AAIB
Air Accidents Investigation Branch

AAIB Bulletin 9/2020

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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 A320-214, G-EZWE
No & Type of Engines:	2 CFM56-5B4/3 turbofan engines
Year of Manufacture:	2012 (Serial no: 5289)
Date & Time (UTC):	16 September 2019 at 1959 hrs
Location:	Lisbon Airport, Portugal
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers -167
Injuries	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	16,000 hours approximately (of which approximately 8,000 were on type) Last 90 days - approximately 130 hours Last 28 days - approximately 20 hours
Information Source:	AAIB Field Investigation

Synopsis

Under international protocols, this investigation was delegated to the AAIB by the Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF) in Portugal.

During pre-flight preparations, both pilots completed a takeoff performance calculation for a takeoff from Runway 21 at Lisbon Airport. In calculating the performance, the crew believed they had selected the shortest runway length available (from the intersection with Taxiway S1) but had, in fact, used the runway full length (from Taxiway S4). The aircraft was cleared for takeoff from another intersection (Taxiway U5) and used performance calculated for the full runway length. The takeoff distance available from U5, although longer than from S1, was 1,395 m less than that used for the performance calculation, and the aircraft became airborne with only 110 m of the runway remaining.

As a result of this and previous, similar incidents, the airport operator renamed part of Taxiway S to have only one intersection on Runway 21 with the letter S.

The aircraft operator moved onto a newer software version for performance calculations in December 2019 which gives a pictorial representation of the runway. They also worked with the data supplier to change the menu for intersection selections for Lisbon Airport to eliminate any confusion over which position refers to the full runway length.

History of the flight

G-EZWE arrived into Lisbon Airport at 1825 hrs having flown in from Manchester Airport. The passengers were disembarked, and the crew began the process of preparing the aircraft for its return flight to Manchester. Once the cabin preparation was complete, the passengers were released from the terminal for boarding. During pre-flight preparations both flight deck crew members were subjected to numerous interruptions. These included details of a sick passenger at the back of the aircraft, a change in fuel requirements, a mix-up over passengers released from the terminal and a late change to the loading figures. Both crew members calculated takeoff performance as required by the operator's procedures and cross-checked their results. During this process, the crew inadvertently selected what they believed to be an intersection on Runway 21 for takeoff but was in fact the full length. This error was not picked up during the initial calculation or during the pre-takeoff check of the performance.

The commander was PF for the return flight. The aircraft pushed back from its parking position at 1945 hrs and proceeded to taxi to the holding point for Runway 21 on Taxiway U5. The aircraft took off from Taxiway U5 at 1959 hrs with performance calculated for the full runway length. The commander reported that the takeoff initially seemed normal but both flight crew realised there was something wrong as they saw the red and white alternate lights of the last 900 m of the runway. Takeoff/go-around (TOGA) thrust was not selected.

The takeoff distance available from U5 was 1,395 m less than that used for the performance calculation, and the aircraft became airborne with only 110 m of the runway remaining (Figure 1). During the flight the crew realised what had happened, and they reported it to the operator after landing.

The operator had two very similar events in April and May 2019[1].

Figure 1

Image of Lisbon Airport showing the calculated and actual takeoff points
©Google Earth

Footnote

1 Takeoff using incorrect performance data, Lisbon Airport, Portugal, 24 April 2019 https://www.gov.uk/government/news/aaib-report-airbus-a320-214-takeoff-with-insufficient-thrust-to-meet-regulatory-requirements [Accessed July 2020].

Recorded information

Flight recorders

G-EZWE was fitted with a Cockpit Voice Recorder (CVR) but this was not removed from the aircraft. The aircraft remained in service, with power applied to the CVR, for longer than the two hours recording capability of the CVR before the AAIB were made aware of the event, and therefore any recording would have been overwritten.

The aircraft was also fitted with a Flight Data Recorder (FDR), but the operator supplied Quick-access Recorder (QAR) data, therefore there was no need to remove the FDR from the aircraft.

The QAR data (Figure 2) showed that the aircraft commenced its takeoff roll at 1958:19 hrs having entered Runway 21 from Taxiway U5. 44 seconds later, at 1959:03 hrs, after a ground roll of 1,775 m and with approximately 570 m of runway remaining ahead of the aircraft, a V_1 of 162 kt was achieved. Five seconds later, at 1959:08 hrs, the aircraft became airborne approximately 110 m from the end of Runway 21. At the speed the aircraft was travelling over the ground this distance would have taken approximately 1.3 seconds to cover. One second later, whilst still over the paved surface of Runway 21, the aircraft achieved the regulatory screen height of 35 ft, for a dry runway, and crossed the airport boundary at 225 ft radio altitude. TOGA thrust was not selected at any point.

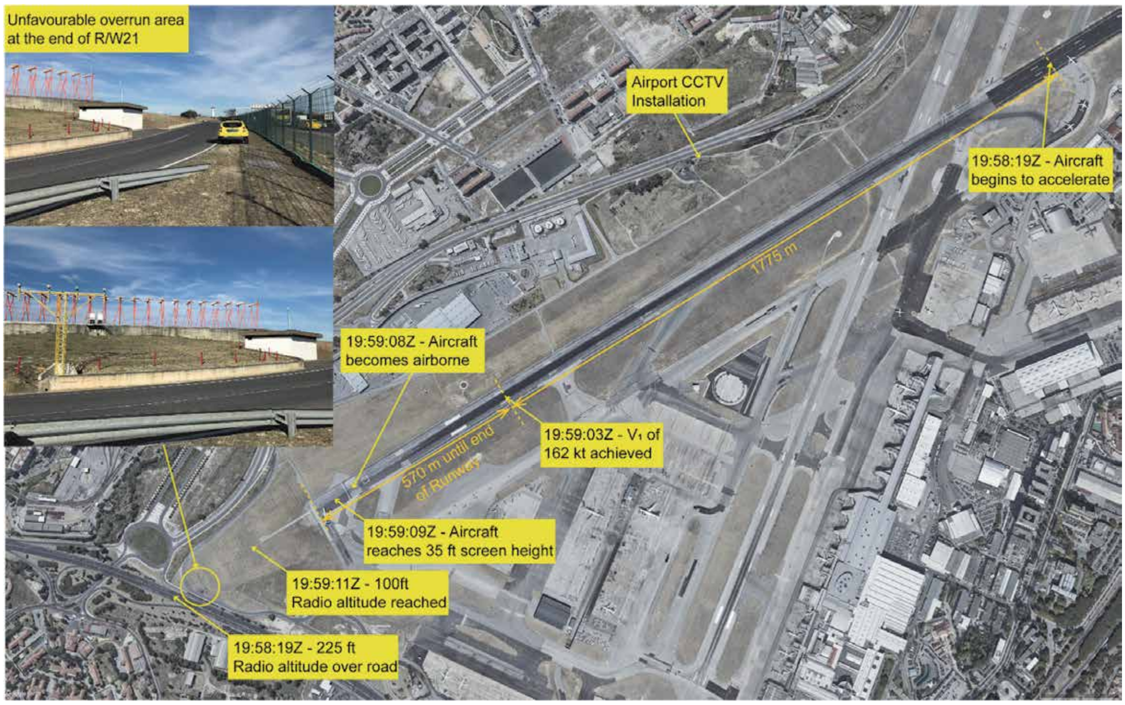

Figure 2

QAR Data showing G-EZWE's takeoff roll

Closed-circuit Television (CCTV) recordings

G-EZWE's takeoff roll was captured on several CCTV cameras around the airport. One of these cameras (situated as shown in Figure 2) covered the latter part of the aircraft's takeoff roll. The frame shown below (Figure 3), where the aircraft is highlighted by the yellow circle, was recorded just after the aircraft reached V_1, and the end of the runway is indicated by the row of red lights towards the right of the image.

Figure 3

CCTV screenshot showing G-EZWE just after reaching V_1

Aircraft information

The aircraft manufacturer has developed a system to provide crews with a warning when the thrust levers are set for takeoff if there is insufficient runway ahead to lift-off. This system compares the runway distance ahead of the aircraft at the point the thrust levers are set for takeoff with a lift-off distance for the takeoff, drawn from an internal dataset. The system is not designed to take account of the case of an aircraft stopping, or the climb-out performance. G-EZWE was not fitted with this system, but calculations by the aircraft manufacturer showed that in this case the system may have warned the crew, although the event was at the edge of the detectable envelope.

Aircraft performance

The purpose of the takeoff performance application in the Electronic Flight Bag (EFB) is to calculate the maximum takeoff weight or the maximum takeoff thrust reduction (known as FLEX on this type) for that particular aircraft, for a given runway and intersection taking into account all the regulatory requirements and the ambient conditions.

When the runway length is not limiting, there may be a range of valid V_1 speeds available. In this case, the program will select a V_1 which provides performance margins on both the accelerate-stop and the accelerate-go cases. In the case of the performance calculation for the full length of Runway 21, this generated a V_1 which was a balance from those that were valid for the Takeoff Run Available (TORA), Takeoff Distance Available (TODA) and Accelerate-Stop Distance Available (ASDA). This V_1 was higher than that which would have been generated if the performance had been calculated from U5 (the actual takeoff point), from where the runway distances were 1,395 m less. The V_1 generated for G-EZWE was 162 kt from the full length but would have been 142 kt for a calculation from U5. As the takeoff was from U5, the takeoff data used for G-EZWE's takeoff was invalid.

As part of the EFB calculations, an accelerate-stop distance (ASD) is calculated. This is the distance required to accelerate the aircraft to V_1 and, on experiencing an engine failure or emergency at that point, discontinue the takeoff and stop the aircraft. The ASD for G-EZWE from U5 was calculated as 2,995 m whereas the ASD available from U5 is 2,410 m. These figures suggest that, had the aircraft been required to stop from near V_1, a significant overrun of up to 585 m could have occurred. The calculated ASD includes a number of performance assumptions and factorisations, such as: no credit being taken for the use of reverse thrust; a delay being assumed before stopping action is taken by the pilot; and an increase in the two-engine distance to V_1 to account for other variables. The calculated ASD is therefore conservative.

A calculation was then made using the point at which the aircraft reached V_1 (162 kt). This calculation used none of the assumptions or factorisations used in the ASD case above and instead used a figure for the maximum rate of deceleration possible in the aircraft type (10 m/s^2). This calculation indicated that it would have required a minimum of around 580 m to stop from the V_1 speed of 162 kt. G-EZWE reached V_1 with approximately 570 m of Runway 21 remaining. Even using this idealised calculation, the aircraft could have overrun the available tarmac.

As shown in Figure 2, there are several obstructions beyond the runway that could have caused significant damage to the aircraft and its occupants should an overrun have occurred.

Previous incidents

The operator had two similar incidents at Lisbon which occurred within 14 days of each other earlier in 2019. As a result of these incidents the aircraft operator took action to try and prevent a further occurrence, including issuing a notice to crews, as part of the NOTAMs for Lisbon, to clarify the available takeoff points on Runway 21. They issued a full description of the events to all crew to raise awareness of the risks of using the wrong intersection and distance for takeoff. They also began work with the EFB data supplier to change the nomenclature of the takeoff points for Runway 21 in the performance software.

Airfield information

At the time of the incident Lisbon Airport had two runways which were orientated 03/21 and 17/35 (Figure 4). Runway 03/21 is the preferential runway for both takeoff and landing, and the prevailing winds mean that Runway 03 is more commonly used. Runway 17/35 is currently closed for use as a runway due to building work and is being used as a taxiway instead.

Lisbon Airport is unusual in that it uses named Positions to describe the available takeoff points on the runways. The reason for this has been described as “historic”, and it would be more commonplace for an airport to use taxiway nomenclature to describe takeoff points. The use of Positions is limited to the airport’s description within the Aeronautical Information Publication (AIP), but it is this information that commercial chart companies use in generating their publications. The information is also used by companies to generate the performance data for airlines. Positions are not generally referred to by ATC at Lisbon.

When Runway 21 is in use, the preferred departure point for all aircraft, except heavy jets, is ‘Position U’, which is the intersection of the runway with Taxiway U5. Pilots must advise air traffic control on start-up if they require the full length of the runway for departure. Full length departures are from holding point S4 which is known as ‘Position S’. At the time of the incident, Taxiway S began abeam Runway 17, before crossing Runway 21 at Taxiway S1, and then turning north-east to run parallel to Runway 21. This is marked on Figure 4 in blue. The taxiway ends at the threshold of Runway 21. There were therefore two points on Runway 21 where Taxiway S intersected the runway.

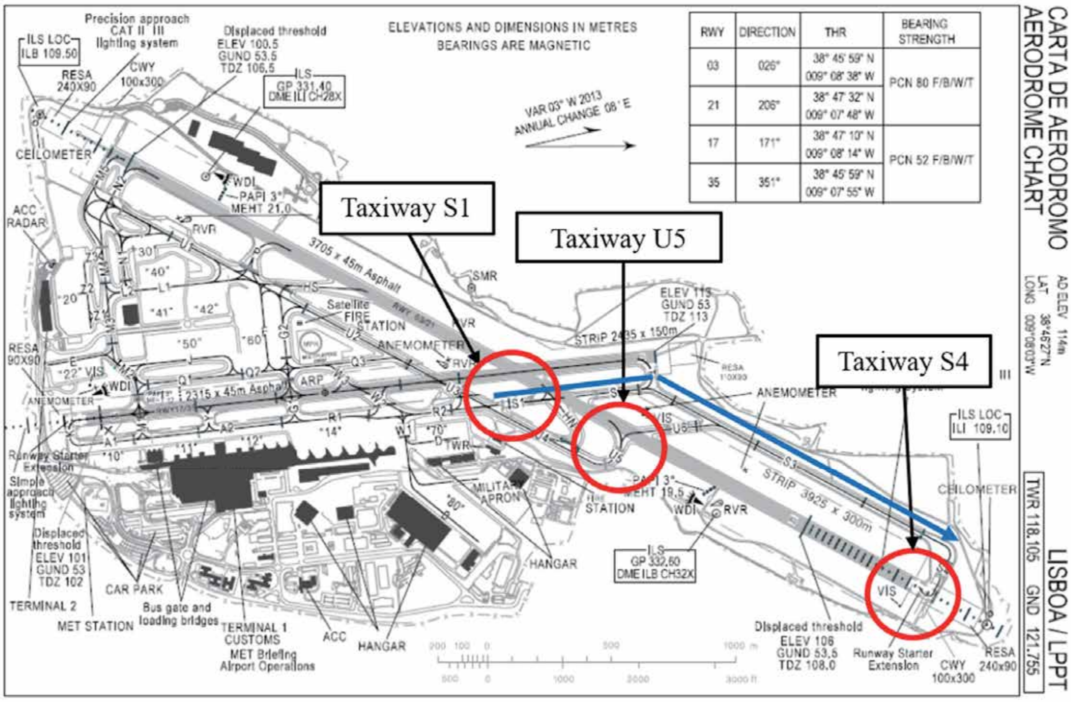

Figure 4

Plan of Lisbon Airport showing Taxiways S1, U5 and S4

Note: north is to the right of the image

As a result of the two previously reported incidents, but after this occurrence, the airport operator re-designated the taxiways on 5 December 2019 to eliminate this issue. The new taxiway designations are shown in Table 1.

Previous Designation	New Designation
A2 (BTN Y and G1)	A3
R1	A4
R2	A5
S1	A6
S2	A7
T	S1
S3 (BTN A7 and U6)	S2

Table 1
Taxiway re-designation

Also as a result of previous incidents in Lisbon, the AAIB issued a Safety Recommendation to the airport operator in January 2020:

Safety Recommendation 2020-003:

It is recommended that ANA Aeroportos de Portugal discontinue the use of takeoff Positions at Lisbon Airport to minimise confusion concerning takeoff points.

Electronic Flight Bag

The operator uses an EFB to calculate the weight and balance of the aircraft as well as takeoff performance. Both pilots have a tablet computer on which they do the required calculations. The tablet computers also provide the crew with aeronautical and aerodrome charts.

Power and stowage of the tablets

The tablets are provided with power from the aircraft, but they also have an integral battery should the power supply be disconnected or unavailable. Both sides of the flight deck have a cradle in which to mount the EFB. On the day of the incident, the commander's EFB cradle had been removed as it was broken. This meant that the commander would need to hold the EFB or use the tray table to use it. It became apparent to the commander during the pre-flight preparation in Manchester that it was difficult to use the EFB when it was connected to the aircraft power supply without the usual cradle, but that disconnecting from the power supply meant only a very short time of operation as the battery was unable to power it for any length of time. The very limited battery power available and the need to hold the EFB without the cradle also meant that using the EFB (including checking the aerodrome plates) was challenging.

The United Kingdom's Civil Aviation Authority (UK CAA) approves the use of EFBs used by the Air Operator Certificate (AOC) holders that they oversee. An operator applying to use EFBs must complete the UK CAA's form SRG1849, which was first published in July 2019 and is in the form of a compliance checklist. This checklist would normally be completed on initial application for use of an EFB and for subsequent significant changes, such as a change of operating system, a change of EFB hardware or the introduction of certain types of new applications. None of these criteria applied to G-EZWE's operator, which already had approval to use EFBs, but it completed the checklist retrospectively as part of a Special Objective Check[2] by the UK CAA in late 2019. The checklist includes several questions on the maintenance of EFBs, together with references to the relevant EASA regulations, and details the need for:

- a programme to replace EFB batteries.
- procedures to ensure the serviceability of the EFB before flight.
- procedures detailing how EFB failures are reported and crews notified of any unserviceability.
- general maintenance procedures and dispatch guidance for unserviceable elements of the EFB.

EASA publishes further guidance material to assist in the interpretation of the regulations and this states that:

> *'As part of the EFB system's maintenance, the operator should ensure that the EFB system batteries are periodically checked and replaced as required.'*

A section of the guidance material covering the dispatch of aircraft carrying EFBs details mitigations that should be considered by operators and includes the following statement:

> *'Mitigation should be in the form of maintenance and/or operational procedures for items such as:*
>
> *(1) replacement of batteries at defined intervals as required;'*

Electronic flight bag nomenclature

Data for the EFB performance software is supplied to the operator by a third party. Within the software the crew must initially select the runway for departure and then a point on that runway from where the takeoff will begin. Some runways may have multiple intersections

Footnote

2 A Special Objective Check (SOC) is a UK CAA process used to audit areas of risk or non-compliance across either the whole industry or segments of it. The need for a SOC is identified by the UK CAA's Safety Risk Panel and managed centrally by the relevant Flight Operations Manager who appoints a SOC lead.

available for departure and, in the case of Lisbon Runway 21, two positions are available, Position U and Position S. These are named in the software as PSNU and PSNS. At the time of the incident, there was a NOTAM affecting the takeoff performance calculation (referring to an obstacle in the climb-out zone). This meant that the data supplier had inserted two further temporary selections for the two takeoff positions for Runway 21, which were labelled PSNUTMP and PSNSTMP as shown in Figure 5.

Figure 5

EFB drop-down menu showing the all the intersections available
(not the actual incident data)

The crew discussed the likely takeoff point and decided that they could use the S1 intersection if necessary, from which there was a lower TORA than from U5. They then performed the calculation in the EFB, using PSNSTMP as the selection for the S1 intersection. S1 is not an approved intersection for departure on Runway 21.

Operator developments

As a result of this incident and the two previous cases, the operator changed the nomenclature in the EFB for Runway 21. This change eliminated the use of Position S, instead using merely '21' to indicate that this point is the full length of the runway. The new drop-down selection is shown at Figure 6.

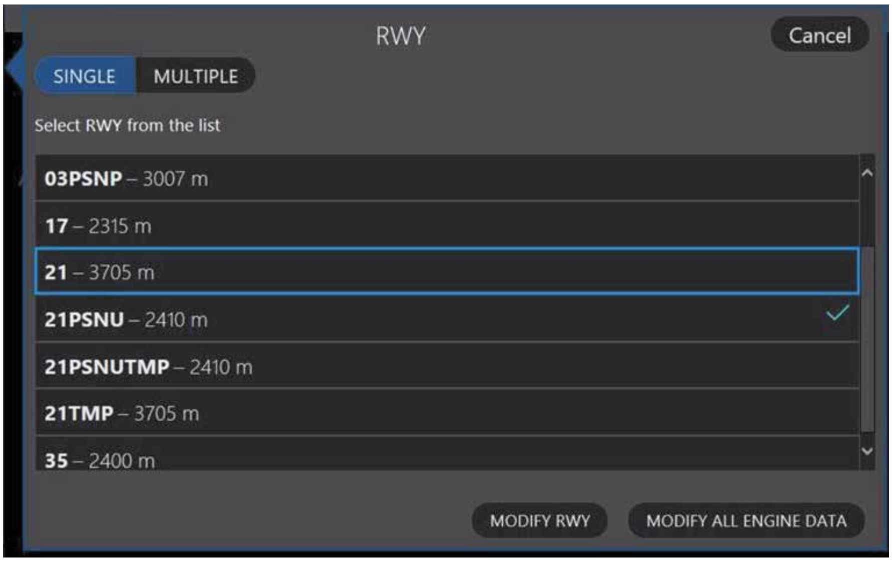

Figure 6

New nomenclature in EFB drop-down menu

In December 2019, the operator also moved onto a newer version of the performance software, Flysmart L6, which offers a pictorial representation of where the performance calculation was referenced to. Figures 7 and 8 show how the new software would have shown a calculation from Position S and Position U on Runway 21 (not using incident data).

Figure 7

New software calculation display for Runway 21 Position S

Figure 8

New software calculation display for Runway 21 Position U

Human factors

Distraction during the process of calculation

Both crew members reported that they were interrupted numerous times during the pre-flight preparation. This included during the period in which they were entering the data for the performance calculation. The operator has recognised that distraction can be detrimental to weight and balance as well as performance calculations. The Standard Operating Procedures (SOP) were designed to try to minimise this with steps such as an EFB validation check, where both pilots check their calculations against the other before the data is entered into the Flight Management Guidance Computer, and a takeoff data cross-check before completion of the Before Takeoff checklist. These are designed to focus the pilots' attention on the task at hand and avoid distraction. The performance figures are also first calculated based on the initial load figures, which tend to be given to the crew early in the turnaround which is normally a stage of low interruption. These are then not altered for any last minute changes, unless they are significant, as last minute changes typically occur at a higher workload phase.

Recognition of the invalid takeoff performance

The AAIB has investigated numerous serious incidents where aircraft have taken off using performance information calculated from a different start point. Worldwide, similar events present a significant hazard to civil aviation despite SOPs containing measures designed to prevent them, such as cross-checks and independent calculations. Pilots performing cross-checks often fail to notice errors or differences when the figures are unexpected, and incorrect calculations can lead to insufficient thrust, and therefore acceleration, during takeoff. Humans are poorly adapted physiologically to discriminate between slightly different acceleration rates, and many years of training have made pilots reluctant to move the throttles once takeoff power is set[3]. In recognition of this, the AAIB has previously made safety recommendations that a technical barrier should be developed which would recognise events where the takeoff acceleration is lower than expected.

Analysis

During pre-flight preparation, both flight crew of G-EZWE selected PSNSTMP in the EFB believing it to be where Taxiway S1 crossed Runway 21, but the position was actually for the full length of the runway. The operator's SOPs required the crew to cross-check the distance shown in the EFB against that shown in the aerodrome ground chart for the takeoff position, but this cross-check did not capture the error. As a result, a lower power setting was used for takeoff than was required for the actual takeoff from Taxiway U5 intersection (Taxiway S1 intersection was more limiting). G-EZWE lifted off 110 m or, at the speed at which the aircraft was travelling, approximately 1.3 seconds before reaching the end of the runway. This was the third aircraft from the same operator, although one was operating under a different AOC, which had experienced similar incidents in the previous six months.

In all three cases the pilots were confused by the EFB intersection selections as they did not use the actual taxiway names. Also, there were two points on the runway which intersect Taxiway S (1 and 4) both of which might have been thought by the crew to be in the EFB as PSNSTMP as the taxiway numbers are not used in the nomenclature.

During the completion of the initial calculation the crew were interrupted numerous times despite the SOP mitigations that the operator had in place. The commander also had no access to the EFB once the aircraft taxied due to an inoperative cradle. He was not, therefore, in a position to see the taxi plate or the performance calculation, although he was not required to be by the company SOPs. The EFB battery condition had substantially deteriorated over time and the EFB was not useable for long without being charged by the cradle. The UK CAA decided to revise the EFB compliance checklist, SRG form 1849, to ensure that the requirement for a periodic battery replacement programme is emphasised. The crew did not recognise the takeoff performance was incorrect until a late stage of the takeoff run. This would match with previous investigations completed by the AAIB which have shown that humans are not physiologically adapted to identify different acceleration rates, and often do not realise something is wrong until the end of the runway comes into view. As in previous incidents, TOGA thrust was not selected despite the compromised takeoff performance.

The magnitude of the error meant that had the aircraft stopped from a speed close to or at V_1, a significant overrun could have occurred. This could have caused significant damage to the aircraft and its occupants.

Footnote

3 AAIB report into a serious incident in Belfast Aldergrove Airport. Boeing 737, C-FWGH, took off with insufficient thrust for the environmental conditions and struck an obstacle after lift-off.
https://www.gov.uk/aaib-reports/aircraft-accident-report-aar-2-2018-c-fwgh-21july-2017
[Accessed July 2020.]

Conclusion

The aircraft took off using incorrect performance data for the intersection used. A selection error was made in the EFB calculation which led the crew to believe that they had calculated performance information for a departure from S1 when in fact they had selected the full length of the runway. In this case, as in the two previous identical incidents, the final barrier of checking the runway distance in the performance calculation against the aerodrome ground chart failed to prevent the error. Human performance limitations mean it is difficult for pilots to recognise and react to the performance error once the takeoff has begun, so robust adherence to procedures is a key defence against such incidents occurring.

Safety action

Following the previous incidents, the AAIB reported that the Lisbon Airport operator intended to rename taxiways to remove the risk of confusion between the two points where Taxiway S crossed Runway 21. The taxiways would be renamed so that Taxiway S intersected the runway at only one point; S4 (full length). This safety action was completed, albeit after the incident to G-EZWE, and is reported here.

The operator has moved onto Flysmart L6 performance software which now shows the crew a pictorial image of the takeoff point used for the calculation. The takeoff point selection menu was also amended to eliminated Position S making it clear to the crews that this was full length for Runway 21.

The UK CAA decided to revise the EFB compliance checklist, SRG form 1849, to ensure that the need for a periodic battery replacement programme is emphasised.

Published: 6 August 2020.

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A320-214, OE-LOA
No & Type of Engines:	2 CFM56-5B turbofan engines
Year of Manufacture:	2007
Date & Time (UTC):	1 March 2019 at 2020 hrs
Location:	London Stansted Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 7 Passengers - 169
Injuries:	Crew - None Passengers - 10 (Minor)
Nature of Damage:	Left engine contained failure
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	14,128 hours (of which 10,308 were on type) Last 90 days - 195 hours Last 28 days - 71 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was on a scheduled flight from London Stansted Airport to Vienna International Airport, Austria. Shortly after the takeoff roll was commenced it was rejected, due to a contained failure of the left engine, and the aircraft was brought to a stop on the runway. Just as the flight crew were about to taxi the aircraft off the runway, an evacuation was commanded by the Senior Flight Attendant. The investigation identified several factors that contributed to this decision. Ten passengers were treated for minor injuries that occurred during the evacuation and there was a risk of serious injury due to one of the engines running during the evacuation. The operator has taken several safety actions, principally based around the training of its flight attendants. Two Safety Recommendations regarding passenger evacuation have been made in this report.

The left engine experienced a contained failure following the rupture and release of several blades from the first stage of the high-pressure compressor. The investigation found that the blades fractured as a result of high-cycle fatigue loading which initiated in the dovetail (part of the blade root), due to a once-per-revolution aerodynamic excitation. An inlet guide vane lever arm had been improperly assembled which led to aerodynamic excitation of the passing blades and the resulting forces exceeded the design loads of the blades.

History of the flight

The aircraft was on a scheduled flight from London Stansted Airport to Vienna International Airport, Austria, having previously flown in from Vienna about an hour earlier. The commander was the PF for the sector and it was a line training sector for the co-pilot. There were five flight attendants[1] (FAs), including an additional crew member (ACM)[2].

The aircraft pushed back and taxied out to Runway 22 without event. ATC clearance was then given for the aircraft to line up and take off. At the time it was dark outside, and the weather was clear with the wind from 160° at 5 kt. In the cabin, the lights had been dimmed for takeoff, as is normal practice.

Flight crew observations

Having lined up on the runway, the commander set the throttles to FULL POWER/TOGA[3] and commenced the takeoff roll. About one second after the co-pilot said "THRUST SET", at a groundspeed of 31 kt, a loud bang was heard and the aircraft immediately drifted towards the left of the runway. The commander said "STOP STOP STOP" and rejected the takeoff. The aircraft came to a stop between the centreline and the left side of the runway. The commander then set the parking brake, selected the public address system (PA) button and announced "ATTENTION CREW: ON STATION"[4] twice. The co-pilot then informed ATC that they were stopping on the runway and then completed the actions for '*ENG 1 FAIL*' and *'ENG 1 REVERSER UNLOCKED'* electronic centralised aircraft monitor (ECAM) messages; there were no fire indications. The left engine was shutdown at 2006:23 hrs.

