Air Accidents Investigation Branch

AAIB Bulletin 10/2020

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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.

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SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A320-216, EC-KLT
No & Type of Engines:	2 CFM56-5B6 turbofan engines
Year of Manufacture:	2007 (Serial no: 3376)
Date & Time (UTC):	26 August 2019 at 1205 hrs
Location:	On approach to Birmingham Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 189
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	40 years
Commander's Flying Experience:	9,700 hours (of which 8,080 were on type) Last 90 days - 150 hours Last 28 days - 61 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft made two approaches above the correct descent profile, on each occasion leading to a missed approach. On the second missed approach the aircraft initially continued descending and was not configured appropriately, reaching an angle of attack at which the ALPHA FLOOR[1] energy protection mode activated to increase engine thrust. The aircraft made a subsequent approach, landing without further incident.

During a subsequent event, involving the same operator and aircraft type (but different flight crew), the aircraft remained above the correct approach descent profile initially but descended below it later in the approach and performed a missed approach. The pilots in this case managed the vertical profile manually using a flight control mode with which they were not familiar.

In both cases the pilots appeared not to have understood when to commence the final descent to follow the vertical profile of the approach. The operator's safety department has recommended improvements in approach training and strategies to assist situational awareness. The operator and air traffic services provider are working to gain a better understanding of each other's approach requirements.

Footnote

1 A system designed to protect the aircraft from stalling by applying TOGA thrust.

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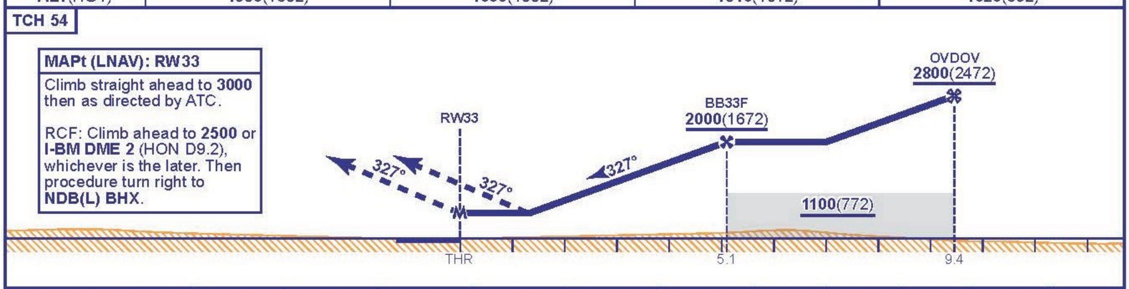
History of the flight

After an uneventful flight from Barcelona, the aircraft positioned for an RNAV[2] approach to Runway 33 at Birmingham Airport. Both pilots were experienced on the aircraft and the co-pilot was acting as the handling pilot. The weather at the time was good with light winds reported and no cloud below 5,000 ft agl.

The aircraft was at 4,000 ft approximately 11 nm south of the airport when ATC cleared it to descend to 2,000 ft and carry out the RNAV approach (Figure 1). The pilots read back the clearance correctly but, thirty seconds later, the aircraft had not changed altitude and they contacted ATC to request descent. ATC again cleared the aircraft to descend to 2,000 ft and to carry out the approach. The aircraft was 10.5 nm from the runway when it started descending. At 9.4 nm it was at 3,800 ft, 1,000 ft above the correct profile.

RECOMMENDED PROFILE VERTICAL PATH ANGLE 3.0° (LNAV 5.2%) 320FT/NM				
NM to RW33	5	4	3	2
ALT(HGT)	1980(1652)	1660(1332)	1340(1012)	1020(692)



Aircraft Category		A	B	C	D
OCA (OCH)	LNAV/VNAV	740(412)	740(412)	740(412)	740(412)
	LNAV	750(422)	750(422)	750(422)	750(422)
VM(C)OCA (OCH AAL)	Total Area	810(471)	920(581)	1080(741)	1180(841)

Rate of descent						
	G/S KT	160	140	120	100	80
	FT/MIN	850	740	640	530	420

Figure 1

Vertical profile of RNAV approach to Runway 33 at Birmingham Airport
(Extract from UK Aeronautical Information Publication)

When the aircraft was 3 nm from the runway, ATC cleared it to land, at which point the aircraft was at 2,000 ft, 660 ft above the correct profile. The pilots continued the approach, but at about 0.3 nm from the threshold and at 470 ft, they announced they were going around. ATC cleared the aircraft to climb to 4,000 ft and gave radar vectors for a further approach.

Shortly after the aircraft began climbing, the commander took over as handling pilot and informed ATC that the crew had experienced a navigation problem on their initial approach, requesting a localiser/DME approach[3] for the second approach. ATC accepted the request and provided radar vectors to position the aircraft to commence the approach. When the aircraft was on base leg, ATC cleared it to descend to 2,000 ft, but the crew mistakenly read back the clearance to descend only to 3,000 ft. This mistake was missed by ATC and was not corrected.

Footnote

[2] An approach providing both lateral and vertical guidance based on a global navigation satellite system.
[3] In which lateral but not vertical guidance is provided by ground-based radio aids.

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The aircraft descended to 3,000 ft whilst positioning to establish on the localiser, during which it was given further clearance to descend with the approach. When the aircraft began its final descent from 3,000 ft it was about 7 nm from the runway and crossed the final descent point, 5.1 nm from the runway and 200 ft above the correct profile altitude.

Initially the crew continued the approach, but then informed ATC they were too high and requested a left turn. In response, ATC instructed the crew to turn left onto a heading of 240° and to climb to 4,000 ft. The crew commenced the turn 2.5 nm from the runway, descending through 1,900 ft. At the same time, they selected a climb to 4,000 ft using the OPEN CLIMB mode[4], leaving the landing gear down and full flaps set. They did not select the TOGA thrust mode appropriate for a standard go-around manoeuvre. This caused the aircraft to pitch up to about 10° nose-up.

The aircraft began to decelerate, and the crew changed to the VERTICAL SPEED mode, reducing pitch to about 1° nose-up. However, the aircraft entered the ALPHA FLOOR protection mode, automatically setting TOGA thrust and causing the speed to increase. The commander then set the thrust levers to prevent the aircraft exceeding the full flap limiting speed. With pitch reducing, the aircraft continued to descend and ATC again instructed the crew to climb. The crew selected a climb of about 900 ft/min still using the VERTICAL SPEED mode and the aircraft, having descended to 1,300 ft (about 940 ft agl), then started to climb.

The aircraft climbed to 4,000 ft and ATC gave further vectors for another localiser/DME approach. The aircraft then landed without incident.

Further occurrence

On 20 December 2019 there was a further occurrence involving the same operator and aircraft type, but with a different crew, during a localiser/DME approach to the same runway. The cloud base at the time was reported to be broken at 1,300 ft AGL and scattered at 900 ft agl.

ATC records reveal that on this occasion the pilots had been cleared to descend to the platform altitude of 2,000ft and, when established on the localiser, to descend further with the approach. The pilots subsequently explained that they had been unsure of the correct decent point when ATC had cleared them for the approach, but from a higher altitude than the platform altitude for the approach depicted on their chart. They had then attempted to calculate what they believed to be the correct descent point, in the process losing situational awareness and descending too late. This resulted in the aircraft remaining above the correct approach profile and going around.

ATC provided vectors for an RNAV approach to Runway 33 and then asked the pilots to confirm whether they wanted to perform an RNAV approach or a localiser approach. The pilots reported that this made them believe they should have been making an RNAV

Footnote

[4] In which the aircraft climbs at an indicated airspeed selected by the pilots, with up to CLIMB power set.

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approach which confused them. They however asked for, and were given, a further localiser/DME approach.

During this second approach the aircraft was again high and the pilots attempted to regain the correct approach path, but at 6.5 nm from the runway, the aircraft had descended 700 ft below the correct approach profile to 1,300 ft. The aircraft then climbed 500 ft before descending again and was 360 ft above the correct approach profile at 3 nm but continued the approach and landed.

Operator's stable approach criteria

The operator's standard operating procedures required crews to go around if, on passing a nominal gate at 3 nm or 1,000 ft above the touchdown zone elevation, the aircraft was not stable on the approach. The definition of 'stable' was:

- aircraft in the final configuration,
- checklist completed,
- on the glide slope and localiser,
- speed V_{APP} +25 kt to -5 kt, and
- no excess deviations.

The operator commented that it considered it acceptable for pilots to delay the commencement of the go-around manoeuvre slightly in order to not become rushed, but only when it was considered safe to do so.

Operator's investigation

The operator conducted its own investigation into both incidents and found:

Fatigue

The fatigue level of each pilot involved in both events was assessed by means of a Samn-Perelli score. This uses a seven-point scale to define the level of pilot alertness. A score of 1 indicates the lowest level of fatigue and 7 the highest. The operator determined that the score for each of the four pilots varied between 2.22 and 2.43, with a score of 2 being defined as *'very lively, responsive, but not at peak'* and 3 as *'Okay, somewhat fresh'*.

Crew experience

The operator determined that the crews in both occurrences were appropriately experienced.

Event on 26 August 2019

The operator's investigation found that the crew had struggled to reduce the speed of the aircraft in the distance available once they commenced the final stages of the approach, but that, with correct energy management, there had been sufficient distance available to manage the speed whilst descending with the approach profile.

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The investigation also highlighted a difference between the descent profile for the RNAV approach published in the UK AIP[5] and that published by the operator's chart provider[6]. Whilst the former had a platform altitude for the approach of 2,000 ft with final descent starting at 5.1 nm from the threshold, the operator's approach charts showed a continuous descent starting from 2,800 ft at 7.6 nm (Figure 2). This led to confusion by the pilots when initially they were cleared to 2,000 ft on the first approach, causing them to delay their descent and to ask ATC again for the descent instructions. This had served to compound the issue of the late configuration of the aircraft for the approach whilst trying to slow down, resulting in the aircraft not establishing on the correct approach profile and leading to the missed approach.

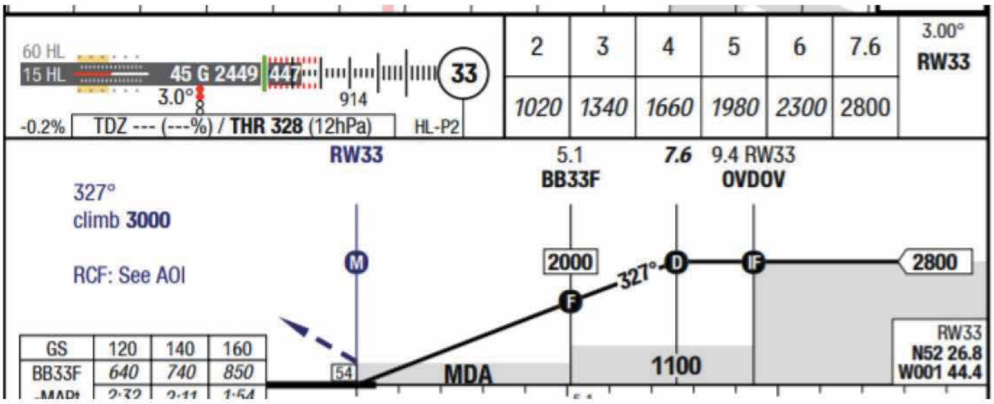

Figure 2

Extract from operator's chart for RNAV approach to Runway 33 at Birmingham

On the subsequent approach the crew were once again unsure about where to start the descent from 3,000 ft, having been cleared to do so. The aircraft remained above the correct approach profile and the pilots discontinued the approach again. On this occasion the commander was concerned that going around a second time would alarm the passengers, and he requested a turn instead. The operator's report did not determine what the commander intended to do next.

Regarding the event on 20 December 2019

The operator's investigation again found that whilst the aircraft in this case had initially been slightly high, there was sufficient distance remaining during the approach to successfully manage the descent profile, although the pilots involved still believed this was inadequate. However, the pilots did not establish the aircraft on a stable approach and commenced a missed approach 1 nm from the threshold.

During the second approach the aircraft again started slightly high. The pilots attempted to re-establish the aircraft on the correct profile from above by selecting a descent of 2,900 ft/min in the VERTICAL SPEED mode. This was maintained until 6.2 nm from the

Footnote

5 Aeronautical Information Publication.
6 There is no regulatory requirement for the two to be the same.

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threshold, at which point the crew switched to the TRK-FPA (track-flight path angle) mode[7]. The operator found that flight crews were not accustomed to descending using this mode, which had contributed to the crew's continued lack of situational awareness and their descent below the correct approach path. The pilots did not notice this immediately but, when they did, started a climb before once again descending, remaining above the correct profile but landing nonetheless.

The operator commented that the normal procedure for establishing the aircraft on the correct descent path when too high relied on the presence of vertical guidance such as a glideslope. In this case, where there was no glideslope, this would have hampered the successful implementation of the procedure.

The pilots reported that being asked several times by ATC if they wished to conduct an RNAV approach instead, undermined their confidence in continuing with the localiser/ DME approach.

Studies of go-around handling

The BEA[8] *'Study on Aeroplane State Awareness during Go-Around'* concludes that time pressure and high workload are features of events in which crew awareness of the aircraft state during a go-around is degraded. Startle, preoccupation with other tasks and difficulties in managing the automatic systems are often involved.

Airbus Flight Operations Briefing Note *'Decent Management – Being Prepared for Go-Around'* notes that failure to recognize the need for and to execute a go-around when appropriate is a major cause of approach-and-landing accidents, and that it is necessary to be *'go-around minded'* and prepared to do so correctly. It also offers recommendations for training and operational procedures to promote safer outcomes.

Analysis

It was possible to complete the approaches successfully at the point the aircraft were originally cleared to do so. In the August incident, the aircraft's speed was not managed early in the initial approach and the crew were not certain of the correct descent point, leading to an increasingly difficult situation for them to manage. In the December incident, not maintaining the correct profile early in the initial approach again led to difficulties maintaining the correct flight path.

The approaches were continued whilst not meeting the stable approach criteria, and go-arounds were carried out late in the approach, both of which reduced safety margins as highlighted in previous safety studies.

Having gone around, the subsequent approaches should also have been safely achievable. In the August incident the commander chose to change the type of approach, which placed additional pressure on the pilots in setting up the aircraft and re-briefing. Positioning the

7 This mode allows the crew to select a flight path angle (eg 3°, rather than by rate of descent (eg 700 ft/min).
8 Bureau d'Enquêtes et d'Analyses – the French aviation safety investigation authority.

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aircraft further from the airport before commencing the subsequent approach would have allowed the crew more time to prepare.

The commander in this case stated that he did not wish to alarm the passengers by conducting a further go-around but did not explain his plan thereafter. The aircraft was in VMC and, if his intention was to reposition visually for another approach, this might explain why the aircraft was not reconfigured for a go-around (nor TOGA selected) when ATC instructed the aircraft to climb. The result was both a further descent and increase in angle of attack which triggering of the aircraft's ALPHA FLOOR protection system. Even when the climb was initiated, the crew continued without changing the aircraft's configuration, indicating the startle and high workload likely to arise from this unintended situation.

The pilots of the aircraft involved in the December occurrence chose to conduct a localiser/ DME approach on both occasions. The aircraft did not maintain the correct profile on either approach. When ATC vectored the aircraft for an RNAV approach this caused the pilots to doubt that they were conducting the correct type of approach.

The December incident involved a high rate of descent being selected to regain the appropriate approach path. The operator's own investigation suggested the crew may have overlooked the fact that there was no glideslope for the aircraft to capture, resulting in it continuing its descent below the correct approach profile. Unlike the first incident, this occurred whilst the aircraft was in IMC, which removed any visual cues for the crew and resulted in a significant departure below the correct profile, taking the aircraft below the minimum safety altitude for that part of the approach.

The challenge faced by both crews in managing their descent has been the subject of discussions between the operator and air traffic service provider. ATC commented that had the incorrect readback of the cleared altitude been perceived and corrected, this might have prompted the crew on that occasion to continue their descent.

Different chart providers have different ways of depicting approach profiles. However, the AIP remains the source document and ATC will naturally rely on this, rather than individual operator's charts, when managing air traffic. Where differences exist, it is desirable for operators and ATC to ensure their effect is understood.

Conclusion

The aircraft did not maintain the correct vertical profile because the pilots were not sure when to commence the final descent. The depiction of the descent profile on charts provided by the operator may have contributed to this uncertainty.

