the boundary of the stand, but the central retaining pin remained intact. The passengers and crew disembarked without injury from the rear right exit door.

Figure 1

Position of the tug and the towbar after the accident

Footnote

2 The tow hitch is the connection interface between the tug and the towbar.

Figure 2

Image showing head of retaining pin and locating holes for failed shear pins

Ground handling investigation

The ground handling company, the airport operator and the aircraft operator investigated the accident and produced their own internal reports.

Examination of a number of towbars and their servicing records identified that past failures of a single shear pin had been resolved by replacement of that pin only, whereas they both need to be replaced because the unbroken pin may have been subjected to extra stress. One of the pins on this towbar had failed 16 days before the accident and only that pin had been replaced. It was also established that other maintenance procedures for the shear pins had not been followed. They had not been lubricated correctly and the training given to ground crews did not prepare them for conducting adequate serviceability checks on the pins. Additionally, the retaining pin (fitted between the two shear pins) was found to have been over-tightened and this might, over time, have contributed to the failure of the shear pins. The towbar comprised two sections, a short, forward section that connects to the aircraft and a longer section that connects to the tug. The shear pins and the retaining pin join the two sections through locating holes. The retaining pin that was fitted was intact and was found not to have the correct part number. However the loads in this event were probably not sufficiently high to cause a correctly fitted retaining pin with the correct part number to fail.

When the pull forward manoeuvre commenced, the two sections of the towbar pivoted around the retaining pin, allowing the aircraft to turn right, possibly influenced by thrust from the idling left engine and a slight downslope. This was not noticed initially by the headset operator who was looking forwards in the intended direction of movement. When the tug driver realised the aircraft was deviating from the intended path, he assumed the towbar sections had separated close to the aircraft's nosewheel, as designed, and tried to reverse the tug away. Because the towbar had not separated, the nose of the aircraft was pulled left, towards the tug. Although the headset operator had realised by this time that the aircraft was deviating from its intended route, he was unable to get the pilots to stop the aircraft before the collision occurred.

Many of the stands at Manchester have specific pushback procedures, but because of the number of variations they are not listed in the Aeronautical Information Publication. Hence flight crew rely on the ground crews' knowledge of stand-specific pushback and engine start procedures. These are documented on laminated sheets placed in each tug, but they were not referred to before this pushback. The headset operator believed it was permissible for the engines to be started when the aircraft was clear of Stand 1 but the tug should have been pulled forward to the release point before the engines were started.

Tug conspicuity

The commander noted that some ground handling services equip their tugs with flags on an extended aerial to increase their conspicuity to pilots. In this instance, flags might have alerted the crew that the tug had become misaligned with the aircraft and, possibly, given the crew additional time to react to the event before the collision occurred.

Aircraft manufacturer's comments

The aircraft manufacturer studied the accident and noted that the towbar used was not fitted with a damping system as recommended in the '*Aircraft Characteristics Manual*'[3]. This damping device is aimed at reducing the impulse loads generated at the connection interface between the towbar and the tug. Such a damping device is also requested by the latest industry standards for towbar design (eg SAE ARP1915E and ISO 9667).

Tables are provided in the *Aircraft Characteristics Manual* to enable operators to calculate the minimum weight of tug required to move an aircraft, depending on the aircraft's weight and local conditions. In this instance the aircraft manufacturer calculated that an 8 tonne tug would have been adequate, but the tug used was approximately three times heavier than this and consequently it was capable of loading the towbar above the minimum required load. The aircraft manufacturer stated that when the tug used is heavier than the minimum required, larger forces will be transmitted to the shear pins and this can increase the possibility of the pins breaking.

The manufacturer also warns that extra caution should be exercised when using tugs that are a lot heavier than the required minimum, in order to prevent damage to the aircraft or the towbar, particularly when the tug is pushing an aircraft rather than pulling it. If a shear pin fails when the tug is pushing, there is an increased likelihood of it colliding with the aircraft.

Footnote

[3] Ref Section 5-8-0, '*Ground Towing Requirements: A conventional type towbar is required which should be equipped with a damping system (to protect the nose gear against jerks) and with towing shear pins.*'

The aircraft manufacturer has recently published an amendment to the Aircraft Characteristics Manual for the Airbus 320 and this states '*Use a tractor with a limited drawbar pull to prevent loads above the tow-bar shear-pin capacity'*.

Safety actions

There have been several safety actions made by three organisations as a result of this accident. These are outlined below.

The ground handling company has instigated several changes to its procedures and to personnel training, including:

- Improvements to towbar maintenance and inspection procedures.
- A training aid has been developed to help ground crew recognise when shear pins are unserviceable.
- A standard fault-finding procedure has been introduced for ground crews when they hear an unusual sound or suspect a shear pin has broken while pushing or pulling an aircraft.
- Improvements have been made to ground crew training to ensure that correct procedures for aircraft engine start are followed for each stand at Manchester.

The airfield operator has issued safety alerts to airfield users regarding inspections and maintenance of pushback equipment and also regarding stand-specific pushback procedures.

The aircraft operator has reviewed its pushback procedures in response to the aircraft manufacturer's comments.

ACCIDENT

Aircraft Type and Registration:	Cessna 510 Citation Mustang, OE-FHK
No & Type of Engines:	2 PW 615F turbofan engines
Year of Manufacture:	2010 (Serial no: 510-0315)
Date & Time (UTC):	15 June 2017 at 1128 hrs
Location:	London Biggin Hill Airport
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Leading edge of left wing and forward fuselage dented, and cabin access door hinge distorted
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	2,658 hours (of which 450 were on type) Last 90 days - 81 hours Last 28 days - 37 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB

Synopsis

The aircraft rolled forward from its parked position and struck a fuel bowser when the chocks were removed without hydraulic pressure in the brake system.