After the ECAM messages had been actioned the commander contacted the RFFS, who were quickly on the scene, on frequency 121.6 MHz to confirm that there were no signs of fire visible from the outside. As a result, it was decided to vacate the runway using the thrust from the right engine and he asked ATC for clearance to do so.

At 2007:21 hrs, just as the commander was about to make a PA to instruct the FA to return to normal operations, he noticed an amber *'DOOR L [LEFT] FWD [FORWARD] CABIN'* caution message illuminated on the ECAM. At first, he thought it was a fault but then saw the evacuation slide deployed at Door L1 out the left cockpit window and passengers moving across the front of the aircraft. The commander then had a conversation with the Senior Flight Attendant (SFA), over the interphone, during which the commander asked why the evacuation had been initiated. She replied that she believed he had ordered one, which he denied. After this conversation, the APU was started and the right engine, which was still operating while the evacuation was underway, was selected OFF at 2009:38 hrs.

Footnote

1 The operator refers to its cabin crew as flight attendants.
2 An ACM is a member of the flight attendant team who is not designated an operational role. She was having a familiarisation flight having recently completed her training.
3 It was a requirement of the operator to do a full power/TOGA takeoff, for maintenance purposes, on the first day of each month. The flight crew elected to carry this out on the sector from Stansted to Vienna.
4 In an emergency on the ground, this command is issued as an advance warning. Upon this command, flight attendants should immediately move to their doors, remain on high alert and wait for additional commands from the cockpit.

The co-pilot then went into the cabin while the commander stayed in the cockpit and maintained contact with ATC and the RFFS. In the cabin the co-pilot found no passengers but noted a lot of baggage near the exits. There were also only three of the five FA present, as two had left the aircraft to assist the passengers on the ground. The commander then requested they return to the aircraft, which they subsequently did.

Flight attendants' observations

Soon after the takeoff roll started, all the FAs heard a loud noise and felt the aircraft drift to the left before coming to a stop a few seconds later. All except the SFA heard the commander announce "ATTENTION CREW: ON STATION" over the PA after which they all stood up at their assigned exits. At the front of the cabin the SFA stood in the aisle facing rearwards, while FA2 looked out of the Door 1L window. At the rear of the aircraft FA4 and FA3 looked out of Door 3L and 3R respectively while the ACM stood in the middle. No danger was observed; they thus awaited further instructions from the commander. Figure 1 shows the location of the seating positions of the FAs and doors.

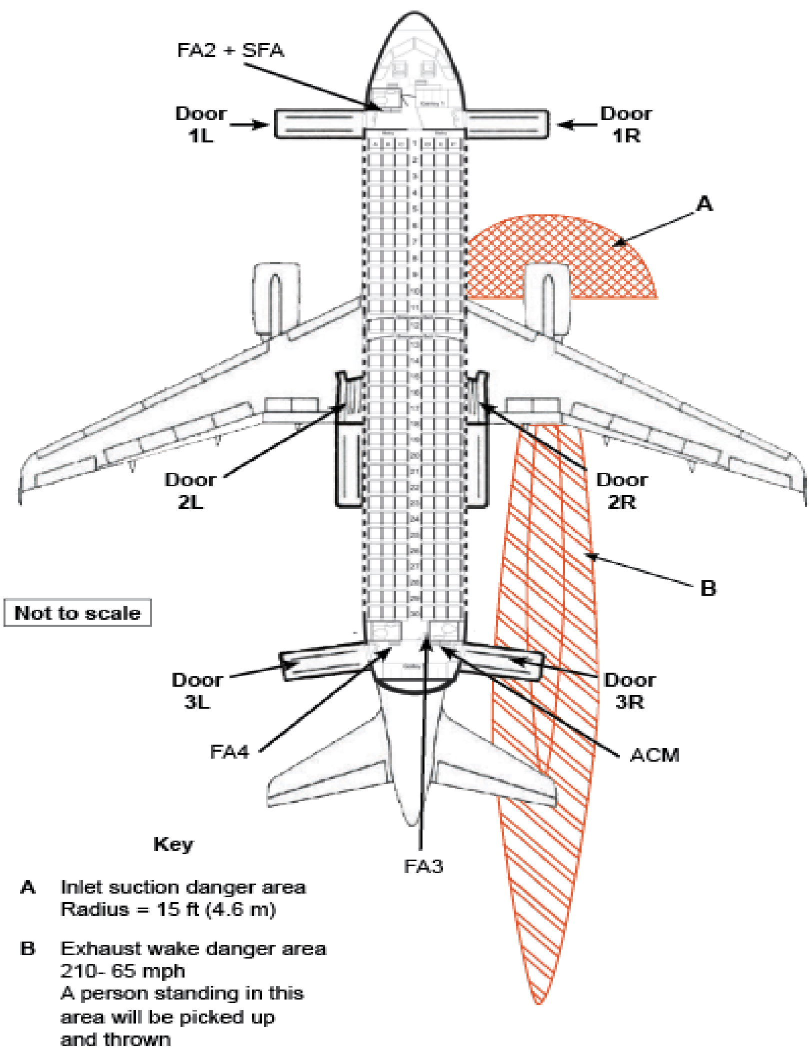

Figure 1

A320 doors, FA seating locations and engine hazard areas

The SFA then tried to call FA3, in the rear of the aircraft, using the interphone, to check if everything was alright. However, when FA3 stood up, his crew swivel seat displaced the attached handset from its stowage and its cable became trapped in the now folded seat[5]. This caused the crew high/low chime[6] in the cabin to be suppressed so it was difficult for the SFA to attract FA3's attention. There then followed an exchange between the SFA and FA3 which resulted in the SFA commanding an evacuation over the PA. See the *Flight attendants' comments* section for details of this exchange. Upon hearing the command, the FAs and passengers commenced the evacuation.

When FA3 opened Door 3R the escape slide inflated and floated in the air, close to the horizontal, but he did not understand why at the time. However, knowing it was unsafe to use, he blocked the exit. The slide at Door 3L inflated correctly and FA3 and 4 shouted their evacuation commands to the passengers as the passengers exited the aircraft. Several passengers brought hand baggage with them, but it was removed from them and placed by Door 3R. A similar situation with baggage occurred at Doors 1L and 1R. See the *Emergency evacuation* section for more on the evacuation.

Once all the passengers had left the aircraft, the FAs checked the cabin. FA3 then instructed the ACM to exit the aircraft to assist the passengers. He was about to follow her but the SFA instructed all the FAs to remain on the aircraft. Shortly thereafter the FAs found out that the evacuation was not necessary. As a result, FA3 left the aircraft to find the ACM to inform her to return to the aircraft.

The airport RFFS were quickly in attendance and were subsequently joined by local authority ambulances.

Two injured passengers were taken to hospital and several were treated for minor injuries at the scene. The passengers were subsequently taken to the airport terminal by buses. The majority of them were able to travel on to Vienna on a replacement aircraft later that evening.

The aircraft was subsequently towed off the runway to a remote parking position.

Flight attendants' comments

All the FAs were initially interviewed by the AAIB the following day. Further interviews were later conducted with the SFA, FA3 and FA4.

SFA's comments

The SFA stated that the noise of the engine failure was very loud. The noise and the movement of the aircraft to the left scared her. She reported that her attention was focused on the noises made by the aircraft and she did not hear the commander announce "ATTENTION CREW: ON STATION" over the PA.

Footnote

5 See *FA3 crew seat and cabin interphones* section for more details.

6 The high/low chime alerts the FAs that there is an incoming call on the interphone. Lights in the ceiling indicate who is calling.

The SFA reported that she stood up when the other FAs stood up. She was aware of all the passengers looking at her and felt under pressure because of this. She was feeling "*shocked*" and overwhelmed. She attempted to contact FA3 at the rear of the aircraft, initially without success. She reported that it felt like a long time that she was trying to contact FA3. There was confusion while they attempted to communicate using a combination of the interphone, hand signals and the PA. The darkness in the cabin made the use of hand signals difficult and she could not see well enough to understand signals given by FA3.

The SFA commented that she intended to obtain information from FA3 to help her decide whether an evacuation was needed. She added that FA3 said he had seen flames and sparks from the engine. Her impression was that FA3 was "scared and shocked" and FA2 was "completely shocked". She stated she attempted to discuss what to do with FA3. However, at some point during this exchange she said "EVACUATE, EVACUATE, EVACUATE" over the interphone and subsequently over the PA.

The SFA stated that she knew the guidance from the operator's flight safety manual about the circumstances to initiate an evacuation but was not thinking about this at the time. See *Flight attendants' training and experience* section. The SFA explained that she generally had very limited interaction with the pilots and a limited understanding of their responsibilities in an emergency. She said, "For me, it was the door closed, I have nothing to do with them." And she did not think about contacting the flight crew at any point.

FA3's comments

FA3 reported that he heard a bang when the engine failed and saw red and yellow lights through the passenger windows for one or two seconds. He recalled that FA4 told him and the ACM to stay calm and expect instructions from the flight crew.

After the "ATTENTION CREW: ON STATION" announcement he fumbled with the seat when standing up. It closed very fast, knocking the interphone from its cradle. The interphone fell to the floor and the cable became trapped in the seat.

The next communication he was aware of was the SFA asking "Can you hear me?" over the PA. FA3 said he subsequently had difficultly freeing the interphone. He stated that when he was eventually able to speak to the SFA she said "evacuate, evacuate, evacuate". He did not understand why she would command an evacuation over the interphone and felt he could not open the door alone, so he told her to announce it over the PA.

FA3 commented that in this situation "A few seconds feels like minutes" and it is difficult for FAs waiting after the "ATTENTION CREW: ON STATION" command because they do not know what is going on in the flight deck and feel responsibility for the passengers' safety.

FA4's comments

FA4 reported that she started briefing FA3 and the ACM after the engine failure. She told them to stay calm and wait for the "ATTENTION CREW: ON STATION" command and not to open the doors. She explained that she did this because she was aware of their inexperience and to keep herself calm.

She did not follow all the conversation between FA3 and the SFA, but she remembered FA3 saying that he had seen fire outside. She heard him tell the SFA to say the evacuation command "out loud". She attempted to contact the SFA via the other interphone at the rear of the aircraft but was unsuccessful. Then the SFA announced "*EVACUATE, EVACUATE, EVACUATE*" over the PA.

FA4 initially hesitated to begin the evacuation but when she realised that FA3 had already opened the Door 3R, she opened Door 3L.

Emergency evacuation

AAIB passenger questionnaire

The airport operator commented that it has a requirement in its *Terminal Emergency Orders* for the AAIB's passenger questionnaire to be distributed to passengers after an evacuation. However, none were given to the passengers on this occasion as an alternative aircraft had been sourced by the parent company of the operator. As a result, the airport operator's staff were busy organising those passengers that wanted to complete their journey to Vienna. Most passengers subsequently completed their journey later that evening.

After the accident the AAIB emailed its *Passenger Questionnaire* to the 169 passengers; 46 (27%) were subsequently returned.

Injuries

Local authority ambulances attended the scene. They reported that 10 patients were treated for minor injuries at the scene by paramedics. Most of the injuries were cuts, grazes, bruises and sprains. Two were subsequently taken to a local hospital for further treatment but were later discharged. While the physical injuries sustained were minor, a few passengers stated on the questionnaires that they have suffered from post-traumatic stress which they were receiving treatment for.

Passengers' comments

Several of the passengers commented that after the aircraft came to a stop the FAs seemed to have problems with the PA. Additionally, they used the PA to communicate between the front and rear of the aircraft in German. Four passengers commented that they either did not hear or did not fully understand the command to evacuate.

Numerous passengers also commented that the aisle and Doors 2L and 2R and the overwing exits, were impeded as people were trying to take their baggage from under seats and overhead bins. As a result, passengers were shouted at by some to leave their baggage behind. One passenger thought that about half of the passengers took their hand baggage with them. Images of passengers leaving the aircraft with baggage from the right overwing exit were captured by the RFFS's onboard infrared CCTV camera (Figure 2).

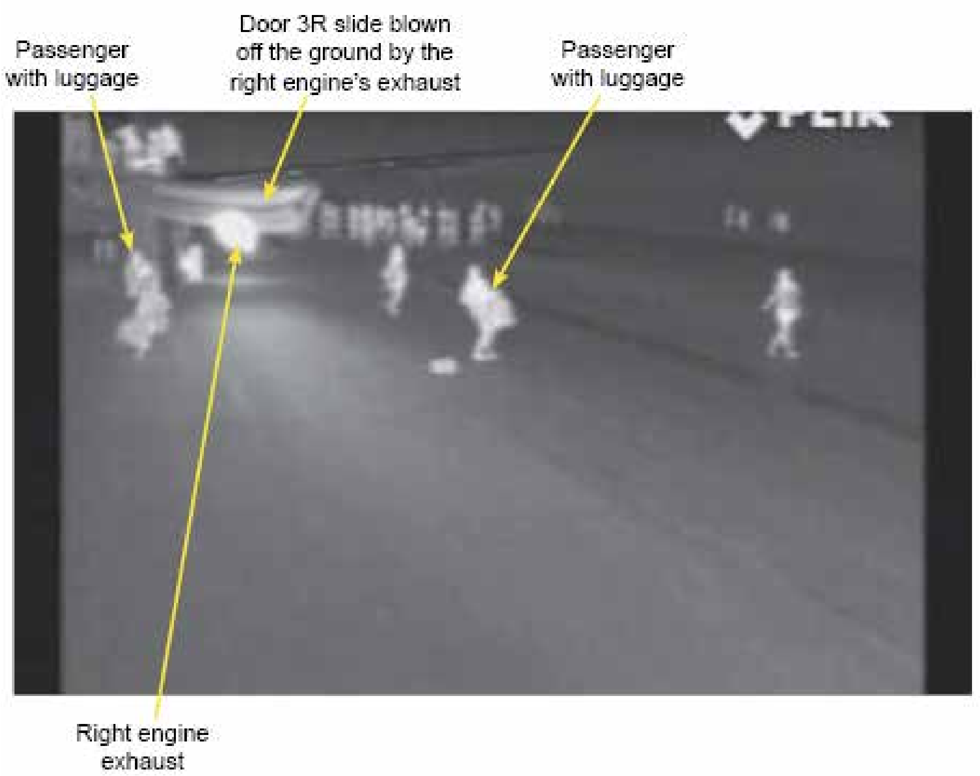

Figure 2

RFFS infrared CCTV showing some passengers leaving with baggage

Of those passengers that used Door 2R, several commented that they were either nearly blown over, or were blown over several times by the jet exhaust from the right engine, with some of their belongings blown away. Figure 1 shows passengers crossing behind the engine exhaust could have been exposed to 'wind' speeds of 65 mph or greater, even with the engines running at idle.

A320 emergency evacaution checklist

The '*EMER*[GENCY] *EVAC*[UATION]' checklist from the A320 Quck Reference Handbook (QRH) (Figure 3) was what the flight crew would have actioned had the commander elected to command an evacaution.

[QRH] EMER EVAC

Ident.: PRO-ABN-MISC-00012083.0001001 / 09 MAY 17
Applicable to: ALL

Apply this procedure when considering an emergency evacuation, or when required by the ECAM. Carefully analyze the situation before deciding to evacuate passengers. However do not waste valuable time.

AIRCRAFT / PARKING BRK...STOP / ON
ATC (VHF1)...NOTIFY

Notify ATC of the nature of the emergency, and state intentions.
Only VHF 1 is available on batteries.

CABIN CREW (PA)...ALERT

Make a short and precise announcement to warn that an emergency evacuation may be required.

ΔP (only if MAN CAB PR has been used)...CHECK ZERO

If ΔP is not at zero, MODE selector on MAN and V/S CTL FULL UP, to fully open the outflow valve.

- **If ΔP not at zero:**
  CAB PR MODE SEL...MAN
  V/S CTL...FULL UP

ALL ENG MASTER...OFF

Associated LP and HP valves close.

ALL FIRE pb (ENGs & APU)...PUSH
ALL AGENTS (ENGs & APU)...AS RQRD

Engine Agent 2 is not available.
The use of agents is required if the ENG FIRE or APU FIRE is displayed.

- **If evacuation required:**
  EVACUATION...INITIATE
  Make a short and precise announcement to order the emergency evacuation.
  Press the EVAC COMMAND pb .

- **If evacuation not required:**
  CABIN CREW AND PASSENGERS (PA)...NOTIFY

Figure 3

A320 Evacuation checklist

Safety studies regarding passenger behaviour during evacuation

The issue of passengers taking baggage with them during an evacuation has been well documented.

An NTSB safety study on evacuation of commercial aircraft[7] stated that '*Passengers exiting with carry-on baggage were the most frequently cited obstruction to evacuation.*' The study collated questionnaires from passengers who had been evacuated and found that almost 50% attempted to remove a bag during the evacuation. The primary reason given was to keep hold of high value items in the bags such as money, keys and medicine.

Footnote

[7] National Transportation Safety Board (2000). Emergency Evacuation of Commercial Airplanes. Safety Study NTSB/SS-00/01. Washington, DC: NTSB https://www.ntsb.gov/safety/safety-studies/Documents/SS0001.pdf [Accessed July 2020].

A similar safety study by the Transportation Safety Board (TSB) of Canada[8] studied 21 evacuations and found nine in which passengers stopped to retrieve carry-on baggage and attempted to take it with them as they exited the aircraft, despite being told not to by the flight attendants.

An EASA-sponsored study on CS-25 cabin safety requirements published in 2009[9] identified 13 evacuations in which evacuees attempted to collect cabin baggage and five where they carried baggage out of exits or down the slides.

In 2018 the Royal Aeronautical Society published a paper entitled '*Emergency Evacuation of Commercial Passenger Aeroplanes*[10]'. It highlighted many of the factors that influence the success of an evacuation, including the tendency for passengers to take baggage with them. The paper identified six accidents where passengers evacuated with baggage.

These studies identified accidents and incidents where passengers evacuated with baggage. Appendix 1 provides a list of those cases where the full report was available online and described the issues with the passengers' behaviour.

The Royal Aeronautical Society commented '*This trend appears to be increasing and can only be exacerbated by the increasing volume of cabin baggage being permitted by some operators for commercial reasons.*'

The paper stated that operator practice of charging for hold baggage has resulted in there being more baggage in the cabin and an increased number of passengers travelling with only cabin baggage.

The Royal Aeronautical Society paper emphasises the point that passenger behaviour is not strongly influenced by briefing or flight attendant instructions and recommends:

> *'Aviation authorities should consider the feasibility of introducing a certification requirement for a means of remotely locking, from the flight deck, overhead bins in passenger cabins that do not contain emergency equipment, for taxi, take-off and landing.'*

Footnote

8 Transportation Safety Board Canada (2013). Aviation Safety Study SA9501: A safety study of evacuations of large passenger carrying aircraft. https://skybrary.aero/bookshelf/books/2699.pdf [Accessed July 2020].

9 European Aviation Safety Agency (2009). Project EASA.2008.C18 Study on CS-25 Cabin Safety Requirements. https://www.easa.europa.eu/sites/default/files/dfu/1%20-%20Study%20on%20CS-25%20Cabin%20Safety%20Requirements-easa.2008.c18.pdf [Accessed July 2020].

10 Royal aeronautical society (2018). *Emergency Evacuation of Commercial Passenger Aeroplanes*. https://www.aerosociety.com/media/8534/emergency-evacuation-of-commercial-passenger-aeroplanes-paper.pdf [Accessed July 2020] .

Safety recommendations following previous evacuations

On 16 April 2012 an Airbus A330, registration G-VSXY[11], was en route from London Gatwick Airport to McCoy International Airport in Orlando, USA, when a smoke warning in the aft cargo compartment illuminated. After a successful emergency landing an emergency evacuation was ordered. The AAIB report concluded that some passengers slowed their own evacuation due to issues with cabin baggage. As a result, the following Safety Recommendation was made:

Safety Recommendation 2014-005

It is recommended that the European Aviation Safety Agency amend AMC1 CAT.OP.MPA.170, 'Passenger briefing', to ensure briefings emphasise the importance of leaving hand baggage behind in an evacuation.

The EASA's response to this Safety Recommendation was that it had evaluated this safety issue within the framework of rulemaking tasks RMT.0516 and RMT.*0517 Updating Air OPS Regulation (EU) No 965/2012/Implementing Rules and related Acceptable Means of Compliance (AMC) & Guidance Material (GM).*

The outcome of the evaluation was contained in EASA Executive Director (ED) Decision 2017/008/R, which was published on the EASA website on 30 March 2017.

The ED Decision introduced new text under AMC1 CAT.OP.MPA.170 on 'passenger briefing' which states that, before takeoff and before landing, passengers should be briefed on/reminded of the importance of leaving hand baggage behind in case of evacuation. This is stated in Section 1.2.12, *Passenger briefing*, of the operator's *Flight Safety Manual.*

The ED Decision also introduced guidance under GM2 CAT.OP.MPA.170, (f)(5)(vi) *Passenger briefing - safety briefing material* which states that the operator should consider including information on leaving hand baggage behind, in its safety briefing material on emergency exits. The operator of OE-LOA had this information on its passenger safety cards that were in each seat pocket of the aircraft and in Section 1.1.12.4, *Safety card*, of its *Flight Safety Manual*.

The EASA stated that emergency evacuations had also been captured as a candidate safety issue within their safety risk portfolio for commercial air transport (fixed wing), as part of the EASA's safety risk management process.

Footnote

[11] The full report into the accident involving G-VSXY can be found here: https://www.gov.uk/aaib-reports/1-2014-g-vsxy-16-april-2012 [Accessed July 2020].

CS-25 requirements for evacuation emergency demonstration

CS-25.803[12] requires that all passengers and crew can be evacuated within 90 seconds and compliance must be shown using a demonstration. Appendix J of CS-25 specifies test criteria and procedures for the demonstration. It must be conducted in the dark with a certain mixture of passengers in terms of age and gender. It requires a proportion of cabin baggage and other items to be placed in the cabin to act as minor obstructions. It does not require any of the simulated passengers to retrieve their own baggage and attempt to leave the aircraft with it.

Flight attendants' training and experience

The SFA initially qualified as a FA in May 2017 and flew from then until November 2017 for the previous operator[13]. Between December 2017 and March 2018 she did not fly due to the previous operator going bankrupt and the current operator commencing operations. She resumed working for the current operator who had taken over as the AOC holder. She completed SFA training and was promoted to SFA in May 2018.

FA4 also worked for the previous operator and had a period of not flying between December 2017 and March 2018. All the other FAs were recruited after this. The ACM was completing her first familiarisation flight following her initial training.

The operator reported that the initial FA training course was designed for 20 to 25 trainees, though there was no formal limit. It consisted of a six-week classroom-based course and practical training using a Cabin Emergency Evacuation Trainer (CEET)[14]. The SFA's initial FA course was attended by 39 trainees. Her SFA course was a five-day classroom-based course.

Though the SFA and FA4 were initially trained by a previous operator, there was a lot of continuity of practice and staff between the previous and current operators. All practical training scenarios in the CEET resulted in a simulated evacuation. The initial and senior training received by these FAs did not include examples of the pilots' activities when responding to an emergency or the potential effects of startle and surprise on FA performance.

The operator did not have their own FA simulation training facility and relied on the use of a facility owned by another operator.

All FA training met the relevant requirements and was approved by the national aviation authority.

Footnote

[12] European Union Aviation Safety Agency (2020) *Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes CS-25.* Amendment 24, 10 January 2020. https://www.easa.europa.eu/sites/default/files/dfu/CS-25%20Amendment%2024.pdf [accessed on 30 March 2020].

[13] The current operator started on 1 March 2018. All references in this report to the 'operator' refer to this current operator unless they are specifically identified as the 'previous operator'.

[14] A simulation device that approximates the passenger cabin environment and equipment to enable practical emergency scenarios to be trained.

Organisational information

The operator's Operations Manual, Part A, stated: '*the designated senior flight attendant must have at least one year's experience as an operating cabin crew member.*'

The operator did not have any requirements for the composition of the FA team in terms of experience.

Emergency evacuation initiation

Normally the commander would initiate an emergency evacuation using the PA. However, FAs can command an evacuation under certain circumstances. These are stated in the operator's *Flight Safety Manual*:

> '***1.16.1 Carrying out an evacuation***
> …
> *If no evacuation command is issued from the cockpit, and there is no doubt that an evacuation is necessary, the Senior FA or any other FA can initiate an evacuation under the following conditions:*
>
> ***a) Immediate danger (fire, smoke, explosion, water etc.)***
>
> ***b) Cockpit crew is incapacitated (injured, not on board)***
>
> ***c) Communications down due to heavy damage to aircraft***'

Aircraft information

Evacuation routes

The slides available on the aircraft are shown in Figure 1. FAs do not supervise the overwing exits but give a brief to those passengers adjacent to them about their duties in the event of an evacuation before departure.

FA3 crew seat and cabin interphones

There were three interphone handsets located in the aircraft; one at the front and two at the rear.

A rear aisle swivel seat folded away from the wall and locked into position to provide a forward-facing view into the passenger cabin. When the release latch was lifted, the seat automatically folded back into the stowed position (Figure 4).

The rear interphone intended for use by FA3 was located on the aisle swivel seat.

Figure 4

Rear aisle swivel seat in stowed (left) and forward-facing (right) positions

Figure 5

Example picture of interphone dislodged from the cradle and trapped in the stowed seat

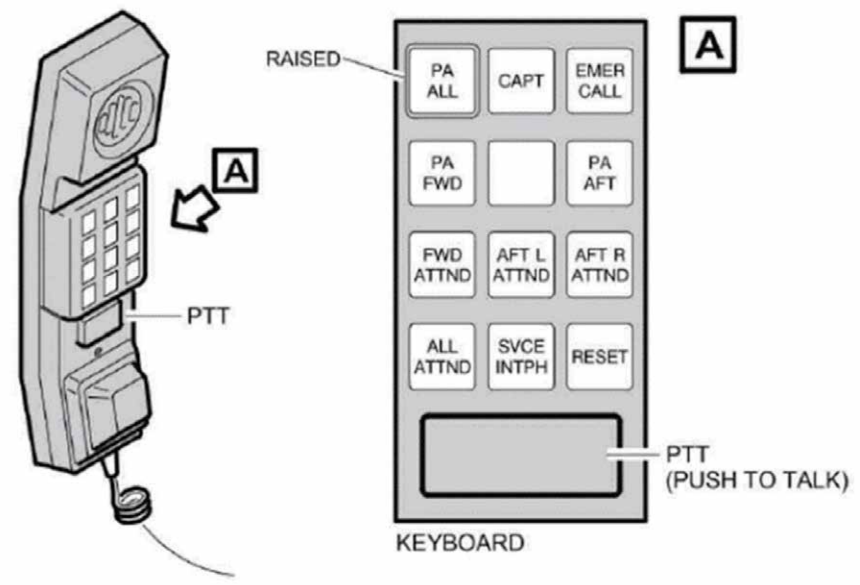

Figure 6
Interphone handset

Figure 6 shows the buttons available on the passenger cabin interphones. It was possible to call the FA3 interphone handset individually from the front handset using the AFT R[IGHT] ATTND [FLIGHT ATTENDANT] button or to call all handsets together using the ALL ATTND button. If the handset was called individually, and it was not fitted on its cradle, the attention getters of the chime and panel lights would not activate.

According to the FAs, it was common for the interphone handsets to fall from their cradles. The aircraft was serviceable and there were no entries in the aircraft technical log or cabin log about the interphone. An example interphone on the folding seat was inspected in the CEET during the investigation and it was easily dislodged from the cradle when the seat was released to fold back. The equipment manufacturer was informed about this during the investigation. There were no previous reports in their in-service experience database of seat-mounted cabin interphones becoming dislodged when the seat was released.

Evacuation signal

The aircraft was fitted with an evacuation signal. The operator's procedure was for the evacuation signal to be set only to be activated from the cockpit and not from the passenger cabin.

Recorded information

The FDR and CVR were recovered from the aircraft and downloaded at the AAIB. Both recorders captured the event and the recordings have been used to help write the *History of the flight* section. The CVR contained a number of discussions between the flight crew and the FA, but not the PA in the cabin.

The CVR is a 4-channel recorder which records audio from the commander, co-pilot, cockpit third occupant station and the Cockpit Area Microphone (CAM). Each of the occupants can control their audio (and subsequent CVR recording) using a dedicated Audio Control Panel (ACP). If the PA RECEPT[ION] is selected on an ACP, the CVR will record any PA announcements.

The operator's FCOM contains a number of the checklist items required to be completed prior to each flight. One of these items is to ensure the third occupants ACP is set to enable audio from the PA system so the CVR will record it:

<u>THIRD OCCUPANT AUDIO CONTROL PANEL</u>

PA knob……………………………………….........……………..RECIEPT

- *This allows cabin attendant announcements to be recorded on the CVR.*
- *For proper recording, set volume at or above medium range.*

The co-pilot stated that he checked this item before the flight.

It is believed RECEPT is deselected when there is a third occupant, as this avoids all PA announcements being heard through their headset.

A check of the system by the operator's engineers found it to be serviceable.

