AAIB
Air Accidents Investigation Branch

AAIB Bulletin 7/2018

TO REPORT AN ACCIDENT OR INCIDENT PLEASE CALL OUR 24 HOUR REPORTING LINE

01252 512299

Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
Aldershot
Hants GU11 2HH

Tel: 01252 510300
Fax: 01252 376999
Press enquiries: 0207 944 3118/4292
http://www.aaib.gov.uk

AAIB investigations are conducted in accordance with Annex 13 to the ICAO Convention on International Civil Aviation, EU Regulation No 996/2010 and The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 2018.

The sole objective of the investigation of an accident or incident under these Regulations is the prevention of future accidents and incidents. It is not the purpose of such an investigation to apportion blame or liability.

Accordingly, it is inappropriate that AAIB reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

AAIB Bulletins and Reports are available on the Internet
http://www.aaib.gov.uk

This bulletin contains facts which have been determined up to the time of compilation.

Published 12 July 2018

Cover picture courtesy of Stephen R Lynn
(www.srlynnphotography.co.uk)

ISSN 0309-4278

Published by the Air Accidents Investigation Branch, Department for Transport
Printed in the UK on paper containing at least 75% recycled fibre

CONTENTS

SPECIAL BULLETINS / INTERIM REPORTS

None

SUMMARIES OF AIRCRAFT ACCIDENT ('FORMAL') REPORTS

None

AAIB FIELD INVESTIGATIONS

COMMERCIAL AIR TRANSPORT

FIXED WING

ROTORCRAFT

None

GENERAL AVIATION

FIXED WING

None

ROTORCRAFT

None

SPORT AVIATION / BALLOONS

None

AAIB CORRESPONDENCE INVESTIGATIONS

COMMERCIAL AIR TRANSPORT

GENERAL AVIATION

CONTENTS Cont

AAIB CORRESPONDENCE INVESTIGATIONS Cont

(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Field Investigation Reports

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

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

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

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 747-8R7F, LX-VCF
No & Type of Engines:	4 x GEnx-2B67 turbofan engines
Year of Manufacture:	2012
Date & Time (UTC):	30 March 2017 at 1216 hrs
Location:	En route from Houston to Prestwick
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Extensive fuel contamination of aircraft interior and wiring
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	12,900 hours (of which 9,200 were on type) Last 90 days - 164 hours Last 28 days - 47 hours
Information Source:	AAIB Field Investigation

Synopsis

Following an uneventful scheduled cargo flight, it became apparent after landing that a large quantity of fuel had leaked from a Bell 412EP helicopter which was being shipped as cargo on the main deck of the freighter aircraft. The escaped fuel then made its way through the lower deck and spilled onto the airport apron. Airport Rescue and Fire Fighting Services (RFFS) attended the aircraft to contain the fuel spill and manage the associated risk of fire and explosion.

The investigation determined that the helicopter, which was disassembled and prepared for transportation some months prior to the incident, had not been shipped in accordance with the required provisions for transportation of such vehicles by air. In particular, the helicopter had not been drained of fuel prior to transportation. Approximately 322 litres of fuel escaped from the helicopter during the flight.

One Safety Recommendation is made concerning procedures for the preparation of helicopters for air transportation.

History of the flight

On 30 March 2017, LX-VCF was operating scheduled cargo flight CV7754 from Houston, Texas to Luxembourg with an intermediate stop at Prestwick International Airport, UK. Following an uneventful flight, the aircraft arrived at Prestwick and parked on stand. As the flight crew were shutting down the engines they smelled fuel. When the ground operations agent entered the aircraft via the main deck door to commence unloading operations, he too detected a strong smell of aviation fuel and heard the sound of running liquid. He identified the source as a Bell 412EP helicopter, which was being shipped as cargo on the main deck of the aircraft and noted that fuel appeared to be leaking from a vent on the forward right-hand side of the helicopter. The ground operations agent reported the situation to the flight crew. The Airport Authority and RFFS were notified and the airport emergency response plan was activated. The flight crew shut down the aircraft and opened the escape hatch and upper deck service door to ventilate the aircraft. Upon arrival at the aircraft the RFFS noted that fuel was coming out of the bottom of LX-VCF's fuselage, close to the left body landing gear, having leaked through the main deck, lower deck and avionics bay and was pooling on the apron beneath the aircraft (Figure 1). The aircraft was evacuated, electrically isolated and quarantined by the RFFS. The RFFS subsequently stated that the measured fuel vapour levels indicated a high risk of explosion and that the fuel flammability limits were potentially in range. After the aircraft had been made safe, all cargo, including the helicopter, was offloaded manually.