In the first event it is likely that the increased workload of an unplanned missed approach contributed to the pilots not configuring the aircraft correctly for the go-around, resulting in the aircraft entering the ALPHA FLOOR protection mode. In the second event, having also commenced the final descent late, the pilots did not maintain the correct profile thereafter because the type of approach required them to manage the vertical flight path manually, and they were not familiar with the flight mode they were using.

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Safety actions

As part of the resolution of the issues raised in these two incidents, the operator's safety department has recommended:

- the inclusion of high energy approaches and go-arounds in future company simulator training;
- a review of approach intercept procedures to ensure they make adequate provision for approaches without a glideslope;
- the introduction of procedures to assist pilots in estimating distance to run during an approach; and
- procedures to deal more effectively with a loss of situational awareness.

The operator and air traffic services provider are working to gain a better understanding of each other's approach requirements.

Published: 20 August 2020.

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ACCIDENT

Aircraft Type and Registration:	ERJ 190-200 LR (Embraer 195), G-FBEJ
No & Type of Engines:	2 General Electric Co CF34-10E7 turbofan engines
Year of Manufacture:	2007 (Serial no: 19000155)
Date & Time (UTC):	28 February 2019 at 0745 hrs
Location:	Exeter Airport, Devon
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 5 Passengers - 100
Injuries:	Crew - 1 (Minor) Passengers - 1 (Serious)
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	13,211 hours (of which 3,069 were on type) Last 90 days - 77 hours Last 28 days - 15 hours
Information Source:	AAIB Field investigation

Synopsis

As the thrust levers were advanced for takeoff, on an early morning scheduled passenger flight, the flight crew detected an unusual odour and observed smoke entering the cockpit. They then moved the thrust levers to the idle position and applied the parking brake. The cabin crew subsequently reported that there were smoke and fumes in the cabin. Following an assessment of the situation, the commander initiated an emergency evacuation. During the evacuation, passengers who evacuated via the overwing exits reported being unsure of how to get down from the wing to the ground and several re-entered the cabin and exited via one of the escape slides.

The smoke and fumes were subsequently attributed to an incorrectly performed engine compressor wash procedure, which was carried out by maintenance personnel the night before the occurrence flight.

As a result of the findings of this investigation, the European Union Aviation Safety Agency (EASA) has undertaken two safety actions relating to the certification requirements for overwing emergency exits. The operator has also undertaken several safety actions relating to passenger safety briefings, processes for maintenance planning, engineer training, competency and welfare and monitoring of ground equipment.

Four Safety Recommendations are made relating to the certification requirements for overwing exit markings and the height requirement for overwing exits to be equipped with an assisted means of escape.

History of the flight

The aircraft was operating the first sector of the day and was scheduled to fly from Exeter Airport, UK to Alicante Airport, Spain. While the aircraft was being prepared for flight, both pilots reported being aware of a sweet-smelling odour after the APU and APU bleed had been turned on to heat the cabin. They described the smell as being like caramel but considered that such odours were not unusual after the APU is started and the air conditioning is switched on at the beginning of the day.

Following completion of passenger boarding, the aircraft pushed back and taxied before being cleared to enter Runway 26, back-track and line up for takeoff. It was daylight, the visibility was in excess of 10 km and the wind was from 210° at 5 kt.

The APU was shut down as the aircraft entered the runway and the air conditioning packs remained on with air supplied from the engines. A few seconds later, while back-tracking, both pilots became aware of fumes in the flight deck with a different odour, which the co-pilot described as being like paint or white spirit. The wind was behind the aircraft at this point, so they initially thought the fumes were due to exhaust gas ingestion. Upon lining up at the runway threshold the flight crew had a brief discussion about whether the fumes were decreasing and decided that they were.

Upon receiving takeoff clearance, the co-pilot advanced the thrust levers to 40% while holding the aircraft on the brakes and checked the engine indications, which were all normal. He then slowly advanced the thrust levers towards the takeoff setting, while still holding the aircraft on the brakes. As the engines reached approximately 55% power, he saw something out of the corner of his eye which he believed to have been a puff of smoke coming from an air conditioning vent. He immediately stated that he was not happy with the situation and retarded the thrust levers to idle. By then the smell of fumes had grown worse and smoke was visibly entering the flight deck.

The commander set the park brake and asked the co-pilot to turn the engine bleeds and air conditioning packs to OFF and the flight deck windows were opened to ventilate the flight deck. There were no EICAS messages or warnings.

The commander established contact with the senior cabin crew member (SCCM), who had simultaneously been trying to contact the flight deck. The SCCM reported that there was smoke and fumes in the cabin, but that the cabin crew could not identify the source.

The commander decided to evacuate the aircraft. The co-pilot immediately selected FLAP 5, notified ATC of the intention to evacuate and requested assistance. Both pilots then carried out the Emergency Evacuation 'vital actions'. After the commander had given the order to evacuate over the passenger address system, the flight crew followed the EMERGENCY EVACUATION checklist on the back of the QRH.

The Airport Rescue Fire Fighting Services (ARFFS) arrived at the aircraft and were briefed on the nature of the emergency by the co-pilot through the flightdeck window. The ARFFS then assisted passengers on the ground as they exited the aircraft.

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Aircraft evacuation

General

The aircraft was equipped with six emergency exits: four doors fitted with inflatable slides, two at either end of the cabin, and two 'Type III' emergency exits located approximately midway along the cabin, over the wings. On hearing the order to evacuate, the cabin crew opened their allocated doors and all four escape slides inflated automatically. Passengers opened the overwing exits.

The cabin crew reported that the passengers remained calm. The vast majority of passengers reported being able to hear and follow the announcements made by the flight and cabin crew, and the instructions contained therein. Some passengers attempted to take baggage with them, but most complied with the emergency evacuation instructions and left their belongings behind. Several passengers commented that the cabin crew were calm throughout and acted efficiently and professionally.

Overwing exits

Passengers evacuating via the overwing exits reported that once out on the wing, there was confusion as to how they should get off the wing down to the ground. Passengers still in the cabin reported that this led to a bottle-neck forming around the overwing exits. Two passengers who evacuated via the left overwing exit were able to jump down from the wing and assist other passengers to the ground. Despite this, several passengers commented that it was a very long drop to the ground and some landed awkwardly, sustaining minor injuries. Many of the passengers who exited via the overwing exits commented that the wing surface was "very slippy" and one fell over resulting in a minor injury. The overriding comment from those who had exited via the overwing exits was that it was not obvious to them that they were meant to climb off the wing via the trailing edge and some re-entered the cabin to find an alternative exit route. A 61 cm-wide walkway was demarcated at the wing root in black paint, with arrows pointing towards the trailing edge (Figure 1). None of the passengers mentioned noticing this, but several did mention a lack of instructions, support or guidance once they were out on the wing.

Escape slides

Several passengers commented that they found the rear slides very steep and were surprised by the speed at which they slid down them. The slides at the rear do not round out at the bottom unlike the front slides, which means that individuals slid very fast onto the ground. This, and attempts by passengers to slow themselves on the slides, were the principal causes of the reported injuries. Two passengers assisted other passengers at the bottom of the rear slides. A number of passengers suffered minor cuts and grazes and one elderly passenger who had exited via D2R sustained a broken ankle. Two cabin crew members who exited via the rear slides, one carrying the megaphone and the other carrying the first aid kit, reported that this made it difficult to slow themselves down and one sustained an ankle injury.

Cabin crew noticed that some passengers hesitated when instructed to jump and slide. They therefore advised the passengers to sit and slide rather than jump and slide.

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Figure 1

Overwing exit escape route markings on E195 (view towards wing trailing edge)

When the cabin crew believed that all passengers had left the aircraft, they checked the cabin and found several passengers stood on the wings unwilling to jump due to the height above the ground. These passengers were escorted back into the cabin and subsequently exited via the rear slides.

On completing the emergency evacuation checklist, the commander left the flight deck and confirmed with the SCSM that all the passengers and other cabin crew members had evacuated. They were joined by the co-pilot and all three left the aircraft via the forward left slide. Out of the 100 passengers on board G-FBEJ, 93 completed AAIB questionnaires regarding the evacuation. Figure 2 illustrates the exits used by the passengers, correlated by seat position.

Post-evacuation

Following the evacuation, the ARFFS entered the aircraft with protective breathing equipment and a thermal imaging camera but were unable to identify the source of the smoke and fumes.

The flight crew later returned to the aircraft to retrieve personal belongings and the commander noted that although the slat/flap selector was set to FLAP 5, the EICAS showed that the movement of the flaps and slats had not been completed. He concluded that insufficient time had elapsed between selecting FLAP 5 and shutting down the engines for the slats and flaps to deploy to the selected positions. The commander commented that this was not a situation he had encountered during simulator training before, when an evacuation most commonly occurs following a rejected takeoff scenario. In that scenario, FLAP 5 is selected as soon as the decision to reject is made and the flaps have time to travel to the selected position while the aircraft is slowed, turned into wind and stopped, before the emergency evacuation drill is actioned.

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The FLAP 5 selection is made to facilitate passengers, exiting via the overwing exits, to get off the wing by sliding down the extended flaps. Figure 3 shows the drop to the ground from the left wing during the evacuation. The operator subsequently measured the height of the wing trailing edge above the ground when the flaps were not deployed and determined that it would be in excess of 2 m, depending on the aircraft weight and fuel load.

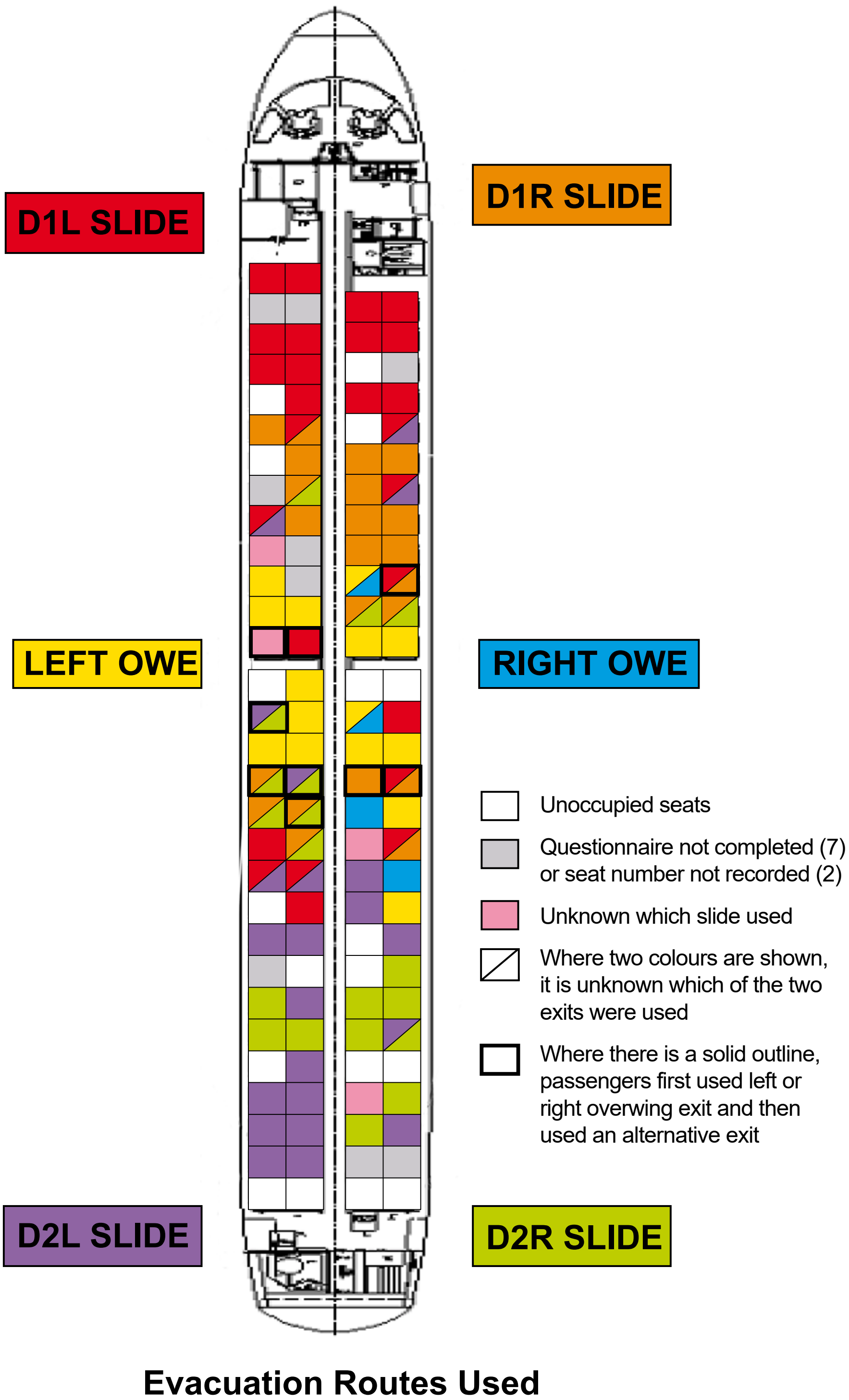

Figure 2

Evacuation routes used by passengers, correlated by seat position

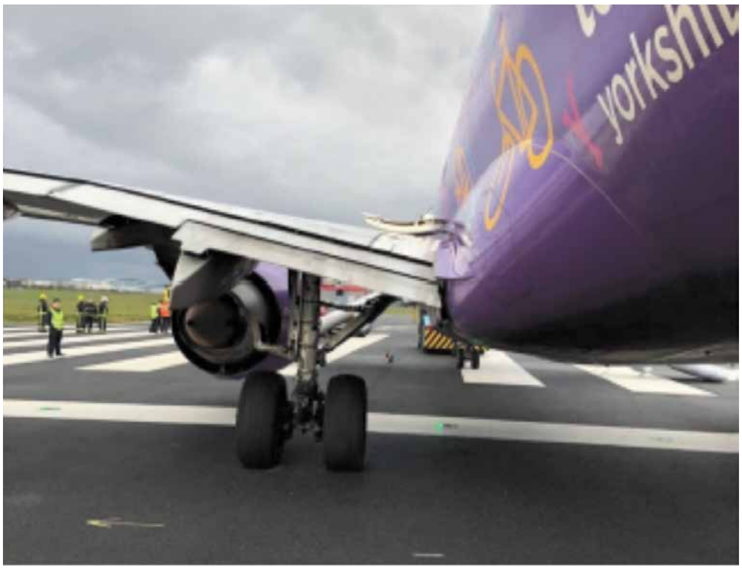

Figure 3

Drop to the ground from wing trailing edge with flaps in FLAP 1 setting

Pre-flight emergency briefing

Prior to departure, passengers seated next to the overwing exits were briefed by the cabin crew on how to operate the exit. While the cabin crew passenger brief for the overwing exits included mention of the height between the exit and the wing surface and instructions on the direction of evacuation, it did not provide instructions on how the passengers should get off the wing (eg jump, or sit and slide).

The passenger safety information cards, provided for all passengers, included diagrams showing the direction of evacuation from the wing but it was not clear whether passengers would understand that they need to slide off the wing from the information depicted on the card.

Following this accident, the operator revised its briefing to passengers seated next to the overwing exits of the Embraer 195 (E195). Changes included: simplifying terminology, instructing those passengers of the need to be first out on the wing, informing them of the need to help and direct other passengers, and highlighting that there is no escape slide attached to the overwing exits.

Recorded information

A review of the DFDR data confirmed that the flap selector lever was moved from the takeoff flap setting (FLAP 1) to FLAP 5. Although the flaps started moving in response to this selection, the engine 1 and 2 selectors were set to the OFF position approximately 2 seconds later when the flight crew shutdown the engines. This removed electrical power to the flaps and prevented them from travelling to the selected position. In the FLAP 1 position the flap angle had been 6.9°; the flaps reached 7.2° before stopping.

Evacuation procedures

The operator's Emergency Evacuation vital actions and callouts, assigned by flightcrew member are shown in Figure 4:

Table 3.5 – Emergency Evacuation Actions and Call-outs	
Captain	**First Officer**
"Carry out the emergency evacuation procedure"	
Puts the parking brake on	
	Confirms Flap 5
Sets both thrust levers to IDLE Sets both START/STOP selectors to STOP	
	Pulls fire handle 1 and rotates it to the left Pulls fire handle 2 and rotates it to the right (The fire handle actions are not required if the engine fire checklist has been completed) Presses the APU emergency stop button Presses the APU fire extinguishing button Presses the pressurisation dump button
Sets the passenger seat belt signs to OFF	
"This is the Captain, Evacuate, Evacuate." Notifies ATC	
Both pilots review the emergency evacuation checklist	
	Selects the batteries off

Figure 4

Emergency Evacuation actions from operator's operations manual

The E195 QRH EMERGENCY EVACUATION checklist is shown in Figure 5. The flight crew did not action the QRH SMOKE/FIRE/FUMES checklist.