History of the flight

At the end of its previous flight the aircraft was parked and shut down before being towed to a second parking position. Approximately 20 minutes later, ground personnel towed the aircraft to a third parking position. The wheels were chocked with the parking brake OFF when the flight crew attended the aircraft in readiness for a local flight. The purpose of the flight was to achieve a series of takeoffs and landings and for the commander, a Type Rating Examiner, to complete the co-pilot's type rating training. All the co-pilot's previous type rating training had been achieved using a flight simulator.

After the aircraft had been refuelled, the fuel bowser was reversed away and the commander believed it was moving clear but it stopped, approximately two metres in front of the aircraft, while the driver waited for other aircraft to move. Before the crew began their flight deck checks, the commander realised there were no ground personnel immediately available so he went outside to remove the wheel chocks. He stood to the left of the aircraft, which was parked on a slight slope, and signalled to the co-pilot to set the aircraft's parking brake. The co-pilot pressed the brake pedals and pulled the parking brake handle before indicating, using a thumbs-up signal, that he had done what was requested.

The commander removed the wheel chocks and moved away, to place the chocks on the ground clear of the aircraft. When he turned back he saw the aircraft was rolling towards the fuel bowser and called to the co-pilot to apply the brake. He could see the co-pilot was trying to apply the brake but the aircraft did not stop until it hit the fuel bowser (Figure 1). As the cabin door had been forced closed, the co-pilot, who was un-injured, could not leave the aircraft until the fuel bowser had moved away and the aircraft was secured.

Figure 1
OE-FHK after colliding with the fuel bowser

Brake system

A description of the brake system is included in the Pilot Training Manual (PTM) provided by the aircraft operator. This manual stated that the landing gear and normal brakes are powered by a hydraulic system which is pressurised by an electric pump and that an accumulator stores a supply of pressurised fluid. It continued by stating:

> *'During pump inactivity this pressurised fluid maintains pressure against normal internal leakage within the system.'*

There was no guidance regarding the length of time the accumulator might maintain pressure for, or how many applications of the brakes might be possible without the pump running.

The PTM stated that '*the parking brakes are a locked configuration*' of the brake system. By pulling the parking brake handle (situated to the left of the central pedestal), to the PARK position, while pressing on the brake pedals, the pilot will mechanically actuate non-return valves which are designed to trap hydraulic pressure in the mainwheel brakes.

A handle situated on the left side of the flight deck controls the emergency brake system. When the handle is pulled, pressurised nitrogen from a dedicated storage bottle actuates the mainwheel brakes pneumatically.

The electric hydraulic pump is turned on when the battery controller switch is moved to the BATT position but the trainee co-pilot stated that he had not been instructed to ensure this was done before applying the parking brake. The normal brake system functioned correctly when it was checked after the accident.

The commander was surprised to discover after the accident that it is not unusual for the hydraulic system pressure to dissipate within 30 minutes of electric power being disconnected. He had anticipated that there would be pressure available to actuate the brakes without turning on the battery.

The co-pilot had not appreciated that, without electric power, there would be a limited number of brake applications available. He had no previous experience using a pressurised brake system and was not aware of a requirement to complete any checklists before attempting to set the parking brake.

Aircraft operator's procedures

The aircraft operator's Standard Operating Procedures (SOPs) were specified in its Operations Manual (OM) and included an abbreviated checklist for use on the flight deck. The checks that were relevant to this flight were titled '*Quick Turnaround*' and '*Before Starting Engines*' and these were to be conducted using 'challenge and response'; the co-pilot being permitted to read the challenge, check the item and make the response if necessary. In certain circumstances the co-pilot was also allowed to start the right engine while the commander escorted any passengers to the aircraft.

In the '*Quick Turnaround*' checklist, the sixth check was to set the battery switch to BATT while in the '*Before Starting Engines*' checklist, the second check was to ensure the battery was turned on and the voltage correct. The fourth of the seven checks before engine start was written as '*Wheel Chocks / Parking Brakes…Removed/On*'.

Elsewhere in the OM the normal '*Cockpit Preparation*' procedures were listed in an expanded format. Item 10 instructed setting the battery switch to BATT and item 10 instructed setting the parking brake with a note which stated:

> *'Parking brakes are a locked configuration of the brakes. Brakes are locked when the parking brake valve traps hydraulic fluid in the brake lines. The valve can only be set by pulling on the PARKING BRAKE knob on the right lower side of the pilot instrument panel while pressing on the brake pedals or by setting the parking brake and pressing the brakes 2 or 3 times.'*

The aircraft operator stated its normal procedure was for ground personnel to remove the chocks at the appropriate stage during the '*Before Starting Engines*' checklist. However, in '*exceptional*' circumstances, with no ground personnel available, it was acceptable for the flight crew to remove the wheel chocks, provided the checklist was still followed. There was no mention of this latter procedure in the OM.

Safety actions

Following this accident the aircraft operator took the following Safety Actions;

> A '*Safety Bulletin*' to flight crew was circulated which stated that the parking brake is only to be set with the battery switch in the BATT position and that the appropriate checklists are always to be followed. This notice also warns crew not to remove chocks if there are obstacles such as a fuel bowser nearby and states that trainee pilots are always to be accompanied by an experienced crew member while operating the aircraft.
>
> The SOPs were modified and additional guidance on operation of the parking brake and the use of wheel chocks was placed in the OM.
>
> Pilot training was revised to try to ensure a comprehensive understanding of the hydraulic system and the aircraft brakes.