Figure 1
Fuel exiting lower fuselage of LX-VCF

Examination of the aircraft and helicopter

The aircraft and helicopter were examined on 4 April 2017 by representatives from the aircraft operator, the UK Civil Aviation Authority (CAA), the airport authority, the helicopter owner and the owner's insurer. Based on the initial information available, the AAIB had initiated a Correspondence Investigation and did not attend this examination. However, those who participated in the examination provided information to the investigation and the AAIB subsequently upgraded the investigation to a Field Investigation.

The helicopter was encased in strong white plastic shrink-wrap and had been secured to a cargo pallet for the flight, which occupied three loading positions on the right side of the aircraft's main cargo deck (Figure 2). During the aircraft examination, some fuel was present in the wells of the pallet and the securing straps were soaked with fuel.

Figure 2

Bell 412-EP fuselage, wrapped in shrink-wrap, on main deck of LX-VCF prior to being offloaded at Prestwick

In the area of the helicopter's forward right-hand fuel vent, from which fuel was reported to have leaked, the shrink-wrap had been applied so that the opening of the vent was exposed (Figure 3). White tape had been applied on top of the shrink-wrap in the vicinity of the vent.

Fig 3

Forward right-hand fuel vent on Bell 412-EP helicopter

By comparison, the forward left-hand fuel vent on the opposite side of the helicopter was completely covered in shrink-wrap, so that the vent opening was sealed. White tape had also been applied in this area, but there was no evidence of fuel having leaked from this vent.

The shrink-wrap was removed from the helicopter. No standing fuel was observed inside the shrink-wrap but some oil staining was evident on the inner surface of the wrapping. Some absorbent pads were also found inside the shrink-wrap.

Upon opening the helicopter cabin, it was noted that the helicopter's main battery (which displayed a 'Class 8 (corrosive) hazard' label) was installed in its normal stowage, but was disconnected. A fire extinguisher was secured to a stowage on the cabin floor. A number of cardboard packages containing various items were also found inside the helicopter cabin.

During the examination the helicopter, including all wrapping and the internal packages, was weighed on the pallet and the total pallet weight was noted as 4,200 kg.

The fuel filler cap was removed, allowing access to visually inspect the right upper fuel cell; fuel was present and the level was observed to be approximately half-way up the cell. There was no means to visually inspect the remaining cells.

The helicopter was powered-up and the cockpit fuel quantity indicator indicated a total quantity of fuel on board of 1,440 lb. The helicopter was subsequently refuelled to full, after which the total fuel quantity indicated was 2,160 lb. The fuel bowser meter registered 467 litres. Following refuelling, the helicopter was observed by the onsite team for a period of two hours and the RFFS continued to observe the helicopter overnight. No fuel leaks were observed. The helicopter was subsequently defuelled and shipped to the owner, after which it underwent a '5-year' maintenance inspection. The owner advised that no defects were noted on the fuel system during this inspection which could have accounted for the fuel leak.

Aircraft damage

The interior of LX-VCF had suffered extensive fuel contamination. After the fuel vapours had dispersed, internal floor panels, ceiling panels and sidewall liners in the aircraft were lifted and contaminated insulation blankets were removed. Additionally, all aircraft system electronics, avionics wire looms and harnesses required decontamination.

The aircraft undertook a ferry flight to its home base on 11 April 2017, after which a number of additional actions were required to return it to a fully airworthy condition, including extensive inspections, cleaning and application of corrosion-inhibiting fluid. All insulation blankets and lower deck ceiling liner panels and some elements of the cargo loading system required replacement.

Background information

In December 2016, the helicopter, a Bell 412EP serial number (S/N) 36414 had been sold by Bristow US LLC based in Louisiana, United States (the seller) to Agrarflug Helilift GmbH and Co in Germany (the buyer).

Several agencies and individuals were involved in various aspects of the sale, preparation and transport of the helicopter. In addition to the seller and buyer, these included a sales agent acting as the buyer's representative in the United States (US) and his assistants. Freight forwarding[1] work was carried out by three organisations. A routing agent based in New Zealand was appointed to oversee the export requirements and transportation of the helicopter to Germany. It subsequently sub-contracted this work to a US-based cargo logistics company to act on their behalf in the US, which in turn appointed a US-based shipping agent to prepare the Air Waybill[2] and report on progress.