EMERGENCY EVACUATION

EMBRAER 195

EMERGENCY EVACUATION

Emergency/Parking Brake	ON
SLAT/FLAP Lever	5
Thrust Levers	IDLE
Engine 1 and 2 START/STOP Selectors	STOP
Engine 1 and 2 FIRE EXTINGUISHER Handles	PULL AND ROTATE (1-L and 2-R)
APU EMER STOP Button	PUSH IN
Fire Extinguisher APU Button	PUSH
DUMP Button	PUSH IN
ATC	NOTIFY
Emergency Evacuation	ANNOUNCE
BATT 1 and BATT 2 Knobs	OFF

Figure 5

QRH Emergency evacuation checklist

Certification requirements

The E195 is a derivative model of the E190 and both have been certificated by the FAA and the EASA. Certification requirements for emergency egress and escape routes on large transport aircraft, specified in FAR 25.810[1] and CS 25.810[2] respectively, only require provision of evacuation slides for exits or escape routes, overwing or otherwise, that are 1.8 m (6 ft) or more above the ground. For lesser heights, passengers are expected to jump down to the ground.

Information from the aircraft manufacturer

The aircraft manufacturer was not aware of any previous events involving delays in emergency evacuation due to the flaps not reaching a surface deflection of 20°, which corresponds to FLAP 3, 4 AND 5. It stated that it did not consider the evacuation checklist required amendment as a result of this incident, because the normal flow of actions allows enough time for the flaps to reach a position beyond FLAP 1, which has a flap surface deflection of 7°. It indicated that, among the available takeoff and landing configurations, FLAP 1 results in the greatest flap trailing edge height above ground and complies with the maximum of 6 ft certification requirement of FAR 25.810(d), under which the E190/195 aircraft were certified.

Additional information

Previous evacuation incidents

The AAIB investigated a serious incident on 1 August 2008, in which the cabin of an E195 G-FBEH (EW/C2008/08/01) filled with smoke and fumes during flight. An emergency evacuation was subsequently carried out, during which passengers using the overwing exits experienced similar problems getting from the wing to the ground. As a result of that investigation the AAIB made Safety Recommendation 2010-007.

> **Safety Recommendation 2010-007**
>
> It is recommended that the European Aviation Safety Agency review the design, contrast and conspicuity of wing surface markings associated with emergency exits on Public Transport aircraft, with the aim of ensuring that the route to be taken from wing to ground is marked unambiguously.

Safety Recommendation 2010-007 was a re-issue of previous Safety Recommendation 2002-42, which had been made to the Civil Aviation Authority (CAA) and Joint Aviation Authority (JAA), following an AAIB investigation into an incident on 1 April 2002 (EW/C2002/4/1), in which the cabin of a Fokker F28 filled with smoke. In FACTOR F7/2003[3], the CAA accepted Safety Recommendation 2002-42 and indicated that action was due to be taken by the end of October 2003. But no response was received from the JAA and the responsibility for aircraft certification within Europe subsequently passed to the EASA.

Footnote

1 US Federal Aviation Regulations (FAR), 14 Code of Federal Regulations (CFR), Part 25.810.
2 EASA Certification Specification (CS) 25.810.
3 https://publicapps.caa.co.uk/docs/33/FACTOR200307.PDF [accessed 23 June 2020].

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In its initial response to Safety Recommendation 2010-007, the EASA agreed to review ways of improving the specifications relating to emergency exit escape routes. In its final response on this matter EASA indicated that a study it had commissioned in 2009 into cabin safety threats[4] (the 2009 EASA study) did not identify any issues relating to overwing exit markings, and on that basis could not justify changing the existing specifications of CS 25.810(c) on markings for overwing exits.

Royal Aeronautical Society paper on Emergency evacuation

In April 2018, the Royal Aeronautical Society (RAeS) published a paper titled '*Emergency evacuation of commercial passenger aeroplanes'* (RAeS paper). The intention of the paper was to provide aviation authorities, aircraft manufacturers, operators, and air accident investigation authorities, with a wide range of information on evacuation issues. With respect to aircraft which are not required to be equipped with evacuation slides, the paper states:

> *'For aeroplanes that are not required to be equipped with evacuation slides, passengers and crew will have to jump down from a height which some will find challenging or even injurious. Delays in an evacuation are possible if passengers decide to sit on the emergency exit sill and jump, or sit and slide at exits equipped with evacuation slides. This is more likely to be the case for elderly and infirm passengers, for children, as well as for adults with infants. The 1.8 metre maximum height limit for evacuation slides might be too high for such passengers to manage without serious injury.'*

With respect to overwing exits, the paper states:

> *'Having evacuated via a Type III or Type IV emergency exit, passengers usually have to reach the ground without any supervision from the aeroplane crew. Such an evacuation would normally be achieved by use of the trailing edge of the wing. Arrow markings are required to be on the surface of the wing to indicate the evacuation route but these are not always readily identifiable to evacuating passengers, and even less identifiable in conditions of darkness.*
>
> *For all aeroplanes, including those that have Type III or Type IV emergency exits installed over the wings, and do not need to meet the 1.8 metre (6 foot) CS 25 criteria for evacuation slides, the usual route for passengers to evacuate is by the trailing edge of the wing. In order to facilitate evacuation, the flight crew have to retract the wing spoilers and extend the trailing edge wing flaps. Failure to do so will hinder the evacuation and may cause injury to passengers and crew. Flight crew emergency evacuation checklists usually specify such actions; for example, the Boeing 737 evacuation checklist states: "Verify that the flaps are 40 before the engine start levers are moved to cutoff". Some operators have decided that this should be a checklist 'memory' item.'*

Footnote

[4] 'Study on CS-25 Cabin safety requirements', Issue 6, dated December 2009, prepared for the EASA.

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The RAeS paper referenced an NTSB Safety Study on *'Emergency evacuation of commercial aeroplanes'* published in June 2000 (the NTSB safety study). Safety Recommendation A-00-79 made in the NTSB safety study, recommended that the FAA:

> *'Review the 6-foot height requirement for exit assist means to determine if 6 feet continues to be the appropriate height below which an assist means is not needed. The review should include, at a minimum, an examination of injuries sustained during evacuations.'*

The RAeS paper also identified that the 2009 EASA study addressed similar issues and quoted the following extract from it:

> *'The evidence available from accidents and research studies suggests that the requirement to jump to the ground from a height of 1.8m (6 feet) during evacuation, without assist means, may potentially cause serious injury or may delay the progress of an evacuation due to hesitation or unwillingness to jump.'*

Overwing escape route markings

As a result of the issues identified in the accident, the AAIB asked the EASA to review the subject of markings on overwing emergency exits. In its initial response the EASA indicated that all applicable certification requirements for the E195 with respect to evacuation from overwing emergency exits had been met. It stated:

> *'In general, EASA finds that the requirements applicable to the marking of evacuation paths over the wings of CS-25 types are adequate and ensure that evacuees are effectively directed to the safest location from which they can descend from the wing onto the ground. However, based on the experience gathered in certification projects in recent years, EASA considers to introduce a new [acceptable means of compliance] AMC 25.810(c) in order to identify acceptable guidelines and options for the measurement of the contrast between the marking of the escape path located over the wing and the background colour of the wing surface.'*

With regards to the requirement for the provision of escape slides in CS 25.810(a) and (d), the EASA indicated that it intended to discuss and coordinate with other aviation authorities and with the aviation industry. It outlined its intention to discuss these issues at an FAA Aviation Rulemaking Committee (ARC) on Emergency Evacuation Standards[5], which had been tasked to review data from commercial air transport accidents and incidents involving passenger evacuations in the past ten years, to identify safety issues. The EASA indicated that the ARC would provide a forum for participants to discuss and provide recommendations to the FAA on the certification of emergency evacuation

Footnote

[5] https://www.faa.gov/regulations_policies/rulemaking/committees/documents/index.cfm/document/information/documentID/3983 [accessed 23 June 2020].

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systems and procedures which may in the future be translated in harmonized rulemaking tasks by the participating Aviation Authorities. It stated that:

> *'EASA will propose to the ARC to evaluate to which extent we can consider reasonable that evacuees may jump from a 1.8 m height to reach the ground instead of benefitting from the installation of a properly designed emergency egress assisting* [sic]*.'*

In April 2020, the EASA stated that its cabin safety expert had participated in the ARC meetings and provided the following update:

> *'The ARC has reached consensus to include in the report a recommendation to the FAA to consider, in coordination with other Aviation Authorities, if changes need to be introduced to the requirements currently included in 25.810 with the scope to allow easier identification of the evacuation path by the evacuees and their faster and safer transition from the wing to the ground. The regulatory changes may involve a combination of one or more of the following options:*
>
> 1. *Improvement of the marking that for each overwing exit describes the proper method of opening the exit (ref. 25.813(c)), to include, if the exit is over a wing, and the aircraft design does not include an off-wing assist means per 25.810(d), indication of the evacuation route on the wing.*
> 2. *improvement of marking visibility/design to facilitate better recognition by passengers evacuating through overwing exits of proper direction to exit from wing.*
> 3. *revision of the requirements under 25.810 to define conditions that would require an escape slide. Other factors may drive different recommendations for overwing exits (25.810(d)) verses non-overwing exits governed by 25.810(a).*
>
> *The report will include another recommendation that will address the need to improve passenger briefing materials in regards to egressing an overwing exit without assist means.'*

Aircraft maintenance

Engine compressor wash - general

During overnight maintenance on the night before the accident, an engine compressor wash was carried out on G-FBEJ's No 1 engine.

Aircraft gas turbine engines can accumulate substances such as dust, sand and salt on the compressor blades and stator vanes. This can lead to a reduction in compressor performance and increased fuel consumption. The engine manufacturer recommends engine cleaning to reduce contaminant build-up and counteract these effects. Compressor washes are performed by maintenance personnel, using a wash rig, which uses either water or a water and detergent mix.

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Compressor wash rig used on G-FBEJ

The engine wash rig used on G-FBEJ was fitted with two pressurised fluid tanks, one which contained water and the other a water/detergent mix. During operation, the fluid can be directed into a water-wash manifold installed on the engine, to dispense water/detergent into the compressor.

Compressor wash procedure

The Engine Service Manual (ESM) task used by the maintenance personnel was 72-00-00-100-801 *'Engine performance recovery,'* revision date 31 March 2016. The following general information is included at the beginning of the ESM task:

> *'For some environments, washing with a cleaning solution … may be more effective than washing with water only….If a cleaning solution is used, it is important to follow instructions for rinsing and drying-out the bleed systems.'*

The ESM task lists several approved detergents[6] and indicates that the cleaning solution should be mixed according to a ratio of one part detergent to four parts water and rinses should be conducted with fresh water.

The task requires a minimum of two people, one to operate the engine and system controls in the cockpit and one to operate the compressor wash rig.

One subtask describes the procedure to wash the internal engine airflow components with water only and an alternative subtask[7] describes the procedure to do the wash with a cleaning solution. It recommends that to get the best cleaning results, two washes should be done as well as a soak period between application of the cleaner, followed by two rinses to make sure that the cleaning solution is removed. A further subtask[8] describes the rinse procedure and states that any remaining cleaning solution should be drained from the compressor wash rig and the fluid tanks filled with rinse solution (water).

Post compressor wash engine drying procedure

Following completion of the engine wash and disconnection of the compressor wash rig, a further subtask[9] describes the procedure to dry the internal engine airflow components. A caution in the procedure states:

> *'FAILURE TO ADEQUATELY DRY THE INTERNAL ENGINE AIRFLOW COMPONENTS AFTER AN ENGINE WASH CAN RESULT IN ODOR-IN-CABIN EVENTS WHICH HAVE CONTRIBUTED TO SITUATIONS SUCH AS AIR TURNBACKS AND ABORTED TAKEOFFS. PROPER ENGINE DRY-OUT IS IMPORTANT TO PREVENT THOSE SITUATIONS.'*

Footnote

[6] The detergent used by the operator was Turco 5884.
[7] ESM Subtask 72-00-00-110-009.
[8] ESM Subtask 72-00-00-170-004.
[9] ESM Subtask 72-00-00-410-004.

The procedure instructs personnel to run the engine at idle for five minutes before operating the anti-ice and engine bleed systems, while the engine continues to be run at idle. The aircraft's pneumatic and environmental control (ECS) systems use bleed air extracted from the high pressure compressor (HPC). The purpose of this procedure is to purge fluid which may be trapped in the engine bleed ducts or ECS. A note in the procedure states:

> *'… If the engine is installed on an aircraft, the idle speed cannot fully dry-out the aircraft ECS system. If the ECS system can be verified to be dry or a water-wash without cleaner was done, engine run at 65 percent N1[10] can be considered optional. If not, drying-out the ECS system via operation up to 65 percent N1 is recommended.'*

At low engine power settings engine bleed air is extracted from the ninth stage of the HPC while at high engine power settings, bleed air is extracted from the fifth stage of the HPC. The purpose of reaching 65 % N1 during the engine dry-out ground run is so that the engine speed is high enough that the ECS bleed source has switched to HPC fifth stage bleed, so that the fifth stage bleed ducts are dried out. A further caution states:

> *'OPERATORS MAY OBSERVE SOME RESIDUAL VAPOR IN THE CABIN AS A RESULT OF THE WASH DURING ENGINE DRY-OUT. IF VAPORS ARE OBSERVED IN THE CABIN DURING ENGINE DRY-OUT, IT IS RECOMMENDED THAT THE OPERATOR EXTENDS THE ENGINE DRY-OUT UNTIL VAPOR EVAPORATES. THESE VAPORS ARE THE RESULT OF RESIDUAL DETERGENT IN THE BLEED SYSTEM, WHICH IS NON-TOXIC BUT CONSIDERED A NUSIANCE TO OPERATORS.'*

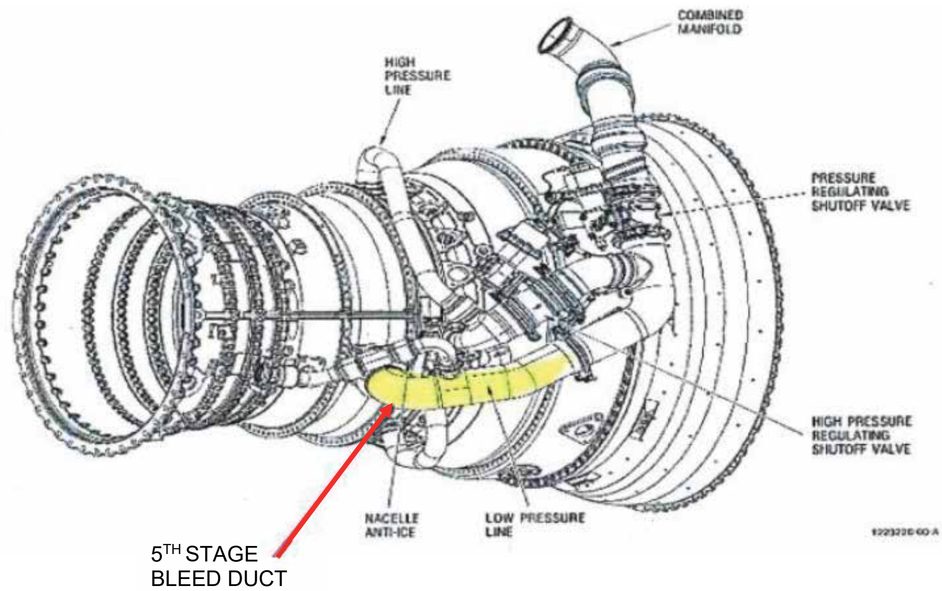

Figure 6

Engine schematic showing location of high pressure compressor fifth stage bleed duct

Footnote

10 Engine fan speed.

The procedure requires that an observer is positioned in the aircraft cabin to detect any odour or detergent after completion of the ECS and anti-ice dry-out procedure. If odours or fumes are detected, the engine dry-out should be continued until none are detected.