SERIOUS INCIDENT

Aircraft Type and Registration:	Cessna 525A Citationjet CJ2, G-SONE
No & Type of Engines:	2 Williams International FJ44-2C turbofan engines
Year of Manufacture:	2001 (Serial no: 525A-0031)
Date & Time (UTC):	20 September 2017 at 0600 hrs
Location:	In flight from Bristol Airport to Paderborn Lippstadt, Germany
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 6
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	8,890 hours (of which 3,727 were on type) Last 90 days - 92 hours Last 28 days - 40 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst climbing through FL200, the crew became aware of a pressurisation issue and initiated a descent. The cabin masks automatically deployed when the cabin altitude reached 12,500 ft. The aircraft returned to Bristol for an uneventful landing. Post-maintenance examination did not identify the cause of the fault and the aircraft was returned to service.

The CVR was not disabled following the incident and the operator is taking action to remind flight crews of their obligations in this respect.

History of the flight

G-SONE was on a flight from Bristol Airport to Paderborn Lippstadt Airport Germany, with two flight crew and six passengers on board. As the aircraft climbed through FL200 the crew were presented with a 'cabin altitude' master warning, indicating that the cabin altitude was above 10,000 ft. The crew donned their oxygen masks and carried out emergency actions, with the aircraft initially cleared to descend to FL170. The cabin altitude continued to climb, and at 12,500 ft, the cabin oxygen masks automatically deployed. The passengers donned their masks and the crew declared an emergency to ATC and descended to FL080. The aircraft landed back at Bristol without further incident.

The operator carried out ground tests and a maintenance flight, but no fault with the aircraft's pressurisation system was identified. The aircraft returned to service and has since flown over 30 flights without further incident.

The aircraft was equipped with a 120 minute duration CVR. A recording of the incident was not available as no immediate action was taken to preserve it. Commission Regulation (EU) 965/2012 part CAT.GEN.MPA.105 states that:

> *'it is the responsibility of the aircraft commander to preserve CVR and FDR records following 'an accident or an incident that is subject to mandatory reporting'.'*

The operator is issuing a 'Safety Notice' to all crew to remind them of their obligations to preserve CVR and FDR data following a reportable incident, and is publishing an article to provide further information in its 'Flight Safety Newsletter'.

SERIOUS INCIDENT

Aircraft Type and Registration:	Beech A36 Bonanza, G-JLHS
No & Type of Engines:	1 Continental Motors Corp IO-550-B piston engine
Year of Manufacture:	1990 (Serial no: E-2571)
Date & Time (UTC):	20 July 2017 at 1110 hrs
Location:	Alderney Airport
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Private Pilot's Licence
Commander's Age:	78 years
Commander's Flying Experience:	3,337 hours (of which 3,207 were on type) Last 90 days - 38 hours Last 28 days - 24 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

As a result of a hard landing at Alderney, a momentary short circuit of the master avionics power at a stub terminal on the firewall caused the avionics to turn off and remain off. Following a number of bounces, the aircraft became airborne again and departed initially to the south. Without radio, the pilot was unable to communicate with Alderney TWR and to advise of his intention to divert to Guernsey. However, on the approach to Guernsey, he made contact with Guernsey TWR via mobile phone before making a successful landing.

The electrical problem was investigated by a Guernsey maintenance organisation and identified that the rubber boot to cover the stub terminal on the firewall was missing. This had allowed arcing between the engine and the exposed stud.

ACCIDENT

Aircraft Type and Registration:	Cessna 152, G-BIDH
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1981 (Serial no: 152-80546)
Date & Time (UTC):	27 August 2017 at 1425 hrs
Location:	Beverley Airfield, East Riding of Yorkshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose landing gear, engine cowling and propeller, and engine shock-loaded. Windsock pole knocked down
Commander's Licence:	Student Pilot
Commander's Age:	27 years
Commander's Flying Experience:	22 hours (of which 22 were on type) Last 90 days - 5 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After touchdown a student pilot was unable to prevent his aircraft veering off the runway and hitting a pole supporting the airfield's windsock.

History of the flight

The aircraft was being flown by a student pilot who had earlier completed three satisfactory landings accompanied by an instructor and then one satisfactory, solo 'full-stop' landing. Following a further takeoff and circuit the student made an into-wind approach for a touch-and-go landing on the dry, grass runway. He judged his approach and touchdown to be better than those he had previously completed but, once all three wheels were on the ground, the aircraft veered left. The student reported that he responded by applying right rudder and increasing power; in preparation for takeoff. However, he could not prevent the aircraft from departing the runway to the left and travelling across an adjacent area of long grass. He applied the brakes and thought that he reduced power but the aircraft did not stop until it collided with a windsock pole and the propeller detached. The student turned off the fuel and the electric master switch before exiting the aircraft, which had pitched nose-down (Figure 1).

Figure 1

The aircraft in its resting place with the detached propeller on the ground to the left (photograph courtesy of Hull Aero Club Ltd)

The instructor witnessed the accident from the clubhouse where he was operating the air/ground radio. He thought the student's landing was good but then saw the aircraft veer off the runway. He made a radio call instructing the student to reduce power but the student had no recollection of hearing this transmission and the instructor watched as the aircraft hit the windsock pole.

Aircraft inspection

The operator discovered that the left nose leg support strut had broken and suggested this may have caused the pilot to lose directional control. However, it is also possible that this occurred when the aircraft collided with the pole. The right arm of the nosewheel fork had fractured and this appeared to be a direct result of the impact. The operator reported that the throttle was found to be fully open, while the damage to the pole was consistent with the propeller striking the pole at a high power setting, causing all six threaded inserts on the crankshaft flange to be torn out as the propeller detached.