The helicopter was disassembled and prepared for transportation by the seller's staff at their facility and loose items were loaded into crates. To protect it during transport, the helicopter fuselage was shrink-wrapped by a specialist company contracted by the sales agent. A road transport company then collected the shipment from the seller's facility in Louisiana on 23 January 2017 and transported it by road to Houston Airport.

It was intended that the buyer's sales agent would oversee the disassembly and preparation of the helicopter for transport; however, he was unable to attend and instead sent two assistants to oversee the preparations on his behalf and to ensure that no

Footnote

[1] A freight forwarder, or forwarding agent, is a person or organisation that organises shipments of goods, often contracting with multiple carriers to move the goods. Freight forwarders who handle international shipments typically have additional expertise in preparing and processing customs and other shipping documentation.

[2] The Air Waybill is a document issued by, or on behalf of, the shipper for the air transportation of cargo. It acts as a contract of carriage between the shipper and the carrier(s).

damage occurred to the helicopter. One assistant was present at the seller's facility when the helicopter was shrink-wrapped; however, it had already been disassembled prior to his arrival. A second assistant was present to observe the helicopter shipment being loaded onto the delivery trucks.

Shipping of the helicopter

The shipping agent booked the shipment with the operator's sales department on 23 January 2017, having previously obtained a quotation for shipment from the operator in August 2016. During the quotation and booking process, the shipping agent explicitly indicated in writing that all fuels and batteries had been removed from the helicopter and that the shipment was non-hazardous. The shipping agent issued an Air Waybill for the shipment on 24 January 2017. The final destination for the shipment was Germany, and it was planned to travel by air via Luxembourg to Brussels and then onward by road to Germany.

The shipment, comprising nine loose crates and the helicopter secured to a 20 ft pallet, was delivered to the operator's facility at Houston Airport on 26 January 2017. After checking the documentation and conducting a visual inspection of the exterior of the wrapped helicopter, it was accepted for travel by the Dangerous Goods Manager from the operator's contracted Ground Handling Agent (GHA). The loose crates were built-up on two pallets.

The shipment was subsequently placed on hold by both the US Department of Commerce and US Customs, and was not released for export until 21 March 2017. It remained in the operator's cargo warehouse during this time.

The shipment was booked to travel on flight CV8617 on 24 March 2017; however, the operator was unable to produce a lashing scheme to secure the helicopter due to a software problem and only the nine loose crates travelled on this flight. The helicopter was re-booked to travel on flight CV8617, on 27 March 2017. However, after having been loaded onto flight CV8617 the operator's loading supervisor noticed a small fuel leak from the helicopter. The leak was described as a *'patch/stain of fluid on the ULD under the centre of the helicopter, approximately 6 to 10 inches in diameter'* and was reported to smell like jet fuel. The helicopter was offloaded and returned to the cargo warehouse. The operator's sales department informed the shipping agent and asked it to arrange for an inspection of the helicopter.

On 28 March 2017, a mechanic[3] inspected the helicopter at the operator's cargo facility. Also present was a representative from the shipping agent[4] and one from the operator's sales department. The mechanic, again accompanied by the shipping agent, returned later the same day to re-inspect the helicopter and perform additional work. They were escorted by a GHA agent. Review of CCTV footage from the cargo facility showed that

Footnote

[3] Who was also one of the sales agent's assistants and had witnessed the helicopter being loaded onto the road transportation at the seller's facility.

[4] Who had prepared the Air Waybill.

this inspection lasted approximately 30 minutes. No walkaround was conducted and the mechanic appeared to focus his attention on the lower surface of the helicopter. He did not use any tools or remove the shrink-wrap to facilitate inspection of the helicopter. He used a cleaning spray to clean parts of the exterior surface, inserted absorbent pads between the shrink-wrap and the helicopter skin and applied some white tape over the shrink-wrap. The mechanic and shipping agent informed the cargo operator, and the other agencies involved in the transportation including the cargo logistics company, that the fuel leak had originated from residual fuel in the fuel lines and had been capped off.

On 29 March 2017, the shipping agent provided the cargo operator with a revised Air Waybill and Air Cargo Manifest, together with a Purge Certificate indicating that the helicopter was free from fuel.