Engine aspects

General description

The CFM 56-5B engine is a two spool, high bypass ratio turbofan engine. It has a single-stage fan and a four-stage booster which together comprise the LP compressor (LPC) and a nine-stage HP compressor (HPC). The LPC is driven by a four-stage LP turbine and the HPC is driven by a single-stage HP turbine. It has a Full Authority Digital Engine Control (FADEC) which provides engine control and monitoring via the Engine Control Unit.

The HPC increases the pressure of the air as it passes from stage to stage, in order to supply the combustor section. It is comprised of a rotor, front stator and rear stator. The Variable Stator Vane (VSV) system, located at the forward end of the HPC (Figure 8), positions the Inlet Guide Vanes (IGV) and the stage 1, 2 and 3 stator vanes to the appropriate angle to optimise the airflow over the HPC rotor blades (Figure 9).

The VSV actuation system consists of two hydraulic actuators located at the 2 o'clock and 8 o'clock positions, a series of bellcranks, tie rods and four actuation rings (one for each stage) made in two halves. The actuation ring halves are connected at the split-line of the compressor casing by a connecting link, to which the actuator tie rods are connected. Each vane is connected to the actuation ring by a lever arm. The connecting links and actuation rings rotate circumferentially about the horizontal axis of the compressor in response to actuator inputs and this movement is transmitted through the lever arms to change the angular position of the vanes.

The Variable Bleed Valve (VBV) system is located forward of the HPC. It regulates the amount of air discharged from the LPC into the HPC.

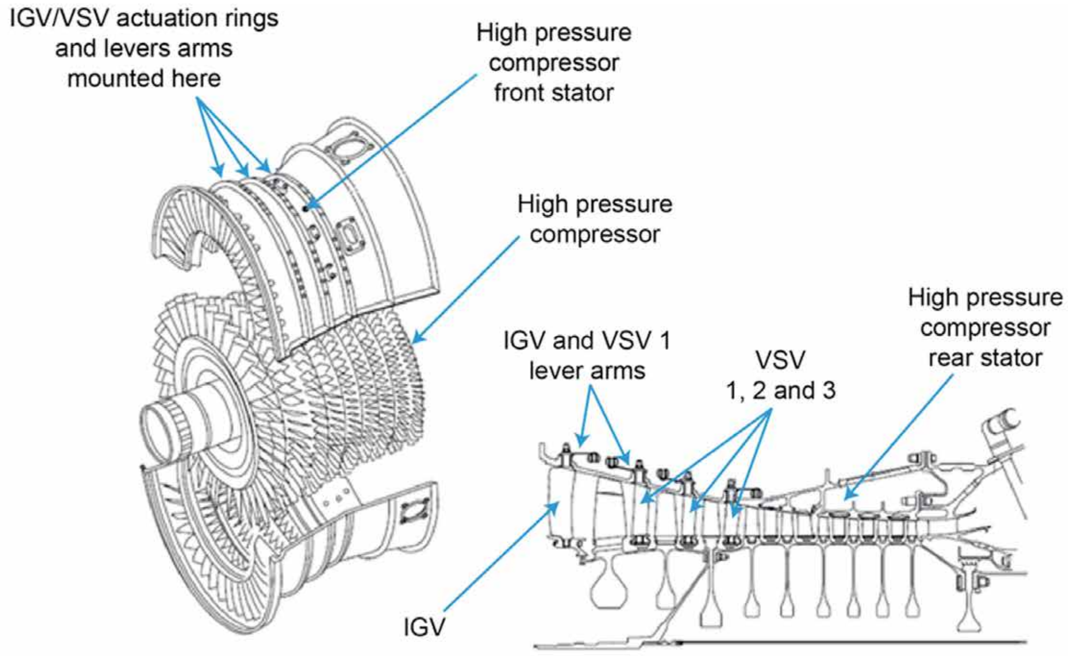

Figure 8

Section of High Pressure Compressor showing rotor, IGVs and VSVs

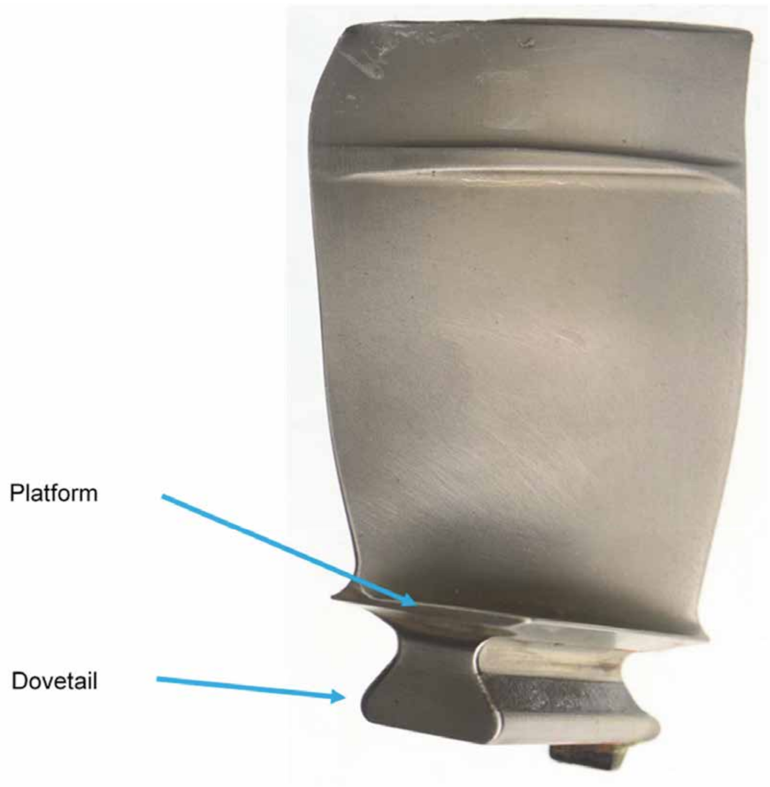

Figure 9

Example High Pressure Compressor rotor blade

Engine maintenance history

The left engine, engine serial number (ESN) 697283, was manufactured in 2007 and had been fitted to the aircraft since new. The aircraft had been leased to an Indonesian operator prior to entering service with the current operator. During the return-from-lease inspection several defects were identified with the engine which resulted in its removal and subsequent repair at an engine overhaul facility in Indonesia. During the repair process, the IGV and VSV actuation rings were split to remove the top half of the HPC case (front stator), allowing access to replace two damaged HPC blades. This involved disassembly of the connecting links on the IGV and VSV actuation rings.

The IGV and VSV actuation rings and connecting links were reassembled after reinstallation of the HPC case. No defects were noted during the post-repair inspections or the subsequent engine test cell runs and the engine was refitted to the aircraft.

The operator took delivery of the aircraft, registered as OE-LOA, on 22 December 2018. No maintenance was performed on the left engine between then and the accident, other than routine oil replenishment, and there were no relevant defects in the technical log. At the time of the accident the engine had accumulated 513 operating hours and 220 cycles since the engine repair.

Engine examination

The aircraft had been moved from the runway but debris which had exited the left engine was collected from the runway by the Airport Authority and provided to the AAIB (Figure 10). The items collected included multiple IGVs, fragments of compressor blades and fragments of engine acoustic liner.

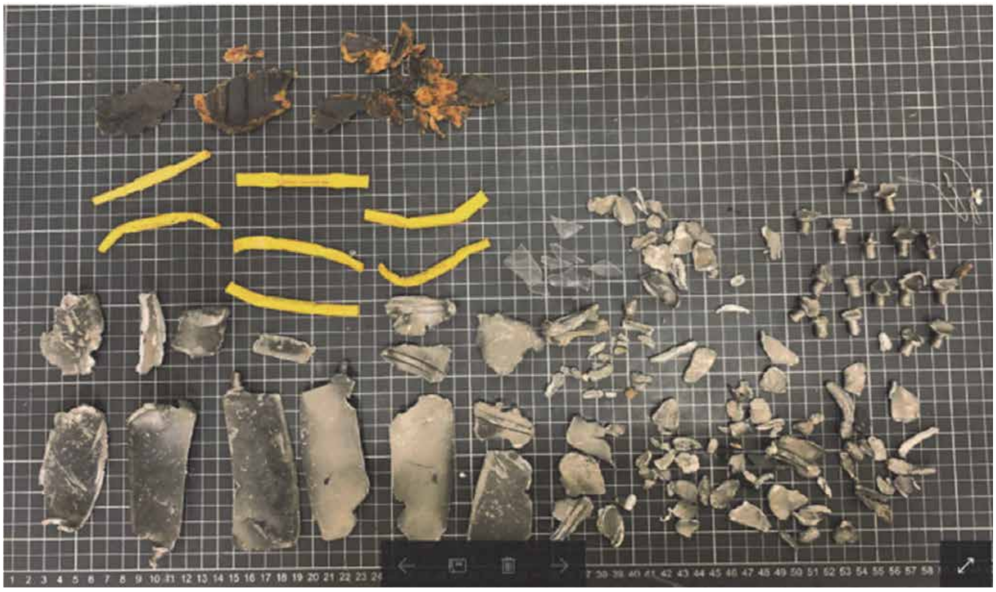

Figure 10

Items collected from the runway
(Note: the yellow items are frangible links from the emergency evacuation slides)

Preliminary examination of the engine identified that the engine casing had not been breached but that engine parts, predominantly IGVs, had exited the engine through the VBV louvre panels. Other parts, later identified as IGV vanes and HP compressor stage 1 blade fragments, had collected in the VBV sumps. The engine centrebody exhibited a circumferential crack running around approximately 270° of its diameter.

Debris retrieved from inside the engine cowlings was identified as fragments of washers and bushings from the IGV and variable stator vane (VSV) actuation rings.

Engine borescope inspection

An engine borescope inspection identified that the fan blades and LPC booster stages 1 to 3 were undamaged but the trailing edges of all LPC stage 4 blades and stators exhibited substantial impact damage including dents, tears and missing material. The HPC rotor could not be rotated, but it was evident that all IGVs were missing and extensive damage had been sustained by all HPC stage 1 blades. The downstream stages of the HPC exhibited extensive damage and some stage 1 VSVs were missing.

Engine strip examination

General

An engine strip examination was conducted at an approved engine overhaul facility under the supervision of the AAIB.

External examination

A single IGV lever arm in the 3 o'clock position (aft looking forward) immediately below the split-line of the HPC case, was found to be disengaged from the connecting link on the IGV actuation ring (Figure 11). This lever exhibited no distortion or damage but did have a small impact mark on its forward edge, which coincided with where the lever arm could come in to contact with the HPC case if it was not connected to the connecting link. There was no corresponding mark on the HPC case. Approximately half of the remaining IGV lever arms were bent or distorted and many of the bushings in the IGV actuation ring were absent or damaged.

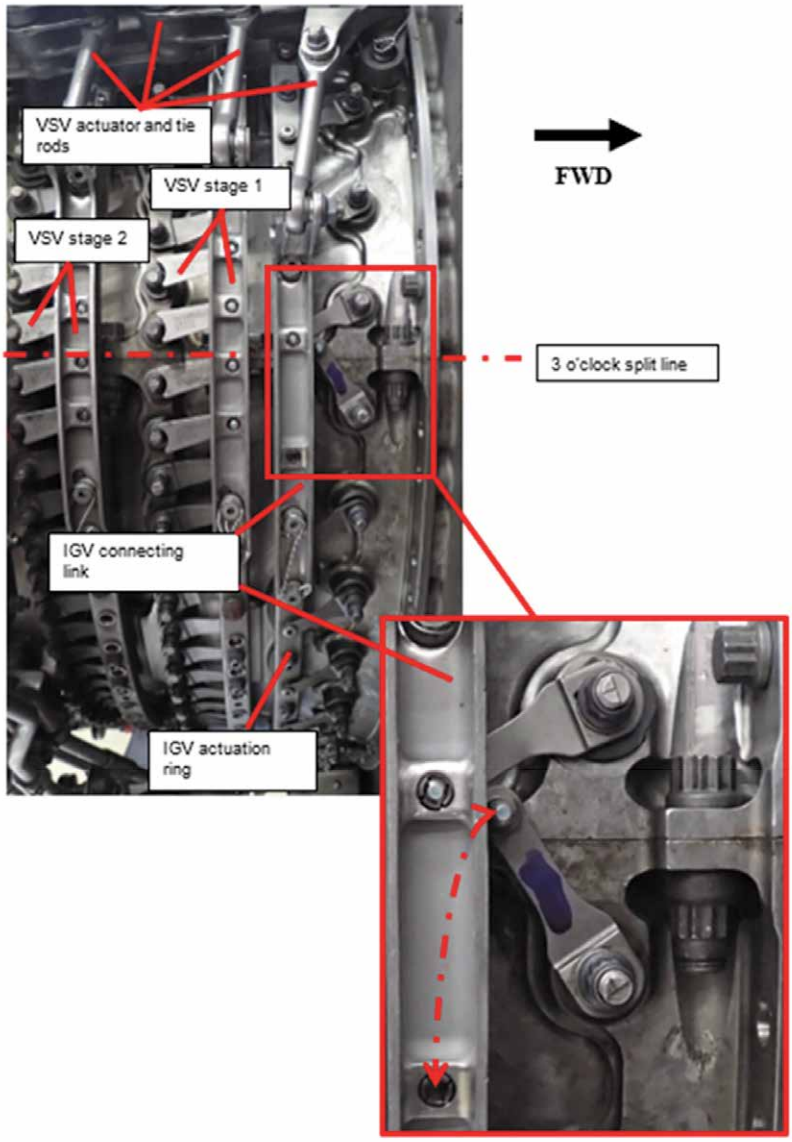

Figure 11

Lever arm disconnected from connecting link on IGV actuation ring

Internal examination of the HPC module

Disassembly of the HPC module showed that all the IGVs had sheared at their outer platform. All 38 HPC stage 1 blades were damaged. Four blades (Nos 10, 12, 13 and 37) had ruptured below the blade platform and one blade (No 9) had separated above the blade platform, releasing the remainder of the blade (Figure 12). Another three blades exhibited cracking below the platform.

The damage to HPC stator vanes and blades downstream of stage 1 was consistent with secondary impact damage from the release of the stage 1 blades and the resulting rotor imbalance.

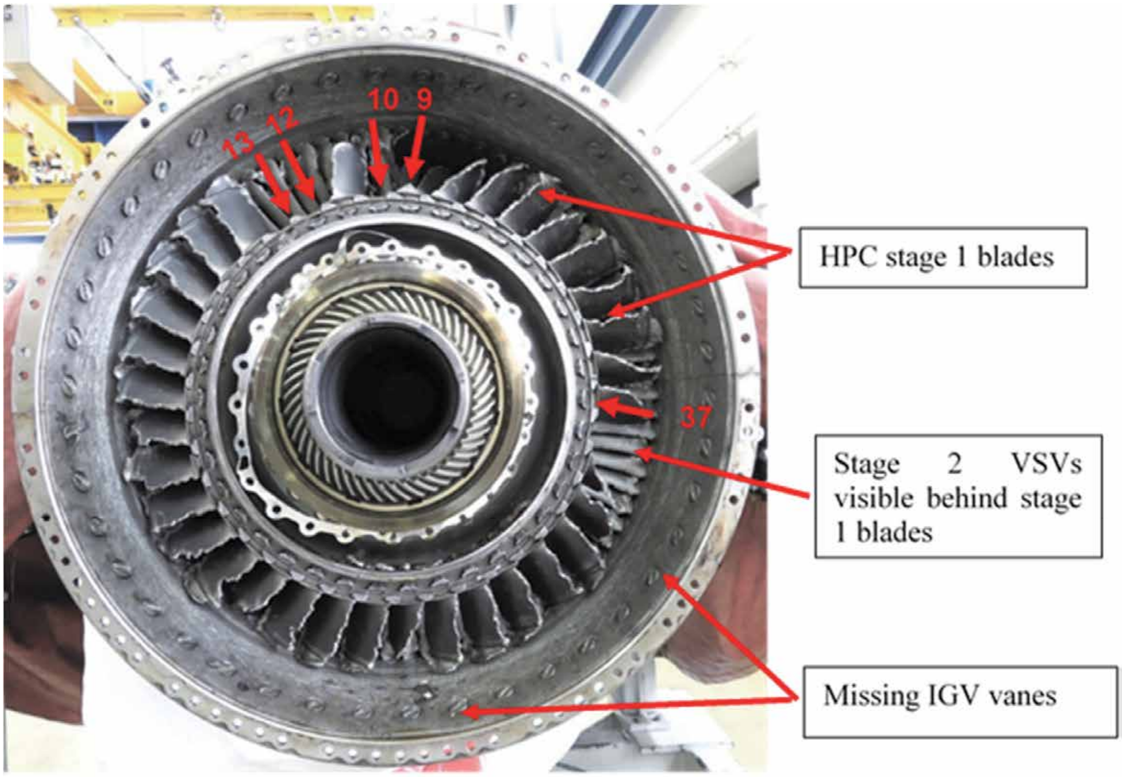

Figure 12

HPC module showing missing IGVs and damaged stage 1 blades

Detailed examination of the fracture surfaces of the HPC stage 1 blades which had separated below the platform, showed initiation of high-cycle fatigue (HCF) above the pressure surface on the concave side of the blade, near the leading edge. The fatigue had propagated downward and through the thickness of the blade. Beyond the area of HCF, the fracture surface was consistent with tensile overload. Blade 10, which exhibited the greatest area of fatigue, was most likely the first blade to be released (Figure 13). The fracture surface of the blade which had failed above the platform was consistent with tensile overload and had been heavily smeared, which was indicative of secondary damage.

On the blades which exhibited below-platform cracking, the cracking was consistent with the initiation of HCF in the blade dovetail, but the fatigue had not yet propagated to the point of tensile overload.

Detailed component examination – IGV hardware

The IGV connecting link exhibited no damage. Approximately half of the lever arms were bent or distorted, including several immediately adjacent to the disconnected lever arm. The disconnected lever arm, which was free to rotate exhibited a contact mark, most likely from contact with the HPC case.

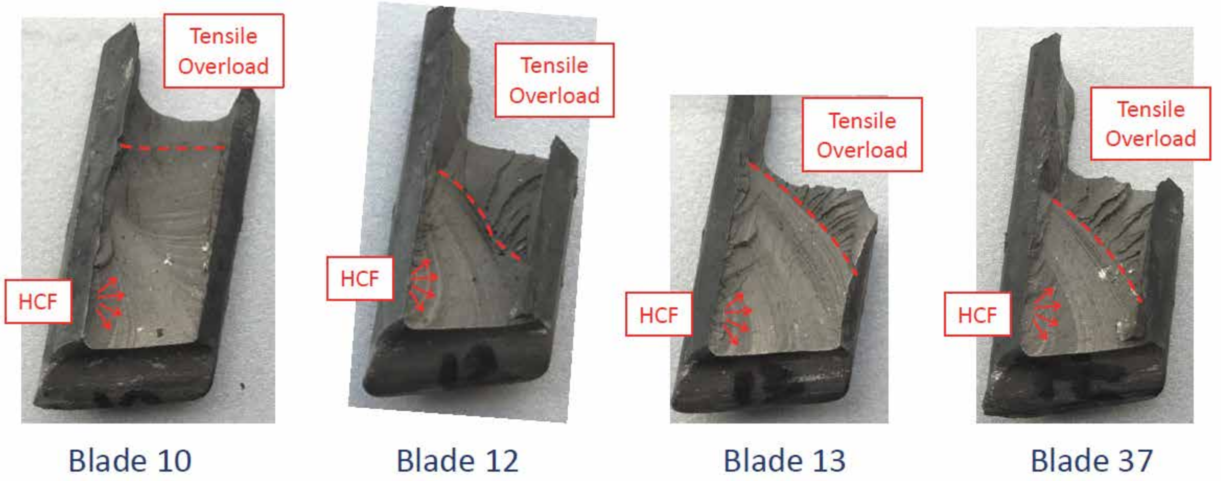

Figure 13

Fracture surfaces of blades exhibiting below-platform liberation

Known effects of disengaged IGV/VSV lever arm

The engine manufacturer advised that a disengaged, bent or broken IGV or VSV lever arm will result in an off-schedule variable vane which does not move in unison with the other vanes. This will cause variation in the airflow around the vane, and lead to a once-per-revolution (1/rev) excitation of the adjacent blades as they rotate past the vane. The force of the excitation is proportional to the angle of the off-schedule vane. The excitation creates stresses in the blade which are beyond the design limit. This phenomenon typically results in below-platform fracture in the blade dovetail, caused by a fatigue crack which initiates on the concave face of the blade and propagates towards the convex face. The crack grows with every loading cycle (aerodynamic excitation) and as it does, the load-carrying capability of the blade reduces, until ultimately it fails in tensile overload.

The engine manufacturer determined that the blade fracture surfaces from this event, were consistent with its experience of previous events where 1/rev aerodynamic excitation had occurred as a result of one or more disengaged, bent or broken IGV/VSV lever arms.

The engine manufacturer is aware of approximately 200 off-schedule VSV findings and/or events, of which 22 were attributed to improper engagement of lever arms in the connecting links. Thirteen of those, including this event resulted in HPC blade release. Of those, ESN 697283 had the lowest cycles to failure (220 cycles) and was among those with lowest time to failure (513 hours). The remaining nine occurrences were detected before blade release occurred.

The previous thirteen events have shown that the time to blade release is variable and can be influenced by the magnitude of the excitation force, the individual blade material properties and the nature of the improper engagement of the lever arm.

Other findings during engine disassembly

During the engine examination several non-conformances were noted with components which may have been disturbed during the recent engine repair, but these were not considered causal or contributory to the engine failure. Non-conformances were also noted with engine components which were not disturbed during the recent repair and it was outside the scope of this investigation to determine when these non-conformances had occurred.

Maintenance documentation

CFM56 Engine Shop Manual (ESM) task 72-00-32-430-001 '*Compressor Front Stator Assembly – Installation'* includes the following instructions to verify that the IGV and VSV lever arms are correctly installed in the connecting links.

> *'…. **CAUTION:** HIGH PRESSURE COMPRESSOR BLADE DAMAGE WILL OCCUR IF THE LEVER ARM PINS ARE NOT CORRECTLY ENGAGED INTO THE CONNECTING LINKS AND ACTUATION RING BUSHINGS.*
>
> *(6) Do a visual inspection to make sure all of the lever arm pins are correctly engaged as follows:*
>
> *(a) Verify the lever arm pins are properly installed into each of the connecting links.*
>
> *1 Place a white stripe across four IGV lever arm pins and bushings (2 each side). Use a temporary marking pen.*
>
> *2 Place a white stripe across eight stage 1, 2 and 3 lever arm pins and bushings (4 each side). Use a temporary marking pen.*
>
> *(b) Verify that all IGV and stage 1, 2 and 3 lever arm pins are engaged around the entire VSV system.'*

Information from the engine maintenance facility

Personnel from the engine overhaul facility were interviewed on behalf of the AAIB by the Indonesian National Transportation Safety Committee.

The mechanic who installed the IGV and VSV connecting links, reported that although access was difficult in some places, he did not find any discrepancies with the lever arms when performing the task. Similarly, the certifying engineer who inspected the installation of the IGV and VSV connecting links and those involved in other related tasks on the VSV actuation system, did not note any discrepancies with the lever arms. Additionally, no defects were identified during the post-maintenance inspections. The maintenance job card for the installation of the IGV and VSV connecting links referenced the relevant ESM task and was stamped as having been completed and inspected. When asked about what circumstances might have contributed to the IGV lever arm not being attached to the connecting link, the mechanic involved stated that he did not know how this occurred, but that since there are several external accessories that needed to be moved for access, it might be possible to overlook tightening a lever arm. The certifying engineer indicated his belief that if an IGV was not secure, an engine surge or stall would occur during the post-maintenance engine run or post maintenance check flight.

ESN 697283 was the first CFM56-5 engine that the engine overhaul facility had worked on, but the engineers working on ESN 697283 had undertaken CFM-56-5 training and were accustomed to working on CFM56-3 and CFM56-7 engines. They reported that they did not encounter any significant differences or difficulties working the IGV/VSV system.

The engineers reported that there were no issues with workload, overtime or night working during the engine repair, as all maintenance tasks were planned to be completed within a day shift. They indicated that they had good access to tools and that the ESM was available at every workstation.

Analysis

Flight crew aspects

After the failure of the left engine the flight crew responded correctly by rejecting the takeoff, bringing the aircraft to a stop and announcing "ATTENTION CREW: ON STATION" to the FAs and actioning the ECAM checklist. As the engine failure was secured by the crew actioning the ECAM checklist and there were no other causes for concern, the decision to vacate the runway under the power of the right engine was appropriate.

The crew were subsequently surprised to see a cabin door open, a slide deployed and passengers walking in front of the aircraft. The commander then contacted the SFA to ask why an evacuation had been initiated. After this exchange he realised that passengers were going towards the right engine, which was still operating. Had any of them entered the right engine's inlet suction danger area (Figure 1, Area A), it is possible that they could have been sucked into the engine. The right engine was shutdown 2 minutes after the commander noticed that Door 1L was open.

Once they had noticed that an evacuation had commenced there was realistically no way that the flight crew would have been able to recover the situation. It may have been prudent to action the *EMER EVAC* checklist to ensure that the aircraft systems were all in as safe a state as possible for the passengers to exit the aircraft. However, given that passengers were potentially going to encroach into the right engine's inlet suction danger area it was probably quicker to select the ENG MASTER to OFF. Had the commander prioritised shutting down the engine and thus had a more succinct discussion with the SFA, the right engine could have been shut down sooner.

Flight attendant aspects

All evacuations carry risk of passenger injury so flight attendants should not command an evacuation unless there is no doubt that it is required. The operator's *Flight Safety Manual* listed the circumstances when flight attendants should initiate an evacuation and none of these criteria applied. A combination of factors combined to overwhelm the SFA and cause her to command the evacuation over the PA.

At the front of the aircraft, the noise of the engine failure sounded very loud to the two FAs. The SFA was startled by the noise of the engine failure and the movement of the aircraft to the side of the runway. This appears to have caused her to narrow her attention to the aircraft sounds so that she did not hear the "ATTENTION CREW: ON STATION" command. The other FAs all heard it and were not aware that she had not.

Initially it was organised and calm in the cabin at the rear of the aircraft. The crew members there were helped by the calming influence of FA4 who was more experienced. Also FA3 and the ACM were recent recruits and may have benefitted from the recency of their training.

Communication between the SFA and FA3 was not effective in either means or content. The crew members' and passengers' accounts suggested that communication was attempted using a combination of the PA system, the interphone, shouting and hand gestures. A combination of English and German language was used.

The interphone at the FA3 seat was knocked off by the force of the folding seat closing. This resulted in the attention-getting chime and lights being inhibited so there was a delay between the SFA calling and establishing communication. The FAs reported that the handsets were prone to falling out of the cradle.

It was dark outside, and the cabin lights were dimmed for takeoff. The lack of light in the cabin made it difficult to see what was happening at the rear of the aircraft so communication by hand signals was not effective and the SFA could not see that the interphone was stuck.

The communication difficulty meant that the SFA could not establish whether the situation was safe at the rear of the aircraft. The SFA formed the impression that all the other flight attendants were scared. Only one minute and twenty seconds elapsed between the "ATTENTION CREW: ON STATION" command and the 'evacuate' command by the SFA. It would have felt like much longer to the flight attendants, especially the SFA who had heard nothing from the cockpit and felt under pressure from the passengers. Altogether this increased her anxiety and uncertainty and contributed to her commanding the evacuation.

Any FA could have contacted the cockpit during this time. The FAs who heard the "ATTENTION CREW: ON STATION" command would have been unlikely to do so because they understood the procedure to wait. The SFA had not heard this command but it did not occur to her to contact the pilots. As well as her emotional state, this may have been partly because her interactions with them were so limited under normal circumstances. The operator did not provide training for FAs and pilots designed to increase their interaction and understanding of each other's roles. All FAs had been trained that the pilots would be busy in an emergency, but they had no understanding of the tasks the pilots were doing or how long they would take.

Not all passengers heard the evacuation command on the PA. If the evacuation signal had been used the passenger response and the overall evacuation may have been quicker. However, this was not available to the FAs and the pilots were unlikely to operate it given they had not commanded the evacuation.

The SFA had recently been promoted after a relatively short time as an FA. During her time as FA, there was a period where she did not fly due to the operator's bankruptcy. As a result, she did not meet the operator's requirement for promotion in terms of duration of operational experience. Her initial training course as an FA was within a large group which may have resulted in aspects not being fully explained or understood by all that attended. The pressure to have staff operationally available for flights after the bankruptcy and change of operator meant that the subsequent training for SFA was purely theoretical and short in comparison to the operator's more recent practice. These factors may have meant that the SFA was not well prepared for her role in the emergency.

All FA practical training for emergencies involved a practice evacuation. None of them had practiced a return to normal operation. This may have resulted in a false expectation that all emergencies would result in an evacuation.

Overall, it seems that the SFA's emotional response to the emergency was aggravated by her general inexperience and the communication difficulties the FAs encountered. Despite meeting regulatory requirements, there were weaknesses in her training that meant she was not well prepared for the situation. Together this resulted in an overwhelming 'flight' response in which she felt the need for herself and everyone else in the cabin to escape the situation as quickly as possible. She did not contact the pilots and ended up commanding an evacuation. The operator has undertaken to implement a range of improvements to FA training and to instruct FAs to attempt to establish communication with the flight deck before commanding an evacuation.