ACCIDENT

Aircraft Type and Registration:	Evans VP-1 Series 2 Volksplane, G-AYUJ
No & Type of Engines:	1 Volkswagen 1834 piston engine
Year of Manufacture:	1983 (Serial no: PFA 1538)
Date & Time (UTC):	13 July 2017 at 1300 hrs
Location:	Barton Ashes Airstrip, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller, left landing gear leg and possible crankshaft damage
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	78 years
Commander's Flying Experience:	190 hours (of which 110 were on type) Last 90 days - 4 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was returning to Barton Ashes Airstrip and approached Runway 25 from the north-west. The wind was from 260° at 3 kt and visibility was in excess of 10 km. During the latter stages of the approach, the pilot reported that he had allowed the aircraft's speed to decay and subsequently it stalled, landing heavily onto the runway. The pilot was able to vacate the aircraft without assistance and sustained no injuries.

SERIOUS INCIDENT

Aircraft Type and Registration:	Sling 4, G-LDSA
No & Type of Engines:	1 Rotax 914-UL piston engine
Year of Manufacture:	2017 (Serial no: LAA 400-15412)
Date & Time (UTC):	27 July 2017 at 1355 hrs
Location:	Near Hailsham, East Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Right canopy door detached in flight
Commander's Licence:	Private Pilot's Licence
Commander's Age:	72 years
Commander's Flying Experience:	865 hours (of which 31 were on type) Last 90 days - 12 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The right canopy door detached in flight. Subsequent inspection of the aircraft, and in particular the canopy latch pins, by the LAA indicates that the canopy locking lever had not been in the fully closed position, which allowed the canopy to open and then detach. The canopy, incorporating the locking lever and mechanism, was not recovered. There have been no other reported incidents of canopy loss for this aircraft type. The LAA is to publish a safety article reminding pilots to check that canopies are fully locked prior to flight.

History of the flight

The aircraft's owner, who was piloting the aircraft, and a passenger who was also a pilot, were flying from Lydd Airport to Shoreham Airport. The pilot was in the front left seat and the passenger was seated next to him. About 30 minutes into the flight, at an altitude of 2,200 ft and airspeed of about 116 kt, there was a sudden increase in wind noise in the cockpit accompanied by the passenger feeling a "blast of air on his face". The passenger then noticed that the right canopy door had opened about 5 cm at its upper forward corner, with the gap tapering back to the rear of the canopy. After about 15 to 20 seconds, there was a loud bang and the canopy departed the aircraft. The pilot informed ATC at Shoreham, where the aircraft subsequently landed without further incident. Sussex Police were also notified. The canopy door has not been located to date and no injuries to persons or damage to property on the ground have been reported.

The Sling 4 is fitted with two canopy doors, one on the left and one on the right side of the cockpit that open in a ‘gullwing’ design. Each canopy door is attached to the top of the fuselage by two hinges and secured by a single over-centre lever that moves two latches, one adjacent to the lever assembly and one at the rear of the canopy via by a pull-push rod (Figure 1). The levers are located forward of the pilot and passenger seats (Figure 2).

Figure 1

Passenger canopy locking lever and latches

Figure 2

Passenger canopy locking lever position

The LAA inspected the aircraft and contacted the aircraft manufacturer. Analysis of damage to the forward and aft hinge fuselage attachment points indicate that both hinges failed in overload. Both forward and aft latch pins remained attached to the fuselage and were both intact. The canopy was not recovered and so it was not possible for the canopy locking lever and mechanism to be examined.

The pilot stated that the passenger had advised him that the lever had remained in the closed position until the canopy detached from the aircraft. However, the LAA found that it was possible to partially lock the canopy with the lever not fully in the closed 'over-centre' position.

There have been no other reported incidents for this aircraft type of a canopy opening in flight. The LAA is to publish a safety article reminding pilots to check that canopies are fully locked prior to flight.

Conclusion

The inspection of the aircraft by the LAA indicates that the canopy opened in flight because the passenger door lever was not in the fully closed position. It is possible that the lever may not have been in the fully closed position prior to the commencement of the flight, or that the lever was inadvertently moved at some point during the flight.

SERIOUS INCIDENT

Aircraft Type and Registration:	Cameron Z-275 balloon, G-CCNC
No & Type of Engines:	None
Year of Manufacture:	2003 (Serial no: 10504)
Date & Time (UTC):	17 June 2017 at 2000 hrs
Location:	Kirkby in Ashfield, Nottinghamshire
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 13
Injuries:	Crew - None Passengers - 4 (Minor)
Nature of Damage:	None
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	68 years
Commander's Flying Experience:	1,331 hours (of which over 1,200 were on type) Last 90 days - 8 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

After an uneventful flight, the commander identified a potential landing site three fields away and a reserve landing site. He started a descent towards the planned landing site but, as the balloon descended, he realised that he would actually be able to land in the first field. During this landing, which was heavier than the commander expected, a lady cried out in pain. Another passenger then turned towards the lady and, in doing so he lost his grip and fell out of the balloon's basket, which was now being dragged across the ground by the surface wind. The balloon became airborne again but landed safely at the reserve landing site. The lady suffered minor bruising to the ribs and the passenger who fell out of the basket was not injured. Subsequently, a further two passengers have reported minor injuries to the commander.

The commander, in a frank report, attributed this serious incident to changing his intended landing field, at a low level, despite having already identified and planned to land in a different field.