The cargo operator accepted the shipment for travel and it was loaded on flight CV7754, which departed Houston on 30 March 2017. The loading supervisor responsible for this flight checked the helicopter several times prior to, during, and after loading and there was no evidence of a fuel leak or spill.

Documentation

The aircraft sales agreement for purchase of the helicopter was signed on 30 December 2016. The supporting documentation which formed part of the sales agreement stated that the helicopter was sold on an *'As is – where is'* basis; that the helicopter was in a non-flyable condition at the time of sale; that the helicopter would be 'delivered' (handed over) at the seller's (Bristow US LLC) facility for shipment at the buyer's (Agrarflug's) expense; that the seller would assist the buyer in disassembly and packaging of the aircraft at the seller's facility, using reasonable packing practices; and, that the buyer's representatives would be on hand to supervise and accept the packaging.

A US Department of Commerce Shipper's Export Declaration prepared by the cargo logistics company, stated that no hazardous materials were being exported. This document was signed by a Bristow US LLC employee on 23 January 2017, authorising the cargo logistics company to act as a forwarding agent for export control and customs purposes for the export of the helicopter.

The original Air Waybill, issued by the shipping agent on 24 January 2017, described the helicopter as *'Civil Model B412EP Helicopter (Helicopter main cabin)'* and declared the shipment as: *'Consolidated cargo[5] as per attached manifest',* which was also reflected on the original Air Cargo Manifest issued on 29 January 2017. Both the Air Waybill and the Air Cargo Manifest listed the cargo logistics company as the shipper. An Air Waybill requires two signatures, one from the *'Shipper or his agent'* and one from the *'Issuing carrier or its agent'*. The original Air Waybill had a single signature across both fields.

Footnote

5 Consolidated cargo refers to a consignment comprising of multiple packages, originating from more than one person, and shipped under one Air Waybill.

Following inspection of the helicopter in Houston, a new Air Waybill and Air Cargo Manifest were issued by the shipping agent with the following statement added: *'Not restricted as per special provisions A70.'* The revised Air Waybill was not signed. Additionally, a Purge Certificate dated 29 March 2017, produced by Agrarflug and signed by its Director of Maintenance, was provided to the cargo operator. This stated that the helicopter had been:

> *'flushed, purged of all fluids and is clean and dry. Inhibiting fluid in accordance with (IATA) International Air Transportation Associated* [sic] *and is NOT considered as DANGEROUS GOODS.'*

The load sheet for flight CV7754/30 March 2017 on which the helicopter travelled stated that the weight of the helicopter pallet was 4,455 kg. The Notification to Captain (NOTOC[6]) document for flight CV7754/230 March 2017 did not include any reference to the helicopter shipment.

Additional information

Bristow US LLC advised that, under the terms of the sales agreement, the buyer had complete responsibility for inspecting and transporting the helicopter.

Agrarflug advised that it understood that the seller was responsible for preparing the helicopter for transport. It provided an email from the seller written in December 2016 which stated that *'the aircraft will be prepared for shipping on 09 Jan.'* Other email correspondence from the buyer indicated that its representatives would oversee preparations of the helicopter for movement to Germany.

The buyer's sales agent confirmed that neither he nor his assistants had performed any work to disassemble, clean, drain, or package the helicopter and were not present when it was disassembled for transport. Additionally, he stated that he had no reason to suspect that the helicopter was fuelled as the Shipper's Export Declaration provided to him by the seller indicated that no hazardous materials were being exported. Furthermore, based on his previous experience, he was aware that Bristow US LLC usually drained all fuel from helicopters it sold.

A representative from the company who shrink-wrapped the helicopter advised that an open-flame torch was used to shrink the plastic wrap and stated that they would not have wrapped the helicopter if they had known it was fuelled.

Representatives from both the cargo logistics company and the shipping agent reported that they were not aware that there was fuel or other dangerous good onboard the helicopter, when making arrangements for its transport or producing the Air Waybill. They based this understanding on the Shipper's Export Declaration which indicated that no hazardous materials were being exported.

Footnote

6 The NOTOC is a form which is used to notify the commander of an aircraft when dangerous goods are to be loaded on the aircraft board their flights. The NOTOC describes the nature, quantity of the dangerous goods and the location where it is loaded on the aircraft.

The mechanic who inspected the helicopter in the cargo warehouse in Houston informed the investigation that he had not seen any active dripping of fuel, just fuel residue. He concluded that escape of fuel was due to residual fuel in a fuel line that had been released when the helicopter was moved. He stated that the drip appeared to have come from the right side of the helicopter in the area of the fuel booster pump.