The evacuation

Once the evacuation was commenced it was important that it proceeded in as safe and efficient a manner as possible to minimise the risk of passenger injury. In general, the evacuation proceeded swiftly, without significant panic or delay. The event provided an opportunity to learn about factors that influence a safe and efficient evacuation.

Many passengers in this evacuation collected their bags and attempted to leave the aircraft with them. At the supervised doors, the FAs removed baggage from them. At the unsupervised overwing exits passengers with bags could exit unchallenged. Baggage brought to the exits created difficulty for the FAs who then needed to remove it and store it somewhere which could have created an obstruction. The carried baggage probably slowed the evacuation and had the potential to damage the escape slides or injure other passengers on the slides. It was not possible to determine how long the evacuation took compared to the CS-25 requirement of 90 seconds.

The safety studies by the NTSB, TSB Canada, EASA and the Royal Aeronautical Society show that carried baggage has long been an issue. Appendix 1 lists many of the evacuation events identified in these four studies and provides additional details. It shows that it is extremely common for passengers to carry off bags in evacuations, even when there is a clear and immediate threat to life from remaining on board the aircraft. One of the events shows that even trained flight crew are not immune from the compulsion to keep their possessions with them. There were several examples where witnesses reported that this passenger behaviour slowed the evacuation or that the evacuation took longer than 90 seconds.

The Royal Aeronautical Society commented that:

> *'This trend appears to be increasing and can only be exacerbated by the increasing volume of cabin baggage being permitted by some operators for commercial reasons.'*

The Society made a recommendation to consider physical means of preventing passengers retrieving their baggage:

> *'Aviation authorities should consider the feasibility of introducing a certification requirement for a means of remotely locking, from the flight deck, overhead bins in passenger cabins that do not contain emergency equipment, for taxi, take-off and landing.'*

Current mitigations for the issue include passenger briefing and printed instructions on the cabin safety card. However, the motivation for passengers to remain united with their baggage is extremely powerful and, in some cases, the danger is not immediately apparent to passengers. These factors may lead passengers to feel it is safe to pause and collect baggage and for the evacuation to proceed at a slower pace. For a high proportion of passengers, briefing and instruction by FAs does not overcome this.

The EASA addressed previous Safety Recommendation 2014-005 and published new acceptable means of compliance in AMC1 CAT.OP.MPA.170 on '*passenger briefing'* and new guidance material in GM2 CAT.OP.MPA.170, (f)(5)(vi) '*Passenger briefing - safety briefing material'* almost two years before this accident. The operator was compliant with the new material but, despite these improvements, the instructions about baggage still did not influence this behaviour for a high percentage of passengers.

The evidence from this accident, in combination with the collated evidence from previous cases shows that, even despite recent improvements, it remains the case that passenger briefing, safety cards and FA instructions are insufficient to stop passengers retrieving cabin baggage during an evacuation. This hazard will still exist in future emergencies unless additional measures are taken to either reduce the impact of that behaviour on the safety and speed of an evacuation or to prevent passengers evacuating with baggage. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2020-018

It is recommended that the European Union Aviation Safety Agency commission research to determine how to prevent passengers from obstructing aircraft evacuations by retrieving carry-on baggage.

This incident has shown once again that, during an emergency evacuation, a proportion of passengers will attempt to leave the aircraft with their carry-on baggage slowing the evacuation process. The emergency evacuation demonstrations conducted to show compliance with CS-25 do not include a realistic simulation of this aspect of passenger behaviour which will slow down the evacuation and increase the risk of injury. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2020-019

It is recommended that the European Union Aviation Safety Agency consider including a more realistic simulation of passenger behaviour in regard to carry-on baggage in the test criteria and procedures for the emergency demonstration in CS-25.

Engine failure

The left engine experienced a contained failure as a result of the release of several HPC stage 1 blades. The blade failures were caused by crack progression due to HCF with final failure due to tensile overload. Several other blades also exhibited fatigue initiation in the blade dovetail. The fatigue failures on the liberated blade fracture surfaces were consistent with failure due to a known aerodynamic excitation phenomenon which results from an off-schedule IGV/VSV condition and creates stresses in the blade which are beyond the design limit. One IGV lever arm was found disconnected from the connecting link on the IGV actuating ring and would have provided the stimulus for the aerodynamic excitation.

In comparison with other blade liberation events arising from improper engagement of IGV/VSV lever arms with the connecting link, ESN 697283 demonstrated a low time to failure. The magnitude of the excitation force, and therefore the time to failure, depends on the extent to which the affected vane is off-schedule (the angle between it and the other vanes). The fact that the lever arm was fully disengaged from the connecting link and the vane was therefore free to move, may have influenced the comparatively low time to failure.

The release of the HPC stage 1 blades resulted in separation of all the IGVs and the forces experienced by the vanes would have been transmitted through the lever arms and into the actuation ring. The absence of damage on the disconnected lever arm indicates that it was disconnected from the connecting link prior to, and not as a result of, the engine failure.

The IGV actuation ring connecting links were removed and reassembled during the recent engine repair, and it is probable that mis-assembly of the lever arm occurred at this time. The relevant ESM task contains instructions for a visual inspection to verify proper installation of the lever arms. But the mis-assembly was not identified by maintenance staff during installation of the IGV connecting link, visual inspection, or during other maintenance conducted in the immediate vicinity of the lever arm.

As reassembly of the engine progressed, it is unlikely that the disconnected IGV lever arm could have been easily detected as it would have been obscured by the external hoses, pipes and brackets. It is also highly unlikely that post-maintenance engine-runs would have detected an improperly assembled IGV lever arm.

The time elapsed between the engine repair and the subsequent investigation and the absence of anything particularly memorable about the installation of the connecting links, meant that there was limited information available regarding the factors which may have contributed to the IGV lever arm mis-assembly.

The engine manufacturer commented that it considered incomplete installation of components as "a common skill-based error". Additional training or revisions to maintenance documentation have typically been shown to be ineffective in preventing improper component installation. In general, such occurrences can only be reliably prevented by design solutions, or an error-tolerant design from the outset.

The engine manufacturer has considered these aspects and determined that the addition of further instructions in the ESM is not likely to be an effective mitigation. Mitigating or eliminating the possibility of an improperly assembled IGV/VSV lever would require an engine redesign which it does not consider feasible based on the low rate of occurrence. It further indicated that the limited space, concentration of moving parts and engine temperatures in the vicinity of the IGV/VSV actuation rings would preclude the installation of a placard to highlight the correct assembly of the IGV/VSV connecting links.

The engine manufacturer presented on the subject of improper IGV/VSV lever arm assembly and its consequences at an All Operators Conference in June 2019 and published an article in its monthly publication *'Fleet Highlites',* available to all CFM operators and approved overhaul facilities, in January of 2020. It also intends to highlight this subject during calls with its field service representatives for onward dissemination to operators and overhaul facilities.

There is currently no means, other than visual inspection, to detect improper lever arm assembly. The engine manufacturer has recently implemented an HPC performance analytic tool that is designed to detect shifts in HPC efficiency. Relevant alerts from the analytic tool are notified to operators. While there is not currently enough experience with the analytic tool to determine if the effects of a mis-assembled lever arm could manifest as a detectable shift in engine performance, the engine manufacturer intends to evaluate this possibility as experience with the tool increases.

CVR

Discussions between the flight crew and FAs were captured on the CVR which aided the investigation. However, the PA announcements were not recorded which would have provided useful information for this investigation. The operator's pre-flight checklist required ACP selections to ensure the PA was recorded. It was not established why the CVR did not record the PA audio.

Conclusions

The left engine experienced a contained engine failure. All the damage found in the engine was consistent with the release of one or more high-pressure compressor stage 1 blades as a result of high-cycle fatigue arising from aerodynamic excitation of the blades. A single inlet guide vane lever arm, which had been improperly assembled in the connecting link on the inlet guide vane actuation ring, was identified as the source of the stimulus that resulted in the blade release.

As a result of the engine failure and subsequent rejected takeoff, the Senior Flight Attendant commanded an emergency evacuation that was not necessary in the circumstances. This was probably the result of a combination of factors that heightened her emotional response to the event and affected her decision making. The factors included inexperience as a flight attendant, weaknesses in her training and communication difficulties during the event.

As a result of the flight crew not being consulted before the evacuation was commenced, the right engine remained running for the first few minutes of the evacuation. This led to an increased risk of serious injury to those passengers that evacuated on the right side of the aircraft. Indeed, several passengers sustained minor injuries having been blown over by the exhaust.

During the evacuation several passengers hindered the evacuation by taking their cabin baggage with them. While some were removed by the flight attendants at the supervised exits, this was not possible at the overwing exits. Two Safety Recommendations are made regarding passengers evacuating with carry-on baggage.

Safety actions

As a result of this event the operator has stated that several safety actions have been or will be completed, including:

Procedures

- The operator sent a Memo, on 19 May 2020, to all its Airbus pilots instructing them to ensure the PA RECEPT is selected on an Audio Control Panel, thus ensuring the CVR records any PA announcements.
- The operator's *Flight Safety Manual* will be amended to instruct the Flight Attendants to attempt to establish communications with the flight crew to check that an evacuation is safe and necessary before commanding it independently.

Training

The operator has taken the following safety actions in relation to its flight attendant training. The operator has:

- Augmented the team responsible for training with the addition of a deputy manager of flight attendant training.
- Introduced a maximum limit of 25 trainees in initial flight attendant training courses. After approval from the operator's competent authority, it was subsequently increased to 30 in April 2020.

- Added practical training in the CEET to the senior flight attendant course as standard. Practical training has also been incorporated in their annual recurrent training.
- Improved variety of training scenarios in the CEET, including scenarios that result in a return to normal operations rather than an evacuation.
- Improved the syllabus of flight attendant training to include the performance effects of startle, an improved 30-second review[15] technique and enhanced communication training.
- Produced a video training aid that will introduce flight attendants to the actions of the flight crew after a rejected takeoff.
- Extended the aeroplane familiarisation phase during initial training with additional familiarisation flights.

Crew composition

- The operator has introduced a requirement in the *Operations Manual* regarding flight attendant team composition. A minimum of two experienced flight attendants shall be part of the operating crew's complement. This is 50% of the operating crew members, as their A320s are operated with four flight attendants.

The engine manufacturer has stated the following safety actions have or will be taken:

- Provided a presentation on the subject of improper IGV/VSV lever arm assembly and its consequences at an All Operators Conference in June 2019 and published an article in its monthly publication *'Fleet Highlites'* in January 2020.
- Highlight the issue of improper IGV/VSV lever arm assembly during calls with its field service representatives for onward dissemination to operators and overhaul facilities.
- Evaluate the use of a HPC performance analytic tool to determine if the effects of a mis-assembled lever arm could be identified from a detectable shift in engine performance.

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Footnote

15 A process where FA mentally rehearse the steps they would have to take during an evacuation before each takeoff and landing.

Appendix 1

Previous accidents and incidents where passengers evacuated with baggage

Aircraft type	Location	Date	Registration	Comments	Link
B747-200	London Gatwick, UK	07/08/1990	N303TW	Tailpipe fires in three engines. Witnesses reported that passengers attempted to carry hand baggage to the exits and to re-stow it in the overhead lockers when instructed not to take it. Some passengers carried baggage down the emergency slides. The time taken to complete the evacuation exceeded 90 seconds.	https://assets.publishing.service.gov.uk/media/5422fca2e5274a13170008ef/Boeing_747-200__N303TW_11-90.pdf
McDonnell Douglas MD-80	San Francisco, USA	19/12/1997	N932AS	Noxious fumes during taxi. Flight attendants reported they had to remove carry-on baggage from passengers during the evacuation.	https://app.ntsb.gov/pdfgenerator/ReportGeneratorFile.ashx?EventID=20001208X09328&AKey=1&RType=Final&IType=IA
McDonnell Douglas MD-11	Hong Kong	22/08/1999	B-150	Crashed on landing in poor weather, caught fire and became inverted. Some passengers commented that their evacuation was slowed by other passengers trying to recover their hand baggage.	https://reports.aviation-safety.net/1999/19990822-0_MD11_B-150.pdf
A330-243	Terceira-Lajes, Azores, Portugal	24/08/2001	C-GITS	Emergency landing after double engine failure due to fuel exhaustion. Many passengers attempted to leave with carry-on baggage.	https://reports.aviation-safety.net/2001/20010824-1_A332_C-GITS.pdf
McDonnell Douglas MD-88	Groningen Airport, Netherlands	17/06/2003	TC-ONP	Rejected takeoff above decision speed and runway overrun. Most passengers took their hand baggage with them or re-entered the aircraft to retrieve their hand baggage. Some passengers reported that the evacuation took too much time and attributed this to people collecting their baggage before leaving. Identified in the EASA study as taking longer than 90 seconds to complete the evacuation.	https://www.onderzoeksraad.nl/en/page/750/runway-overrun-after-rejected-take-off-md-88-groningen-airport-eelde

Appendix 1 (Cont)

Previous accidents and incidents where passengers evacuated with baggage

Aircraft type	Location	Date	Registration	Comments	Link
B747-438	Sydney, Australia	02/07/2003	VH-OJU	Landing gear fire. Some passengers evacuated with cabin baggage. Cabin crew reported they were unsure whether to remove baggage or not. Those that did remove baggage reported a build-up of baggage that potentially slowed passenger movement from the aircraft.	https://www.atsb.gov.au/media/24408/aair200302980_001.pdf
DC10-10F	Memphis, Tennessee	18/12/2003	N364FE	Cargo flight, fire following a hard landing. Non-revenue pilots travelling as passengers threw their bags out during the evacuation because they contained travel documents, clothes and baggage.	https://www.ntsb.gov/investigations/accidentreports/reports/aar0501.pdf
B737-406	Barcelona, Spain	28/11/2004	PH-BTC	Runway departure after a bird strike to the nosewheel. The report stated 'A lot of passengers took baggage and personal items with them despite of the commands and instructions of the cabin attendants. This somewhat delayed the evacuation'. Safety cards did not contain an instruction to leave baggage behind in an emergency and no specific pre-flight instructions were provided to that effect. Identified in the EASA study as taking longer than 90 seconds to complete the evacuation.	https://www.fss.aero/accident-reports/dvdfiles/ES/2004-11-28-ES.pdf
A340-3300	Toronto, Canada	02/08/2005	F-GLZQ	Runway overrun and fire. TSB reported 49 percent of passengers stated they attempted to take carry-on baggage when leaving the aircraft and 48 percent reported that this slowed the evacuation. Identified in the EASA study as taking longer than 90 seconds to complete the evacuation.	https://www.tsb.gc.ca/eng/rapports-reports/aviation/2005/a05h0002/a05h0002.pdf

Appendix 1 (Cont)

Previous accidents and incidents where passengers evacuated with baggage

Aircraft type	Location	Date	Registration	Comments	Link
B737-319	Auckland, New Zealand	12/09/2006	ZK-NGJ	Electrical failure and smoke in the cabin on takeoff. Some passengers took their carry-on bags with them and were allowed to take them down the slides rather than block the exits with discarded bags. Identified in the EASA study as taking longer than 90 seconds to complete the evacuation.	https://www.taic.org.nz/sites/default/files/inquiry/documents/06-003.pdf
A330-300	London Gatwick, UK	16/04/2012	G-VSXY	Smoke warnings from the cargo hold. A number of passengers took their hand baggage with them and others commented that passengers retrieving hand baggage delayed the evacuation.	https://assets.publishing.service.gov.uk/media/54230155e5274a1314000a95/AAIB_1-2014_G-VSXY.pdf
A320-200	Halifax, Canada	29/03/2015	C-FTJP	Aircraft crashed landing short of the runway in bad weather. Despite a pre-departure briefing that included instructions to leave carry-on baggage behind and pictorial instructions on the safety card, some passengers exited the aircraft with their carry-on baggage.	https://www.tsb.gc.ca/eng/rapports-reports/aviation/2015/a15h0002/a15h0002.pdf
B777-200	Las Vegas, USA	08/09/2015	G-VIIO	Uncontained engine failure during takeoff roll and fire. Cabin crew reported that some passengers evacuated with carry-on baggage. It was not thought to slow the evacuation in this case, but the flight was only 55% percent full.	https://app.ntsb.gov/pdfgenerator/ReportGeneratorFile.ashx?EventID=20150908X35241&AKey=1&RType=HTML&IType=FA
B777-300	Dubai, Emirates	03/08/2016	A6-EMW	Aircraft crashed during attempted go-around with thrust at idle. Although passengers were instructed to leave their carry-on baggage behind and evacuate, several passengers exited with their carry-on baggage. The evacuation took approximately 6 minutes and 40 seconds for 298 passengers and flight crew.	https://www.gcaa.gov.ae/en/ePublication/admin/iradmin/Lists/Incidents%20Investigation%20Reports/Attachments/125/2016-Published%20Final%20Report%20AIFN-0008-2016-UAE521%20on%206-Feb-2020.pdf

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A320-232, G-EUYB
No & Type of Engines:	2 International Aero Engine V2527-A5 turbofan engines
Year of Manufacture:	2008 (Serial no: 3703)
Date & Time (UTC):	23 September 2019 at 0710 hrs
Location:	On approach London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 139
Injuries:	Crew - 2 (Minor) Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	12,700 hours (of which 6,000 were on type) Last 90 days - 150 hours Last 28 days - 52 hours
Information Source:	AAIB Field Investigation

Synopsis

During approach to London Heathrow Airport the flight crew detected strong acrid fumes on the flight deck. They both donned oxygen masks and continued to land at Heathrow. After shutting down on a taxiway and removing their masks, the co-pilot became incapacitated and the commander felt unwell; both pilots were taken to hospital but released later that day.

Investigations carried out by the AAIB and the operator did not identify the source of the fumes.

Numerous other similar fume events have been reported to the AAIB and the CAA. This report reviews five other similar events which occurred with the same operator on the same aircraft type. It was not possible to identify the cause of these events, but, several common features have been identified.

The operator and aircraft manufacturer have taken action to try to reduce the number of events, which includes; the development of detailed maintenance procedures to identify the source of fumes, changes to flight crew operating procedures and the evaluation of modifications to enhance cabin air recirculation filtration systems.

History of the flight

On the day prior to the incident, the flight crew operated three flights together in a different aircraft. The first two sectors were return flights from Heathrow to Paris Charles de Gaulle Airport, the third sector was from Heathrow to Zurich Airport. The crew arrived in Zurich at approximately 1330 hrs and spent the night in the crew hotel.

Both flight crew had previously been involved in separate fume events on the same aircraft type. They reported that they had discussed these events during the evening.

G-EUYB was flown, by a different crew, from Heathrow to Zurich on the day prior to the incident. The aircraft landed at 2043 hrs and was parked at Zurich overnight. There were no deferred defects with the aircraft. It rained overnight and the temperature was approximately 13°C.

The incident crew reported for the return sector to Heathrow at 0345 hrs for a scheduled departure at 0510 hrs. Both flight crew reported that they were well rested. The initial departure from Zurich was uneventful. It was still raining during the departure and the aircraft entered cloud at approximately 1,000 ft agl and remained in cloud for the majority of the climb. Shortly after passing through FL100 the flight crew detected a slight odour on the flight deck. The commander initially thought the smell was coming from the galley ovens. The co-pilot described it as a “sweaty socks” smell; he reported that he had smelt similar smells on this type of aircraft before, but this was stronger than he had previously experienced. The commander was concerned that they were preconditioned to detect fumes because of their previous experience of fume events and their discussion the evening before. He proposed they waited 30 seconds prior to taking any action to see if the smell dissipated. After 30 seconds the smell had gone. The crew discussed further options and agreed to continue the flight.

The flight crew’s previous experience suggested that if the smell was going to reoccur it was most likely to occur when thrust was reduced for descent so, during the cruise, they discussed their actions if the smell returned and reviewed the SMOKE / FUMES / AVNCS SMOKE checklist. They briefed for the co-pilot to fly the descent and approach for the commander’s landing.

The initial descent into Heathrow was uneventful. There were clear skies throughout the descent. The aircraft held briefly at BIGGIN HILL and was then radar vectored for an ILS approach to Runway 27L. As the aircraft intercepted the localiser ATC requested the aircraft to reduce speed to 160 kt. The aircraft was slightly above the glideslope so the co-pilot used speed brake to intercept the glideslope from above and decelerate.

Having intercepted the ILS, as the aircraft passed through 4,000 ft both flight crew detected a sudden, very strong smell. The commander described it as a “manure smell”; “like a field which had just been muck spread”. He described the smell instantly “hitting him” in the back of the throat. There was no smoke and no obvious source of the smell. The co-pilot described it as a “strong sweaty socks” smell. He reported feeling itchy skin around his eyes and a scratchy throat. The commander took control and instructed the co-pilot to put on his oxygen mask. Once the co-pilot was on oxygen and communication was re-established the co-pilot took control whilst the commander donned his oxygen mask.

The commander requested an early hand-over from the approach controller to the tower controller, which was granted. He then made a PAN call to Heathrow Tower; he reported that they had fumes on the flight deck and required a priority landing. The flight crew then selected the landing gear down and landing flap then decelerated to the final approach speed. ATC advised the two aircraft ahead of G-EUYB and one behind to expect a go-around and then instructed them to go-around in sequence. The flight crew discussed options and agreed the safest course of action was to continue the approach. The aircraft was stable at 1,000 ft agl. The commander elected to use Autoland. He advised ATC that they would vacate onto the parallel taxiway where they would require an inspection from the emergency services. The aircraft landed at 0644 hrs, vacated the runway at N6 and stopped on Taxiway A.

Once the aircraft had stopped the commander asked the co-pilot to complete the after landing procedure and the initial actions of the SMOKE / FUMES / AVNCS SMOKE checklist. The co-pilot made initial contact with 'Fire 1'[1] and advised them that they had fumes on the flight deck and were completing some checklists. The commander made the Alert Call[2] and gave the Senior Cabin Crew Member (SCCM) a NITS[3] briefing via the interphone. The SCCM confirmed there was no smell in the cabin and the passengers were not aware of anything unusual. The commander then spoke to Fire 1 and made an announcement to the passengers to explain what was happening.

The co-pilot removed his oxygen mask briefly to confirm if the fumes were still present. He confirmed the fumes were still present so the flight crew decided to shut down both engines and open the flight deck windows. At this stage the co-pilot started to feel nauseous. The Auxiliary Power Unit (APU) was started for electrical power and the engines were shutdown. The co-pilot then vomited out of the flight deck window. The commander initially planned for the aircraft to be towed to a parking stand but as it became apparent that the co-pilot needed urgent medical attention, he requested steps be brought to the aircraft. The co-pilot went to the aircraft toilet and continued to vomit. The SCCM came on to the flight deck to assist the commander. The SCCM reported that he smelt a "chemical smell", "a clean clinical smell" on the flight deck. He confirmed that there was no smell in the cabin.

The fire service brought access steps to the aircraft. Communication between the fire service and the flight crew was challenging due to the wind noise with the flight deck windows open. The fire service initially thought the co-pilot was trying to exit the aircraft via the flight deck window so positioned the step adjacent to the window. However, after further discussion

Footnote

1 'Fire 1' is the callsign used by the lead fire service vehicle.

2 The Alert Call is a standard PA made by the flight crew to alert the cabin crew to a non-normal situation – 'Will the Senior Cabin Crew Member please report to the flight deck, via the interphone'. The 'via the interphone' is added when the flight crew are on oxygen as it is difficult to communicate if the SCCM comes onto the flight deck.

3 NITS is an acronym used for cabin crew briefings in non-normal situations. It stands for Nature, Intentions, Time and Special Instructions.

the steps were repositioned to Door 1 right. It took the fire service some time to position the steps at the door due to the turning circle of the vehicle, limited space on the taxiway and a concern that the vehicle would become stuck in soft grass at the side of the taxiway. The aircraft door was opened at approximately 0706 hrs and fire crews and paramedics entered the aircraft. The fire crew inspected the aircraft and reported that they could not detect any unusual smells or fumes. A member of the operator's engineering staff also boarded the aircraft after the event and did not detect any fumes or odours.

The co-pilot and commander were assessed by the paramedics and both taken to hospital. The passengers subsequently disembarked via steps onto coaches and were transported to the terminal. None of the passengers or cabin crew reported any ill effects.

The co-pilot and commander were released from hospital later the same day.

Recorded information

Recorded information was available from the FDR, CVR and Digital ACMS recorder (DAR)[4]. Analysis of parameters related to the control of the engine pneumatic bleed and air conditioning system did not identify any anomalous operation during the incident flight.

Weight and balance

The aircraft departed Zurich with 7,000 kg of fuel at a takeoff weight of 65,300 kg. The aircraft weight was approximately 62,000 kg when it landed at Heathrow. There were no dangerous goods loaded on the aircraft.

Flight crew

Both flight crew had previously been involved in separate fume events.

The commander had experienced a similar fumes event to this incident on 21 December 2018 during a flight from Heathrow to Geneva. Fumes were detected on the flight deck during descent into Geneva. After landing the commander required hospital treatment.

The co-pilot was involved in a serious incident during landing at Valencia Airport on the 5 August 2019 which is being investigated by the Spanish State Investigation Authority[5].

Aircraft information

The Airbus A320 is a twin engine, narrow-body passenger aircraft, designed for short to medium haul operations. The aircraft internal layouts are generally similar and consist of the four main areas within the fuselage: the flight deck, the forward galley, the main passenger cabin with moveable curtain divide and the rear galley. The flight deck is divided from the rest of the cabin by a reinforced cockpit door.

Footnote

4 Digital ACMS Recorder that recorded additional parameters than the FDR.
5 Available at https://www.mitma.gob.es/organos-colegiados/ciaiac [accessed 30 March 2020].

Air conditioning system

The aircraft is fitted with a fully automatic air conditioning and pressurisation system known as the Environmental Control System (ECS).

It separates the fuselage into three independently controlled zones which are: the flight deck, the forward cabin and the aft cabin. A schematic of the ECS is shown in Figure 1.

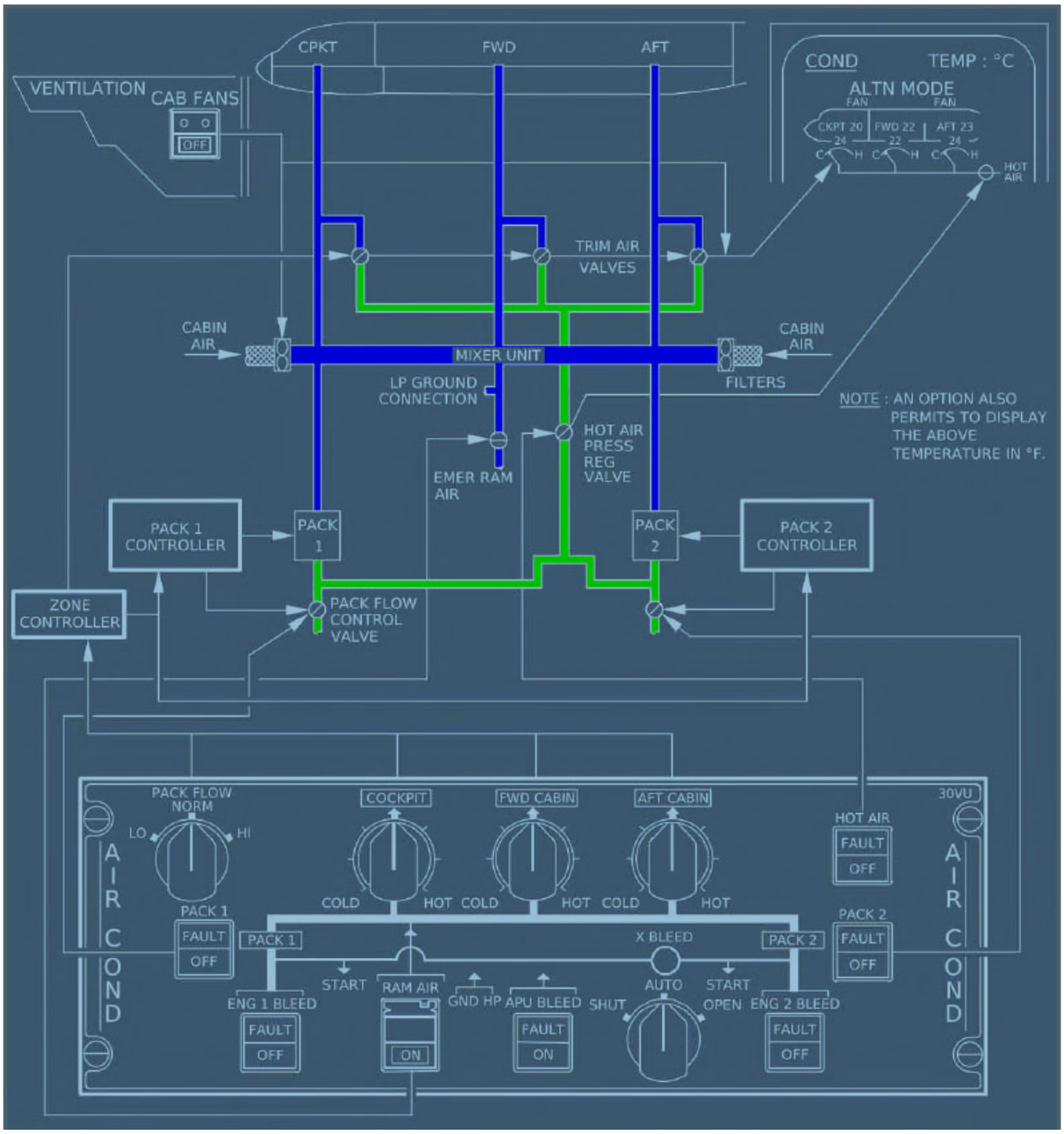

Figure 1
ECS schematic

In normal operations, the left engine supplies bleed air to the left pack[6] and the right engine supplies bleed air to the right pack. When the engines are not running, the APU can supply bleed air to both packs.