ACCIDENT

Aircraft Type and Registration:	Flight Design CT2K, G-CBIE
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2001 (Serial no: 7879)
Date & Time (UTC):	19 August 2017 at 1300 hrs
Location:	Private airstrip, Peasemore Common, Berkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose landing gear leg, wing and propeller
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	3,200 hours (of which 500 were on type) Last 90 days - 120 hours Last 28 days - 50 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Whilst the pilot was reducing speed following an aborted takeoff, the aircraft hit an area of rough ground towards the end of the grass airstrip. This caused the nose landing gear leg to fail. The section of gear leg still attached to the aircraft then dug into the ground and the aircraft pitched inverted, damaging the propeller and the wing.

ACCIDENT

Aircraft Type and Registration:	Pegasus Quantum 15-912, G-MZDH
No & Type of Engines:	1 Rotax 912 piston engine
Year of Manufacture:	1996 (Serial no: 7248)
Date & Time (UTC):	15 August 2016 at 1843 hrs
Location:	Holy Cross Green, Clent, West Midlands
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	702 hours (of which 172 were on type) Last 90 days - 5.0 hours Last 28 days - 3.5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The weight shift microlight was returning from Otherton to Halfpenny Green when the accident occurred. The pilot was seriously injured in the accident and had little memory of the accident flight. There were various witness descriptions of the final descent, including the wing collapsing and the microlight spiralling down but the initiating event was not identified. The pilot was not able to recover from a tight spiral or tumbling condition which continued to the ground.

History of the flight

The pilot had flown from Halfpenny Green to Otherton in order to carry out his annual flight test. The weather was good with visibility in excess of 10 km, high cloud and light winds. During the flight, he noticed that the 'Flydata' instrument indicated an abnormally high value for the engine's cylinder head temperature (CHT). When he arrived at Otherton, he spoke to the examiner and they tried to establish the cause of the high CHT but were unable to do so. The examiner offered to use his aircraft but the pilot decided to abandon the test and return his aircraft to Halfpenny Green. Before departure the CHT was normal and the pilot did not recall any abnormal indications during the return flight.

The pilot thought that he had climbed to 2,000 or 3,000 feet for his return flight but witnesses who saw the microlight immediately prior to the accident thought it was at about 200 to 500 feet.

There were various descriptions by the witnesses of the aircraft's descent but, generally, it was seen to spiral to the ground. Some witnesses thought the engine noise changed or had stopped and saw smoke with the aircraft believed to be on fire. The change in engine noise may have been the pilot closing and opening the throttle. The most graphic description was from a witness who reported that the pilot:

> *'powered up and climbed steeply. A minute later and the engine cut out. He then seemed to go into a controlled stall. The engine restarted and he climbed again very steeply. It was in the steep climb that I saw the wings fold in half and the microlight went spinning to the ground and disappeared behind some trees. I did not see any flames or smoke.'*

Due to his injuries, the pilot was unable to recall details of the accident flight other than that:

> *'the 'A' frame came back abruptly at some point and the aircraft adopted a spinning motion.'*

It is not known what caused the accident but it appears that, following an event, the pilot lost control of the aircraft and was unable to recover it to normal flight before impacting the ground. A witness who saw the aircraft in the final moments reported that it had come down on top of a large farm bale which had absorbed a lot of the impact energy.

Accident site

The pilot's injuries, although serious, were not life threatening. The wreckage was removed with the approval of the AAIB but was not viewed by AAIB inspectors and has since been disposed of. The engineer who recovered the wreckage described it as "heavily broken up".

Aircraft information

The Pegasus Quantum 15-912 is a weightshift microlight consisting of a wing, suspended under which is a tandem two-seat 'trike' on the rear of which is mounted an engine with a three bladed 'pusher' propeller. Attached to the 'trike' is a tricycle landing gear comprising a nose and two main wheels. An 'A frame' is attached to the wing and is used to control the aircraft.

Aerobatic manoeuvres are not permitted and nose-up or nose-down attitudes must not exceed 45° with maximum bank angles not to exceed 60°. The normal acceleration limits are +3.8/-0g.

The 'A frame' is used to manoeuvre the microlight in pitch and roll. Moving the base bar at the bottom of the 'A frame' forward causes the wing leading edge to move up which results in the nose pitching up and the microlight climbing. Moving the base bar aft has the opposite effect and causes the microlight to descend. Moving the base bar to the left causes the microlight to bank and turn to the right whilst moving the base bar to the right will cause the microlight to turn to the left. The microlight is responsive to control inputs with large and rapid movements of the base bar resulting in equally large and rapid attitude changes. The stall speed recorded on the BMAA Check Flight Schedule was 36 mph.

Microlight 'tumbling'

The microlight 'tumble' is a rapid uncontrolled rotation about the pitch axis from which there is no known recovery technique. It usually results following rapid movement from a large nose-up attitude to a large nose-down attitude such as at a 'whip stall'[1]. This is accompanied by the pilot pulling back on the base bar to adopt a nose-down, stall recovery attitude, which when combined with the natural pitching forward of the wing, causes the microlight to tumble. The tumbling achieves very high rates of rotation up to, and possibly exceeding, 360° per second. This induces transient accelerations in the region of 8g.

The 'tumble' can result in the failure of the wing and publically available recorded images show that, once the wing has failed, the microlight can assume a spinning motion akin to a falling sycamore leaf.

A comprehensive explanation of the microlight tumble is set out in a paper, '*Towards the Tumble Resistant Microlight*', by Dr Guy Gratton and Dr Simon Newman[2].

Survivability

The pilot was properly dressed for the flight with a weatherproof flying suit, boots, gloves and protective helmet. During the impact with the ground he received serous leg injuries but no life threatening other injuries. The arrival on the large agricultural bale with its energy absorbing qualities was probably the main element that made this a survivable accident.