In email correspondence relating to the fuel leak and subsequent inspection of the helicopter in Houston, the cargo logistics company indicated that if the mechanic could remove all the residual fuel, it might still be possible to ship the helicopter as non-hazardous cargo, but that a purge letter would be required from the shipper on company letterhead to verify this. The routing agent indicated that he did not believe the seller would provide this and instead asked Agrarflug to provide this.

An email sent by the mechanic on 28 March 2017 following his inspection of the helicopter stated that *'there was a minimal amount of residual fuel which had collected in the left-hand sump area and was seeping out of the drain'*. He also indicated in the email that he had cleaned up the escaped fuel and placed approximately 50 absorbent pads between the fuselage and the shrink-wrap to absorb any additional fuel which might move to the sump area when the aircraft was moved.

The buyer's Director of Maintenance informed the investigation that he had issued the Purge Certificate stating that the helicopter had been flushed and purged of all fluids, following confirmation from the mechanic that the fuel leak in Houston was caused by residual fuel in the fuel lines.

Shipping of dangerous goods by air

ICAO Annex 18 to the Chicago Convention describes the international standards and recommended practices relating to the 'Safe transport of dangerous goods by air'. It requires that dangerous goods are carried in accordance with ICAO document 9284 '*Technical instructions for the safe transport of dangerous goods by air*' (known as the "Technical Instructions"), which contains requirements for the classification, preparation, packaging, documentation and transportation by air of dangerous goods. The International Air Transport Association (IATA) publishes the Dangerous Goods Regulations (DGR), a field manual which describes the requirements of the ICAO Technical Instructions, along with additional explanatory material. It is widely used by IATA member airlines and shippers and, is recognised as the industry standard guidance on the transportation of dangerous goods by air. The 58th edition of the DGR, effective 1 January 2017, was valid at the time the helicopter was packaged and transported. Air transportation of a vehicle, such as the helicopter, falls into the category of *'UN3166 Vehicle, flammable - liquid powered'* and is considered as Class 9 Dangerous Goods. Shipment by air would require compliance with stringent requirements for preparation, packaging and labelling of the helicopter to identify it as dangerous goods. However, the DGR contained Special Provision A70 relating to the transport of engines and vehicles, which states:

> *'A70 Internal combustion or fuel cell engines of machinery, being shipped either separately or incorporated into a vehicle, machine or other apparatus, without batteries or other dangerous goods, are not subject to these Regulations when carried as cargo, provided that:*
>
> *(a) For flammable liquid powered engines:*
>
> *1. The engine is powered by a fuel that does not meet the classification criteria for any class or division; or*
>
> *2. The fuel tank of the vehicle, machine or other apparatus has never contained any fuel, or the fuel tank has been flushed and purged of vapours and adequate measures taken to nullify the hazard; and*
>
> *3. The entire fuel system of the engine has no free liquid and all fuel lines are sealed or capped or securely connected to the engine and vehicle, machinery or apparatus.*
>
> *……*
>
> *When this special provision is used, the words "Not Restricted" and the Special provision number must be included in the description of the substance on the Air Waybill as required by 8.2.6., when an Air Waybill is issued.'*

The DGR defines the shipper's responsibilities when offering a consignment of dangerous goods for air transportation. Section 1.3.2 *'Specific Responsibilities'* states:

> *' ….*
>
> *(b) the shipper must ensure that the articles or substances are not prohibited for transport by air*
>
> *(c) the articles or substances must be properly identified, classified, packed, marked, labelled, documented and be in the condition for transport in accordance with these Regulations.'*

Helicopter transportation guidance

Bell Helicopter publish transportation guidance for the 412-series helicopter in a document entitled '*M412 Transportation Guide*'. It describes the actions taken by Bell when a helicopter is prepared for shipping from its manufacturing facility. In the list of components removed for shipping, it recommends that fuel is drained from the helicopter. Agrarflug indicated that it believed the helicopter had been prepared for transportation in accordance with this guidance.