Operator's internal safety investigation

General

The operator conducted an internal safety investigation into the circumstances around the compressor wash on G-FBEJ. This included interviewing the maintenance personnel involved and reviewing relevant procedures, policies and training records. The findings of the internal safety investigation are described in the subsequent paragraphs.

Information from interviews with maintenance personnel

Several engineers were involved in this task. Engineer 1 carried out the engine ground runs from the cockpit and certified the task. Two safety personnel were positioned outside the aircraft, one to operate the compressor wash rig and communicate with Engineer 1 via a headset and the other to check the engine. When Engineer 1 arrived at the aircraft, the compressor wash rig fluid tanks were full and it was already attached to the No 1 engine, having been attached by the day shift. One compressor wash cycle was carried out using a water/detergent mix and four rinse cycles using water. Engineer 1 then performed the engine drying procedure using idle power only.

He could not recall any warnings or cautions for the ECS when carrying out the dry-out run. Although he could smell the cleaning solution when the dry-out run began, he could no longer smell it after the run had finished but the aircraft doors had been opened to aid venting.

Engineer 1 commented that when compressor washes had previously been done by the night shift, they were part of a larger maintenance input rather than a stand-alone task; this allowed for the high-power engine dry-out runs to be carried out by the oncoming day shift. He considered that the night shifts were generally undermanned and there was a lack of support functions that would be present during the normal working day.

Engineer 2 was the hangar bay supervisor and allocated the compressor wash task to Engineer 1. He stated that the night shift was normally pushed for time, with aircraft often not arriving in the hangar until 2200 hrs and needing to be back on-stand by 0300 hrs. He stated that he does not have the opportunity to review resources and required materials before work is carried out and it is often left to him to address any issues with the work packs, missing materials or tasks that cannot be performed.

Engineer 4 accepted the aircraft into the hangar for the compressor wash. Although he attempted to check if the engineers on the oncoming shifts had the approval to carry out the task, the databases he consulted were out of date and he did not have the knowledge to verify the approvals by other means. The work had been planned in for the day shift but problems encountered with sourcing a serviceable compressor wash rig meant the task had to be carried out by the night shift.

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Preparations for the compressor wash had been undertaken by the hangar day shift. This included replenishing the compressor wash rig with air, detergent and water and attaching it to the No 1 engine. Engineer 3 had undertaken these actions. He reported that prior to replenishment, the cylinder with the detergent/water mix was already approximately half full, with what he assumed to be the correct concentration of detergent/water. He then continued to add to the liquid already in the cylinder using a ratio of four parts water to one part detergent.

Engine ground runs

There were only two engineers (including Engineer 1) on the night shift who were qualified to conduct engine ground runs on the E195. Both had limited experience in doing so and were only approved to conduct low power engine ground runs. Engineer 1 was an experienced engineer who held company approvals for the E195 and another aircraft type in the operator's fleet. He predominantly worked on the other aircraft type, on which he was experienced in conducting engine compressor washes, but these required only idle power engine runs. He did not have any recent experience carrying out engine ground runs on the E195 and had not performed a compressor wash on an E195 before.

There were only two engineers within the operator's maintenance organisation company who were qualified to train others on conducting engine ground runs on the E195. A lack of trainers, training opportunities and access to simulators had resulted in a reduction in the number of competent authorised engineers available.

The engineers involved, and others consulted, considered that the ESM task used to carry out the compressor wash was poorly laid out and difficult to interpret. The maintenance organisation typically used process sheets for complicated maintenance tasks but did not have a specific process sheet for performing compressor washes.

Ground equipment

Prior to being replenished by Engineer 3, it was not determined when or by whom the compressor wash rig had last been used. When the rig was examined after the accident the water cylinder was empty and the water/detergent cylinder was half full.

It was found that the organisation had limited processes in in place to trace ground servicing equipment such as the compressor wash rigs. No records were kept of when, or on which aircraft, the rigs had been used, when they were last replenished and with what type or concentration of fluid. The limited and simple instructions shown on placards on the compressor wash rigs were considered insufficient and no detailed instructions or training on how to use the rigs was available. The operator identified that this was a specific type of maintenance task that would benefit from on-the-job training. An audit of compressor wash rigs following the accident found that many were in poor condition and that the fluid tanks did not have sight glasses or any method of establishing the correct fluid concentration. The compressor wash rigs were subsequently quarantined until they had been drained, flushed and replenished with a known concentration of fluids.

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Maintenance planning

The requirement for the compressor wash had been identified by the operator's maintenance control department on the preceding afternoon, to rectify a decreasing trend in engine turbine temperature, which had been highlighted by routine engine performance monitoring. Maintenance planning for the task did not identify the time, resources or competence required for the compressor wash task, nor confirm that the required resources were available. There was no process in place for the acceptance of aircraft maintenance at short notice.

Engineer 4 accepted the aircraft into the hangar on the understanding that the compressor wash would be completed by the day shift, which had appropriately authorised engineers available. Due to the poor condition of the compressor wash rig engineers on the day shift spent considerable time getting it ready and as a result, the task was handed over to the night shift for completion.

Engineer 2 allocated the compressor wash task to Engineer 1, without fully understanding the requirements of the task. The night shift did not have engineers available with the correct authorisations to complete the task. Information regarding approvals and authorisations held by engineers was not readily accessible by managers, shift supervisors and maintenance planners which made it difficult to plan resources and assess the capabilities of the current or oncoming shift. This information was normally accessible by staff working core office hours.

Engineer 1 did not hold the necessary approvals to conduct high powered engine ground runs on E195 aircraft, and thus was not qualified to carry out all the required maintenance actions described in the ESM compressor wash and engine dry-out procedure. Engineer 1 certified the task despite several elements of the task not being completed.

Engineer 2 signed the certificate of release to service following the compressor wash despite not holding the correct approvals to release E195 aircraft to service.

Nature and scope of maintenance work

In the months preceding this incident, the nature and volume of the maintenance work carried out by the night shift at the operator's base had changed considerably. Termination of a contract with an external maintenance provider had resulted in an increase in maintenance work being undertaken at the operator's own maintenance facility. Previously the bulk of the work undertaken was in-depth planned maintenance tasks, but in the period preceding the accident most of the maintenance undertaken was reactive with short turnaround times and little prior notice of the type of work required. Engineers considered that the maintenance was often not correctly resourced with respect to spares, tooling or manpower and the time allocated for tasks was often incorrect and did not take account of the time needed to tow the aircraft from its location to the hangar and back.

While the operator had implemented a change management process to support the transition of maintenance from the external maintenance provider to its own maintenance facility, the internal investigation identified that procedures and processes had not been adapted to cater for the change in maintenance type.

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In common with other shifts, on the night shift a small number of engineers, often in supervisory roles, held the majority of approvals and authorisations for conducting maintenance such as engine ground runs, certifying maintenance and certifying the release of aircraft to service. This placed substantial responsibility on a small number of individuals.

Maintenance culture

Although the aircraft required a compressor wash, this was not an urgent requirement and could have been allocated to a suitably resourced shift. The operator's investigation identified that there was a 'can do' culture throughout its engineering departments and a 'willingness to get the job done'. This may have contributed to several opportunities being missed, to prevent the improperly authorised maintenance, at the maintenance planning, task acceptance and task allocation stages and during the task itself.

Company policies implemented as part of its change management process had endeavoured to empower engineers to call 'stop' if they felt they could not complete maintenance safely but in the absence of supporting procedures, these were found to place an over-reliance on the individuals.

Welfare

During the investigation Engineer 1 and Engineer 2 disclosed that they were each experiencing personal issues which had been occupying their thoughts, but each considered that they were fit to continue working and to certify maintenance. Although their managers had been aware of their circumstances, no specific support had been put in place, nor any restrictions on what they could supervise or certify. Supervisors and managers had received only minimal training in how an individual's welfare can affect their performance.

Fatigue

The engineers on the night shift worked a permanent shift pattern of four 12-hour night shifts, followed by four nights off. The compressor wash was carried out on the third night of the shift and the work was performed between 2300 hrs and 0300 hrs. The operator did not determine whether fatigue was a factor in how the compressor wash was performed, but its internal investigation identified that although the operator had a fatigue risk management system in place for flight crew, no such system was in place for engineers.

Post-accident maintenance

Before the aircraft was returned to service the operator's maintenance staff, in consultation with the engine manufacturer, performed several additional compressor rinse cycles to flush any residual detergent from the No 1 engine and fifth stage bleed ducts. Despite this, detergent bubbles continued to come out of the engine during idle power engine runs, which led the operator to consider that the dilution of the cleaning solution used may have been incorrect. A sample of the detergent/water mix taken from the compressor wash rig was subjected to FTIR[11] analysis and compared to a calibration curve for the detergent.

Footnote

[11] Fourier transform infrared spectroscopy.

This determined that the concentration of the sample was 31.3% detergent. It could not be determined if and to what extent the compressor wash rig had been topped up during the compressor wash and rinse cycles, which could have altered the dilution from that used on G-FBEJ's engine. Given the difficulty purging the residual detergent from the engine, and the result of the sample analysis, the operator considered that the compressor wash rig may have contained an overly strong concentration of cleaning solution, prior to being replenished by Engineer 3. As the precise concentration of cleaning solution used could not be established, nor the effect of its long exposure to engine parts, the engine was withdrawn from service on the engine manufacturer's recommendation.

Analysis

General

On the aircraft's first flight of the day fumes became apparent in the cockpit during the latter stages of the taxi out and were subsequently accompanied by smoke as the thrust levers were advanced for takeoff. The takeoff was discontinued after which the intensity of the smoke and fumes increased. Following the flight crew's assessment of the situation, and confirmation from the SCCM of fumes and smoke in the cabin, the commander made the decision to evacuate.

An engine compressor wash had been performed on the aircraft's No 1 engine during overnight maintenance on the night before the accident. A high-power engine ground run was not performed following the compressor wash, resulting in residual cleaning solution remaining in the compressor bleed air ducts. This can lead to fumes or unusual odours entering the cockpit and cabin.

Source of the smoke and fumes

During the engine dry-out procedure following the compressor wash, the engines were run only at idle power. At idle power the engine power setting would have been insufficient for the engine bleed source to switch to the HPC fifth stage bleed. To dry out the fifth stage bleed ducts, the procedure recommended running the engine up to 65% N1. By not performing a high-power engine ground run, residual cleaning solution remained within the fifth stage bleed ducts.

As the thrust levers were advanced for takeoff the ECS bleed source would have switched to HPC fifth stage engine bleed, allowing smoke and fumes from the residual detergent to enter the cockpit and cabin.

Compressor wash and dry-out procedure

The ESM task for *'Engine performance recovery'* is comprised of many subtasks covering several wash, rinse and drying scenarios. It contains multiple notes and cautions, not all of which stand out from the main text and some of which contain critical information. In particular, the information relating to the need to perform a high-power engine run during the dry-out procedure is included in a note rather than in a procedural step. The ESM indicated that this was a recommended rather than required action. The AAIB questioned the engine manufacturer's rationale for this step being recommended rather than required.

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They advised that for consistency with the other strong cautions throughout the ESM task, conducting a high-power engine run should be a required step following a compressor wash with detergent. In June 2020, it updated ESM subtask 72-00-00-410-004 task to reflect this.

Engineer 1 was more accustomed to working on another aircraft type. He had never performed a compressor wash on an E195 before, had limited experience in conducting engine runs on the E195 and was not qualified to conduct high-power engine runs. This, coupled with the fact that the procedure only recommended rather than required, a high-power engine run, likely influenced his decision to proceed with and certify the task without alerting his supervisors of the need for a high-power ground run.

The operator's internal investigation identified that complex maintenance tasks, such as that for a compressor wash would benefit from a company process sheet to supplement manufacturer's procedures.

Organisational factors

Maintenance planning, both at the operator and hangar level, did not adequately identify the resources required to undertake the compressor wash, nor attempt to match the requirements of the task to the capabilities of the oncoming hangar shifts. Systems in place did not assist maintenance planners and managers to easily establish the competence and approval status of individual engineers.

As a result, this maintenance task was allocated to a shift which did not have the correct competence and approvals to carry out and certify the task, or to release the aircraft to service. Had Engineer 2 fully understood the requirements of the task, the resources required to complete it and the approval status of the engineers on the night shift, it is likely that the task would have been rejected by the night shift instead of being allocated to Engineer 1. Similarly, had Engineer 4 understood these aspects, it is likely the task would have been deferred when it could not be completed by the day shift. The operator's internal investigation found that willingness to get the job done, may have led to opportunities to stop the task being missed and existing policies may have placed too much reliance on individual engineers to identify tasks that could not be safely accomplished.

With regard to conducting engine ground runs, the operator's internal investigation identified a lack of suitably trained engineers, trainers and training opportunities. It also identified a lack of specific training or assisting documentation for conducting engine compressor washes and using compressor wash rigs.

Many of the compressor wash rigs were found to be in poor condition. There were no records of when they were last replenished, the type or concentration of detergent used or on which aircraft they had been used. The lack of records meant that it was not possible to determine the concentration of cleaning solution that had been in the rig, prior to its replenishment by Engineer 3.

Although night shift engineers permanently worked nights, no fatigue risk assessment had been carried out to understand the potential impact on individual performance. Both Engineer 1 and 2 disclosed that they had been experiencing personal issues, which could have been affecting their mental state. Although aware, it was not determined whether their managers had taken any steps to determine whether they were capable of being on duty and certifying aircraft, and the operator's internal investigation identified that only minimal training was available for supervisors and managers in this regard.

The operator had taken several safety actions to address these and other issues. However, it ceased operations before all intended safety actions could be fully implemented.

Evacuation

The commander's decision to evacuate was based on his concern that there may have been a fire on the aircraft and was likely influenced by the increase in intensity of the fumes, the appearance of smoke in the cockpit and confirmation of smoke and fumes of unknown origin in the cabin.

The flight crew actioned the emergency evacuation vital actions (memory items) followed by the QRH EMERGENCY EVACUATION checklist. Both the memory actions and the QRH checklist require the flight crew to set the emergency/parking brake to ON, select FLAP 5 and then move the thrust levers to IDLE. In this case, as the aircraft was stationary the thrust levers had already been retarded to flight idle and the parking brake set. The vital actions were therefore performed somewhat out of sequence and proceeded more rapidly than might be expected if an emergency evacuation followed a rejected takeoff or emergency landing scenario. Therefore, despite selection of FLAP 5, the flaps had insufficient time to travel to the selected position before the engines were shutdown. This resulted in an increased drop to the ground for passengers evacuating via the overwing exits, with many reluctant to jump or slide off the wing, leading to an increase in the time taken to complete the evacuation.

The emergency evacuation vital actions use the term 'confirm FLAP 5,' which suggests that this action requires the flight crew to confirm that the flaps have already travelled to FLAP 5. The commander commented that in training, an emergency evacuation is most often practiced following a rejected takeoff scenario and FLAP 5 is selected as soon as the decision to reject is made and before the aircraft has been brought to a stop. The flaps would therefore have travelled to the selected position by the time the emergency evacuation vital actions were actioned.

The aircraft manufacturer did not consider that any amendment of the QRH EMERGENCY EVACUATION checklist was required as a result of this occurrence. It considered that the normal flow of actions allows enough time for the flaps to reach a position beyond FLAP 1 and even if this did not occur, the drop to the ground from the FLAP 1 setting was still within with the maximum of six feet certification requirement of CS/FAR 25.810(d).

Some passengers attempted to take their baggage with them during the evacuation. This can slow down an evacuation, as cabin crew attempt to remove baggage from the passengers. Removed baggage can also create an obstruction in the cabin for others. In its report into the accident involving A320 registration OE-LOA on 1 March 2019 (AAIB report AAIB-25599, published in September 2020) the AAIB discussed the increasing trend in passengers attempting to carry cabin baggage with them during emergency evacuations. The AAIB made Safety Recommendations SR 2020-018 and SR 2020-019 to the EASA on this subject.

Overwing escape route markings

Despite the presence of a marked exit route on the wing with a non-slip surface, many passengers who exited via the overwing exits reported being uncertain where to go once out of the aircraft. None of them mentioned noticing the marked walkway on the wing. The evacuation took place during daylight hours with good visibility. As noted in the RAeS paper, overwing exit route markings are not always readily identifiable and may be even less so in darkness. Poor weather conditions or the presence of smoke could also hinder identification of an exit route.

The large drop to the ground and the absence of obvious immediate danger meant that passengers did not feel compelled to jump or slide off the wing. This led to passengers gathering on the wing surface, which was reported as slippery, increasing the risk of slips and falls. A bottle-neck also formed in the cabin around the overwing exits creating a delay for those still trying to exit.