Information from the pilot

The pilot did not recall performing a manoeuvre which might have resulted in overstressing and folding of the wing structure as was observed. He commented that he always respects the limitations contained within an aircraft's Pilot's Operating Handbook.

Analysis

Given the evidence of those who saw the final moments of the aircraft, it appeared that it either entered a whip stall or carried out a rapid turn. After this, the aircraft possibly tumbled or the wings were overstressed in the manoeuvre. Whatever the initiating event, the wings folded and this caused the microlight to adopt a spinning motion akin to a sycamore leaf. No explanation of the entry manoeuvre was positively identified – and the pilot's comments suggested that extreme manoeuvring would have been out of character – but, at some point, wing loading was clearly excessive.

Footnote

[1] The whip stall is caused by an aggressive entry at a high deceleration rate to the aerodynamic stall, followed by an equally aggressive recovery initiation by the pilot, pulling back the control bar rapidly.

[2] Available: https://eprints.soton.ac.uk/43858/1/GrattonNewman_TumbleResistance.pdf

Conclusion

The microlight entered an irrecoverable spinning flightpath probably due to some manoeuvre that induced overstressing and failure of the wing structure.

ACCIDENT

Aircraft Type and Registration:	Pegasus Quik, G-CGLW
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2010 (Serial no: 8509)
Date & Time (UTC):	18 June 2017 at 1053 hrs
Location:	Old Park Farm Airfield, Port Talbot, West Glamorgan
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Propeller, fuselage, wings and nose
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	321 hours (of which 225 were on type) Last 90 days - 25 hours Last 28 days - 19 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

As the aircraft turned final for Runway 36 in a light westerly wind, the pilot considered he was too high so steepened the approach. The aircraft bounced on touchdown before becoming airborne again for approximately 100 m. The pilot decided to go around by applying full power but the aircraft slewed left into some crops.

The pilot was wearing a lap and diagonal harness and helmet but sustained a serious injury.

ACCIDENT

Aircraft Type and Registration:	Pegasus Quik, G-FFIT
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2007 (Serial no: 8238)
Date & Time (UTC):	10 August 2017 at 1200 hrs
Location:	Maypole Airfield, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Front forks buckled, fibreglass pod
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	160 hours (of which 129 were on type) Last 90 days - 12 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

After passing over some trees and buildings on the approach to Runway 02, the pilot described encountering “dirty air” and “lost lift”. This lead to an increased rate of descent and a hard landing on the main landing gear, causing the aircraft to bounce. The subsequent landing was “slightly nose first” and, during taxi, the nosewheel forks collapsed and the fibreglass pod impacted the ground.

The pilot was uninjured and considered that a go-around would have been an appropriate decision once he noticed the high rate of descent near to the ground.

ACCIDENT

Aircraft Type and Registration:	Quest Q-200 UAS
No & Type of Engines:	1 3 phase AXI electric motor - engine
Year of Manufacture:	2015
Date & Time (UTC):	12 July 2017 at 1427 hrs
Location:	Hinkley Point, Somerset
Type of Flight:	Commercial operation
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Extensively damaged
Commander's Licence:	Other
Commander's Age:	48 years
Commander's Flying Experience:	24 hours (of which 20 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquies by the AAIB

Synopsis

The unmanned aircraft (UA) was surveying a foreshore close to a construction site using a flight plan of pre-programmed waypoints.

During the flight the UA was affected by a change in the wind that resulted in it flying larger than normal turns. This caused the UA to overshoot its downwind waypoints and fly over the construction site. During one such overshoot the UA began to descend, as programmed, and collided with a crane on the construction site about 250 m inland.

As a result of this accident the operator made several changes to its procedures.

History of the flight

The fixed-wing unmanned aircraft (UA) was being used to survey a foreshore, flying at 35 kt and 200 ft agl, using a flight plan of pre-programmed waypoints. Adjacent to the foreshore was a large construction site which was outside the planned flight area. Prior to the flight the operator carried out pre-flight checks and an on-site risk assessment was completed without any hazards being identified. At the time of planning the weather forecast was fine and the wind was from the east-north-east at 7 to 13 kt. As such the pilot selected a flight plan with tracks running across the wind, ie north to south and vice versa, with into-wind turns. Additionally, as there were two 'jack-up' barges located on the foreshore the pilot modified the flight plan so that the UA would fly at 400 ft agl when in the vicinity of the barges.

After launch, the UA began its pre-programmed route at 200 ft agl. However, the first four downwind turns, at the southerly waypoints, overshot the waypoints by about 125 m. These overshoots were larger than expected, indicating a change in the wind's strength and direction. The UA subsequently climbed to 400 ft, as programmed, for the legs in the vicinity of the barges, but the southern waypoint overshoots increased to about 200 m. During the following turn, the pilot felt that these overshoots were becoming problematic, as they were beginning to encroach over the construction site, and he considered aborting the flight on the subsequent northerly leg. However, during the turn, as the UA began to descend back to 200 ft as planned, it collided with the horizontal beam of a tower crane and fell to the ground. The crane was about 370 m from the pilot and 250 m from the foreshore and the previously overflown waypoint. The UA was extensively damaged but there was no third party damage and no injuries.

Pilot's comments

The pilot commented that the main cause of the accident was poor flight planning. The overshoot and collision could have been prevented by aligning the flight legs east/west instead of north/south and maintaining 400 ft near the construction site. The pilot did not do this because optimum imaging uses crosswind legs, in this case north/south. Also the position of the tower cranes, outside the planned flight area, were not fully considered during the planning stage due to their more remote location. Additionally, the pilot did not intervene and initiate a climb before the collision because the distance and height of the cranes were difficult to perceive.