Operator's procedures

The operator's Ground Operations Manual states the following with respect to accepting shipments:

> *'Reasonable measures (e.g. physical check of documentation and/or packages) shall be taken to avoid the transportation of hidden dangerous goods; confirmation shall be obtained from the shipper/forwarder about the contents of any consignment whenever there is any suspicion that it may contain dangerous goods.'*

It also states:

> *'Vehicles including cars, motorcycles, helicopters etc. shall be booked as dangerous goods, unless they are shipped under Special provision A70 and do not contain any hazardous equipment such as a battery, fire extinguisher, tire-inflation canister, safety device, etc. and completely empty of residual fuel. This means that they must be completely drained, sufficiently cleared of residue and purged of vapors* [sic] *to remove/nullify potential hazard.'*

The operator's procedures included a Helicopter Acceptance Checklist to be used when an unpackaged helicopter was booked as dangerous goods however, it was not required to be used if a helicopter was shipped under Special Provision A70.

Operator's safety investigation

The cargo operator's safety department conducted an internal safety investigation. It identified a number of issues relating to recurrent training of its staff; however, both the loading supervisors and the GHA DG Manager involved in the shipping of the helicopter held valid dangerous goods licenses.

The operator also identified some issues with adherence to its internal emergency notification and response procedures, and the reporting of occurrences pertaining to damaged or leaking dangerous goods to its safety department.

Following this event, the operator made a number of revisions to its procedures and made safety recommendations to various areas of its business. This including recommending that its contracted GHA take steps to raise awareness among its staff about the possibility of dangerous goods in general cargo and to improve methods for detecting of undeclared dangerous goods.

Bell 412EP fuel system description

General

The Bell 412EP helicopter is fuelled by Jet A1 fuel and, in its standard configuration, has a total fuel capacity of 337.5 US Gallons (USG)/1,277.58 litres. Fuel is stored in ten interconnected lightweight cells made from a laminated fabric and rubber construction.

There are six cells below the cabin floor; three on each side, and four cells located below the engine compartments aft of the cabin and pylon (Figure 4). The helicopter is fuelled through a filler cap in the upper right cell, located on the right side of the aft fuselage. Fuel gravity-feeds from the upper cells into lower cells through interconnecting fuel lines.

The helicopter being transported in LX-VCF had been modified to add a single rigid auxiliary fuel tank on the left side of the aft cabin, which had a capacity of 81.7 USG (309 litres), giving a total fuel capacity of 419.2 USG (1,587 litres). The auxiliary tank was installed by Bristow US LLC, in accordance with Bell Helicopter's Service Instruction BHT-412-SI-4 *'Bell Model 412 Service Instruction for Auxiliary Fuel Kit'.*

The fuel system includes a number of fuel transfer, boost and ejector pumps located in the lower fuel cells. Each of the six lower cells has a spring-loaded, poppet-type sump drain valve; those in the lower main cells can be opened by either electrical or manual actuation, while those in other lower cells are manually operated, push-to-drain valves. Defuelling valves located in the sump areas of the lower main cells require removal of a plug and insertion of a standard fitting to open the spring-loaded poppet and operate the valve.

To enable fuel transfer, an interconnect system, shown by the pink lines in Figure 4, joins the lower cells together. Each lower forward and lower middle cell is permanently connected to its opposite side cell via the interconnect lines and fuel can pass freely from the left to right side and vice versa. The combined capacity of the two lower forward cells is approximately 48.5 USG (183.6 litres) and the combined capacity of the two lower middle cells is approximately 32 USG (121.1 litres).

At fuel loads above approximately 1,663 lb, all six lower cells would be full.

Fuel vent system

The fuel vent system is shown by blue lines in Figure 4. A collective vent on top of upper aft centre cell connects the four upper cell vent spaces with two vertical lines which vent overboard beneath the fuselage. Each lower main cell vents through a line connecting into the upper forward centre cell.

A forward vent line on each side of the fuselage connects with the respective lower forward and lower middle cells. These lines rise through the helicopter doorposts to a waterline above the upper cells and then double back downward to vent overboard beneath the fuselage.

AAIB investigation

The US Federal Aviation Administration (FAA) Hazardous Materials Safety Division were notified of this event and initiated its own separate investigation to explore the issues relating to undeclared and leaking dangerous goods. The FAA interviewed many of the individuals and organisations involved in preparing the helicopter for transportation and issuing the associated shipping documentation. Details from these interviews were shared with the AAIB; however, not all the individuals and organisations engaged directly with the AAIB safety investigation. The AAIB was therefore limited in its ability to explore more fully some of the issues relating to this event.