It is apparent from this accident and the RAeS paper that the issue of ambiguous overwing escape route markings that resulted in previous AAIB Safety Recommendations 2002-42 and 2010-007 still exists. It is therefore appropriate that this matter is re-examined. The AAIB asked the EASA to review the issues identified relating to overwing escape route markings. The EASA indicated that while it considered all applicable certification requirements for the E195 relating to evacuation from overwing emergency exits had been met, it intended to consider introducing a new AMC to:

> *'identify acceptable guidelines and options for the measurement of the contrast between the marking of the escape path located over the wing and the background colour of the wing surface.'*

The EASA also outlined its participation in the FAA Emergency Evacuation Standards ARC, which was expected to produce its final report on 15 May 2020. The EASA stated that the ARC will recommend that the FAA, in conjunction with other Aviation Authorities, considers changes to the certification requirements for overwing exits, to allow easier identification of the evacuation path by passengers and a faster safer transition from the wing to the ground.

As this regulatory process is ongoing at the time of publication of this report, and it is not known to what extent the FAA will accept the recommendations of the ARC, the following Safety Recommendations are made:

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Safety Recommendation 2020-020

It is recommended that the European Union Aviation Safety Agency amends the certification requirements relating to the design, contrast and conspicuity of overwing exit escape route markings on commercial air transport aircraft, to ensure that the route to be taken from wing to ground is immediately apparent to evacuating passengers, in a range of emergency scenarios.

Safety Recommendation 2020-021

It is recommended that the Federal Aviation Administration amends the certification requirements relating to the design, contrast and conspicuity of overwing exit escape route markings on commercial air transport aircraft, to ensure that the route to be taken from wing to ground is immediately apparent to evacuating passengers, in a range of emergency scenarios.

Provision of evacuation slides

Emergency exits that do not meet the 1.8 m maximum height criteria of FAR/CS 25.810 are not required to be equipped with an evacuation slide. This applies equally to overwing and non-overwing exits. The RAeS paper identified that jumping from heights of up to 1.8 m can be challenging for many passengers and has the potential to cause injury. Similar findings were documented in the 2009 EASA study and prior to that, the NTSB safety study, which made a Safety Recommendation to the FAA on this subject.

Overwing exits on many aircraft types rely on the trailing edge wing flaps being lowered to reduce the drop to the ground below 1.8 m. As this accident, and the findings of the RAeS paper demonstrate, this condition is not always achieved. Failure to lower the flaps, for whatever reason, can hinder an evacuation and may cause injury to passengers and crew.

In addition to the subject of overwing exit markings, the ARC evaluated the extent to which it is reasonable to expect passengers to jump to the ground from a height of 1.8 m, instead of benefitting from the installation of a properly designed emergency egress system. As a result, the ARC proposed that the FAA consider reviewing the requirements of FAR 25.810 (a) and (d) to define conditions that would require the provision of an escape slide at such exits.

As this regulatory process is ongoing at the time of publication of this report, and it is not known to what extent the FAA will accept the recommendations of the ARC, the following Safety Recommendations are made:

Safety Recommendation 2020-022

It is recommended that the European Union Aviation Safety Agency, re-evaluate and reduce the 1.8 m height criteria in CS 25.810(a) and (d), for the provision of an assisted means of escape at emergency exits, to minimise passenger injuries and reduce egress time during emergency evacuations.

Safety Recommendation 2020-023

It is recommended that the Federal Aviation Administration, re-evaluate and reduce the 1.8 m height criteria in FAR 25.810(a) and (d), for the provision of an assisted means of escape at emergency exits, to minimise passenger injuries and reduce egress time during emergency evacuations.

The operator also updated the content of its briefing to passengers seated in the overwing exits of the E195 as a result of this occurrence. Changes included: simplifying terminology, instructing those passengers of the need to be first out on the wing, informing them of the need to help and direct other passengers, and highlighting that there is no escape slide attached to the overwing exits.

Conclusion

A lack of maintenance planning, training and control of resources led to an undesirable situation where a maintenance task was allocated to an engineer who was neither qualified nor competent to complete the task. A key step in the engine drying procedure was only described as 'recommended' and the engineer did not complete all the elements of the task. This resulted in residual cleaning solution remaining within the ECS system, causing smoke and fumes within the cabin and cockpit and leading to an emergency evacuation. The engine drying procedure has since been amended to require this step to be carried out.

Due to the order in which the emergency evacuation vital actions were performed, the flaps had insufficient time to travel to the selected position. This resulted in an increased drop to the ground for passengers evacuating via the overwing exits, with many reluctant to jump or slide off the wing. Additionally, despite the presence of a marked exit route on the wing with a non-slip surface, many passengers who exited via the overwing exits were uncertain where to go once out of the aircraft. Both of these factors increased the time taken for emergency evacuation to be completed.

Safety Actions/Recommendations

As a result of this accident the operator undertook the following safety actions:

- Updated the content of its briefing to passengers seated in the overwing exits of the E195.
- Enhanced the control and tracking of maintenance ground support equipment to enable calibration expiry dates to be managed more effectively.

- Introduced a maintenance planning procedure so that maintenance requirements are identified earlier in the working day to allow appropriate resources to be identified and allocated.
- Undertook a review of tasks performed within the hangar to identify specific training requirements with a view to developing training programmes.
- Launched an engineer's competency passport scheme to enable maintenance planning departments to allocate specific maintenance tasks to maintenance stations where the correct resources are available.
- Introduced additional simulator training for engineers to undertake engine ground runs and committed to review the its recency period for conducting engine ground runs.
- Introduced a programme to verify that engineers have the correct procedures, records, equipment and tooling, personnel requirements, approvals, replacement parts, environment and information before commencing a maintenance task.
- Committed to undertake fatigue risk assessments for night shift maintenance personnel and initiated an engineer welfare programme.
- Updated its change management process to ensure appropriate management of the risks associated with the changing nature of maintenance being conducted in its base hangar.

In June 2020, the engine manufacturer updated ESM subtask 72-00-00-410-004 to require, rather than recommend, that a high-power engine dry-out run is conducted after a compressor wash using detergent.

Additionally, the following Safety Recommendations have been made to the EASA and the FAA:

Safety Recommendation 2020-020

It is recommended that the European Union Aviation Safety Agency amends the certification requirements relating to the design, contrast and conspicuity of overwing exit escape route markings on commercial air transport aircraft, to ensure that the route to be taken from wing to ground is immediately apparent to evacuating passengers, in a range of emergency scenarios.

Safety Recommendation 2020-021

It is recommended that the Federal Aviation Administration amends the certification requirements relating to the design, contrast and conspicuity of overwing exit escape route markings on commercial air transport aircraft, to ensure that the route to be taken from wing to ground is immediately apparent to evacuating passengers, in a range of emergency scenarios.

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Safety Recommendation 2020-022

It is recommended that the European Union Aviation Safety Agency, re-evaluate and reduce the 1.8 m height criteria in CS 25.810(a) and (d), for the provision of an assisted means of escape at emergency exits, to minimise passenger injuries and reduce egress time during emergency evacuations.

Safety Recommendation 2020-023

It is recommended that the Federal Aviation Administration, re-evaluate and reduce the 1.8 m height criteria in FAR 25.810(a) and (d), for the provision of an assisted means of escape at emergency exits, to minimise passenger injuries and reduce egress time during emergency evacuations.

Published: 17 September 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.

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INCIDENT

Aircraft Type and Registration:	Airbus A321-231, G-WUKG
No & Type of Engines:	2 International Aero Engine V2533-A5 turbofan engines
Year of Manufacture:	2018 (Serial no: 8236)
Date & Time (UTC):	16 January 2020 at 1925 hrs
Location:	London Luton Airport, Bedfordshire
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 7 Passengers - 157
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	32 years
Commander's Flying Experience:	8,305 hours (of which 5,175 were on type) Last 90 days - 97 hours Last 28 days - 42 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was departing from Runway 26 at London Luton Airport, but when the PF made a normal aft movement of the side stick control at rotation airspeed, the aircraft did not pitch up. The PF increased the side stick input close to the maximum deflection. When the aircraft still did not pitch up, the PM selected TOGA thrust. The aircraft responded and a climb was commenced with the flight continuing to the planned destination of Prague Airport, Czech Republic.

An aircraft change had been made for operational reasons from an Airbus A320 aircraft (A320) to an Airbus A321 aircraft (A321), but no adjustment had been made to the passenger distribution. This led to the passengers being seated towards the front of the aircraft, placing the CG outside the forward limit of the permitted operating envelope.

Following this event, the operator took action to: highlight this event to its staff and improve their understanding of the issues raised; and improve the flow of information between operational departments when there is a change of aircraft type to reduce the risk that a similar event would occur in the future.

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History of the flight

The scheduled flight from Luton Airport to Prague Airport was to be flown using an A320 aircraft, but earlier in the day there had been a change and an A321 was to be used. Due to a technical issue, an automated message from the Operational Control Centre (OCC) in Budapest, Hungary, was prevented from reaching the Operational Handling Department (OHD) and Passenger Services Department (PSD) at Luton, who were responsible for the redistribution of passengers following a variant change.

Passengers were boarded with their seat allocation for the A320 and therefore were seated within cabin Zones A, B and C. This left the seats at the rear of the A321 aircraft, which has a fourth zone, Zone D, unoccupied. The unusual passenger distribution was not noticed by the cabin crew or dispatcher. The aircraft commander was unaware of the passenger distribution in the cabin but was passed a Load and Trim Sheet for his A321 aircraft, G-WUKG.

The Luton ATIS information X-RAY at 1820 hrs was: surface wind 180° at 13 kt gusting 24 kt, visibility 10 km in light rain with an OAT of 10°C, dew point 8°C and QNH 1008 hPa. The aircraft taxied to Runway 26, lined up at Intersection A and was cleared to takeoff. The co-pilot was the PF and the commander was the PM. The takeoff speeds V_1 and V_R were 112 KIAS and 123 KIAS respectively. At V_R, the PF applied aft side stick in the correct sense and at the normal rate. Due to a lack of aircraft response the PF called that the aircraft was not rotating, and the PF significantly increased the aft side stick movement, which reached almost full aft deflection. The PM selected TOGA thrust, at which point the aircraft rotated.

Due to the standard 'POSITIVE RATE OF CLIMB' call being missed, the landing gear was not retracted until approximately 5,000 feet amsl. The flight was continued to Prague during which the crew analysed the problem and were informed by the Senior Cabin Attendant (SCA) that there were no passengers at the rear of the cabin. The actual passenger distribution did not match the load sheet distribution, which distributed passengers equally throughout the cabin. Close to the top of descent, the conclusion was made that the take-off stabiliser setting on the load sheet was incorrect and this had caused the delayed rotation. It was not realised at that time that the CG was out of limits. It was assumed that the CG was within limits and that the aircraft's auto-trim system had compensated for the different distribution once the aircraft had become airborne. A normal descent, approach and landing was carried out at the destination with no pitch control abnormalities experienced. Subsequently, it was discovered that the aircraft loading had placed it outside the permitted CG envelope.

Weight and balance

The operator allocates specific aircraft to the scheduled flights for the day. This information is passed by email from the OCC in Budapest to the operating bases. At the outstation, the message is received by the OHD and PSD.

The OHD enters the aircraft registration into software, which generates the Load and Trim Sheet from the weight and balance data for the specific aircraft stored in the system. The PSD, knowing the specific aircraft, checks in the passengers and allocates boarding passes

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where the software permits, ensuring the aircraft always remains within its permitted weight and balance envelope. If there is an incorrect allocation of seats and the aircraft would be outside its permitted operating envelope, the software will not generate a Load and Trim Sheet. The operator's fleet comprises Airbus A320 aircraft, with a 180-seat configuration, and the A321 with 230 seats. When all the passengers have boarded, the Load and Trim Sheet is printed, and a copy is passed to the flight crew for them to complete their performance calculations.

On the day of the incident, an A320 was allocated to the flight and this information was passed to OHD and PSD at Luton. Both departments received the information and began their respective activities towards producing a Load and Trim Sheet and checking in the passengers for an A320. Later, the OCC needed to change aircraft from the A320 to G-WUKG, an A321. An email informing OHD and PSD of the change was prepared but, due to a technical problem, was not sent. This was noticed later in the day, at 1405 hrs, and the OCC Duty Manager telephoned the OHD and informed them of the aircraft change. The OHD entered the new aircraft registration into the Load and Trim Sheet software but PSD were not informed and had already allocated passenger seating for the three passenger zones on the original A320. When all the passengers had passed through the boarding gate and taken their allocated seats for the A320, the software produced a Load and Trim Sheet with passenger distribution for the four zones of the A321, maintaining the CG within limits for the flight. This sheet was passed to the flight crew and is shown below at Figure 1.

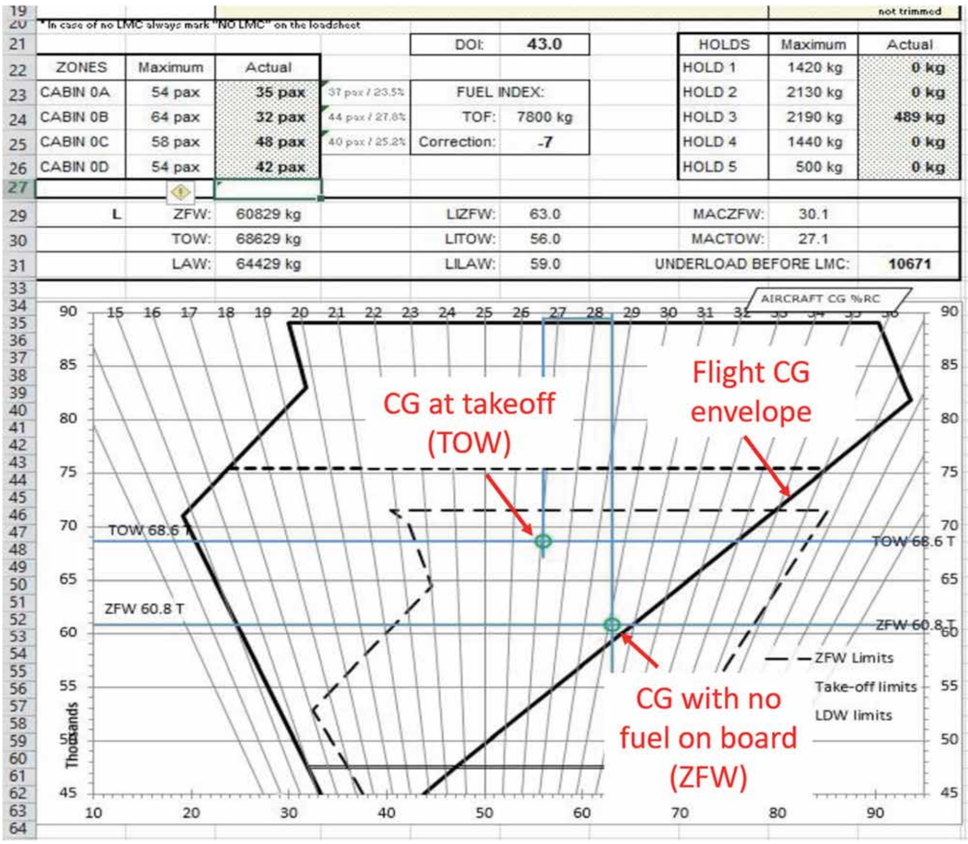

Figure 1

The Load and Trim Sheet as calculated but not as loaded

After the incident, the commander completed a Load and Trim sheet using the passenger seating allocation for the A320, but with the passengers seated in those seating positions in G-WUKG. The result, shown in Figure 2, shows that the total passenger weight was forward in the cabin placing the aircraft CG outside the permitted envelope.