The bleed air from the engines or APU passes through electronically controlled heat exchangers, valves and mechanical devices to produce conditioned air. The conditioned air is at a temperature and flow rate that is suitable to enter the mixer unit where it is mixed with the recirculated cabin air prior to distribution to the flight deck and cabin to maintain a comfortable environment. Trim valves allow hot bleed air to mix downstream of the mixer units to optimise temperature regulation. During normal pack operation with the trim air system operative the cockpit is only supplied with air from pack 1 mixed with the recirculated air. The temperature in each zone can be selected and set from the AIR COND panel on the flight deck and can be fine-tuned for each cabin zone through the temperature control panel installed on the Flight Attendant Panel (FAP).

Cabin pressurisation is automatically maintained by the outflow valves which are controlled by the aircraft pressurisation controller.

There is a constant movement of air throughout the aircraft cabin via a system of ducts, louvres and vents. The ECS is designed to produce a slightly higher air flow per occupant on the flight deck.

Auxiliary power unit (APU)

The APU is a self-contained gas turbine engine mounted within the tail section of the fuselage. The APU is normally used on the ground, when the engines are not running, to supply air and electricity. The APU provides power via an accessory gearbox to drive a generator supplying the aircraft electrical systems and a load compressor to produce bleed air for the ECS and other systems. It uses fuel from the aircraft fuel system and is started using the aircraft batteries. It is started from the flight deck and its operation is automatically controlled by an electronic control unit. Once it is running, electrical power and bleed air is manually selected from the flight deck as required. A schematic of the APU is shown at Figure 2.

Footnote

[6] A ‘pack’ consists of an air cycle machine, heat exchangers and valves which adjust the temperature of the bleed air supplied from the engine or APU to a temperature suitable for the cabin air conditioning.

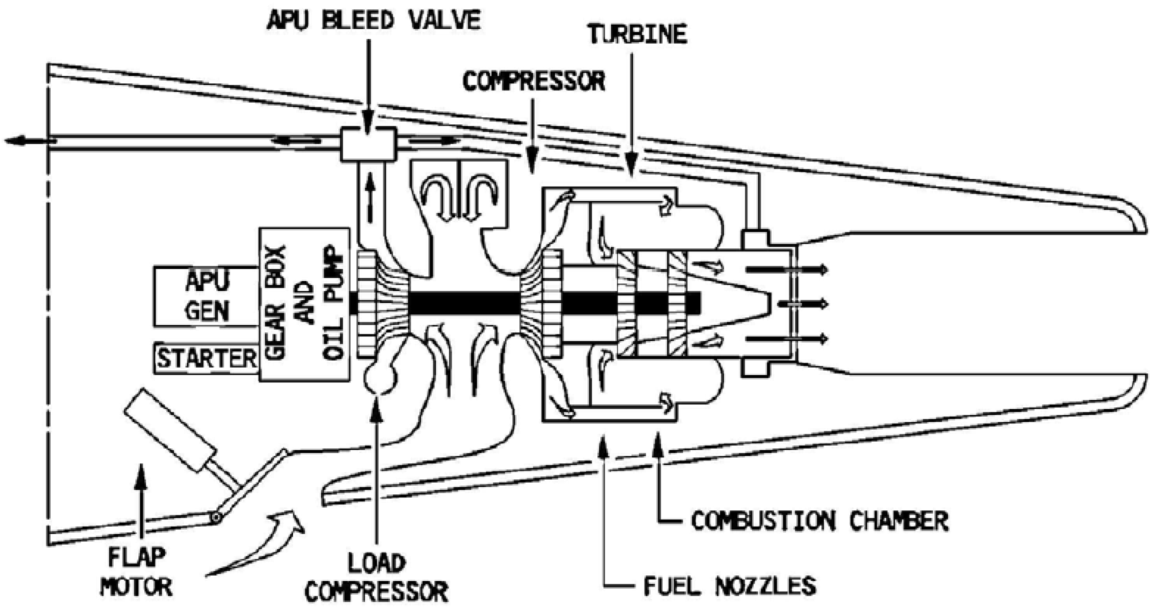

Figure 2
APU schematic

Aircraft examination

After the passengers had disembarked with their hand baggage, the aircraft was towed to a remote stand. Once catering, hold baggage and cargo had been removed the aircraft doors were closed. However, the flight deck side windows were left open.

When the AAIB Inspector boarded the aircraft approximately six hours after the incident, there were no residual abnormal odours or fumes apparent.

With assistance from the operator's engineering staff the aircraft systems were run in various combinations using the battery, the APU and the engines to try to establish the source of the fumes and odour. At various points during the testing, the left, right and forward avionics bays were accessed. There was no abnormal odour or fumes in these bays and there was no evidence of wiring, line replaceable units or avionics equipment cooling system failure. There was also no evidence of excessive dust, moisture or microbiological growth in the bays. Whilst the systems were being operated a handheld air testing device was used but showed no evidence of organic substances within the cockpit atmosphere.

The aircraft was then handed back to the operator to carry out further testing.

Based on the previous experience of fume and odour events the operator had developed a series of post fume event Work Packages (WP). These comprised of a set of conditional inspections that were to be carried out based on the evidence and data available:

- Work package 0 – Inspection in case of localised odour event within the cockpit or cabin. This WP lists a set of steps looking for localised domestic causes within the cockpit and cabin areas including fluid spillages and residue on surfaces and in ancillary catering equipment. It also draws attention to the possibility of electrical equipment failure sources which requires circuit breakers, light fittings, power sockets and avionic cooling fans to be checked.

- Work package 1 is subdivided into 1A, 1B and 1B Plus and sets out a methodical step by step approach as follows;
    - Work package 1A – Basic exterior visual inspection from the ground. This set of checks focusses on hydraulic, APU and engine fluid levels. It also details a series of visual examinations for signs of fluid leakage on or around the engine fan blades and nose landing gear. In addition, it requires inspections for leakage apparent from the APU bay and on the rear fuselage and lower surfaces, looking specifically for leakage from fairings, overboard drains and panel seals.
    - Work package 1B – Includes all of WP 1A with the addition of access to the APU bay to carry out detailed inspections of the APU and its associated equipment. It also requires an inspection of the rudder yaw damper servo and the cargo door operating switch for signs of hydraulic leakage.
    - Work package 1B Plus – Includes WP 1A and 1B with the addition of comprehensive inspections of the APU bleed system and ECS system components. This requires detailed inspections of the APU and the left and right ECS air conditioning pack components, accessory seals and drains. To enhance detection of leakage and contamination this WP requires most of the inspections to be carried out using black light[7].
- Work package 2 – This set of inspections follow WP 1 where evidence is suggesting the air contamination originates from the APU or engines. It requires internal inspections using borescopes in accordance the Aircraft Maintenance Manual (AMM).
- Work package 3A – This WP requires an ECS check with the APU and engines at idle and is used to confirm the presence or absence of any smells or fumes following nil findings during WP 1A, 1B or 1B Plus.
- Work package 3B – This WP requires an ECS check with the APU and engine bleeds at higher power settings and is designed to isolate an odour when it is suspected to be originating from one of the engines. It is carried out on the ground with both engines and the APU running and the aircraft doors closed. There are various safety notes within this WP. Those onboard the aircraft are restricted to essential personnel only and all should have

Footnote

[7] Black light. An inspection light source producing ultraviolet light in the safe UVA wavelength. This causes traces of many types contaminant to fluoresce and become visible to the naked eye.

access to a portable oxygen bottle and mask. It includes the requirement to allow sufficient time between each engine and ECS configuration test to allow them to clear through prior to each stage in the testing.

- Work package 4 – ECS system decontamination requirements. This WP is carried out when the ECS system is found to have been contaminated and requires the ECS and APU bleed duct to be internally clean in accordance with the appropriate AMMs. It also directs that removed components must be quarantined for incident investigation.

G-EUYB was withdrawn from service and all the work packages were completed. No fumes or abnormal odours manifested themselves during these tests and the aircraft was released to service. However, four further events were reported up to the end of December 2019. In each case no faults could be found during the troubleshooting.

Actions taken by the aircraft manufacturer

The aircraft manufacturer has been collating data from operators relating to past and current fume events and has carried out research to identify the source and identify solutions. In reviewing the data, they observed that the presence of fumes dissipates at higher altitudes.

In many cases their advice, used in conjunction with the steps set out in the various AMMs, have led to a decrease in the number of fume events. However, in some cases the source of the fumes could not be found. As a result, the manufacturer has initiated several work programmes to further alleviate odour and fume events. This includes the introduction of an enhanced ECS filtration system, to be made available as a modification, and providing active support to supplier led investigations into further filter enhancements.

In order to address the issue of fume events the manufacturer has taken the following action:

> Project FRESH has been initiated to investigate and regularly inform operators of fume event arisings.
>
> The manufacturer has published an In-Service Information paper (Ref ISI 21.00.001.139) setting out all the known aspects of fumes and smoke events and includes the details of a filter and sensor product research and development programme.

The operator of G-EUYB, and the other aircraft detailed in this report, has joined this project which provides regular updates to operators from the manufacturer's customer services team. In addition, they have issued an In-Service Information paper to inform all operators of the background information, mitigations available (or ongoing) and best practices to address fume events.

Other similar events

During the investigation into the circumstances surrounding G- EUYB, the operator reported many similar events on their Airbus A320 fleet[8]. Figure 3 shows the number of events reported during 2019 and the start of 2020. Summaries of five of these events, all of which occurred during the latter part of 2019, are included below to show the circumstances, the various outcomes and common factors.

Fume events are not unique to this operator or to the Airbus A320. In the past 12 months the AAIB had received 37 reports of fumes events in Commercial Air Transport aircraft from various operators and aircraft types (including the six events included in this report). In the last five years 107 events have been reported. In the last year the AAIB has published two other reports on fume events (EI-DEO - AAIB Bulletin 2/2020 and G-YMMU – AAIB Bulletin 12/2019).

The CAA mandatory occurrence reporting (MOR) scheme has received 674 reports of smell, smoke or fumes events in the past 12 months and 3,166 in the last five years. In 2019, the operator involved in this event reported 536 smell, smoke or fumes events to the CAA, of these 398 involved the Airbus A320 series aircraft.

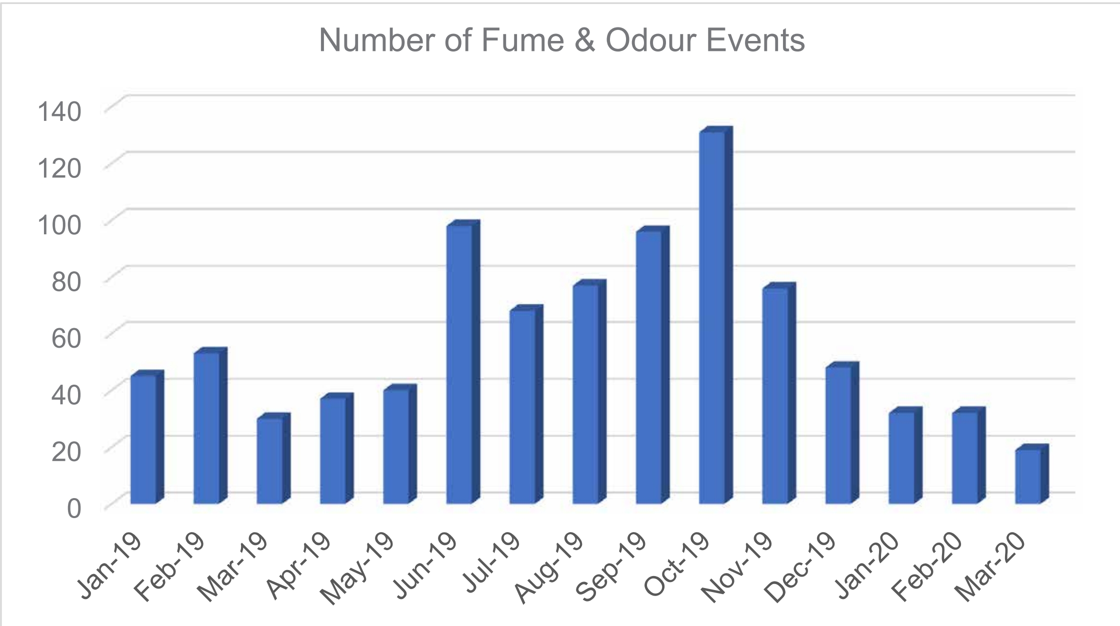

Figure 3

Fume and odour events on the operator's Airbus A320 fleet in 2019 and early 2020

Footnote

8 Airbus A320 fleet in this report refers to A318/A319/A320 and A321 narrow body aircraft.

Airbus A320-232 G-EUUK

The aircraft had been parked overnight at Copenhagen Airport and was scheduled for a return flight to Heathrow on the morning of 1 October 2019. After completion of boarding the APU was started and run for one minute with its air bleed selected OFF. The air bleed was then selected ON, and after a further minute, the right air conditioning pack was selected ON. Almost immediately a strong odour, described as being like “sweaty socks” became apparent on the flight deck. The left pack was selected ON and a similar odour but to a lesser extent was apparent throughout the cabin. Both packs were selected OFF and the cockpit windows opened to vent the fumes which dissipated in approximately seven minutes. After a 30 minute delay, the aircraft preparations for departure were completed and the aircraft flew without incident until the final approach to Heathrow.

As the aircraft commenced final approach to Runway 27 at Heathrow, at about 5,000 ft, a “sweaty sock” odour was detected throughout the aircraft. The smoke and fumes abnormal and emergency procedures were completed and, within 60 to 90 seconds, the fumes dissipated from the flight deck. Fumes were still apparent in the cabin, so engineering and medical assistance was sought. Some of the cabin crew reported a “fuzzy headed” feeling, tingling throats and nasal congestion. This alleviated in fresh air and medical assistance was not required.

G-EUUK pilots’ observation

The pilots of G-EUUK had noted that another fume event had taken place on the previous afternoon during descent into Heathrow and was recorded in the maintenance log. The log showed that the prescribed post event work pack had been completed and the aircraft had been released to service. It then flew to Copenhagen without incident prior to its overnight stop.

Airbus A320-232 G-EUUM

G-EUUM had a fume event on route to Fiumicino Airport (Fiumicino) in Rome. After this event the operator’s post smoke and fume events work package had been carried out with no conclusive results. However, during the checks the APU lubricating oil level had been found to be slightly above maximum and so a small amount of oil had been removed to re-establish the correct level. No contamination was found in the APU ducts and passages.

The aircraft was repositioned on a non-revenue flight from Fiumicino to Heathrow. The flight was uneventful until the aircraft was approaching Heathrow. During descent there was some atmospheric electrical activity, but the aircraft did not enter cloud until FL150. The aircraft was in and out of cloud until approximately 1,200 ft aal. Engine anti-ice was used whilst in cloud along with a single use of the igniters[9] once the total air temperature had increased above 10°C.

Footnote

[9] Engine ignition should be on whenever severe turbulence or heavy rain is encountered. Engine ignition is automatically selected on when engine anti-ice is selected on. If engine ignition is required when anti-ice is not being used it must be selected manually.

Whilst heading downwind to Heathrow, the pilots became aware of an unusual odour, described as being like a "mouldy, wet laundry" smell. At this stage in the flight, the pilots were unable to determine whether it was throughout the aircraft or just on the flight deck. The odour remained and the pilots decided to don oxygen masks which they did, albeit with some difficulty due to the air hoses being incorrectly clipped over the nose piece at the front of the mask. They carried out the smoke and fumes abnormal and emergency procedures. A PAN was declared, and the pilots completed a normal approach and landing at Heathrow. The flight crew did not require any medical treatment.

G-EUUM pilots' observations

No passengers were carried, but the air conditioning systems were operated normally during the flight. However, the galley and cabin electrical systems were turned off. As it was a non-revenue flight there were only the two pilots on board and the cockpit door remained latched open.

Despite the fume event the pilots' main concern was that they discovered the oxygen masks incorrectly stowed. The way in which the hoses had been clipped together prevented donning of the mask until they had been undone. In this situation it had a minor effect. However, in a depressurisation event at high altitude, it could potentially be more of a problem.

The operator investigated the incorrectly stowed oxygen mask. There was no record of restowing the masks in the aircraft maintenance log and the maintenance provider in Rome did not have a record of restowing the mask. It could not be determined who restowed the masks. The AMM instructions for restowing the mask contained the following note:

> *'When you put the oxygen mask in its stowage box, the harness upper spacer and the harness lower spacer can become caught on the oronasal cone. To prevent this, you must not put the inflatable harness in the oxygen mask.'*

The following safety action was taken to prevent reoccurrence:

> The operator carried out a fleet-wide check to confirm that oxygen masks were correctly stowed and issued a Quality Alert Bulletin to all engineering staff to remind them of the importance of stowing the masks in accordance with the AMM.

Airbus A319-131 G-EUPG

The aircraft was climbing out from Brussels Airport when an unusual odour became apparent within the flight deck. The SCCM contacted the pilots and advised that a "plasticine" like odour had become apparent in the forward galley area. In addition, the SCCM reported that the cabin staff in the rear galley area were beginning to experience headaches and dry throats. The initial actions of the smoke and fumes abnormal and emergency procedures were carried out and the fumes began to dissipate.

The aircraft continued its transit to Heathrow and during descent, the cabin crew advised that the same odour had returned but this time it was more pronounced. A PAN was declared, and the commander and co-pilot donned their oxygen masks. The aircraft landed and taxied to stand. The passengers were unaffected and disembarked normally. The affected crew were treated by paramedics and taken to a local hospital for further checks but were all later medically discharged.

Subsequently, the likely cause was found to be a burnt pastry in an aft galley oven.

Airbus A320-232 G-EUUP

During the cruise over France on route to Heathrow the purser reported that one of the cabin staff had noticed an unusual odour in the rear galley area. It was described as being similar to “cheesy feet” and that initially it was quite a strong smell but had become less pronounced. It only seemed to be apparent in the rear galley area and had made one of the cabin staff feel “heady”. One of the passengers, who had been in that area also commented on it. The other passengers in the main cabin appeared not to have noticed anything unusual.

The exact source of the smell could not be identified and as a precaution the commander initiated the smoke and fumes abnormal and emergency procedures. As the flight deck was not affected, the pilots decided not to go onto oxygen. An option to divert was also considered and preparations were made should it have been necessary.

The odour appeared to have dissipated to the extent it was barely detectable. However, one member of the cabin crew still felt unwell and moved to the flight deck to see if her condition improved. In the meantime, the odour appeared to return, and a second cabin crew member started to feel unwell. The commander declared a PAN to air traffic control, proceeded to Heathrow and landed without further incident.

The presence of the fire service and paramedics prompted the commander to inform the passengers about the situation and that the crew had been dealing with an issue. The passengers disembarked as normal with no comment being made. Paramedics attended to the crew member who was feeling unwell. During the wait, some of the cabin crew commented on varying degrees of itchy eyes and sore throats. No odours or symptoms were experienced on the flight deck.

After carrying out the troubleshooting process the No 1 engine was replaced.

Airbus A319-131 G-EUPO

The aircraft was flying from Brussels Airport to Heathrow when, at approximately 4,000 ft on final approach, the flight crew noticed acrid fumes within the flight deck, described as smelling like “strong sweaty socks”. The Smoke and Fumes Abnormal and Emergency Procedures were actioned and both pilots donned oxygen masks. A PAN was declared and the approach was completed to a normal landing with the airport fire service in attendance. The aircraft was stopped on the taxiway and the pilots carried out the after landing checklist. The flight deck side window was opened, and the oxygen masks removed.

During the NITS brief the SCCM reported a very faint odour on entering the flight deck. Discussion with the cabin crew established that none of the other crew members or passengers had been affected.

G-EUPO commander's observations

The absence of any effects on the cabin crew or passengers confirmed that the fumes were confined to the flight deck. The fumes were very noticeable and "difficult to ignore" but they were not debilitating. The commander had detected a very faint odour on the climb out from Brussels and discussed it with the co-pilot. The commander's experience suggested that the faint fumes on climb out were a precursor to fumes during descent as had occurred in this case. Their experience also showed that this sort of event was more prevalent in damp humid conditions such as mizzle, as had in fact been encountered in Brussels. The commander also considered that the main cabin is less susceptible to lingering fume events because the outflow valve has opened, reducing the effect in the cabin.

Summary of common factors

The evidence does not appear to show an obvious single precursor to all these events. However, several common traits were reported by the crews:

- The incidents took place both on the short haul European inter-city flights and with regional flights of less than two hours duration.
- The aircraft often arrived in, and stayed for varying periods of time, usually overnight, in damp humid environments with drizzle or rain present.
- In many cases the pilots described a faint smell during climb out on departure.
- The flights usually continued normally with no signs of any fumes during the cruise phase.
- When events occurred, the pilots described the fumes and odours reappearing on descent and in a number of cases at about 4,000 ft AGL in stable flight.
- The presence of fumes can have a rapid and adverse effect on flight crew.
- The crews described similar smells and odours, such as sweaty socks, manure and farmyard smells, which were unpleasant and distinctive.
- The fumes described in these events were invisible.
- FDR recordings did not show any correlation between the engine settings or other system selections or settings and the point in the flight at which the fumes appeared.
- In most cases the cabin crew were unaware, until they were told, of any fumes or odours; the problem seemed to be confined to the cockpit.
- When the fumes were detected by the cabin crew, they appear to linger in the galley areas.

- In those cases, the passengers were usually unaware and unaffected.
- In the more severe cases, the fumes prompted the pilots to declare a PAN and go onto oxygen.
- The generation of fumes appeared to be transient and dissipated very rapidly, in some cases before landing and in others very shortly after landing.
- In most cases when other individuals were given access to the flight deck after landing, they could not detect any smell or odour.
- In the small number of cases where those entering the flight deck were initially able to detect something, it did not have any adverse effect on them and seemed to go away very quickly.
- There were no detectable traces of condensate, solid compound or dust present in the flight deck afterwards.
- The use of the smoke and fumes abnormal and emergency procedures appeared to alleviate, but not completely eradicate, the effects in the main cabin.
- The use of aircraft washing fluids, detergents and anti-icing fluids. In most cases washing or anti-icing operations had not been carried out prior to the flights in which the events occurred.

To date, operators have not been able to reproduce the exact symptoms on the ground. It has not been possible to capture a sample of the fumes because of the rapid onset and transient nature of the fumes which do not linger after the event.

Other information

The human olfactory system is extremely sensitive and complex and can detect minute concentrations of airborne compounds; as few as four molecules can give a recognisable smell[10]. The ability of a person to interpret a smell requires a cognitive process and therefore the perceived intensity and the effect of a smell will vary between individuals[11].

When exposed to an unusual or stressful situation a person will experience an unconscious ‘stress’ response based on several factors, including: the context of the event, any prior anticipation of the situation, the perceived level of danger the situation presents and previous experiences of a similar situation. This reaction can produce physiological effects which differ markedly from person to person[12 13]. For example, the act of cutting up an onion often causes an extreme reaction resulting in excessive tear production, stinging and

Footnote

[10] https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.0020146 [accessed 14 April 2020].
[11] https://www.frontiersin.org/articles/10.3389/fpsyg.2013.00819/full#B125 [accessed 14 April 2020].
[12] https://www.simplypsychology.org/stress-biology.html [accessed 14 April 2020].
[13] https://psychologyhub.co.uk/the-physiology-of-stress-including-general-adaptation-syndrome-gas-the-hypothalamic-pituitary-adrenal-system-hpa-and-the-sympathomedullary-pathway-sam-and-the-role-of-cortisol/ [accessed 14 April 2020].

watering of the eyes. In a kitchen environment where cutting up an onion is quite normal the affected individual can quickly and easily understand what is happening and, although uncomfortable, it is not a cause for concern. However, if the same adverse stimuli, watering and stinging of the eyes, occurs in a situation that cannot be explained by the context of the environment, a person will experience an increased level of stress and associated physiological response.

Other safety investigations

Smoke and fume events have been sporadically occurring in recent years in various types of commercial aircraft. These have been reported via the normal channels and have led to investigations being carried out. To date these investigations have not been able to determine the exact cause in all but a few events. Those that have been able to establish the exact cause, have often identified a precursor fault such as an engine oil seal failure that allowed oil residue into the gas path within compressors upstream of the air bleeds.

The investigations that have not identified a source were of great concern and so the German Federal Bureau of Aircraft Accident Investigation (BFU)[14] carried out a safety study which focussed on the potential health impairments of such events. Despite a large range of data and evidence, a common physical cause of these events could not be identified. The report concluded that in the events that were examined no significant reduction in flight safety occurred. It also found that fume events can result in health impairments, but it had not been possible to assess the long-term effects.

In 2004 the AAIB published Aircraft Accident Report 1/2004, an investigation into a serious incident involving cabin air contamination on a BAe 146, registration G-JEAK, which resulted in the incapacitation of one flight crew member. The report also examined other reported events across a number of different aircraft types.

Sections 2.3.2 and 2.3.3 contained the following statements:

> *'Irritants may affect people in different ways, due to slight physiological differences and their individual sensitivities to different substances. This may explain why in some reported events, where flight crews are exposed to the same environment, one person is affected more than another.'*

and:

> *'The research so far indicates that substances acting as an irritant(s) may be the cause of the effects experienced by the flight crew on G-JEAK, and possibly during other incidents. The donning of oxygen masks at the first indication of the problem would have reduced the exposure time to these suspected irritants, reducing their effects, and may have prevented the apparent incapacitation of the first officer and the reduced capacity of the commander to operate normally.'*

Footnote

14 https://www.bfu-web.de/EN/Publications/Safety%20Study/Studies/140507_Fume_Events. html?nn=817288 [accessed 30 March 2020].

In addition, the AAIB made Safety Recommendation 2001-47 in May 2001:

> It is recommended that the CAA should consider issuing additional advice to the crews of jet transport aircraft on the best operational practice when there is a suspicion of flight deck or cabin air contamination. The advice should include the necessity for all flight crew to use oxygen masks selected to 100% and the importance of cabin crew taking an active part in monitoring the flight crew in such circumstances.

This resulted in the CAA publishing a number of FODCOMS[15] on the subject and subsequent changes to flight crew operating manuals instructing flight crew to don oxygen masks when contamination of cockpit or cabin air is suspected

Analysis

This event was one of many very similar occurrences that had taken place with this operator and other operator's fleets of aircraft. These events had been reported via the operator's safety system and as MORs to the CAA. With the majority of these events, no immediate adverse effects on the flight crew were reported. It is not known if there are or will be any long-term health effects.

The fumes and odours are usually not visible but have a similar characteristic pungent smell. In some cases, this has resulted in stinging eyes and the sensation of "catching in the throat". However, it does not have the same effect on every individual. In this case, G-EUYB, one of the flight crew was affected to the extent they were incapacitated by feelings of nausea. After removing their oxygen mask, they vomited and were eventually taken to hospital for checks. Regarding the wider issue, crew opinions vary; some individuals describe it as an irritation and as "an annoying" trait of the aircraft type, whereas others consider it a significant flight safety hazard and a cause for concern.

Abnormal events in the cockpit, such as the presence of smoke and fumes, could be the first indication to the flight crew of a hazard which threatens the safety of the aircraft and requires an immediate response from the flight crew. The unique way individuals interpret smells, coupled with their unconscious response to a stressful situation can result in markedly different physiological reactions between flight crew members. The donning of oxygen masks as part of the flight crew actions when smoke or fumes are detected should isolate them from the source of the smoke and fumes.

Outside influences

In all the cases mentioned in this report, the possibility of influences from outside the aircraft has been considered, such as the use of aircraft washing fluids and detergents or anti-icing fluids. However, in most cases, washing or anti-icing operations had not been carried out prior to the flight in which the event occurred.

Footnote

[15] CAA Flight Operations Division Communications.

Damp and rainy conditions were often reported during these events and so is considered a potential factor. It is not known specifically why this is the case but ambient humidity around or within the aircraft and its systems may be a contributory factor.

Actions by the manufacturer

The manufacturer has been investigating fume events based on reports and information received from operators. The nature of the unidentified fume events has meant there has been no residual physical evidence of the fumes which could be identified as the source and thereby lead to specific measures to address the causes of these events. The unpredictable nature of the events has also meant that it has not been possible to construct an experimental flight test schedule to capture more data. This has left the manufacturer reliant on reported data, making the issue difficult to resolve in practical terms.