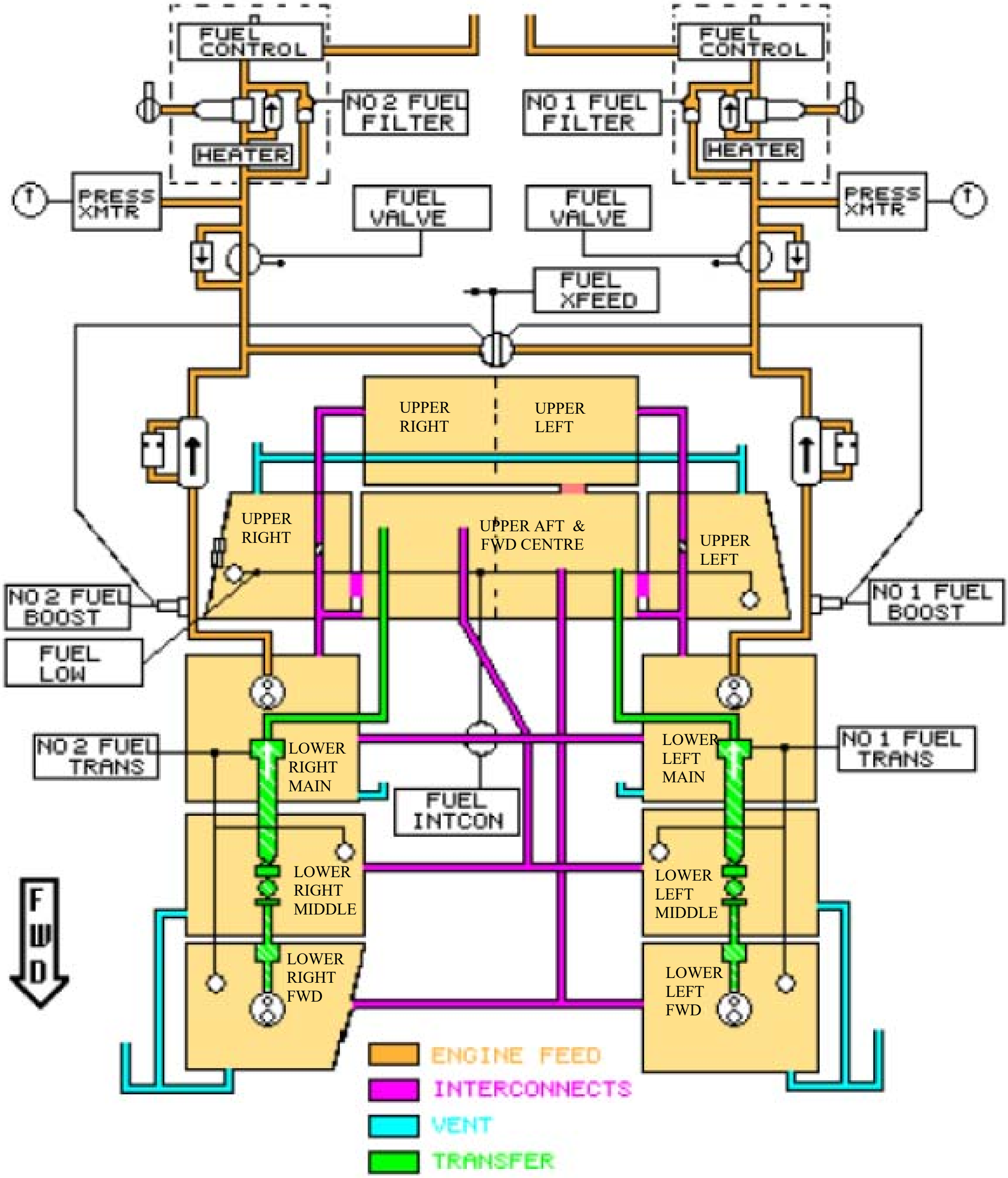

Figure 4

Bell 412EP Simplified fuel system schematic (Note: auxiliary tank not shown)

Discussion

General

The escape of fuel from the helicopter represented a substantial hazard to the safety of the aircraft, the flight crew and those on the ground at Prestwick Airport. The airport RFFS advised that the measured fuel vapour levels within the aircraft indicated a high risk of explosion and that the fuel flammability limits were potentially in range. Additionally, photographs show that fuel was exiting the aircraft close to the left body landing gear and pooling beneath the aircraft. The presence of fuel in proximity to potentially hot wheel brakes created a substantial risk of fire.