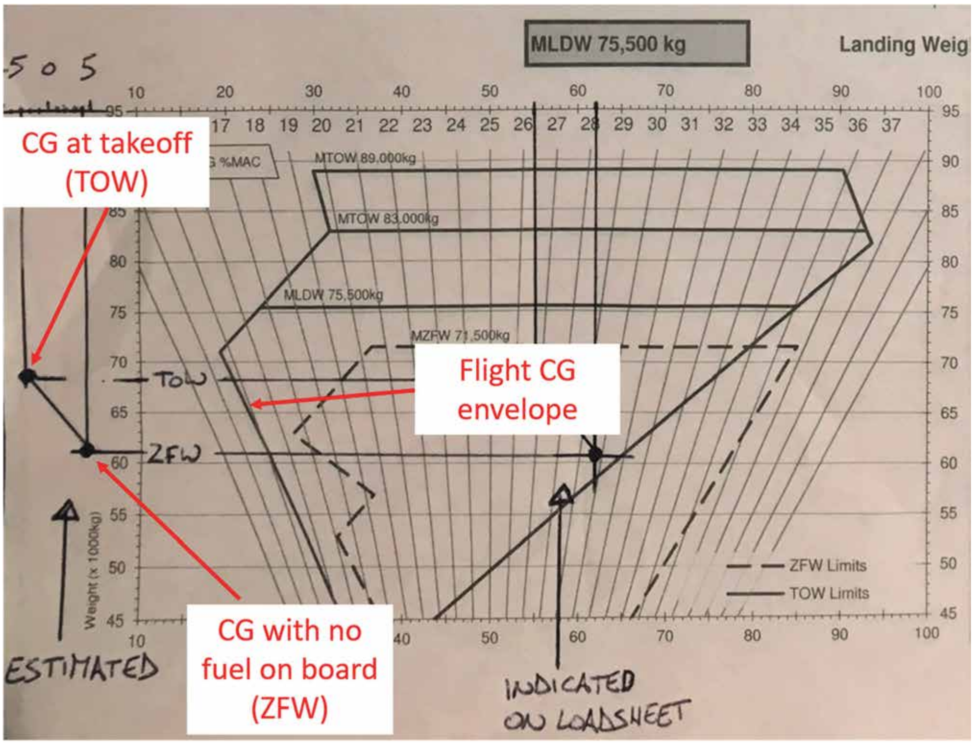

Figure 2

The A321 Load and Trim Sheet that would have resulted on the incident flight

Analysis

The incident occurred due to the aircraft change from an A320 to an A321 not being notified to both OHD and PSD. As a result, the passengers were seated at the front of the aircraft, placing the CG outside the forward limit of the operating envelope. The effect of this was that, at rotation, the aircraft appeared to the crew not to respond as expected to the normal side stick control inputs due to the forward CG. The PF required almost maximum aft control input and the PM selected TOGA thrust before the aircraft nose lifted. The crew analysed the problem but considered that an incorrect stabiliser setting, taken from the load sheet, had caused the problem. Only at the top of the descent for the destination did it become apparent that the passengers had possibly been incorrectly distributed in the cabin. The crew did not experience any unusual control response during the approach and landing.

Safety actions

Following the incident, the operator carried out an internal investigation. It identified safety actions it would take to prevent a reoccurrence, which were to:

- Improve the passage of information between the OCC and the flight crew when a change of aircraft variant takes place.
- Improve Ground Handling Agents' awareness of the implications of a change in aircraft variant.
- Distribute and make highly visible to all staff briefing material on this incident.
- Include any variant change at the flight and cabin crew briefing.
- Provide additional training for cabin crew on weight and balance distribution and its affects.
- Produce a Safety Bulletin to provide staff with a more detailed description of the incident.
- Issue a Crew Order (change to Operations Manual Part A) with enhanced awareness and guidance if suspicion is raised onboard.

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ACCIDENT

Aircraft Type and Registration:	1) DHC-8-402, G-JECK 2) EMB-145EP, G-SAJS
No & Type of Engines:	1) 2 Pratt & Whitney Canada PW150A turboprop engines 2) 2 Allison AE 3007/A1/1 turbofan engines
Year of Manufacture:	1) 2005 (Serial no: 4113) 2) 2001 (Serial no: 145390)
Date & Time (UTC):	16 June 2020 at 1646 hrs
Location:	Aberdeen International Airport
Type of Flight:	1) Commercial Air Transport (Non-Revenue) 2) N/A
Persons on Board:	1) Crew - 2 Passengers - None 2) Crew - None Passengers - None
Injuries:	1) Crew - None Passengers - N/A 2) Crew - N/A Passengers - N/A
Nature of Damage:	1) Damage to forward fuselage section and windscreen 2) Right engine nacelle dented
Commander's Licence:	1) Airline Transport Pilot's Licence 2) N/A
Commander's Age:	1) 31 years 2) N/A
Commander's Flying Experience:	1) 2,677 hours (of which 2,518 were on type) Last 90 days - 0 hours Last 28 days - 0 hours 2) N/A
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries by the AAIB

Synopsis

G-JECK was to be flown from Aberdeen Airport to Weeze Airport, Germany. The aircraft had been in storage at Aberdeen since March 2020 and was parked on a self-manoeuvring stand which had a 1° slope. During the pre-departure checks, the chocks were removed from both the mainwheels and the nosewheels. The hydraulic pressure in the park brake system subsequently reduced to the point where the brakes could no longer prevent G-JECK from moving, and the aircraft rolled across a taxiway before colliding with G-SAJS, which was parked on an adjacent stand. There were no injuries.

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Safety action has been taken by the CAA, operator of the aircraft, maintenance organisation, ground handling company and airport operator regarding the removal of wheel chocks during pre-flight preparation.

History of the flight

G-JECK had been stored at Aberdeen Airport (Aberdeen) since mid-March 2020, following the previous operator ceasing trading. On 16 June 2020, the aircraft was to be flown empty to Weeze Airport, Germany (Weeze) where it was to be placed back into storage. An organisation had been contracted by the aircraft owner to operate the aircraft for the ferry flight. This organisation provided the pilots, with ground handling services sub-contracted to another company based at Aberdeen. The commander and co-pilot for the flight had flown for the previous operator of G-JECK and were using the standard operating procedure (SOP) of that operator.

The pilots had not flown since the beginning of March 2020, so they had arranged to arrive at Aberdeen earlier than normal to provide additional time to prepare for the flight without having to rush. As the aircraft had not flown for some time, they also decided to conduct two separate and independent external and internal inspections. The commander arrived at 1230 hrs and the co-pilot at 1300 hrs, with the departure scheduled for 1600 hrs. The subsequent timeline has been derived from witness statements and a review of CCTV footage of the event.

The pilots were met by a dispatcher[1] from the ground handling company (referred to in this report as the dispatcher), who escorted them to a crew lounge where they were able to prepare some of their paperwork. The dispatcher then left before returning at about 1520 hrs, having collected a representative of the aircraft's owner (referred to in this report as the representative), whose arrival at Aberdeen had been delayed. The dispatcher then drove the pilots and representative to the aircraft, arriving at 1555 hrs. G-JECK was parked on self-manoeuvring[2] Stand 31 with the front of the aircraft facing Taxiway D (Figure 1). Parked on the opposite side of the taxiway, at Stand 11, was an Embraer EMB-145 aircraft, registration G-SAJS.

The co-pilot's luggage had been sent separately to Aberdeen but had yet to be collected and, as the pilots still needed to complete their checks, they decided to reschedule the departure to 1645 hrs. However, there were no specific time constraints, and the pilots agreed to further extend the departure time if necessary.

The pilots, dispatcher and representative were met at the aircraft by three engineers from a Part 145[3] approved maintenance organisation (AMO) that had been maintaining the

Footnote

1 In this report, the dispatcher ground handler was the person providing ramp services, which included the removal of the aircraft wheel chocks.

2 A stand at which an aircraft enters and departs under its own power.

3 Commission Regulation (EU) No 1321/2014 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks Annex II Part 145.

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aircraft under the control of a continuing airworthiness management organisation (CAMO) whilst it was at Aberdeen. Following a brief conversation with the pilots, the engineers returned to their vehicle parked on the adjacent Stand 30.

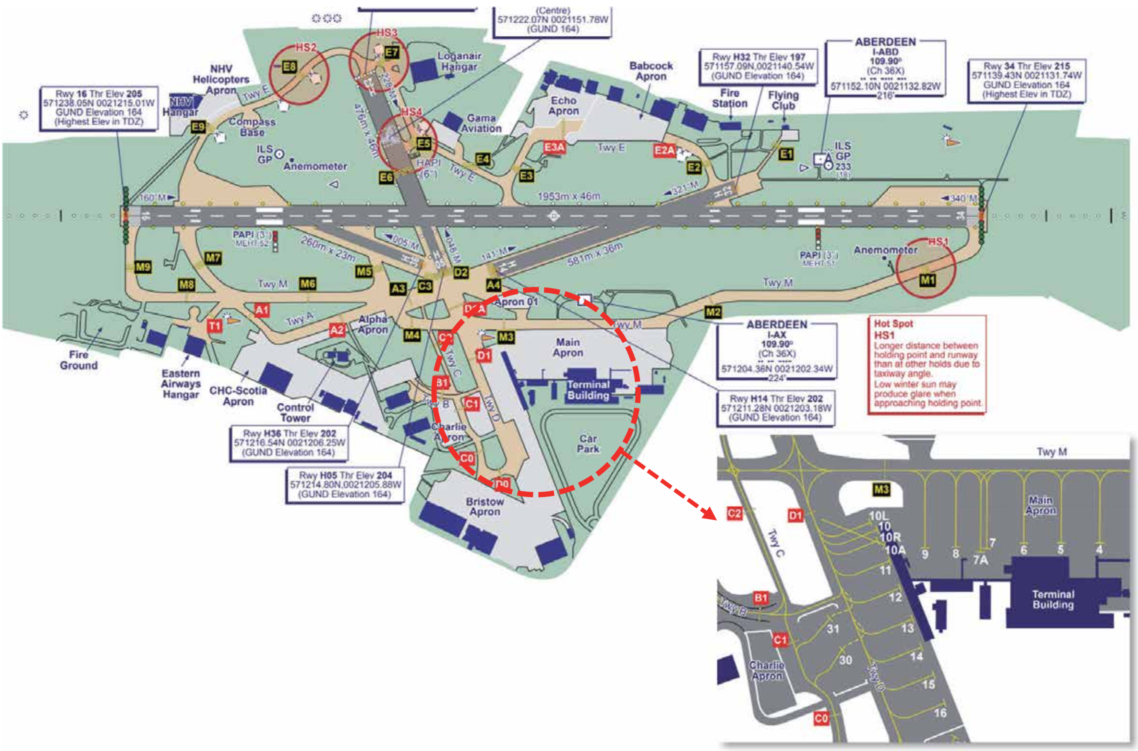

Figure 1

Aberdeen Airport (Stands 31 and 11 shown in inset)

Prior to boarding the aircraft, the pilots had checked that wheel chocks were fitted to the mainwheels and nosewheels. In the cockpit, the parking brake lever was confirmed as being set to the PARK position and whilst the commander reviewed the aircraft technical log, the co-pilot started the APU. The pilots checked the cockpit multi-function display (MFD) and noted that the fluid quantities of the hydraulic systems were adequate. Neither pilot noticed what the park brake hydraulic system pressure was indicating on the MFD, but this was not required to be checked until the end of the aircraft power-on checks and prior to starting the first engine.

Shortly after the pilots had boarded the aircraft, the dispatcher and representative briefly stood near the front of the aircraft, where the representative reported that a brief conversation[4] took place concerning the removal of the chocks. The dispatcher then went to the left landing gear to remove the four wheel chocks. As the dispatcher walked towards the landing gear, the representative removed the four chocks placed around the nosewheels. The dispatcher returned to the front of the aircraft carrying the four left landing gear chocks, by which

Footnote

4 The representative and dispatcher had differing recollections of the content of this conversation which the AAIB investigation was unable to resolve.

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time all of the chocks had been moved clear of the nosewheels by the representative; two chocks were positioned to the right of the nosewheels and one positioned about 0.5 m in front of the left nosewheel.

The representative, carrying the remaining, fourth chock, walked with the dispatcher to the right side of the aircraft nose where they placed the chocks on the ground a few metres away from the aircraft. The dispatcher then walked to his vehicle and reversed it to nearer the aircraft. As he did this, the representative moved the three chocks that had been placed close to the aircraft nosewheels and placed them with the others next to the aircraft. The dispatcher, assisted by the representative, then removed the four chocks from the right landing gear wheels before loading all 12 chocks into the vehicle. The pilots, onboard the aircraft, had not seen the chocks being removed.

The co-pilot's luggage was then collected and loaded into the aircraft, after which the dispatcher returned to the front of the aircraft where he attached a headset to the receptacle near the nose gear in preparation for engine start.

About 15 minutes after the chocks had been removed, the commander exited the aircraft to start his walkaround inspection. This included visual checks of the nosewheel tyres and the park brake accumulator pressure gauge, which indicated about 500 psi. The commander completed his walkaround after about ten minutes, at which point two of the engineers in the nearby vehicle came across to the aircraft to answer queries from the commander. Whilst the commander spoke with the engineers, the co-pilot then carried out a walkaround inspection.

The procedures used by the pilots required one walkaround but, as neither had flown for some months, they agreed to make independent inspections. After about ten minutes, the co-pilot completed his walkaround and returned to the cockpit. The commander also returned to the cockpit shortly afterwards, whilst the two engineers went back to their vehicle. Neither pilot had authorised the removal of any wheel chocks, and neither noticed that all the wheel chocks had been removed.

The park brake accumulator pressure had been checked, but the pilots had yet to reach the part of the checklist that called for the park brake hydraulic system pressure to be checked on the MFD.

As the pilots completed the load sheet, the dispatcher boarded the aircraft via the forward left cabin door and stood near the cockpit entrance. Standing on the ground near the cabin door was the representative. About 45 minutes had elapsed since the chocks had been removed, at which point the representative noticed that the aircraft was starting to move forward and shouted to the dispatcher who alerted the pilots. Both pilots applied the toe brakes and the commander moved the park brake lever OFF and back to PARK twice, but the aircraft continued to roll forward. The commander recalled that, as the aircraft had started to move, he had noticed that the park brake hydraulic system pressure on the MFD was 0 psi. The commander also tried to steer using the tiller, but the aircraft did not respond.

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Having seen the aircraft start to move, the three engineers left their vehicle and ran to the adjacent right landing gear, where they tried to stop the aircraft by pushing and pulling against its main strut. As the representative ran to the vehicle to get some chocks, the dispatcher jumped from the cabin door and moved to the left gear where he pushed against its strut. However, the aircraft continued to gather speed as it crossed Taxiway D whilst heading towards the parked and empty aircraft, G-SAJS. The dispatcher then ran to the front of the aircraft, where he was joined by one of the engineers, who tried to slow the aircraft by pushing against the aircraft nose. A few second later, the engineers and dispatcher ran clear of G-JECK as it approached G-SAJS.

At a ground speed of about 5 kt, G-JECK struck the underside of G-SAJS's No 2 engine, causing its right landing gear to be lifted clear of the ground. G-JECK came to a stop with the No 2 engine of G-SAJS resting on top of its forward fuselage (Figure 2). There were no injuries. The pilots of G-JECK shutdown the aircraft and disembarked as the RFFS arrived.

Figure 2
G-JECK and G-SAJS

Airport information

Aberdeen Airport (Figure 1) had two self-manoeuvring stands, numbered 30 and 31. There was a downward slope from Stand 31 to Stand 11 of just less than 1°.

Personnel information

The dispatcher had worked in his current role for more than ten years and had not been recently furloughed due to COVID-19. The company that employed the dispatcher provided training to its staff every three years on airside safety and the dispatcher had last attended this course in September 2019. The course included a module on chocking wheels that included a practical session on an aircraft. The training material stated that, for a propeller aircraft, the mainwheel chocks should be removed before the dispatcher carried out the walkaround inspection. The training material did not refer to the removal of chocks from the nosewheels.

The representative had worked in the aviation industry for more than ten years and had been a licensed aircraft engineer. He had previous experience of chocking and un-chocking aircraft, and movements of aircraft on self-manoeuvring stands.

Aircraft examination

A photograph taken a few hours after the accident and before both aircraft were moved, showed that G-JECK's brake accumulator pressure was about 500 psi (Figure 3).

A specialist recovery team using airbags separated the aircraft (Figure 4). The upper fuselage skin, cockpit emergency escape hatch and cockpit window of G-JECK, and the No 2 engine nacelle of G-SAJS, were damaged.