Technical cause

It has not been possible to obtain a sample of these fumes for scientific analysis. However, there are a few features and characteristics which may be relevant. The evidence indicates that it is likely that these fumes are derivatives of contaminants entering the ECS. It may not be a single compound but a combination of compounds which react and then become airborne in the bleed air supplies passing through the ECS. The fumes may have similar traits to hydrocarbon compounds combined with water vapour in low concentration which are liberated as water vapour condenses when it enters cooler conditions, for example as it passes into the flight deck or cabin via ducts. The suggestion that aircraft operating in damp or rainy conditions are more susceptible to fume events may add some weight to this theory. This is supported by the manufacturer's observation that the fumes decrease, or in many cases disappear, when the humidity of the air in the cabin decreases at higher cabin altitudes.

Consideration has also been given to whether the source may have been from plastic materials used within the ECS ducting, but this is thought less likely because the plastics tend to be used in the delivery of ECS air to the cabin rather than in production where hot and high energy air is used. The aircraft sub-variants, engine types and ages of the aircraft in which fume events occurred was also considered. This produced no conclusive evidence linking these events to a specific aircraft subset.

The operator of G-EUYB had developed a post fume/odour and smoke event maintenance procedure to tackle the issue. Its development was based on experience and findings over several years and has been successful in identifying the source of many of the previous events. The procedure is based around looking for evidence within supplier and receiver systems. It directs maintenance staff to look for evidence to establish whether engine air/oil seals have malfunctioned. However, in the most recent set of cases, the operator's post-fume check procedure has not been able to pinpoint faults or malfunctions which could have generated fumes. In all but one of these recent cases the engines have not been the source of the fume events.

The procedure for start-up and shutdown of the APU seems to have an effect. The operator has recently advised all flight crew to ensure the correct delay is applied between starting the APU and selecting bleed air and this seems to have reduced the number of events. The theory is that at APU start the generator and load compressor run-up from cold. It then takes a short amount of time for the bearings and seals to 'warm' up and stabilise to be effective. If bleed air from the load compressor is selected early, oil mist or residues can be released and drawn into the ECS airflow.

It does not seem logical that the APU can be a source of these events particularly as they often occur on descent whilst the APU is not in use. However, it is possible that entrained contaminants generated on initial APU start may linger, either as vapours or condensate, upstream of the ECS packs whilst the more predominant bleed air from the engines supplies the system. These contaminants are then entrained into the ECS system as air flow and temperature changes take place during descent. ECS system schematic diagrams are not able to show where and how this may take place. However, in practice the ECS consists of numerous straight, bent and curved ducts, leading to and from valves and conditioning components positioned and shaped alongside numerous other unrelated components. It is therefore possible that small amounts of contaminants could adhere to various internal surfaces or become trapped in 'pockets' within the system.

Conclusion

While it has not been possible to positively identify the compound that was responsible for the fumes and odours experienced in G-EUYB, or any of the other recent events, a number of common factors have been identified. The majority of events occurred after the aircraft had been parked or operated in precipitation. The fumes become apparent during the later stages of the descent, sometimes preceded by a minor event during the climb phase. The generation of fumes appears to be transient; they dissipate rapidly and leave no detectable trace. No link between changes to engine power or changes in other system settings and the generation of fumes was identified.

In some cases, the presence of fumes has resulted in physiological reactions which have interfered with a flight crew member's ability to carry out their normal duties. However, by following the smoke and fume checklist, and donning oxygen masks the flight crew were able to ensure the continued safety of the aircraft.

Safety actions

Although a specific cause has not been found in these and other recent events, the operator and aircraft manufacturer have taken several actions based on current knowledge to alleviate the odour and fume events.

Safety actions undertaken by the manufacturer:

> Project FRESH has been initiated by the manufacturer to investigate and regularly inform operators of fume event arisings.

Published an In-Service Information paper (Ref ISI 21.00.001.139) setting out all the known aspects of fumes and smoke events and includes the details of a filter and sensor product research and development programme.

Safety actions undertaken by the operator:

Developed the post-smoke and fume events maintenance procedure.

Taken action to ensure that the correct APU start up bleed air selection and shut down procedures are used.

Will consider the installation of the manufacturer's ECS air filtration modification when it becomes available

Carried out a fleet-wide check to confirm that oxygen masks were correctly stowed and issued a Quality Alert Bulletin to all engineering staff to reminded them of the importance of stowing the masks in accordance with the AMM.

Published: 30 July 2020.

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.

Accident

Aircraft Type and Registration:	Beechcraft Super King Air 200, G-FLYW
No & Type of Engines:	2 Pratt & Whitney Canada PT6A-61 turboprop engines
Year of Manufacture:	1977 (Serial no: BB-209)
Date & Time (UTC):	20 March 2020 at 1141 hrs
Location:	Exeter Airport
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller damage, engines shock-loaded, minor rear fuselage damage
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	8,500 hours (of which over 3,000 were on type) Last 90 days - 26 hours Last 28 days - 26 hours
Information source:	Aircraft Accident Report Form submitted by the pilot, engineering diagnostic report, ATC investigation report and further enquiries by the AAIB

Synopsis

The accident flight was recurrent training for a pilot who had recently re-joined the aircraft operator's company. G-FLYW took off from Bristol Airport and the pilots conducted general handling training before positioning for two Global Navigation Satellite System (GNSS) approaches at Exeter Airport. The trainee occupied the left seat and was handling pilot for the flight.

The second GNSS approach at Exeter was made in a simulated single-engine configuration and was terminated by an asymmetric go-around to join the visual circuit. The intention was to complete a single-engine landing before returning to Bristol. Due to landing traffic ahead, the handling pilot elected to extend the downwind leg and the landing gear was selected down when the aircraft was on left base. All appeared normal and the pilots remembered seeing three green lights indicating that the landing gear was locked down. No undercarriage position warnings were evident. When the aircraft was being flared for touchdown both pilots heard a loud metallic noise and a go-around was initiated. Eyewitnesses reported seeing the aircraft touch down with the landing gear retracted and its propellers striking the runway.

During the go-around, and before the landing gear was selected up, the pilots noted that the green undercarriage indicator lights were extinguished. After the go-around, the pilots

attempted to recycle the landing gear using the normal system, but it remained retracted. Lowering the landing gear using the emergency mechanism was successful and the aircraft landed at Exeter Airport without further incident.

It was not possible to positively determine how the aircraft had come to touch down with its landing gear retracted.

Following this accident, the CAA undertook to review whether its process for one-off flight approvals should include a wider set of criteria.

History of the flight

The flight was recurrent training for a pilot who had recently re-joined the company that operated G-FLYW. The trainee occupied the left seat and was PF for the detail. The commander, a Type Rating Examiner, was in the right seat and acted as PM for multi-pilot elements of the flight.

The aircraft took off from Bristol Airport and the pilots conducted general handling training before positioning for two GNSS approaches and go-around's at Exeter Airport. The second approach at Exeter was flown in a simulated single-engine configuration where "the simulated failed engine was set at 1,600 rpm and approximately 200 torque lbs. The 'live' engine was set at 400 lbs fuel flow to give appropriate power to maintain asymmetric flight."

After the single-engine go-around, the pilots joined the visual circuit to complete an asymmetric stop-and-go[1] landing before returning to Bristol Airport.

To increase separation from landing traffic ahead of them, the handling pilot elected to extend the downwind leg of the visual circuit, achieving an estimated 3 nm straight-in final approach. Landing checks, including down selection of the landing gear, were carried out on left base. Both pilots remembered seeing three greens[2] after landing gear selection and did not see or hear any landing gear position warnings. They stated that the approach was made with "one stage of flap" and that the approach speed was "spot on around 125 kt". The trainee reported that at a late stage on finals the speed had started to trend upwards unexpectedly, requiring a reduction in power to stabilise it. At the time he thought it was because of minor turbulence but, while diagnosing the approach subsequently, surmised that it could have been a symptom of an uncommanded undercarriage retraction.

When the aircraft was being flared for touchdown both pilots heard a loud metallic noise as its propellers struck the runway. A go-around was immediately initiated and the aircraft climbed away from the runway. Prior to selecting the landing gear up as part of the go-around procedure, the pilots saw that, while the gear handle was down, the three green landing gear position indicator lights were "extinguished". Even though they were wearing active noise reduction headsets, neither pilot thought it possible to have missed the undercarriage warning horn should it have been sounding on the approach.

Footnote

1 A landing coming to a stop on the runway and then taking off using both engines.
2 Cockpit indication that the landing gear is down and locked. See later section, *Landing gear system overview*.

Just before G-FLYW touched down, the driver of an airfield operations vehicle parked on the Main Apron (Figure 1) saw the aircraft approaching the runway with its gear retracted. The driver attempted to alert ATC using his UHF radio, but the aircraft touched down before he could do so. Similarly, the pilot of an aircraft conducting pre-takeoff checks at Holding Point B1 saw G-FLYW too late to transmit an alert over the VHF Tower frequency.

During the latter stages of G-FLYW's approach the preceding landing traffic had been completing its rollout prior to vacating onto Taxiway C towards the South Apron (Figure 1). The Tower ATC controller (ATCO) warned G-FLYW to expect a late clearance and focused on monitoring the runway traffic. As soon as the landing traffic had left the runway, and while still looking at the vacating aircraft, the ATCO issued landing clearance to G-FLYW. When he turned to his left, he saw the King Air climbing away from the runway with its gear retracted and assumed that the pilots had gone around due to the late clearance. It was not until after G-FLYW had landed that the ATCO became aware that it had sustained a double propeller strike.

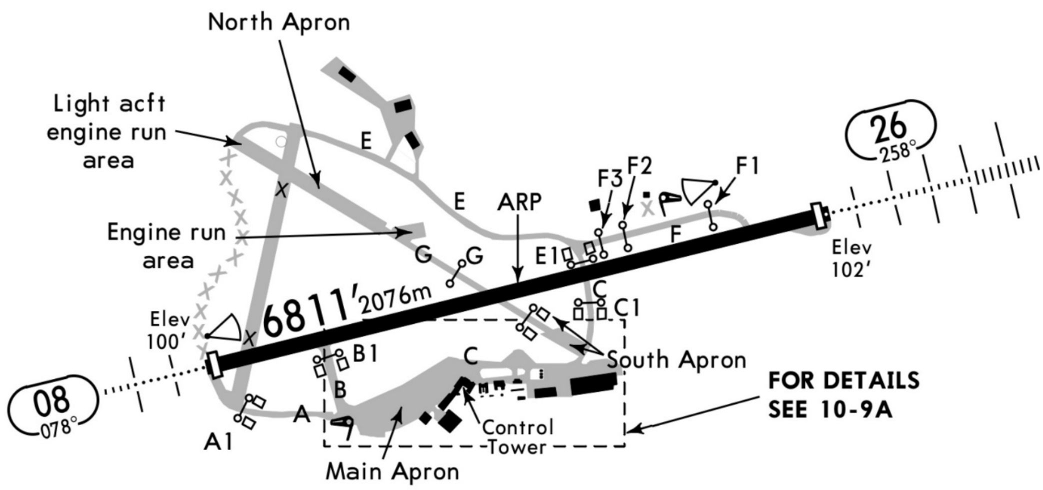

Figure 1

Exeter Airport landing chart

After going around, the pilots repositioned downwind and attempted to lower the landing gear using the normal system, but it did not extend. Confused as to what may have occurred, the pilots held clear of the visual circuit to diagnose the problem. After following the Quick Reference Handbook checklist, they managed to obtain three greens using the emergency undercarriage lowering mechanism. The pilots then flew past the Control Tower for a visual check from ATC to confirm that the landing gear had extended and declared their intention to make an approach to land. The pilots had not formally declared an emergency and the ATCO, unaware of the potential for damage to G-FLYW's engines, had been expecting the aircraft to return to Bristol. On realising that the pilots intended to land at Exeter the ATCO initiated the airfield's '*full emergency*' procedures.

Due to confusion over of the exact weight category of the King Air, G-FLYW was categorised as a 'Large' rather than a 'Small' aircraft when ATC activated their emergency procedures.

The airfield fire service was immediately available and additional Local Authority emergency services were in position to support them 17 minutes after the emergency state was initiated. While assistance is sought from the Local Authority responders for any full emergency, the scale of augmentation is greater when a Large aircraft is involved. G-FLYW could have landed without delay but, when ATC asked the pilots if they wished to wait until the additional emergency assets were in place, it was interpreted as an instruction and the pilots thought they were required to hold off until advised.

Once the emergency services were in position, the pilots carried out an uneventful landing. Due to their suspicion that the landing gear might earlier have self-retracted, the pilots minimised their use of braking during the landing roll.

Accident site

A runway inspection immediately after G-FLYW's go-around found the remains of an aircraft light on the runway in the vicinity of the reported touchdown point. After G-FLYW had landed a second runway inspection discovered propeller strike marks either side of the centreline that corelated with G-FLYW's earlier approach (Figure 2).

Figure 2

Propeller strike marks and debris from broken aircraft light (centre image)

Meteorology

Good weather prevailed at the time of the accident. The measured wind velocity, reported in ATC's landing clearance to G-FLYW, was 050°/23 kt.

Personnel

The handling pilot had previously been employed by the operator as a captain on their King Air aircraft. He was undergoing refresher training on type having recently returned to the company. Due to COVID-19 restrictions adversely impacting simulator availability, and contrary to the operator's normal policy, the training was conducted in the aircraft. The CAA had issued a 'one-off flight approval' for the event, the purpose of which was to conduct a combined LPC/OPC. Following this accident, the CAA undertook to review their internal processes to determine whether the barrier analysis for one-off flight approvals needed to routinely review a wider set of criteria.

Recorded data

G-FLYW was not fitted with flight data or cockpit voice recorders. No other data source was available to support the investigation into how the landing gear came to be up when G-FLYW first touched down at Exeter Airport.

Aircraft information

Landing gear system overview

G-FLYW is a variant of the Beechcraft Super King Air with electro-mechanically actuated landing gear. The Pilots Operating Manual[3] (POM) describes the landing gear operation as being '*controlled by the switch placarded LDG GEAR CONT · UP · DN on the pilot's right subpanel*' (Figure 3). Three lights adjacent to the landing gear selection lever illuminate green when the respective undercarriage leg is down and locked. Two red indicator lights located in the control handle illuminate to show that the gear is in transit or not locked. They also illuminate when the landing gear warning horn is actuated.

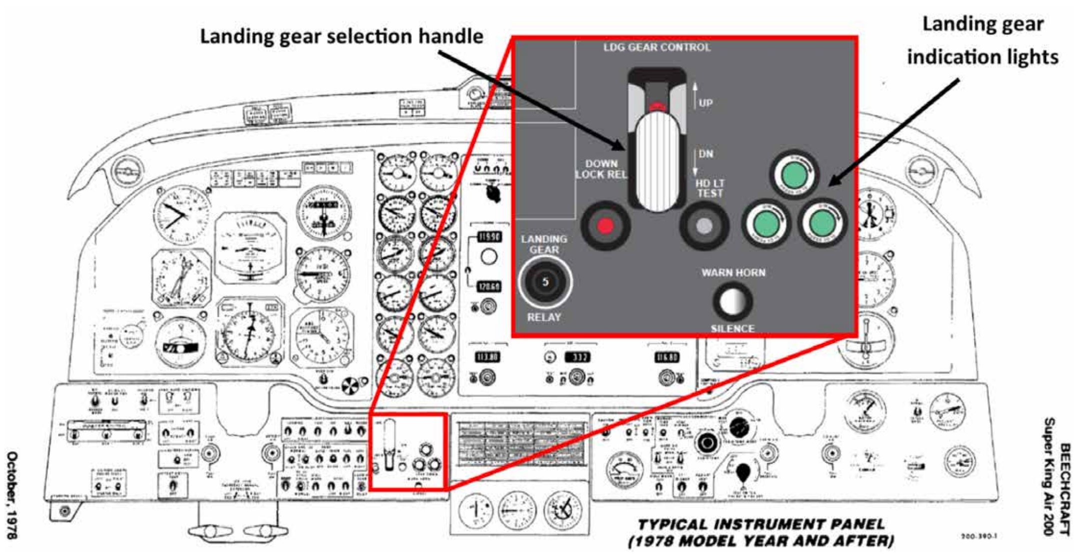

Figure 3

Typical King Air instrument panel with highlighted cockpit controls for landing gear

Landing gear warning system

A landing gear warning system is provided to alert pilots if the landing gear is not down and locked during '*specific flight regimes*.' The system's warning modes depend on the position of the flaps. With flaps in the approach position (single stage of flap) *'… and either or both power levers retarded below a certain power level, the warning horn and landing gear switch handle lights will be activated and neither can be cancelled.*' The POM does not quote a specific figure for the power level below which the landing gear warning system will trigger the visual and audio alerts.

Footnote

3 Beechcraft Super King Air 200 Pilots Operating Manual (101-590010-127) Section 7: Systems Description.

Neither the trainee nor the commander saw or heard any undercarriage position warnings during the asymmetric approach and subsequent go-around.

Landing gear operation

The landing gear selection handle controls a sliding assembly within an undercarriage electrical control unit (Figure 4). Contactor plates mounted at either end of the sliding assembly and on a fixed terminal block control electric current flow to the motor which lowers and raises the landing gear. One set of contactors is associated with landing gear UP selection and the other with DOWN. With the gear handle in either the UP or DOWN position, the respective contactor on the slider presses against its partner contactor on the fixed terminal block to create an electric circuit. If the landing gear is not in the commanded position the electric actuator motor is energised. When sensors detect that the gear has travelled to the required position, the current is interrupted and gear travel ceases. Whenever one set of contactors is made the opposite set is un-made, isolating that side of the circuit until the alternate gear position is selected. With the gear handle in the DOWN position, the sliding assembly's UP contactor is physically separated from the fixed terminal block and it is not possible to energise the landing gear UP circuit. The AAIB found no evidence of previous incidents where King Air landing gear self-retracted.

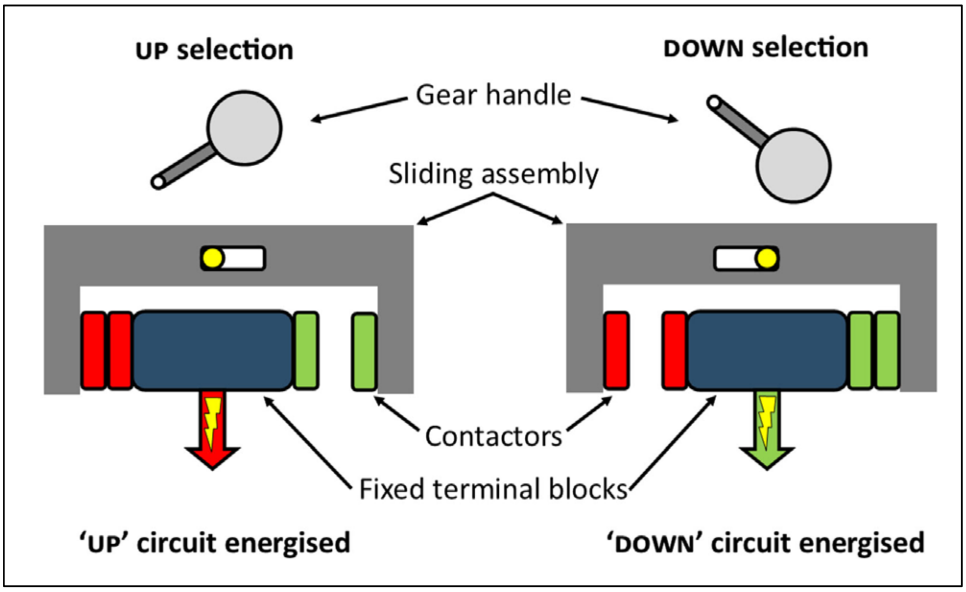

Figure 4

Simplified schematic of G-FLYW's gear electrical contactor assembly and operation

Aircraft examination

As part of the initial engineering fault diagnosis the aircraft was put on jacks and, when the landing gear was selected UP, it retracted normally but a subsequent DOWN selection failed. The fault was traced to a damaged down-select contactor in the undercarriage electrical control system (Figure 5). Once the damaged component had been replaced the landing gear operated correctly. The engineers did not find any fault with the landing gear warning system.

Minor skin damage was found on the lower rear fuselage. In addition, two aerials and the lower anti-collision beacon were also eroded.

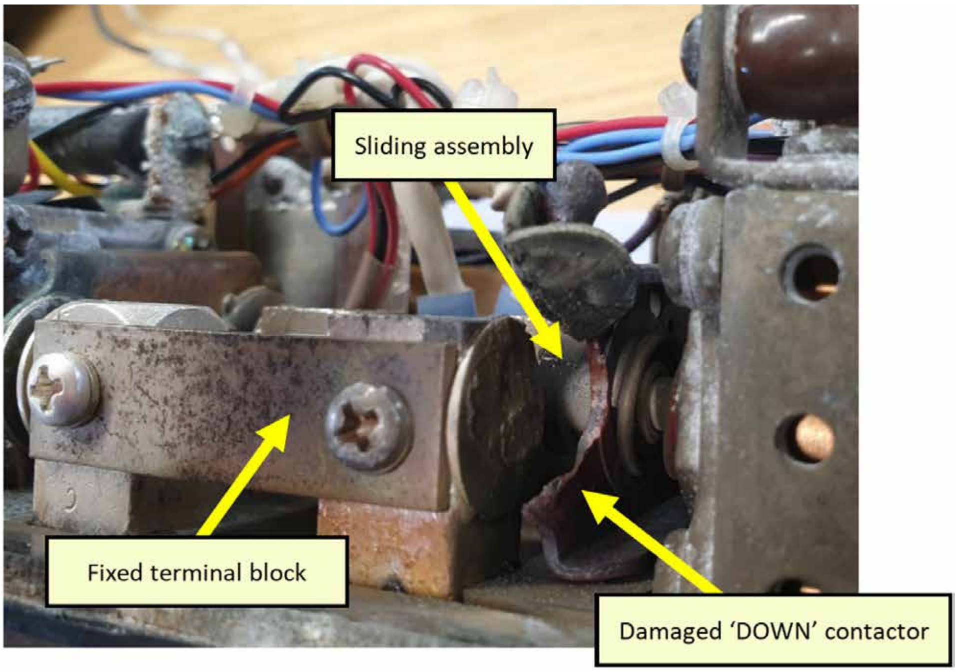

Figure 5
Damaged landing gear contactor

ATC post-occurrence investigation

A post-incident investigation by the ATC Unit found that:

- Traffic levels at the time were of '*moderate intensity and above normal complexity*.'
- The controller had not made a visual check of G-FLYW's landing gear because of '*other activity requiring his attention at the time*.'
- *'Not all of the pieces of information passed to ATC were picked up and understood … which led to … incomplete situational awareness. A report from the 'Checker' vehicle stating "that Beech had his wheels up when he touched the ground" was unacknowledged as it was passed by a UHF radio which broadcasts via a loudspeaker rather than through the controller's headset*.'
- *'The Tower controller was working on the assumption that* [G-FLYW] *had gone around'* and remained unaware that it had suffered a propeller strike.

The report emphasised the high priority that should be afforded to carrying out '*visual checks (including the status of an aircraft's gear)*' before issuing clearances.

The report further stressed the importance of clear and unambiguous radio communication between ATC and pilots.

The report made two recommendations:

- *'That a cross-coupling facility is introduced into the Exeter Tower position as soon as possible to mitigate the risk of safety critical information passed via the UHF radio being missed by the controller*.'
- *'That a list is created which can be quickly accessed … containing aircraft which commonly operate at Exeter whose size category is not immediately apparent*.'

Note: ICAO Doc 4444 PANS-ATM section 7.4.1.7.1 states that *'Whenever an abnormal configuration or condition of an aircraft, including conditions such as landing gear not extended or only partly extended, or unusual smoke emissions from any part of the aircraft, is observed by or reported to the aerodrome controller, the aircraft concerned shall be advised without delay.'* Neither ICAO Doc 4444 PANS-ATM nor the UK's MATS Part 1 (CAP493) make the conduct of a visual check of the status of an aircraft's gear a pre-requisite for the issue of an ATC clearance.

Analysis

G-FLYW's pilots had selected the landing gear down and believed that they had seen three greens indicating that the undercarriage was locked down. They did not see or hear any landing gear unsafe position warnings, but the aircraft arrived at the runway with its gear retracted. An unexpected reduction in the power required to control the aircraft's speed on finals led the pilots to suspect subsequently that the landing gear could have self-retracted. The landing gear handle was in the DOWN position, but the three green indicator lights were not illuminated after the commencement of the go-around.

With approach flap selected and the landing gear up, the King Air undercarriage warning system generates an alert when the power levers' positions are below a '*certain'* level. The landing gear warning lights and horn cannot be cancelled in this configuration. The '*certain power level*' is not specified in the POM. During the go-around the power levers were both fully forward and would have been out of the alert trigger zone.

That there were no warnings evident to the pilots and no fault found during the post-accident engineering investigation, left open the possibility that the power lever position on approach was above the alerting level. Within the bounds of normal human performance, it is also possible that the system generated alerts but that neither of the pilots saw or heard them, perhaps because they were concentrating on the approach. The pilots considered it most unlikely that the power levers would have been above the alert trigger level or that they would not have heard the landing gear warning horn if it had sounded.

A last-chance check of the undercarriage position lights prior to the landing flare may have revealed the unsafe gear position in time for a normal go-around. However, the quick response by the pilots to the sound of the propellers striking the runway enabled them to fly away, thus avoiding further damage to the aircraft.

The ATCO was not required to visually confirm the status of G-FLYW's landing gear before issuing landing clearance.

Post-accident engineering diagnosis confirmed a fault in the undercarriage electrical control system that prevented the landing gear from lowering when selected DOWN. Once the faulty component had been replaced the landing gear worked correctly. The electrical control unit design isolates the opposite actuator circuit when the landing gear operating lever is in the UP or DOWN detent and the sliding assembly is in the matched position. It was not possible to establish how landing gear self-retraction could have occurred when system design prevents it with the landing gear handle in the DOWN position. No fault was found with the undercarriage warning system.

Communications challenges resulted in incomplete situational awareness and a degree of confusion amongst some of the personnel involved. Clear and unambiguous radio calls could have helped generate greater mutual understanding of the situation as it developed.

Observations

The pilots recalled seeing three greens, did not hear any warnings and wondered whether the landing gear raised itself. The AAIB found no evidence that the landing gear had done so before. With the landing gear selected down, the UP-circuit is isolated, meaning that the gear cannot subsequently raise itself, and the sliding contactor mechanism was working when tested after the accident. The landing gear DOWN selection was found on inspection not to work, and it was therefore concluded that when the pilots selected the gear down it probably did not lower.

It was considered possible that the pilots' recollection was incorrect because it is known that pilots sometimes see three green lights when that is what they are expecting to see, and miss aural warnings when they are working hard, in this case on a check flight.

Although the discussion above is a plausible explanation of this event, the pilots were confident in their recollection, and without recorded data it was not possible to provide a definitive account of what happened.

Conclusion

It could not be positively determined how the landing gear came to be up when G-FLYW touched down at Exeter Airport. 'Wheels up landings' are a known hazard for aircraft equipped with retractable landing gear and a final check of landing gear position approaching the touchdown committal point is seldom wasted. When things do go wrong, accurate and effective communication is an important tool for boosting mutual understanding and situational awareness.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 737-8B6, CN-RGJ
No & Type of Engines:	2 CFMI CFM56-7B26 turbofan engines
Year of Manufacture:	2012 (Serial no: 33072)
Date & Time (UTC):	28 February 2020 at 1133 hrs
Location:	London Gatwick Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 139
Injuries	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	13,479 hours (of which 12,755 were on type) Last 90 days - 128 hours Last 28 days - 47 hours
Information Source:	Aircraft Accident Report Form submitted by the operator and further enquires by the AAIB

Synopsis

During the takeoff roll the "V_1" automatic call did not occur and the takeoff speeds were not displayed on the Primary Flight Display (PFD). The aircraft rotated 37 kt above the correct speed for this departure and 120 m from the end of the runway. It is likely that the flight crew did not enter speeds into the Flight Management Computer (FMC) or inadvertently deleted them after they had been entered.

The incident shows that automatic calls may not always work as the flight crew expect and they should be ready to respond appropriately.

History of the flight

The crew were scheduled to operate a return flight from Casablanca International Airport in Morocco to London Gatwick Airport (Gatwick). The outbound flight to Gatwick was uneventful.

The commander reported that the turnaround at Gatwick proceeded normally and the aircraft pushed back from stand at 1106 hrs. The co-pilot was the pilot flying for the return sector. Runway 26L was in use, with a light southerly wind and rain. The cloud was broken at 900 ft and the temperature was 6°C. The flight crew planned to depart from intersection A, using FLAP 1 and an assumed temperature of 55°C. They had calculated takeoff speeds of V_1 - 144 kt, V_R - 152 kt, and V_2 - 155 kt. The commander reported that these takeoff performance figures were loaded into the FMC on stand and no changes were required during the taxi to the runway.

The aircraft entered the runway at intersection A and was cleared for takeoff. At 80 kt the commander confirmed that the airspeed indications were normal and the flight crew were next expecting to hear the aircraft announce "V_1" but, this automatic call did not occur. When the commander realised the automatic call had not occurred, he checked his PFD and saw the V speed bugs were not displayed on the speed tape. He felt "the aircraft was slow" so he allowed it to accelerate whilst he evaluated the situation. He did not recall if the speeds were still displayed on his Control Display Unit (CDU). As the end of the runway approached, he instructed the co-pilot to initiate a smooth rotation. The aircraft took off and the remainder of the flight proceeded without further incident. No aircraft caution or warning messages were seen at any stage.