Safety actions

The operator has made the following procedural changes to minimise the probability of collisions with high obstacles on this and other construction sites:

- Construction site staff will be contacted, prior to launch, to check the height of the highest structure to ensure that sufficient clearance can be met. If this cannot be achieved that part of the site will not be overflown.
- Any flights that have the potential to overfly the construction site will be flown at 400 ft.
- Manual corrective action will be taken to manoeuvre the UA in the event of deviations from the flight plan.

ACCIDENT

Aircraft Type and Registration:	Quik GT450, G-CEUH	
No & Type of Engines:	1 Rotax 912 ULS piston engine	
Year of Manufacture:	2007 (Serial no: 8316)	
Date & Time (UTC):	30 July 2017 at 1132 hrs	
Location:	East Fortune Airfield, East Lothian	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Damage to wing, nosewheel assembly, cockpit area and propeller	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	65 years	
Commander's Flying Experience:	100 hours (of which 31 were on type) Last 90 days - 12 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

After a short local pleasure flight, the pilot joined overhead at East Fortune Airfield and noted that the wind favoured a landing on grass Runway 25. He descended the aircraft and flew a left-hand circuit, reducing power on final approach to practise a glide approach. The aircraft sank more quickly than the pilot expected and he had to reapply power to maintain the correct approach path. After he crossed the runway's threshold, the pilot reduced power and flared the aircraft for landing. However, the aircraft continued to descend, hit the ground and bounced into the air again. The aircraft then hit the ground a second time, nosed over and rolled to the right.

The pilot who was wearing a protective helmet suffered minor injuries and attributed the accident to allowing his airspeed to reduce too much, just prior to initiating the landing flare.

ACCIDENT

Aircraft Type and Registration:	Rotorsport UK Calidus, G-CPTR	
No & Type of Engines:	1 Rotax 912 ULS piston engine	
Year of Manufacture:	2010 (Serial no: RSUK/CALS/014)	
Date & Time (UTC):	10 August 2017 at 1505 hrs	
Location:	Popham Airfield, Hampshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Extensive	
Commander's Licence:	Other	
Commander's Age:	51 years	
Commander's Flying Experience:	72 hours (of which 10 were on type) Last 90 days - 18 hours Last 28 days - 5 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The control stick was moved to the aft position during the takeoff run, the rotors struck the ground and the gyroplane rolled onto its side.

History of the flight

The pilot lined up his gyroplane and pre-rotated the rotor to 200 rpm, prior to an into-wind takeoff from a wet, grass runway which sloped down. He applied maximum wheel braking but, after he disengaged the pre-rotator and before he moved the control stick aft for takeoff, the gyroplane's wheels started to slide. Although the grass was very wet, the wheel brakes had held during an earlier engine check.

The pilot was distracted by the apparent brake failure and when he realised he could not prevent the gyroplane sliding forwards he elected to take off. Thinking that he had already moved the control stick aft, he released the brake and let the gyroplane accelerate.

After travelling approximately 70 m, the pilot pulled the control stick back and the gyroplane rolled quickly left, the rotors struck the ground, followed by the propeller; causing the engine to stop. The gyroplane came to a halt on its left side and, with some difficulty, the pilot managed to force open the canopy and climb out.

Afterwards the pilot realised he should have abandoned the takeoff when the wheels began to slide. His distraction with the braking issue caused him to overlook the important step of moving the control stick aft before releasing the brake. By moving the control stick aft once the gyroplane gained speed, rather than when it was stationary, he had induced a rapid roll to the left[1] which he could not correct.

Footnote

[1] The rotor blades would have stalled when moving rearwards (retreating) on the left side of the gyroplane, due to a high angle of attack and low rotor speed. The ensuing 'retreating blade stall' would have led to reduced lift on the left side of the rotor disc compared to the right side; the advancing blades on the right benefitting from a greater relative airflow due to the wind velocity and the gyroplane's groundspeed.

ACCIDENT

Aircraft Type and Registration:	Skyranger 912(2), G-CCDH
No & Type of Engines:	1 Rotax 912-UL DCDI piston engine
Year of Manufacture:	2003 (Serial no: BMAA/HB/233)
Date & Time (UTC):	5 July 2017 at 1716 hrs
Location:	Filey, North Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nosewheel, propeller, wing
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	110 hours (of which 85 were on type) Last 90 days - 26 hours Last 28 days - 26 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was returning to its home airfield in unfavourable weather conditions. While performing a precautionary landing, the pilot identified what he thought was a field of stubble which turned out to be a standing crop. On landing, the aircraft flipped inverted but both occupants escaped uninjured.

History of the flight

The aircraft was one of two on a flight from Eshott to Little Gransden, near Cambridge, which was its home airfield; a flight of over 200 nm. Just prior to takeoff, the METAR recorded by Durham Tees Valley Airport (EGNV), which is approximately 50 nm south of Eshott, was visibility of 10 km or more but broken cloud at 1,100 ft. The EGNV TAF issued at 1357 hrs was 10 km visibility with broken cloud at 1,200 ft but occasionally between 1500 hrs and midnight, visibility 6,000 m, light rain and drizzle with broken cloud at 700 ft. In addition, between 1500 hrs and midnight there was a 40% chance of 3,000 m visibility with light drizzle, mist and broken cloud at 300 ft.

The aircraft took off from Eshott at 1527 hrs, and followed the coastline south. After flying for approximately 90 nm, the aircraft arrived abeam Filey on the east coast. The formation had discussed making a stop at Bridlington to assess the weather conditions which was a further 6 nm from Filey. At the time the aircraft was flying at a GPS altitude of approximately 850 ft and the pilot reported seeing cloud ahead almost down to sea level.