Figure 3

Brake accumulator pressure after the accident

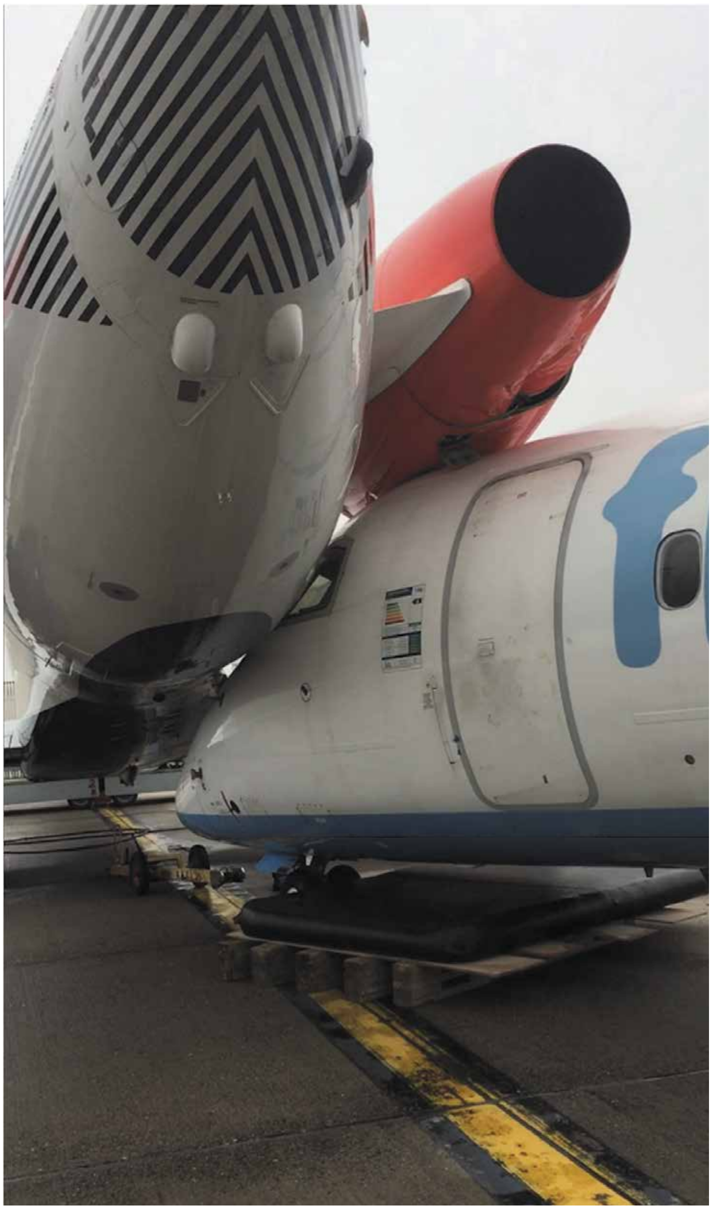

Figure 4
G-JECK and G-SAJS during recovery

Chocking of wheels when self-manoeuvring

The procedures used by the pilots stated that on arriving at the aircraft, they were to confirm that chocks were fitted, and the park brake was applied.

The ground handling procedures of the previous operator of G-JECK for self-manoeuvring stands stated that approval from pilots shall be obtained before removing chocks. The mainwheel chocks were to be removed once pilots indicated they were ready to start the engines whereas the nosewheel chocks were to remain in place until after engine start and permission had been given to remove them. This contrasts with the procedure if not self-manoeuvring for which, once a tug has been attached and permission given by the flight crew, all chocks can be removed.

The ground handling company had not been provided with a copy of the previous operator's procedures. However, the dispatcher indicated that in lieu of this, a generic procedure had been used for G-JECK. This was based on the dispatcher's experience of procedures used by other operators at Aberdeen. Discussions with the dispatcher indicated that the procedures were consistent with those of the previous operator of G-JECK regarding the nosewheels, which were to remain chocked until after engine start.

Removal of mainwheel and nosewheel chocks from G-JECK

The statements of the commander, dispatcher and representative differed concerning the removal of the chocks. The AAIB investigation was unable to resolve these differences.

Commander

The commander stated that he had not given permission[5] to remove any of the wheel chocks.

Dispatcher

The dispatcher stated that when they had initially arrived at the aircraft, the commander had referred to preparing the aircraft for departure. The dispatcher had understood this to mean that he could proceed with removing the chocks from the left and right mainwheels. He further stated that he had not instructed anyone to remove the nosewheel chocks and, had he noticed they had been removed, that he would have refitted them.

Representative

The representative stated that he had offered to assist the dispatcher in removing the chocks and asked him if he wanted the nosewheel chocks removed, which he said that the dispatcher had acknowledged. The representative further stated that he assumed that the park brake was applied because of the response he had received from the dispatcher, but that he had checked, when the last chock was removed from the mainwheels, that the aircraft did not move.

Aircraft information

The De Havilland Canada Dash 8-402 is a high-wing, two pilot, transport category aircraft, with seating for up to 78 passengers and powered by two turboprop engines. The aircraft is fitted with an APU that provides electrical power.

Brake system

The DHC-8-402 brake system is powered by two hydraulic systems that have a nominal working pressure of 3,000 psi. Each system is pressurised by a pump driven by the No 1 and No 2 engines respectively. The No 1 system supplies the normal brake system that is operated using the toe pedals, and the No 2 system supplies the parking brake (Figure 5) which is applied using a lever in the cockpit.

Footnote

[5] The co-pilot also stated that he had not given permission.

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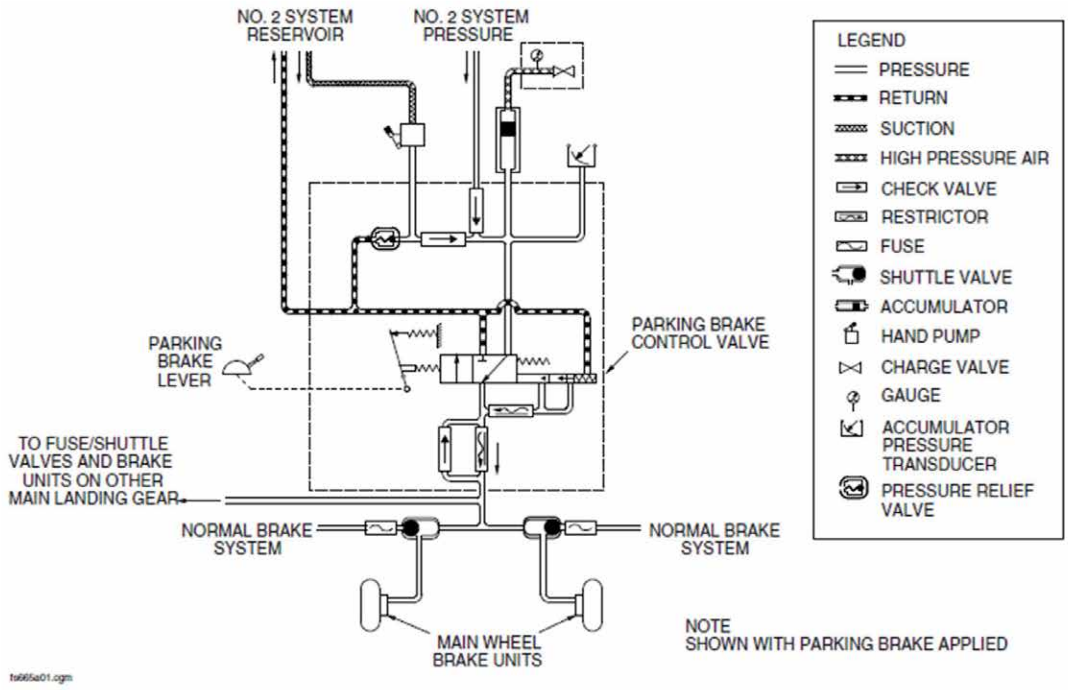

Figure 5

Park brake system schematic

When the park brake lever is set to PARK, the parking brake control valve applies hydraulic pressure that operates shuttle valves to close the inlet ports from the normal brake system. This enables pressure from the parking brake hydraulic system to be applied to the brake units fitted to the main landing gear wheels.

The park brake system is fitted with an accumulator that is pre-charged by nitrogen gas to a pressure of 500 (+/-25) psi. When the No 2 engine driven pump is running, the accumulator gas is pressurised to the normal system pressure of 3,000 psi by the hydraulic fluid. After the No 2 engine has stopped, a check valve closes, and the pressure is stored by the accumulator. The park brake system may also be used in an emergency, such as when normal braking is no longer available. When fully charged, the accumulator provides capacity for six full applications of the parking brake.

When the aircraft is parked, the hydraulic pressure in the park brake system may gradually reduce. The aircraft maintenance manual (AMM) stated that from an initial accumulator pressure of 3,000 psi, the permitted loss was 1,900 psi over two hours. The AMM did not specify a loss rate for periods of more than two hours or a minimum pressure to be retained beyond this period. A hand pump was fitted to the No 2 system that enabled the park brake system pressure to be manually increased when the aircraft was on the ground.

The nitrogen gas pressure in the brake accumulator is read from a gauge fitted in the right wing root, and the park brake hydraulic system pressure is displayed on the MFD in the cockpit. When the park brake system pressure is more than the brake accumulator pre-charge pressure, the pressure displayed on the accumulator gauge and the MFD will be

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similar. However, if the park brake hydraulic system pressure reduces below the pre-charge pressure of the accumulator, the accumulator gauge will show the pre-charge pressure of about 500 psi and the MFD would need to be checked to establish the park brake hydraulic system pressure.

Nosewheel steering

The nosewheel steering system required the No 2 hydraulic system to be at its normal operating pressure of 3,000 psi.

Minimum brake pressure prior to engine start

The procedures used by the pilots and the AMO engineers stated that, if the No 1 engine was to be started first, the park brake hydraulic system pressure should be a minimum of 1,000 psi or, if the No 2 engine was started first, the minimum pressure was 500 psi. The check of the park brake hydraulic system pressure on the MFD by the crew is done at the end of the aircraft power-on checks and prior to starting the first engine.

The aircraft manufacturer advised the AAIB that a park brake system pressure of 400 psi would be sufficient to maintain the aircraft position (with no wind) on an asphalt surface with either a forward or reverse slope of about 7°.

G-JECK maintenance history

Whilst in storage at Aberdeen, the AMO had carried out routine maintenance. This included weekly engine runs and checks of the hydraulic systems. The AMO had also maintained several other DHC-8-402 aircraft in storage at Aberdeen. Discussions with the AMO engineers and the CAMO indicated that it was not unusual for the park brake system pressure of some of the aircraft in storage to reduce to less than 500 psi between weekly checks[6]. However, it was not possible to confirm if G-JECK was one of these aircraft as there was no requirement to record this.

In preparation for the flight to Weeze, a return to service check was carried out. This took several days to complete and included an engine run and test of the park brake system on 12 June 2020, four days before this event.

Recorded information

The event was captured by three CCTV cameras. The recordings provided a complete view of G-JECK, the movement of people around it, and its subsequent roll of 70 m into G-SAJS.

The recordings showed that at 1639 hrs a Sikorsky S92 helicopter had taxied past G-JECK, whilst a refuelling vehicle also manoeuvred nearby (Figure 6). At 1644:30 hrs, G-JECK started rolling forward. The aircraft's ground speed gradually started to increase and by 1645:23 hrs it had travelled about halfway across Taxiway D (Figure 7). At 1645:35 hrs, G-JECK struck G-SAJS (Figure 8) whilst travelling at a ground speed of about 5 kt.

Footnote

6 As previously stated, the AMM did not specify a loss rate for periods of more than two hours or a minimum pressure to be retained beyond this period.

Figure 6
Position of G-JECK and G-SAJS

Figure 7
G-JECK as it rolled across Taxiway D

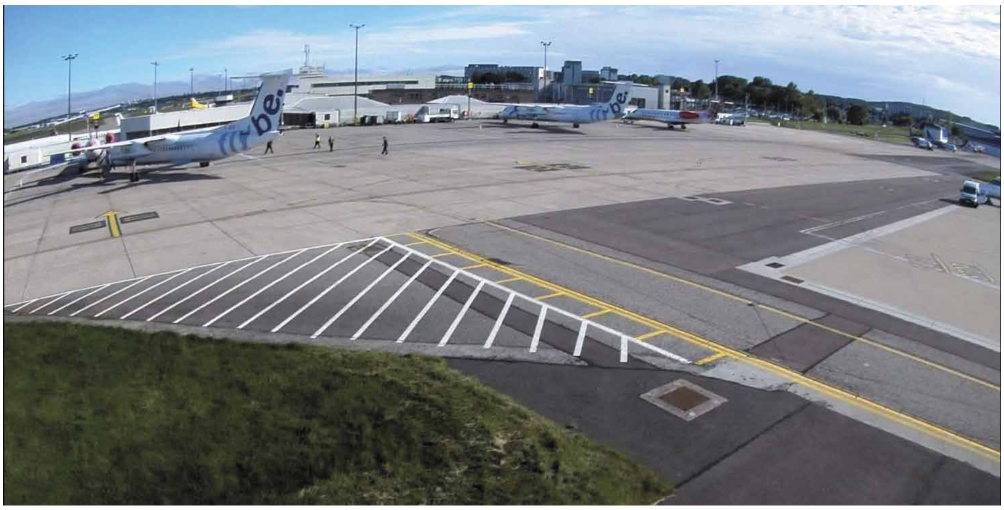

Figure 8
G-JECK as it collided with G-SAJS

Tests and research

The park brake and normal braking systems of G-JECK were tested after the accident. No defects were found.

Analysis

Removal of chocks

The evidence indicates that a misunderstanding led the dispatcher to believe that clearance had been given by the commander to remove the chocks from the mainwheels. The dispatcher was aware that the nosewheels were to remain chocked until after the engines had been started. However, following the representative's offer of assistance to the dispatcher, a miscommunication appears to have led to the nosewheel chocks being inadvertently removed. Both pilots stated that no permission for chock removal had been given.

The removal of the chocks went unnoticed by the pilots, and the dispatcher also did not realise that the chocks had been removed from the nosewheels.

Upon arrival at the aircraft, the pilots followed their normal procedure of checking that the wheels were chocked and, unsighted by them, the chocks were then removed. The pilots' subsequent walkaround inspections did not require them to check the chocks and so their attention would not have been drawn to them. The pilots had allowed themselves plenty of time to conduct duplicate checks of the inside and outside of the aircraft and to avoid missing any checklist items. Being aware of their reduced currency and that the aircraft had not flown for some time, their focus would have been predominantly on ensuring that no checklist item was omitted. This may have left less capacity to notice anything additional that they were not specifically looking for or expecting.

The CCTV showed the representative assisting the dispatcher to remove the chocks from the right landing gear wheels and helping to load the 12 chocks into the vehicle. The dispatcher did not remove the nosewheel chocks and stated that he did not expect them to be removed by anyone else, so he had no reason to focus attention on them at this point in time. The fact that 12 chocks, rather than 8, were loaded into the vehicle did not register as being at variance to these expectations. After the chocks had been loaded into the vehicle, his attention was likely to be focussed on his next task, which was the completion of the load sheet by the pilots.

Brake system

The park brake system had been pressurised to 3,000 psi when the engines had been operated four days before the accident. However, it was not unusual for the pressure to reduce over time whilst DHC-8-402 aircraft were parked; the AMM states that in two hours, the pressure could reduce by as much as 1,900 psi.

The evidence from the pilots' walkarounds and photograph of the brake accumulator taken after the event, showed that the park brake hydraulic pressure could not have been more than the accumulator pre-charge pressure of about 500 psi. Therefore, to establish the hydraulic pressure in the park brake system it would have been necessary to have checked

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the MFD, but the pilots were not required to do this until the end of the aircraft power-on checks and they were ready to start the engines.

The aircraft was parked on a slope of just less than 1° and, following the initial removal of the wheel chocks, it did not roll forward. This indicates that there was residual pressure in the park brake hydraulic system at this time, but that it could have been less than the 400 psi required to hold the aircraft on a 7° slope. About 45 minutes later, the aircraft started to roll forward, at which point the commander noticed that the park brake hydraulic system pressure on the MFD indicated 0 psi.

There was no evidence of an external effect, such as a gust of wind or airflow from a nearby manoeuvring aircraft, that caused the aircraft to start to move. Therefore, the movement of the aircraft appears to have been coincidental with the brake pressure reducing to zero.

As neither the No 1 or No 2 hydraulic systems were pressurised, the application of the park brake and operation of the normal braking and nosewheel steering systems were ineffective in stopping or altering the path of the aircraft.