The commander reported the lack of the automatic call in the aircraft's technical log after the flight. Subsequent investigation by the operator did not find any aircraft faults. The automatic calls worked normally on the preceding and subsequent flights.

Recorded information

The Cockpit Voice Recorder was not downloaded. However, the operator provided a copy of the Quick Access Recorder (QAR) data for the flight.

This showed that the nosewheel lifted off at 189 kt. The aircraft was airborne approximately 120 m prior to the end of the runway at 196 kt and 13 seconds after the planned rotation speed. Figure 1 shows the takeoff roll and highlights key speeds and heights. The data also showed the thrust was slightly increased just prior to the rotation.

The QAR records the assumed temperature and V speeds entered in the FMC, and the Mode Control Panel (MCP) selected speed (which is normally set to V_2 on the ground). However, for the incident flight, the V speeds were blank. The QAR started recording after engine start and the V speeds were blank throughout the taxi and takeoff. The QAR did record an assumed temperature of 55°C[1] and an MCP Selected Speed of 155 kt. The QAR files were checked, by the operator, for the previous and subsequent flights, and V speeds were recorded normally on these flights.

Footnote

[1] Most jet aircraft use less than full engine power for takeoff where runway length permits. On the Boeing 737 the takeoff power can be reduced by either entering a temperature above the actual temperature, known as an 'assumed temperature' or by using a fixed reduction in power, known as a 'fixed derate' or a combination of both.

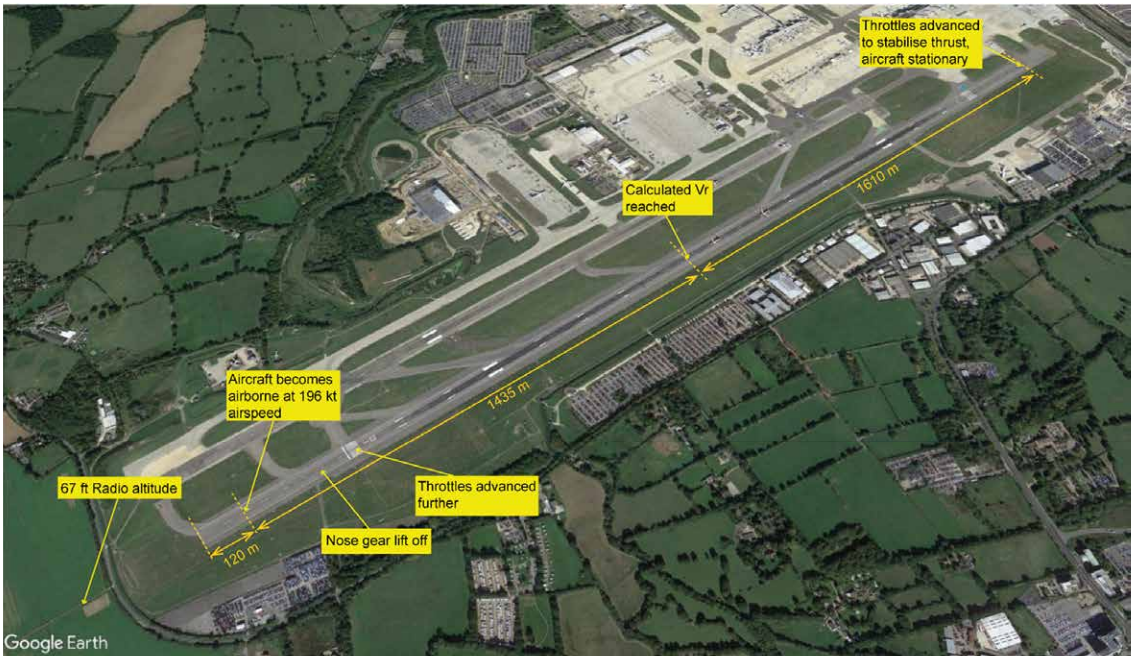

Figure 1

CN-RGJ's takeoff roll showing significant heights and speeds

Aircraft information

Takeoff V speeds are normally loaded into the FMC during the preflight procedure after the takeoff performance has been calculated. The procedure requires the crew to enter the aircraft weight, enter any assumed temperature or fixed derate and then enter the planned takeoff flap setting and V speeds. The V_2 speed is then selected on the MCP. The V_1 and V_R speed are displayed on the speed tape as shown in Figure 2. If the V speeds are not entered a NO VSPD message is displayed in amber on the PFD.

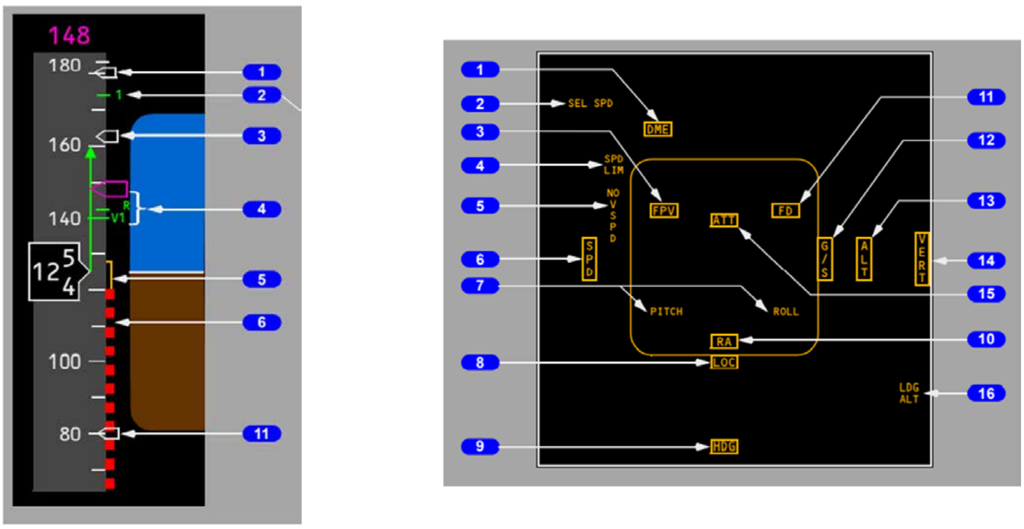

Figure 2

PFD speed tape showing V speeds (label 4) and PFD fail flags showing NO VSPD (label 5)

After the speeds have been entered, if any changes are made to the FMC data (for example, zero fuel weight, takeoff thrust or outside air temperature) the takeoff speeds are automatically deleted. If this happens the FMC will display a message on the CDU, the CDU message light will illuminate, the amber FMC light above the navigation display will illuminate and the NO VSPD message will be displayed on the PFD. The manufacturer stated that it was not aware of any situation in which the V speeds can be deleted without these warnings appearing.

The Boeing 737 Flight Crew Training Manual (FCTM) contains the follow information regarding V speeds:

> *'The PF normally displays the takeoff reference page on the CDU. Display of the takeoff reference page allows the crew to have immediate access to V-speeds during takeoff in the event that V-speeds are inadvertently removed from the airspeed display.*
>
> *There have been incidents where pilots have missed FMC alerting messages informing them that the takeoff speeds have been deleted or they have forgotten to set the airspeed bugs. If, during a takeoff, the crew discovers that the V speeds are not displayed and there are no other fault indications, the takeoff may be continued.* [….] *In the absence of displayed V speeds, the PM should announce V1 and VR speeds to the PF at the appropriate times during the takeoff roll. The V2 speed should be displayed on the MCP* [Mode Control Panel] *and primary airspeed indicators. If neither pilot recalls the correct rotation speed, rotate the airplane 5 to 10 knots before the displayed V2 speed.'*

Automation

Many commercial aircraft have systems to automatically announce various parameters. These systems tend to be reliable and pilots might fly thousands of hours during which the calls work as expected. It is therefore likely that pilots will expect the system to work and may take time to react if it does not behave as expected[2].

Analysis

During the takeoff roll the automatic "V_1" call did not occur and the commander realised the speed bugs were not displayed on the PFD. As he felt the aircraft was slow and thought it was better to have more airspeed then less, he allowed the aircraft to accelerate whilst he evaluated the situation. The aircraft lifted off the runway 13 seconds after the planned rotate speed with 120 m of runway remaining.

It is likely the automatic call and speed bugs were absent because the V speeds were not present in the FMC. No V speeds were recorded on the QAR which suggests they were not

Footnote

2 Parasuramin, R. and Riley V. (1997) 'Humans and Automation: Use, Misuse, Disuse, Abuse', Human Factor, 39(2), pp 230-253. Available at https://doi.org/10.1518/001872097778543886 [accessed 29 April 2020].

loaded into the FMC when the engines were started. It is possible that the flight crew did not enter them, but the commander believes that they loaded the FMC correctly. The aircraft weights and the assumed temperature had been entered into the FMC and the MCP speed had been set to $V_{2,}$ both of which are part of the same procedure as entering the V speeds. This suggests most of the preflight procedure was completed. It is also possible that the speeds were entered correctly and then inadvertently deleted, but the flight crew did not recall seeing the FMC alerting messages or the NO VSPD message on the PFD. Boeing are not aware of any way to delete the V speeds without these messages appearing.

The FCTM provides guidance on how to manage a lack of automatic calls or loss of speed bugs. However, these systems are normally reliable, so it was not exceptional for the flight crew to take a few seconds to react when the automatic call did not occur. The commander also felt the aircraft was slow and thought it was better to have more speed than less. However, 189 kt is considerably more than the typical rotation speed.

Conclusion

During the takeoff roll, the "V_1" automatic call did not occur and the takeoff speeds were not displayed on the PFD. This led to a late rotation.

The incident shows that automatic calls may not always work as the flight crew expect and they should be ready to respond appropriately.

SERIOUS INCIDENT

Aircraft Type and Registration:	1) Fuji FA-200-180 Aero Subaru, G-HAMI 2) Cessna 172R Skyhawk, G-BXGV
No & Type of Engines:	1) 1 Lycoming IO-360-B1B piston engine 2) 1 Lycoming IO-360-L2A piston engine
Year of Manufacture:	1) 1973 (Serial no: FA200-188) 2) 1997 (Serial no: 17280240)
Date & Time (UTC):	23 June 2019 at 0955 hrs
Location:	Near Henley-on-Thames, Oxfordshire
Type of Flight:	1) Private 2) Private
Persons on Board:	1) Crew - 1 Passengers - 2 2) Crew - 1 Passengers - 3
Injuries:	1) Crew - None Passengers - None 2) Crew - None Passengers - None
Nature of Damage:	1) None 2) Damage to right wingtip
Commander's Licence:	1) Private Pilot's Licence 2) Private Pilot's Licence
Commander's Age:	1) 68 years 2) 76 years
Commander's Flying Experience:	1) 531 hours (of which 322 were on type) Last 90 days - 5 hours Last 28 days - 5 hours 2) 890 hours (of which 830 were on type) Last 90 days - 6 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Forms submitted by the pilots and further enquiries by the AAIB

Synopsis

Two aircraft had what was initially believed to be a near miss while giving air experience fights to disabled children at a multi-aircraft charity event. It was later discovered that the two aircraft had collided, with one aircraft sustaining minor damage, but both aircraft landed safely.

The investigation discovered that one of the accident pilots was asked to present the pilots' briefing at short notice. The briefing did not include a discussion of how all the participating aircraft would be deconflicted or how they would communicate. Neither aircraft had any form of Electronic Conspicuity.

The airfield that hosted the event has committed to take safety actions before hosting the event again.

History of the flight

Eight aircraft were participating in an annual charity event at White Waltham Airfield, Berkshire. The purpose was to give air experience flights to disabled children who were accompanied by a parent or carer. The airfield is situated in congested airspace, 11 nm west of Heathrow Airport, on the edge of the London controlled airspace. The route to be flown was predominately under controlled airspace with a base of 2,500 ft amsl. At the time Runway 07 was in use, the visibility was in excess of 10 km and there were scattered clouds at about 1,700 ft amsl.

Prior to the aircraft departing the pilots attended a briefing. As the Deputy Airfield/Safety Manager, who had given the briefing in the past at this event, was not available due to sickness, the pilot of G-BXGV was asked to conduct the brief "at the last minute". This was because he had flown at this event previously, but no guidance was offered. In the brief he instructed the pilots to fly a counterclockwise route from White Waltham via visual reporting points November, Whiskey, Sierra and back to the airfield (Figure 1). They were reminded to keep a good lookout, given the number of aircraft involved, and communicate clearly when approaching the airfield. They were also told that should any passenger feel unwell they were to return to the airfield immediately.

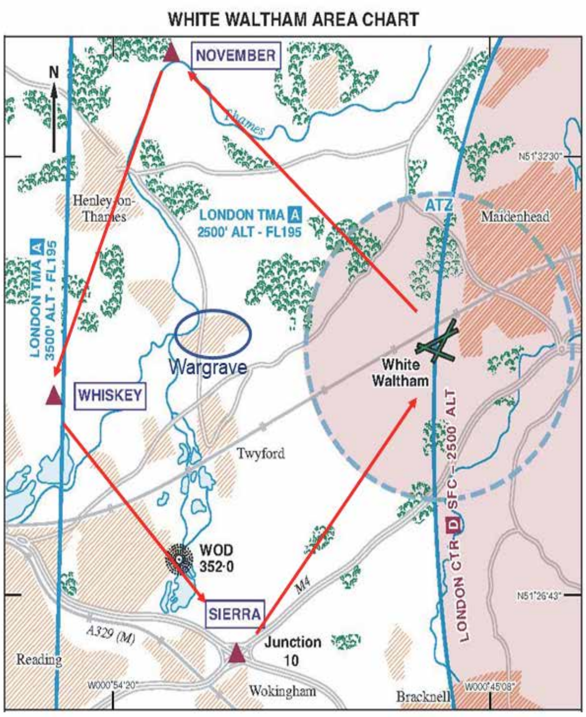

Figure 1

Briefed routing of flights

G-HAMI

The pilot of G-HAMI, a low-wing aircraft, stated that he took off at about 0940 hrs with one disabled child and his carer. He turned right downwind and departed the circuit initially flying west towards a point east of Wargrave, Berkshire, (Figure 1) before turning north towards Point November. He believes he changed frequency from White Waltham's A/G radio frequency to listen on a Lower Airspace Radar Service.

When the aircraft was about 3 nm south-east of November, heading about 325°, he felt a "bump" beneath the aircraft that he believed was an air pocket. He continued with the route and landed uneventfully at about 1015 hrs. He did not hear an Airprox[1] being filed.

G-BXGV

The pilot of G-BXGV, a high-wing aircraft, stated he was allocated two disabled children and one adult carer for his first flight. Prior to engine start, one of the children became verbally and physically unsettled but was reassured by his carer. They took off at 0952 hrs, turned right downwind and departed the circuit on a north-westerly heading towards Point November, remaining on White Waltham's A/G radio frequency.

Once airborne the previously unsettled child became vocal. Fearing he may become physically disturbed again, the pilot decided to shorten the route by flying towards Henley-on-Thames, Oxfordshire. Shortly after leaving the Aerodrome Traffic Zone, while straight and level, the pilot noticed a bright red aircraft above, in his 8 o'clock position, converging on his aircraft. He then lost sight of it above and behind his aircraft's high-wing, becoming visual again when it was in his 1 to 2 o'clock position. It then was seen to descend before disappearing from his sight. He didn't have time to take avoiding action but filed an Airprox on White Waltham's A/G radio frequency. He continued the flight to Henley-on-Thames and Point Whiskey before returning to White Waltham without further event, landing at 1009 hrs (Figure 2).

Figure 2

G-BXGV's routing
(Red circle indicates approximate location of collision)

Footnote

1 An Airprox is a situation in which, in the opinion of a pilot, the distance between aircraft as well as their relative positions and speed have been such that the safety of the aircraft involved may have been compromised.

After landing, G-BXGV's pilot approached G-HAMI's and asked him if he had seen his aircraft while airborne, saying they had come within 20 to 50 ft of each other and he had felt G-HAMI's propwash; G-HAMI's pilot said he had not.

Both pilots then flew another flight without event. After landing, G-BXGV's pilot noticed damage to the aircraft's right wingtip (Figure 3). He then informed G-HAMI's pilot of it and that they must have collided in flight.

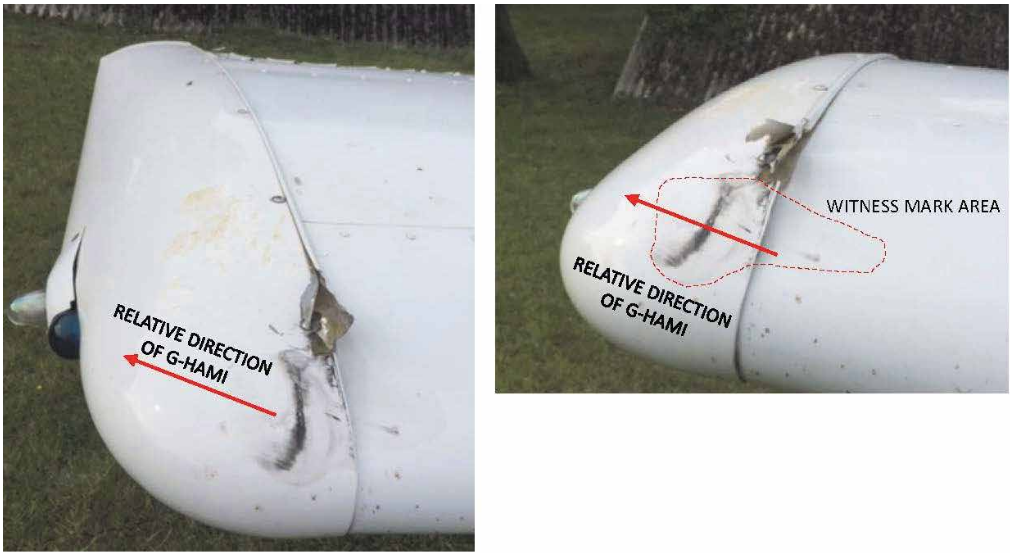

Figure 3
Damage to G-BXGV right wingtip

Pilots' comments

All pilots that flew during the event were contacted by the AAIB.

One pilot, who had flown at the event several times, commented that the event was not as well organised as usual and that not all the pilots that flew were at the briefing.

Aircraft equipment

Both accident pilots stated that their transponders were serviceable, and they were squawking code 7000. However, no secondary radar returns from either aircraft were recorded on the ground.

G-BXGV's pilot was using an electronic navigation aid. Its flight log was made available to the investigation. G-HAMI's pilot was not using an electronic navigation aid.

Neither aircraft had any form of Electronic Conspicuity (EC)[2].

Footnote

[2] The CAA's CAP 1391, *Electronic conspicuity devices*, provides more information about EC devices that have the ability to signal their presence to other airspace users: https://publicapps.caa.co.uk/docs/33/CAP1391_E2_APR2018.pdf [Accessed 1 April 2020].

Aircraft examination

The damage to G-BXGV's right wingtip (Figure 3) was repaired soon after the accident and was not able to be examined by the AAIB. Analysis of the photographs indicated that the tyre of G-HAMI contacted the wing just inboard of the tip and moved outwards leaving the skid mark shown.

G-HAMI was inspected by the AAIB on 5 July 2019 while it was undergoing routine maintenance. No sign of damage was noticed by the maintenance organisation or the AAIB.

Airspace coordination notice (ACN)

An ACN[3] is a means of notifying adjacent ATC units and other aerodrome users of events such as this where there are expected to be increased traffic volumes.

The airfield was aware of ACNs but did not consider applying for one for this event, because it did not consider the event would necessarily have made the airfield busier than usual over a summer weekend.

Organisational information

The charity

The charity's Director of Operations stated that it organises about 10 of these events each year, at airfields around the UK, and has been doing so for 10 years without incident.

While no formal risk assessment was completed, all airfields were visited annually to ensure arrangements were appropriate and properly managed. Discussions were held about the necessary domestic arrangements with the airfield managers, but they did not get involved with the operational aspects; the flying clubs arrange these. He added that he has removed one airfield from their schedule due to a "lackadaisical approach" to the event.

The airfield

The host airfield's Deputy Airfield/Safety Manager commented that while he had no set format for the briefing for this event, his briefing was based "loosely" on the briefing he gave pilots on their Members' Day. Subjects briefed included emergencies, deconfliction by different routes, distractions in the cockpit, the loading and unloading of passengers and the control of non-flying personnel while airside.

He added that the airfield will conduct a risk assessment before future events. They will also ensure that he, or another responsible representative from the airfield, is available to make a full and complete briefing, adopting the template of the Members' Day briefing. An overview of the flying will also be maintained throughout the event.

Footnote

[3] Details on ACNs can be found here: https://www.caa.co.uk/Commercial-industry/Airspace/Event-notification/Airspace-coordination-notices,-large-balloon-releases-and-other-events/ [accessed July 2020].

The airfield has now installed a programme on a personal computer in its operations room that enables staff to see ADS-B and Modes S equipped aircraft, providing a general overview of the local flying area.

Since this system was installed it has been noted that a “surprising number” of aircraft, that are known to have Mode S transponders do not have them turned on, and that this may be because pilots fear the consequences of being observed infringing the surrounding airspace.

CAA comments

The CAA commented that it supports a ‘just culture’ when reviewing airspace infringements, as set out in CAP1404 ‘*Airspace infringements: Review and remedial actions process*’. It stated that education and retraining are the usual courses of action in the event of an infringement. In 2017, of 1,162 airspace infringements, five pilots were prosecuted (0.4%); in 2018 this figure was five out of 1,358 (0.37%) and in 2019, two out of 1,271 (0.16%).

Analysis

The charity event was operated from an airfield on the edge of London controlled airspace, and the route flown under controlled airspace, using the aerodrome’s standard visual reporting points as turning points. This increased the risk of a collision between participants and other aircraft by placing them in vertically restricted airspace and over geographical locations used for all departing and arriving aircraft.

The airfield did not apply for an ACN. Had it done so, it would have highlighted the event, and its routing, to surrounding aerodromes and aircraft that were not participating in the event, thus reducing the risk to all aircraft.

G-BXGV’s pilot was asked to conduct the briefing at the last minute, with no time to prepare and without being provided guidance, and the briefing did not appear to contain information that was sufficiently comprehensive to address the novel hazards of the event.

Pilots were advised to shorten the route if they were concerned for the welfare of their passengers. However, as deconfliction and escape routes were not briefed, a pilot electing to shorten the route had no premeditated strategy for avoiding aircraft flying the complete route. The pilot of G-BXGV decided to shorten the route not long after takeoff.

The pilots were briefed to communicate clearly when approaching the airfield, but there was no communication plan for aircraft while en route. As a result, it appears both aircraft were on a different frequency at the time of the accident, as G-HAMI’s pilot did not hear G-BXGV file the Airprox. Consequently, they would not have been able to communicate had they attempted to do so.

Secondary radar returns were not recorded from either aircraft. It is possible the pilots forgot to select their transponders ON. Neither aircraft had any form of EC. Had both transponders being working correctly and one aircraft had EC, the collision might have been avoided. Recordings of secondary radar might have given the investigation a better understanding of the circumstances of the collision.

The pilot of G-HAMI did not see G-BXGV before the collision and the pilot of G-BXGV only saw G-HAMI moments before. It is likely that both pilots were somewhat engaged with their passengers, which probably affected their lookout. As G-BXGV had a high wing and G-HAMI a low wing, both pilot's visual field in the direction of the other aircraft would have been obstructed.

Conclusion

The aircraft collided while taking part in a multi-aircraft charity event under and adjacent to controlled airspace where no form of deconfliction or a communication plan was briefed to the participants.

This accident highlights the importance of avoiding distractions, looking out and the benefits of employing electronic conspicuity, especially during multi-aircraft events in congested airspace.

There were no active controls to prevent the occurrence having a catastrophic outcome.

Safety actions

> The host airfield stated that it will conduct a risk assessment before holding the event again. It will also ensure that the Deputy Airfield/Safety Manager or another responsible representative from the airfield is available to make a full and complete briefing, adopting the template of their Members' Day briefing. An overview of the flying will also be maintained throughout the event.
>
> The owner of G-BXGV has fitted an EC device and linked it to the navigation software installed on his personal electronic device.

ACCIDENT

Aircraft Type and Registration:	Piper PA-32-300, G-DIWY
No & Type of Engines:	1 Lycoming LO-540-K1A5 piston engine
Year of Manufacture:	1969 (Serial no: 32-40731)
Date & Time (UTC):	23 June 2020 at 1655 hrs
Location:	North Coates Airfield, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - 1 (Minor) Passengers - 3 (Minor)
Nature of Damage:	Major damage to the nose landing gear, engine and airframe
Commander's Licence:	Private Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	81 hours (of which 44 were on type) Last 90 days - 15 hours Last 28 days - 10 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The nose landing gear collapsed on touchdown causing the aircraft to veer off the runway to the left and drop into a dyke.

History of the flight

The pilot was carrying out a flight from Full Sutton Airfield, Yorkshire, to North Coates Airfield, Lincolnshire. The weather was good, with the wind 220° at 6 kt, CAVOK, OAT 27°C, Dew Point 14°C and QNH 996 hPa. The flight was uneventful, and the aircraft joined downwind for Runway 23, which had a mown grass surface 750 m x 18 m, with flaps selected and all checks completed. On the final approach, the surface wind was passed as 140° at 12 kt and the aircraft passed over the runway threshold with 89 mph IAS. A normal touchdown was made on the runway centreline, but the aircraft "jerked" to the left and continued to veer to the left despite rudder inputs to the right. The pilot applied the wheel brakes but, as the aircraft appeared to skid, he released them slightly as it appeared to be exacerbating the problem, and the aircraft continued to turn to the left. It departed the left side of the runway into the long grass at about 55 mph. Approximately six feet into the grass, there was a large dyke, which was not visible to the pilot due to the length of the grass, and the left wing dropped into it. The aircraft yawed sharply to the left, which in turn caused the nose to impact the dyke wall head on. The aircraft yawed a further ninety degrees to the left, coming to a stop facing back towards the Runway 23 threshold. The pilot turned off the fuel and electrical system and everyone exited through the doors, moving to the far side of the runway due to fuel leaking from the wings. The pilot telephoned the emergency services who attended the scene.

A runway inspection showed that the point of touchdown was on the centreline with all three wheels appearing to have touched at the same time. It did not feel like a heavy landing, but the nose landing gear had collapsed, veering the aircraft to the left and preventing the pilot steering it back to the centreline.

The pilot commented that none of the airfield charts available to him had mentioned the presence of the dyke and had he known about it, with the increased crosswind, he may have done things differently. The approach and ground tracks with the position of the dyke are shown at Figure 1 below.

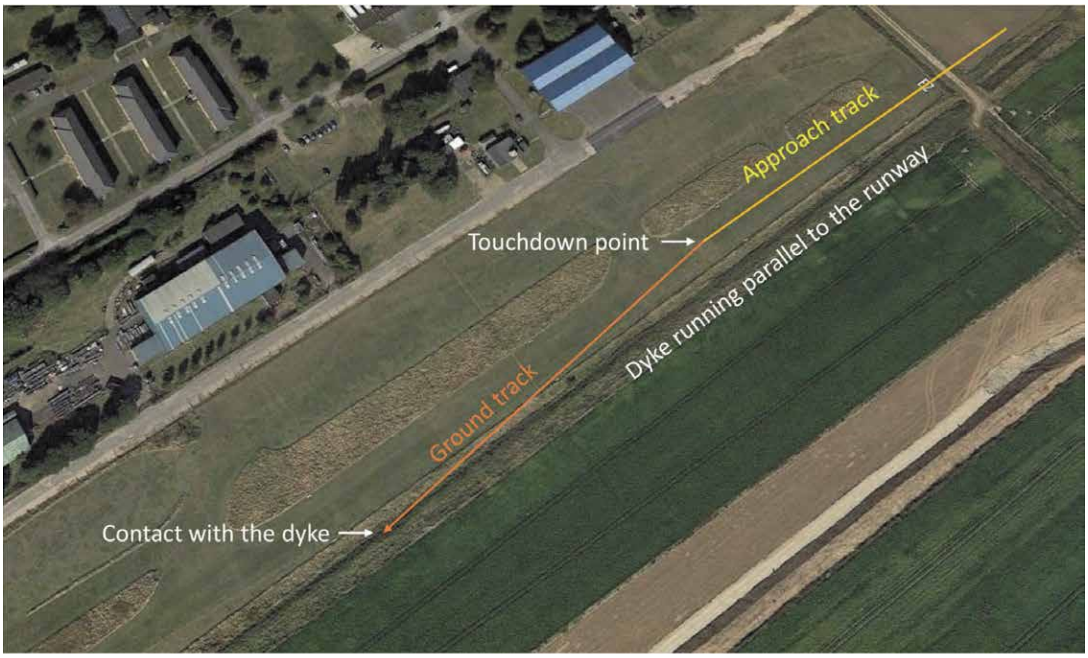

Figure 1

North Coates Airfield showing the position of the dyke

SERIOUS INCIDENT

Aircraft Type and Registration:	Reims Cessna F152, G-BTAL
No & Type of Engines:	1 Lycoming O-235-L2C
Year of Manufacture:	1978 (Serial no: 1444)
Date & Time (UTC):	25 June 2020 at 1340 hrs
Location:	Shobdon Aerodrome, Herefordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries	Crew - None Passengers - N/A
Nature of Damage:	No damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	83 hours (of which 64 were on type) Last 90 days - 0 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries made by the AAIB

Synopsis

The aircraft suffered a partial engine failure shortly after takeoff from Shobdon Aerodrome. The pilot landed the aircraft in a field to the east of the aerodrome. He was not injured and there was no damage to the aircraft.