The pilot decided to turn around and head towards Durham but the cloud to the north had also descended. At this stage he decided to divert immediately but the available airfields were not appropriate due to their elevation and the cloud base. He decided to perform a precautionary landing in a field and after considering all options chose what he perceived to be a stubble field. This was in fact a standing crop and, on landing, the aircraft sank into the crop, causing it to roll over. Both occupants were suspended by their full harnesses but then escaped uninjured.

Figure 1
G-CCDH after impact

Prior to takeoff, the pilot considered that the weather forecast for the coming two days was unfavourable and this influenced his decision to get back to his home airfield. He considered the weather as "not ideal" but also thought that it would clear during the flight. In addition, he considered that the lower light levels and different appearance of the field from the air may have influenced the mis-identification of a suitable field for a precautionary landing.

AAIB comment

This accident highlights the need for careful weather and diversion planning when undertaking a cross-country flight. CAA Safety Sense Leaflet No 23, *'Pilots – It's Your Decision'* provides useful information on factors which may affect pilot decision making.

Miscellaneous

This section contains Addenda, Corrections and a list of the ten most recent Aircraft Accident ('Formal') Reports published by the AAIB.

The complete reports can be downloaded from the AAIB website (www.aaib.gov.uk).

TEN MOST RECENTLY PUBLISHED FORMAL REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

2/2011 Aerospatiale (Eurocopter) AS332 L2 Super Puma, G-REDL
11 nm NE of Peterhead, Scotland
on 1 April 2009.

Published November 2011.

1/2014 Airbus A330-343, G-VSXY
at London Gatwick Airport
on 16 April 2012.

Published February 2014.

2/2014 Eurocopter EC225 LP Super Puma
G-REDW, 34 nm east of Aberdeen, Scotland on 10 May 2012
and
G-CHCN, 32 nm south-west of Sumburgh, Shetland Islands
on 22 October 2012.

Published June 2014.

3/2014 Agusta A109E, G-CRST
Near Vauxhall Bridge,
Central London
on 16 January 2013.

Published September 2014.

1/2015 Airbus A319-131, G-EUOE
London Heathrow Airport
on 24 May 2013.

Published July 2015.

2/2015 Boeing B787-8, ET-AOP
London Heathrow Airport
on 12 July 2013.

Published August 2015.

3/2015 Eurocopter (Deutschland) EC135 T2+, G-SPAO
Glasgow City Centre, Scotland
on 29 November 2013.

Published October 2015.

1/2016 AS332 L2 Super Puma, G-WNSB
on approach to Sumburgh Airport
on 23 August 2013.

Published March 2016.

2/2016 Saab 2000, G-LGNO
approximately 7 nm east of
Sumburgh Airport, Shetland
on 15 December 2014.

Published September 2016.

1/2017 Hawker Hunter T7, G-BXFI
near Shoreham Airport
on 22 August 2015.

Published March 2017.

Unabridged versions of all AAIB Formal Reports, published back to and including 1971, are available in full on the AAIB Website

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

aal	above airfield level
ACAS	Airborne Collision Avoidance System
ACARS	Automatic Communications And Reporting System
ADF	Automatic Direction Finding equipment
AFIS(O)	Aerodrome Flight Information Service (Officer)
agl	above ground level
AIC	Aeronautical Information Circular
amsl	above mean sea level
AOM	Aerodrome Operating Minima
APU	Auxiliary Power Unit
ASI	airspeed indicator
ATC(C)(O)	Air Traffic Control (Centre)(Officer)
ATIS	Automatic Terminal Information Service
ATPL	Airline Transport Pilot's Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot's Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitoring
EGPWS	Enhanced GPWS
EGT	Exhaust Gas Temperature
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure Ratio
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FAA	Federal Aviation Administration (USA)
FDR	Flight Data Recorder
FIR	Flight Information Region
FL	Flight Level
ft	feet
ft/min	feet per minute
g	acceleration due to Earth's gravity
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 1200 hrs)
HP	high pressure
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IP	Intermediate Pressure
IR	Instrument Rating
ISA	International Standard Atmosphere
kg	kilogram(s)
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
KTAS	knots true airspeed
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LP	low pressure
LAA	Light Aircraft Association
LDA	Landing Distance Available
LPC	Licence Proficiency Check
m	metre(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
min	minutes
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
N	Newtons
N_R	Main rotor rotation speed (rotorcraft)
N_g	Gas generator rotation speed (rotorcraft)
N_1	engine fan or LP compressor speed
NDB	Non-Directional radio Beacon
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OPC	Operator Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIC	Pilot in Command
PNF	Pilot Not Flying
POH	Pilot's Operating Handbook
PPL	Private Pilot's Licence
psi	pounds per square inch
QFE	altimeter pressure setting to indicate height above aerodrome
QNH	altimeter pressure setting to indicate elevation amsl
RA	Resolution Advisory
RFFS	Rescue and Fire Fighting Service
rpm	revolutions per minute
RTF	radiotelephony
RVR	Runway Visual Range
SAR	Search and Rescue
SB	Service Bulletin
SSR	Secondary Surveillance Radar
TA	Traffic Advisory
TAF	Terminal Aerodrome Forecast
TAS	true airspeed
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TGT	Turbine Gas Temperature
TODA	Takeoff Distance Available
UAS	Unmanned Aircraft System
UHF	Ultra High Frequency
USG	US gallons
UTC	Co-ordinated Universal Time (GMT)
V	Volt(s)
V_1	Takeoff decision speed
V_2	Takeoff safety speed
V_R	Rotation speed
V_{REF}	Reference airspeed (approach)
V_{NE}	Never Exceed airspeed
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional radio Range

Air Accidents Investigation Branch