Risk of injury

No one was injured during this accident; however, the outcome could have been different. The engineers and dispatcher placed themselves at risk when trying to stop the aircraft and could have been struck by it. Nearby manoeuvring aircraft and their pilots and passengers were also at risk, with a Sikorsky S92 helicopter having taxied past shortly before G-JECK rolled across the taxiway. It was also fortunate that no persons were onboard G-SAJS and that the pilots of G-JECK were not injured.

Conclusion

G-JECK rolled across Taxiway D from its parking position and struck G-SAJS because the nosewheel chocks had been inadvertently removed, and the hydraulic pressure in the park brake accumulator had depleted over several days to the point where it was unable to prevent the aircraft from moving on the 1° slope.

Safety action

Following this event, safety action has been initiated by the following organisations:

The organisation that provided the pilots for the flight and sub-contracted the ground handling services has:

> Reminded its sub-contracted ground handling companies that permission must be obtained from the aircraft commander before removing chocks.
>
> Reiterated that chocks are to remain fitted until either a tug had been attached to the aircraft or, when self-manoeuvring, that nosewheel chocks remain fitted until permission has been given to remove them.
>
> Recommended that pilots check during their walkaround that chocks had not been inadvertently removed.

The CAMO:

Circulated a tutorial, and included it in recurrent training, to all staff within its organisation to raise awareness of the circumstances of this event.

The organisation contracted to provide ground handling for G-JECK has:

Updated its training of dispatchers to ensure that third parties undertake only those duties for which they have been explicitly briefed and trained to carry out.

Aberdeen Airport has:

Issued an airside safety alert at Aberdeen, Glasgow and Southampton Airports highlighting the need to obtain permission before removing chocks.

Undertaken to carry out audits of ground handling companies operating at Aberdeen to better understand chocking procedures and training.

Requested airside operations to audit chocking procedures on the ramp area, with particular attention to self-manoeuvring stands.

Undertaken to share safety lessons with ground handling companies via the ramp safety committee at Aberdeen.

The UK CAA:

On 27 July 2020, the UK CAA published Safety Notice, SN-2020-013[7] - *Returning Aircraft to Service from 'Extended Parking',* which highlights threats associated with this report.

Footnote

[7] http://publicapps.caa.co.uk/docs/33/SafetyNotice2020013.pdf [accessed 27 July 2020].

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SERIOUS INCIDENT

Aircraft Type and Registration:	MBB-BK 117 D-2, G-SASS
No & Type of Engines:	2 Turbomeca Arriel 2E turboshaft engines
Year of Manufacture:	2014 (Serial no: 20022)
Date & Time (UTC):	4 May 2020 at 1255 hrs
Location:	Knockenkelly, Whiting Bay, Brodick, Isle of Arran, North Ayrshire
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Section of static caravan roof partly lifted
Commander's Licence:	Commercial Pilot's Licence (H)
Commander's Age:	53 years
Commander's Flying Experience:	5,865 hours (of which 953 were on type) Last 90 days - 36 hours Last 28 days - 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

A caravan roof was partly lifted by the downwash from a helicopter taking off from a nearby landing site on an air ambulance flight. The accident demonstrates the potential for downwash to cause damage during helicopter operations.

Background

The helicopter was departing a landing site at Sandbraes, which was used for military, coastguard and air ambulance operations to the island. It consisted of a grass sports field measuring 90 m x 140 m and was surrounded by several buildings and other obstructions, as well as several static caravans situated close to, but not immediately next to, the landing site.

The site was secured by local members of the coastguard when being used and, whilst it complied with regulatory requirements, operators were responsible for ensuring it was suitable for their use. The managers of the playing fields were unaware of any previous incidents associated with its use as a helicopter landing site.

History of the flight

The helicopter had been dispatched from its base at Glasgow Airport to transfer a patient from the Isle of Arran to a hospital on the mainland. It arrived at the landing site without

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incident and the patient was loaded onboard for the return flight.
Owing to the nature of the site, on takeoff the helicopter was required initially to climb whilst moving slowly rearwards until reaching its take-off decision point (TDP). This defines the height above which, in the event of an engine failure, the helicopter can safely fly away. By using the described profile, in the event of an engine failure below TDP it is able to carry out a landing on the site it has just departed.

The helicopter took off facing into wind, which was easterly at about 10 kt. The TDP for the flight was calculated to be at a height of 210 ft, which the pilot estimated was reached with the helicopter over the western edge of the landing site. The helicopter then transitioned to forward flight, departing to the east.

Witnesses report that as the helicopter increased power to transition away, part of the roof of a static caravan parked near the landing site to the west lifted, allowing some of the insulation underneath to be blown out.

Analysis

The position of the helicopter at the time it transitioned into forward flight, combined with the associated increase in applied power, resulted in sufficient downwash affecting the caravan roof to partially lift it. It was not possible to ascertain the condition of the roof before the incident and this may have been a contributing factor.

The site had previously been used by larger helicopters with no apparent issues. The operator had also surveyed the site as part of its operating procedures and had not identified the caravans as being an issue. As a result of the incident it was however able to adjust the TDP to a lower height in order to reduce the area affected by downwash for future flights.

The issue of downdraft has become more significant as operators switch to using larger helicopter types in the air ambulance role. It is important that operators remain aware of the potential for damage that may be caused beyond the landing site and ensure their procedures and choice of location take this into account.

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ACCIDENT

Aircraft Type and Registration:	Pegasus Quik, G-CCPC
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2003 (Serial no: 7994)
Date & Time (UTC):	31 July 2020 at 1010 hrs
Location:	East Fortune Airfield, North Berwick, East Lothian
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Fuselage pod, left wheel spat and windshield damaged
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	68 years
Commander's Flying Experience:	312 hours (of which 267 were on type) Last 90 days - 4 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot lost control during a landing in turbulent conditions, resulting in a runway excursion following which the flexwing aircraft struck a fence. The pilot sustained a fractured wrist and the aircraft was substantially damaged.

History of the flight

Following departure from Runway 11 for a local flight from East Fortune Airfield, East Lothian, the pilot realised that the turbulence was worse than anticipated. The pilot described having "to work very hard to try to maintain straight and level flight" in the turbulent conditions and decided to return to the airfield. Two approaches to Runway 11 were flown, but on both occasions the pilot had difficulty in positioning the aircraft for the final approach in the turbulence and went around. The pilot described that, at this stage of the flight, her arms hurt with the effort of controlling the flexwing and that she was very anxious.

The pilot described the wind as becoming light, as shown by the windsock, so she positioned the aircraft for an approach to Runway 29 which has a longer, unobstructed approach compared to Runway 11. After a stable final approach, the aircraft veered to the left in the round-out and the pilot reported that she had insufficient strength to push the control bar forwards to initiate a go-around. The aircraft struck a fence to the left side of the runway,

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during which the pilot sustained a fracture to her left wrist. The aircraft's fuselage pod, windscreen and left wheel spat were damaged in the accident.

The pilot stated that following discussions with other pilots who had witnessed the accident, it was apparent that the wind had veered to the north and strengthened as the aircraft was landing, which had contributed to the loss of control. The other pilots, who had also flown that day, remarked that the turbulent conditions were challenging to fly in.

Pilot's comments

The pilot assessed the cause of the accident to be a combination of the turbulent conditions, which taxed her physical strength, and "a classic case of fear and stress (Atherton, 2020[1])". She stated that a decision on whether to fly solo again would be dependent on increasing her upper body strength and on reducing the weather limits in which she assessed it would be safe for her to fly.

Footnote

1 Atherton, I. (2020) 'The Emotion of Flight', *GASCO Flight Safety magazine*, Summer 2020.

ACCIDENT

Aircraft Type and Registration:	Believer (UAS, registration n/a)
No & Type of Engines:	2 electric motors
Year of Manufacture:	2020 (Serial no: 3)
Date & Time (UTC):	2 May 2020 at 1430 hrs
Location:	Solent Airport, Hampshire
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:	Destroyed
Commander's Licence:	Not applicable
Information Source:	Aircraft Accident Report Form submitted by the operator and additional enquiries made by the AAIB

Synopsis

The flight was part of a test programme prior to the start of commercial operations to the Isle of Wight.

The accident UAS was considerably smaller than the production aircraft but it was representative in terms of the avionics and communications. It crashed shortly after taking off because the safety pilot switched the radio control transmitter off before the automatic flight control system was engaged. Several safety actions have been undertaken by the operator because of this accident.

History of the flight

The UAS had already completed two successful flights on the day of the accident. A pre-flight check was carried out, and a mission profile was loaded into the automatic control system.

A pre-flight briefing outlined the normal plan. The UAS would be hand-launched with a safety pilot manually controlling the initial phase of the flight. When the UAS was airborne and stable, the automatic flight control system would be activated and the ground control system (GCS) operator would authorise the shutdown of the radio control transmitter.

The UAS was launched successfully but the safety pilot turned the radio control transmitter off before receiving the verbal command to do so, and before the automatic flight control system was activated. The pilot reported that he incorrectly believed that this instruction had been issued. It is possible that fatigue could have contributed to the error because the operator stated that the "*crew had been working long hours for* [the] *last few days*".

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The onboard fail-safe logic[1] detected the loss of signal and reduced the throttle to idle and applied an aileron input. With the aircraft at an altitude of approximately 235 m the safety pilot was unable to switch the controller on again and regain control before the aircraft crashed in an open area of the airfield at a speed exceeding 40 m/s. There were no injuries but damage to the aircraft was extensive.

UAS information

The Believer UAS is predominantly constructed from foam and has a maximum takeoff weight of 6.5 kg[2]. It has a V-tail, two wing-mounted electrically driven propellers and a wingspan of approximately 2 m (Figure 1). Information online indicates that the UAS is typically used for aerial survey operations.

Figure 1
General view of the Believer UAS

Analysis

The launch was conducted with the UAS in manual mode, which meant that the safety pilot had full control of the aircraft. The safety pilot believed that the instruction to turn the transmitter off had been issued, but this was incorrect. When the transmitter was turned off, the fail-safe logic operated as designed, and there was insufficient time to regain control before the aircraft crashed.

The operator reviewed their operating philosophy and modified the control system so that takeoffs are performed with the aircraft in automatic mode with the safety pilot correcting the flightpath as necessary. Whilst not a direct cause of this accident, they also reviewed the fail-safe logic to ensure that the settings are automatically configured by the mode the aircraft is in eg if the aircraft is in automatic mode the transmitter failsafe is disabled. Prior to this improvement, the transmitter fail-safe had to be manually turned off, which required human intervention and was open to error.

Footnote

1 The onboard monitoring system detected the loss of the transmitter signal and, because the UAS was in manual mode, it induced a descending turn (fail-safe) to curtail the flight.
2 Maximum takeoff weight quoted in the Operator's operations manual.

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Conclusion

The safety pilot erroneously turned the transmitter off before the automatic control system was activated and before the instruction to turn the transmitter off had been issued.

The operator believed that the accident was unavoidable after the radio control transmitter was turned off because there was insufficient time to switch it back on and regain control of the UAS.

Safety actions

The following safety actions were introduced:

1) Operations were reviewed to minimise the period where a UAS is under manual control. The UAS is now launched in a revised automatic mode where the safety pilot can apply control inputs to correct the flight path if appropriate. The safety pilot can also disable the automatic flight control system and take full control of the UAS in the event of an emergency.

2) The fail-safe logic has been reviewed and modified so that settings are automatically configured depending on the status of the UAS.

3) The operator has reviewed their fatigue risk management strategy and is introducing limitations with respect to permissible crew working times and a requirement for crew members to consider their well-being and declare themselves fit for operation during every flight briefing. The operator is updating their operations manual accordingly.

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ACCIDENT

Aircraft Type and Registration:	DJI Matrice M200, (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: OFZDF550P20045)
Date & Time (UTC):	8 July 2020 at 1220 hrs
Location:	Stranraer Academy, Stranraer, Dumfries and Galloway
Type of Flight:	Commercial Operations (UAS)
Persons on Board:	Crew - N/A Passengers - N/A
Injuries	Crew - N/A Passengers - N/A
Nature of Damage:	Substantial
Commander's Licence:	Other
Commander's Age:	62 years
Commander's Flying Experience:	95 hours (of which 95 were on type) Last 90 days - 6 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The UAS was being operated commercially on a roof survey of a large building in a built-up area, using the pre-programmed flight path. All the normal pre-flight checks were completed, including an assessment of potential bird interference. The pilot launched the drone and flew it manually before engaging the autonomous flight mode. The UAS flew out on the first track before returning on the second when a gull flew over the pilot from behind and attacked it. The pilot tried to engage manual control, but the front right propeller was damaged in the attack and the UAS, which weighed 6.14 kg, fell onto the roof.

The pilot had previously operated the UAS in coastal and onshore locations where gulls were present, and had been cautious while operating in their areas, especially in the nesting season. He had not experienced this level of aggression before and noted that it was one of the black-headed gulls in the area which had attacked the UAS. The distinctive appearance of the Black Headed Gull is shown at Figure 1.

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Figure 1
Black Headed Gull

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 investigations reviewed July - August 2020

18-Mar-20 **Zenair CH 750** **G-CIJZ** Near Aberdeen Airport

The engine stopped in flight and a successful field landing was carried out. The engine stopped as a result of the failure of the No 1 piston connecting rod where it is connected to the crankshaft (big end). There was evidence of a lack of oil in the engine and overheating of the area around the failed section of the connecting rod.

26-Mar-20 **Aeroprakt A32 Vixxen** **G-CLGD** Private strip, near Melton Mowbray, Leicestershire

The pilot reported that he touched down faster than normal and that the aircraft bounced. During the subsequent touchdown the left and right wings struck the ground. The aircraft sustained damage to the landing gear, engine cowling and wings.

20-May-20 **Savannah Jabiru(5)** **G-CEFY** Glassonby, Cumbria

The aircraft became inverted on landing. The pilot reported that it was affected by the wind conditions.

25-May-20 **Pegasus Quantum 15-912** **G-CDVH** Athey's Moor Airfield, Northumberland

On landing, the throttle stuck open and the aircraft ran off the end of the runway and into a wire fence. The pilot sustained minor injuries and the wing, fuel pipes, propeller and wheel spats were damaged.

25-May-20 **Thruster T600N 450** **G-CSAV** Brookfield Farm, Market Rasen, Lincolnshire

The aircraft landed long and while braking heavily, the aircraft veered to the right and went into a small drainage ditch running along the side of the runway. The nose landing gear leg and pod were damaged.

26-May-20 **Ikarus C42 FB80** **G-CDRO** Popham Airfield, Hampshire

The aircraft departed controlled flight shortly after takeoff, having made two successful takeoffs earlier. The aircraft came to rest to the side of the runway with a fractured nosewheel and damage to the propeller. The pilot suggested that the left wing had stalled but could not determine why.

27-May-20 **Eurofox 912(S)** **G-CKAB** Kirton in Lindsey Airfield, Lincolnshire

Following a normal landing, the aircraft tipped over onto its nose during the ground roll.

Record-only investigations reviewed July - August 2020

04-Jun-20 **S200** **G-LKAM** Solent Airport, Hampshire

The aircraft crossed the threshold at about 65 kt in a crosswind from the left. Right rudder and left aileron were used to 'kick off' the drift and the throttle was moved to idle during the round out. After touching down on the main gear, a rapid pitch down then caused the nose gear to collapse and damage to the propeller.

11-Jul-20 **Flight Design CTSW** **G-LCKY** Sandown Airport, Isle of Wight

On return to Sandown Airport on a hot day the pilot's first approach was high resulting in a go around. The second approach was carried out with a greater flap setting but at around 10 ft the pilot was unable to stop the aircraft sinking rapidly towards the ground and the aircraft landed heavily on the nose wheel which collapsed causing the aircraft to roll forward ending up inverted. Both occupants suffered only minor injuries but the aircraft was extensively damaged.

12-Jul-20 **Thruster TST Mk1** **G-MVDF** Braintree, Essex

The aircraft experienced an engine failure and all the fields available to the pilot had a mature crop in them. After touchdown, the landing gear caught in the crop and the aircraft turned upside down and came to rest.

20-Jul-20 **Eurofox 912(S)** **G-ETUG** Lempitlaw Airfield, Roxburghshire

The accident occurred on the approach to Runway 22 at Lempitlaw Airfield. The student had allowed the airspeed to decay excessively over the threshold. The instructor took control to execute a go-around but was unable to prevent the left wingtip touching the runway causing damage to the left wing and a gear attachment bolt. The instructor believed that earlier intervention might have prevented the accident.

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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).

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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.

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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

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Air Accidents Investigation Branch