This report considers why this incident resulted in a good outcome when many previous similar events have resulted in fatal accidents.

History of the flight

The pilot had not flown for several months due to public health restrictions and on the day of the incident was planning to complete three circuits to regain recency. The first two circuits were uneventful. He took off for the third circuit with the flaps up and full power. As the aircraft reached 300 – 400 ft the engine lost all power. The pilot described it feeling like "someone had pulled the throttle to idle". He immediately lowered the nose and selected a field slightly to his left. He recalled that the power returned briefly then reduced again but he decided to close the throttle and treat the engine as completely failed. He made a MAYDAY call then focused on the landing.

The pilot landed the aircraft with the flaps up in a slight crosswind. As the aircraft touched down he noticed a ditch crossing the aircraft's track and decided to pull back on the control column to pass over it. Once clear of the ditch he brought the aircraft to a halt and shut the engine down. The aircraft was not damaged and the pilot was able to exit the aircraft normally.

Figure 1

Aerial view of Shobdon Aerodrome showing G-BTAL in the field to the east

The pilot reported that he had been trained to think through all possible outcomes and had considered different engine failure scenarios at the airfield prior to the event. He also always briefed himself on his actions in the event of an engine failure prior to each takeoff. He believed this helped him manage the situation on the day. He had recently completed ATPL(A)[1] ground exams and had read various articles and reports about managing engine failures and the potential pitfalls. These had taught him to treat a partial engine failure as a complete engine failure, not to try to turn back to the airfield, and the importance of flying the aircraft first.

Footnote

1 Air Transport Pilot's Licence (Aircraft).

Figure 2

G-BTAL ground track showing the ditch the aircraft crossed

Aircraft examination

The maintenance organisation recovered the aircraft and conducted a detailed inspection. It was unable to identify the cause of the loss of power but suspected it was caused by carburettor icing. The inspections included checking the fuel filters and draining the fuel tanks. No contamination was found in the fuel filters, but a 5 - 6 inch piece of tape was found in the fuel tank. However, it was not thought that this had affected the fuel flow to the engine. It was not determined how the tape entered the tank.

The aircraft was returned to flying and at the time of writing no further engine problems had been encountered.

Carburettor icing

The air temperature was 29°C with a dew point of 17°C, suggesting serious carburettor icing was likely at descent power. The pilot reported that he used the carburettor heat for at least 10 seconds whilst flying downwind and did not detect any icing. He selected the carburettor heat again before he reduced power for descent and kept it on until landing.

Figure 3

G-BTAL after the incident
(tie downs were installed to secure the aircraft before recovery)

Managing partial power loss after takeoff

Pilots are taught how to handle a complete engine failure, but partial engine failure is not normally covered during training. Recognising this, the Australian Transport Safety Bureau has published a safety leaflet on managing partial power loss after takeoff in single engine aircraft[2]. The key message in the leaflet is that most fatal and serious injury accidents can be avoided by using the following strategies:

- pre-flight decision making and planning for emergencies and abnormal situations for the particular aerodrome
- conducting a thorough pre-flight and engine ground run to reduce the risk of a partial power loss occurring
- taking positive action and maintaining aircraft control either when turning back to the aerodrome or conducting a forced landing until on the ground, while being aware of flare energy and aircraft stall speeds.

Footnote

2 '*Avoidable Accidents No. 3 - Managing partial power loss after takeoff in single-engine aircraft'* available at http://www.atsb.gov.au/publications/2010/avoidable-3-ar-2010-055/ [accessed 9 July 2020].

Analysis

The pilot attributed the safe outcome to having planned and reviewed his actions in the event of an engine failure prior to taking off. This freed sufficient capacity such that, when the event occurred, he could focus on flying the aircraft. He also treated the partial failure as a complete failure. Having read about previous accidents he was not tempted to turn back and instead selected a field ahead and focused on landing.

The reason for the engine failure was not determined. It is possible it was caused by carburettor icing.

ACCIDENT

Aircraft Type and Registration:	Titan T-51 Mustang, G-TSIM
No & Type of Engines:	1 Suzuki V6 Mini Merlin engine
Year of Manufacture:	2012 (Serial no: LAA 355-14964)
Date & Time (UTC):	21 May 2020 at 1235 hrs
Location:	Shobdon Airfield, Leominster, Herefordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries	Crew - None Passengers - N/A
Nature of Damage:	Extensive damage especially to the underside of the aircraft
Commander's Licence:	Private Pilot's Licence
Commander's Age:	73 years
Commander's Flying Experience:	4,050 hours (of which 73 were on type) Last 90 days - 4 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst turning onto base leg for a V_{NE} run over the runway, the engine lost power. The pilot initially continued towards the runway, but it became clear that he would be unable to make the airfield. He rapidly adjusted his plan and made a forced landing in a field short of the airfield. The aircraft came to rest upright, and the pilot was uninjured. The aircraft was extensively damaged.

History of the flight

The pilot was performing the check flight for a LAA permit renewal. After completing the planned flight, the pilot returned to the airfield for the final item of the check, which was the V_{NE} run. As he turned onto the base leg for Runway 26 at Shobdon Airfield, the engine suddenly lost power and began to wind down. After initially heading straight for the airfield, the pilot made a MAYDAY call and lowered the landing gear. He selected the alternate engine ignition/injection computer but the engine did not pick up.

As the aircraft descended, the pilot realised that he would not reach the airfield. He made a rapid change of plan for an off-field landing, retracting the landing gear and selecting full flap. He saw the only suitable field at 250-300 ft agl and was able to manoeuvre for a landing, levelling the wings just above the ground. After touchdown the aircraft initially skated across the ground before yawing rapidly to the left and sliding sideways until it came to rest. The pilot described the landing as a “very rough ride”. Figure 1 shows the aircraft in the field after the accident and clearly shows the sideways path of the aircraft.

Figure 1
G-TSIM after the forced landing

Engine examination

The propeller had continued to windmill down to the touchdown, so the pilot considered it unlikely that a mechanical fault was the cause of the engine failure. Examination after the accident showed that the engine contained normal oil and coolant levels, both fuel pumps functioned and both fuel filters were free from debris. The engine fuel injection system is controlled electronically by a programmable unit, and the aircraft is fitted with a dual ignition/injection system switchable via a relay unit to ensure redundancy should one unit fail. Although the pilot switched the units after the loss of power, the engine did not recover. He considered it likely that the engine loss of power was caused by an electrical failure in the ignition/injection system, but the actual fault could not be readily identified.

Survivability

The pilot was not injured, despite being aware during the landing of his head striking the canopy several times. He commented that wearing a helmet in the aircraft almost certainly saved him from what could have been a serious head injury.

Analysis

Post-accident analysis of the engine did not find an obvious cause of the loss of power. The pilot considered it was likely to be an electrical failure within the ignition/injection system, but the fault had yet to be identified.

It is good practice to always be prepared for a loss of power, even when positioning for the landing at the end of the flight. The pilot was able to perform a successful forced landing as he remained calm and was able to change his plan when he assessed that the original attempt to get to the airfield was not going to work.

Although the aircraft was extensively damaged, the pilot was uninjured, probably due to wearing a helmet. The use of helmets can provide the occupants of aircraft with a much greater degree of head protection in the event of an accident. Whilst they may not always be appropriate or necessary for the type of flying conducted, they can offer an additional level of protection.

Conclusion

The pilot managed to perform a successful forced landing after the engine failed on the approach to land. Although time was limited, the pilot continued to assess his options and was able to adjust his plan when the initial one became unviable. Despite extensive damage to the aircraft, the pilot was uninjured despite his head striking the canopy several times during the landing. This was probably because he was wearing a helmet. The cause of the loss of power could not be readily established.

ACCIDENT

Aircraft Type and Registration:	Vans RV-9, G-CDXT
No & Type of Engines:	1 Lycoming O-320-D1A piston engine
Year of Manufacture:	2006 (Serial no: PFA 320-14376)
Date & Time (UTC):	5 June 2019 at 1420 hrs
Location:	Private Airstrip, Whippingham, Isle of Wight
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers – N/A
Nature of Damage:	Collapsed landing gear, damage to propeller and wing edges and punctured fuel tank
Commander's Licence:	Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	651 hours (of which 1 was on type) Last 90 days - 18 hours Last 28 days - 12 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft stalled late in the approach to a grass airstrip causing it to land hard. The pilot believes he encountered windshear causing the aircraft to descend and he tried to avoid a collision with a hedge at the perimeter to the airfield by raising the nose, but without increasing power.

History of the flight

The pilot had planned to fly on an overseas trip in G-CDXT, the aircraft being owned by a friend. Most of the pilot's flying experience had been gained on tail-dragging aircraft and he owned a Piper Cub which he operated from a 580 m long private grass airstrip on the Isle of Wight.

A few weeks prior to the accident, the pilot had flown G-CDXT with the owner in order to familiarise himself with the aircraft. The flight had taken place at Clacton Airfield which has a grass runway just over 500 m in length. The dual flight was uneventful and the pilot then undertook a solo flight in the aircraft, again with no problems.

On the day of the accident, the pilot had flown in his Piper Cub to a private airstrip in Sussex to collect G-CDXT and fly it back to the airstrip he used on the Isle of Wight. On his return, the weather was good with a westerly wind of about 10 kt. The pilot positioned G-CDXT for an approach to the grass strip, which was orientated into wind. He reported he had been deliberately low on the approach and that just prior to landing the aircraft had encountered 'windshear', causing it to lose height. The pilot thought the aircraft would hit a low hedge situated at the boundary of the airfield and applied nose-up elevator to avoid it. He did not apply power at the same time. The aircraft stalled, hitting the ground near the start of the airstrip sufficiently hard to cause the undercarriage to collapse and damaging the propeller, wing leading edges and fuel tank. The pilot was uninjured and made the aircraft safe before climbing out unaided.

Analysis

The pilot stated that he had chosen to be low on the approach as he was concerned about overrunning the airstrip after touchdown, due to its relatively short length. He considered that had he flown the normal approach path he would have had sufficient height to lower the nose of the aircraft when encountering the windshear in order to maintain speed. He further commented that the Piper Cub he normally flew had the throttle on the left, whereas the throttle on G-CDXT was on the right. He believes this contributed to him not applying power when he applied nose-up elevator to avoid the hedge.

Despite having had no problems during the familiarisation flights, the pilot commented it may have been beneficial to have gained more experience at a larger airfield on G-CDXT before trying to operate to the more challenging airstrip where the accident occurred.

ACCIDENT

Aircraft Type and Registration:	DJI Phantom 4 (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2019 (Serial no: 0V2DGC6RA30282)
Date & Time (UTC):	5 March 2020 at 13:45 hrs
Location:	Bristol sewage treatment works
Type of Flight:	Aerial Work
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Destroyed
Commander's Licence:	Not applicable
Commander's Age:	20 years
Commander's Flying Experience:	300 hours (of which 4 were on type) Last 90 days - 70 hours Last 28 days - 24 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries made by the AAIB

Synopsis

During an aerial survey of a sewage treatment works, the unmanned aircraft flew into a wind turbine, the height of which the pilot had misjudged.

History of the flight

The unmanned aircraft system (UAS) was being used to conduct an aerial survey of a sewage treatment works that contained four wind turbines in the survey area. The pilot was using the NATS Drone Assist app[1] as part of the flight planning and risk assessment of the flight; however, the app did not mention the wind turbines, so the pilot looked up "wind turbine height" on the internet which returned a height of 328 ft. A search was also made for any guidance material on flying in the vicinity of wind turbines, but none was found. The pilot had been made aware of aeronautical charts during UAS pilot training but did not use them when planning and risk assessing a flight.

Footnote

1 The NATS Drone Assist app, powered by Altitude Angel, is designed to supplement flight planning activities with additional information to help the user decide where it is safe to fly. '*It presents users with an interactive map of airspace used by commercial air traffic so that you can see areas to avoid or in which extreme caution should be exercised, as well as ground hazards that may pose safety, security or privacy risks when you're out flying your drone.*' - https://dronesafe.uk/safety-apps/ [accessed 20 July 2020]. Many of the hazards it identifies, such as schools, train stations and motorways, may not be visible to the pilot on the ground.

The operator's CAA Permission limited the height of the flights to 400 ft above the surface. It also limited the flying to greater than 50 m (164 ft) from any structure not under the control of the pilot; however, since the operator was also the owner of the wind turbines, this second limitation did not apply. Therefore, the pilot decided to fly the aircraft at 400 ft above the ground to provide clearance of 72 ft between it and the top of the turbine blades, which the pilot assessed to be a sufficient distance. However, the aircraft was destroyed when it flew into a wind turbine which had a height of 413 ft above the ground.

CAA aeronautical charts

CAA aeronautical charts show all known land-sited obstacles above 300 ft agl.[2]

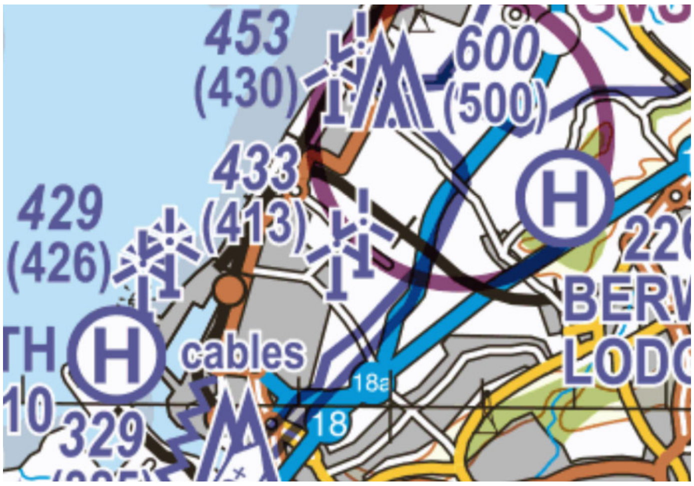

Figure 1

Extract from the CAA 250K aeronautical chart with the wind turbines at the sewage works in the centre of the image

Figure 1 shows the wind turbines, marked 433 (413)[3], at the sewage works, as well as the powerlines (dark blue lines) on the southeast boundary of the works. The same information can be found on apps designed for VFR flying.

Analysis and findings

The pilot was aware of the wind turbines at the site where the aerial survey was to be conducted but was unable to find any accurate information about the height of these either on the app used to plan the flight or from an internet search.

For a UAS pilot flying visual line of sight with the aircraft, tall obstacles may be obvious to see but their actual height is difficult to assess visually. All known ground obstacles greater than 300 ft in height are shown on aeronautical charts. These charts, and apps that use the same obstacle database, are one source of accurate information, and provide a clear

Footnote

[2] A small number of obstacles below 300 ft are shown for landmark purposes.

[3] The first number is the height in feet of an obstacle relative to mean sea level (AMSL) and the second (in parentheses) relative to the ground (AGL).

indication of areas to avoid flying a UAS if limited to flying not above 400 ft. However, for obstacles less than 300 ft, UAS pilots will need to determine their accurate heights from other sources.

UAS pilots are responsible for flying their aircraft within the limitations imposed by their CAA Permission and so must ascertain the accurate height of any hazard or obstacle near the planned flightpath.

Safety action

Having been reminded of the obstacle and airspace information available on aeronautical charts or flight planning apps that have access to this information, the operator has amended its flight planning and risk assessment procedures to include reference to these.

ACCIDENT

Aircraft Type and Registration:	Parrot Anafi Thermal
No & Type of Engines:	4 Standard Parrot Electric motors
Year of Manufacture:	2019 (Serial no: PS728120AA9H002623)
Date & Time (UTC):	11 June 2020 at 1211 hrs
Location:	Near The Dicker, East Sussex
Type of Flight:	Commercial Ops (UAS)
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Damaged gimbal and right front propeller
Commander's Licence:	N/A
Commander's Age:	42 years
Commander's Flying Experience:	113 hours (of which 8 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The operator was conducting training with the UAS for a pilot and observer. About 3 minutes after takeoff the UA was observed to be "twitching". Despite attempts to regain control, it was observed to pitch, yaw and change height by approximately ± 20 ft, and the UA was flown to the emergency landing area.

As the pilot descended the UA for landing it became less responsive. It then pitched down and flew away, without any input from the pilot, and did not respond to any subsequent inputs. The pilot selected the 'return to home' function, without effect, and announced "control lost" to the observer. The UA then collided with a tree about 420 ft from the landing area and 100 ft agl, sustaining damage to its gimbal and front right folding propeller.

The operator believed that the flight characteristics and damage sustained indicated that the right front propeller failed in flight.

Safety actions

The operator had been replacing the propellers on all its UAs every 20 hours of flight time. At the time of the accident the propellers had flown for just under 9 hours. The operator will now change all folding propellers after 5 hours flight time and has made this a scheduled item in its electronic flight and maintenance logging software.

ACCIDENT

Aircraft Type and Registration:	Yuneec H520 (registration N/A)	
No & Type of Engines:	6 electric motors	
Year of Manufacture:	2019 (Serial no: YU18340018B11A03)	
Date & Time (UTC):	24 April 2020 at 2354 hrs	
Location:	Hove, East Sussex	
Type of Flight:	Emergency Services Operations	
Persons on Board:	Crew - N/A	Passengers - N/A
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	Broken legs and cracks to body and battery	
Commander's Licence:	Not applicable	
Commander's Age:	28 years	
Commander's Flying Experience:	6 hours (of which 1.5 were on type) Last 90 days - 3 hours Last 28 days - 0 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries made by the AAIB	

Synopsis

The aircraft dropped to the ground from a height of 15 m when power was lost to the electric motors even though the battery's energy level (State of Charge) was 97.7%. The wind conditions were turbulent and an investigation by the Unmanned Aircraft System's (UAS) manufacturer concluded that the probable cause for the power loss was that the battery had become loose in flight.

History of the flight

After an initial flight, the pilot landed the Yuneec H520 UAS and changed the battery with one that was fully charged, checking to make sure it was secure before deploying the aircraft again. Not long into this flight, while the aircraft was hovering at about 49 ft (15 m) agl, the LEDs on the aircraft flickered. No warning was displayed on the control and, when the LEDs flickered a second time, the pilot decided to bring the aircraft back to the landing site to conduct some checks. The LEDs then flickered a third time and, as the pilot tried to manoeuvre the aircraft, it lost power and fell to the ground. Damage to the aircraft was substantial including broken legs and cracks in the aircraft body, camera casing and battery.

Aircraft information

The Yuneec H520 (Figure 1) is a UAS hexacopter with a mass of 1.6 kg with the battery installed (but without gimbal and camera) and a maximum takeoff mass of 2.133 kg. It is controlled on the ground using a handheld Android-based ST16 all-in-one controller with a maximum transmission distance of 1.6 km. A storage device in the aircraft is used to log data for each flight in a ULog file. Telemetry data is also recorded by the ST16 controller in a TLog file.

Figure 1

Yuneec H520 UAS hexacopter
(Photo courtesy of Yuneec)

Recorded data

A review of the aircraft's ULog data was made which confirmed that this flight log file stopped abruptly after 34 s of flight with the aircraft 15 m above the ground. The data in Figure 2 shows that for the last five seconds of controlled flight, during which the aircraft was flying forwards at about 1 m/s while maintaining altitude, the aircraft's roll attitude oscillated between -5° and +1°, and pitch attitude between -24° and +22°. The flight log also recorded 97.7% battery energy level (State of Charge) at power loss.

Investigation by the UAS manufacturer

An investigation by the aircraft's manufacturer established that the aircraft had experienced a total power loss at the point when the aircraft was moving forward '*aggressively*' in '*windy conditions*'. It concluded that the most probable cause for the power loss was the battery becoming loose and finally disconnecting in flight. This was supported by the flickering LEDs which could have been caused by the '*intermittent bridging/touching of the battery terminals*'. Also, the damage to the battery indicated that it may have been sustained with the battery partially sticking out of its housing when the aircraft hit the ground.

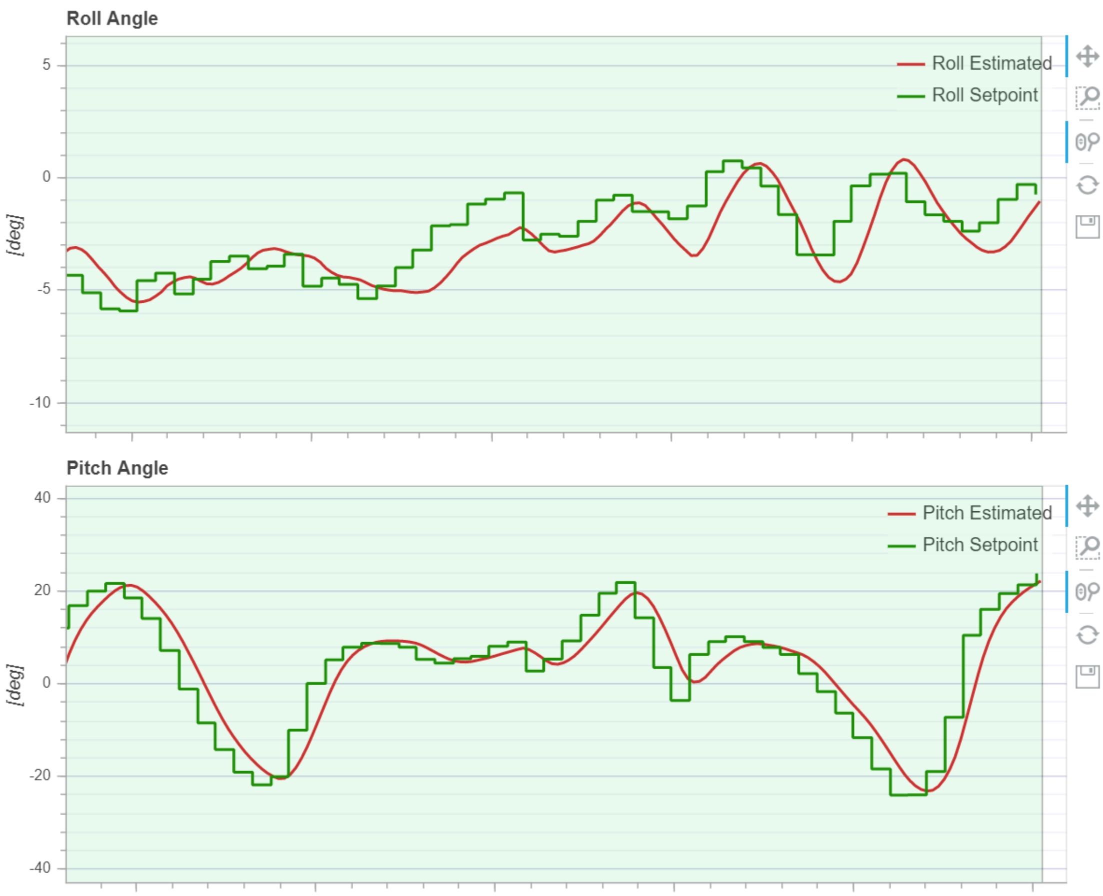

Figure 2

Aircraft pitch and roll for the last five seconds of controlled flight

Analysis

The sudden loss of power to the motors from a battery that was almost fully charged was consistent with the battery disconnecting in flight. The data indicated that the aircraft was pitching through 6° and rolling through 46° as it maintained altitude while moving slowly forward, suggesting that the conditions were turbulent enough to dislodge the battery if it had not been properly secured in place, even though the pilot had checked to make sure it was.

Safety actions

The manufacturer stated that future versions of the Yuneec H520 will include logic to prevent takeoff if it detects that the clip holding the battery in its housing is not securely in place.

AAIB Record-Only Investigations

This section provides details of accidents and incidents which were not subject to a Field or full Correspondence Investigation.

They are wholly, or largely, based on information provided by the aircraft commander at the time of reporting and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

Record-only UAS investigations reviewed June - July 2020

21-Apr-20 **Parrot Anafi Thermal** **Brook Lane, Brocton Cannock Chase Woodland, Stafford**

During the UA's fourth flight of the day, when about 350 m from the pilot, the UAS controller indicated a wi-fi failure. After the 'RETURN TO HOME' function was activated, to no avail, the UA was seen to descend out of sight. It was subsequently located in bushes undamaged.

20-May-20 **Parrot Anafi Thermal SE** **Sankey Valley Industrial Estate, Merseyside**

Following a GPS caution, which appeared on the controller during flight, the UA was observed to become unstable and fall to the ground from a height of about 150 ft. The pilot also advised that a rotor blade may have come loose in flight.

28-May-20 **DJI Matrice 210 V2** **Water pumping station, Usk, Gwent**

While undertaking a photo survey, the UA turned over in flight with no control input, and spun to the ground. It was severely damaged.

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).

FORMAL REPORT ADDENDUM

Aircraft Type and Registration:	Eurocopter AS332 L2 Super Puma, G-WNSB
Date & Time (UTC):	23 August 2013, at 1717 hrs
Location:	Approximately 1.7 nm west of Sumburgh Airport, Shetland Islands
AAIB Aircraft Accident Report:	1/2016

Introduction

During the preparation for the Fatal Accident Inquiry into the accident to AS332L2, Super Puma helicopter, registration G-WNSB on 23 August 2013, additional information was presented to the AAIB which was not made available during the original investigation.

The investigation found that the Emergency Breathing System (EBS) of one of the passengers had been found in a condition which indicated that an attempt had been made to use the system during the accident. The new information confirmed that when the victim was recovered from the sea and taken to shore the EBS had been found stowed in its pouch on the passenger's life jacket. Before being received by the AAIB, the EBS was removed from its pouch and the valve operated; it was not possible to identify when this had occurred.

As a result of this information Section 1.13.1, Section 2.7.1 and Section 3 (a) Finding 26 of the AAIB report 1/2016 has been amended to reflect this information.

Section 1.13.1 (Page 43)

Original text:

> *Passenger E's body was recovered from the water after the fuselage of the helicopter had broken open due to the wave action and contact with the shore. Evidence from the Emergency Breathing System (EBS) indicates that the mouthpiece had been removed from the pouch and the valve opened in an apparent attempt to use the device. Whilst there were some minor injuries, the evidence showed that the passenger had drowned whilst still in the cabin of the helicopter.*

Amended text:

> Passenger E's body was recovered from the water after the fuselage of the helicopter had broken open due to the wave action and contact with the shore. A member of the RNLI lifeboat crew which recovered Passenger E's body stated that the Emergency Breathing System was stowed in its pouch on Passenger E's life jacket. This was verified by an expert from the manufacturer using photographs taken by the police after recovery of Passenger E to the shore. Whilst there were some minor injuries, the evidence showed that the passenger had drowned whilst still in the cabin of the helicopter.

Section 2.7.1 (Page 129)

Original text:

> *The body of the fourth fatality showed no evidence of an anti-mortem incapacitating injury or illness. The post-mortem determined the cause of death to be drowning. Evidence from the inspection of the rebreather supports the conclusion that this individual attempted to use it during the event, successfully deploying it from the stowed position on the life jacket and activating the mouthpiece valve. Subsequent testing confirmed that the air bladder of the EBS was punctured. It was not possible to determine whether this damage was present at the time it was deployed by the passenger or occurred prior to or during recovery of the body. It was not possible to determine whether the user had been able to purge the mouthpiece or successfully breathe from the deployed air supply. There was insufficient evidence to explain why this passenger did not escape from the helicopter.*

Amended text:

> The body of the fourth fatality was recovered from the sea after the fuselage of the helicopter had broken open as a result of wave action and contact with the shore. Post-mortem examination determined that there was no evidence of an anti-mortem incapacitating injury or illness and determined the cause of death to be drowning. There was no evidence that the passenger had attempted to deploy their EBS after the helicopter struck the sea and there was insufficient evidence to explain why this passenger did not escape from the helicopter.

Section 3 (a), Evacuation and survivability, Finding 26 (page 144)

Original text:

> *26. One passenger died as a result of being unable to successfully escape from the cabin; this passenger had attempted to use their EBS.*

Amended text:

> 26. One passenger died as a result of being unable to successfully escape from the cabin.

The online version of the report was amended on 13 August 2020.

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

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.

1/2018 Sikorsky S-92A, G-WNSR
West Franklin wellhead platform,
North Sea
on 28 December 2016.

Published March 2018.

2/2018 Boeing 737-86J, C-FWGH
Belfast International Airport
on 21 July 2017.

Published November 2018.

1/2020 Piper PA-46-310P Malibu, N264DB
22 nm north-north-west of Guernsey
on 21 January 2019.

Published March 2020.

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
DFDR	Digital Flight Data 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)
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)
mb	millibar(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
PM	Pilot Monitoring
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
TODA	Takeoff Distance Available
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
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