Preparation and packaging of the helicopter for transport

Correspondence and documentation relating to the sale of the helicopter indicated that the seller would assist the buyer in disassembly and preparation of the helicopter for transportation, under the supervision of the buyer's representatives. The buyer believed that these preparations would include defuelling of the helicopter. The seller considered that all transportation matters were the responsibility of the buyer, but was aware of the intention for the helicopter to be transported as air cargo.

Notwithstanding the issue of where the contractual commitment for preparation and defuelling of the helicopter lay, the disassembly of the helicopter and preparations for its transport took place at the seller's facility and were conducted by its staff, despite a substantial amount of fuel remaining on the helicopter. The buyer assumed that the helicopter would be prepared in accordance with guidance published by the helicopter manufacturer, which recommends defuelling as part of the preparations for transportation. The preparations also included packaging of the helicopter using an open flame, which would have represented a significant health and safety risk to those involved. Neither the seller's staff undertaking the disassembly, nor the buyer's representatives who were subsequently in attendance, identified the fact that a substantial amount of fuel remained onboard the helicopter prior to it being packaged and transported.

The following Safety Recommendation is therefore made:

Safety Recommendation 2018-011

It is recommended that Bristow US LLC review their procedures relating to the preparation of helicopters for air transportation to ensure that they are defuelled.

Shipping and shipping documentation

The Shipper's Export Declaration for the helicopter indicated that no hazardous materials were being exported. This document formed the basis upon which other transportation documentation was raised. However, it did not accurately reflect the presence of fuel on board the helicopter, nor the battery and fire extinguisher within the helicopter cabin, which also required identification as dangerous goods.

Special Provision A70 of the IATA Dangerous Goods Regulations allows vehicles such as the helicopter to be transported by air without being declared as dangerous goods, providing batteries or other dangerous goods are removed, that the fuel tank and fuel system has been flushed and purged of all fuel and fuel vapours and that the statement *'Not restricted as per special provision A70'* is included on the Air Waybill. When using this provision, it is the shipper's responsibility to ensure that the shipment complies with these requirements.

Email correspondence between the shipping agent and the cargo operator during the booking process specifically stated that all fuels and batteries had been removed and that the shipment was non-hazardous. However, although the paperwork generated for transportation and export of the helicopter indicated that the shipment was non-hazardous consolidated cargo, there were a number of anomalies with the shipping documentation. The original Air Waybill neither declared the shipment as dangerous goods, nor referenced the exemptions of Special Provision A70, and was therefore not in compliance with either the DGR or the operator's own acceptance procedures. Additionally, neither the original nor the revised Air Waybill contained the required signatures. The operator's GHA acceptance staff indicated that the decision to accept the shipment was influenced in part by the description of the helicopter as *'Civil Model B412EP Helicopter Main Cabin'* on the Air Cargo Manifest and the assumption that only the frame of the helicopter was being shipped.

Although the revised shipping documentation subsequently indicated the helicopter was being shipped as unrestricted cargo under the provisions of Special Provision A70, it did not reflect the actual condition of the helicopter and the shipment was not in compliance with the requirements of the Special Provision. As such, the helicopter was shipped as non-declared dangerous goods and this hazard was not identified to the operator, nor the flight crew of flight CV7754.

Proper declaration and documentation of dangerous goods by a shipper ensures that all parties involved in the transportation chain know what type of goods they are transporting, how to load and handle them and what steps to take in the event of an incident such as a leakage. Three entities were involved in organising the shipping logistics and documentation for the helicopter. The routing agent took a coordinating role, having sub-contracted responsibility for the export and transportation of the helicopter to the cargo logistics company. As the designated shipper named on the Air Waybill, the legal contract of carriage by air was between the cargo logistics company and the operator. The DGR identify that it is the shipper's responsibility to ensure articles are properly identified, classified, packed, marked, labelled and documented. However, the cargo logistics company further delegated responsibility for production of the shipping documentation to the shipping agent and the documentation did not fully comply with the DGR, nor did it reflect the actual state of the helicopter. The dilution of responsibility among the various individuals and organisations involved in the shipping of the helicopter meant that no single organisation or individual was able to assure that the shipping documentation reflected the actual condition of the helicopter.

The investigation did not determine whether this was indicative of a wider issue within the air freight industry, however the cargo operator indicated its belief that it was. Due to the limitations of the AAIB investigation there was not considered to be sufficient evidence to make a formal Safety Recommendation on this subject. However, this report has been shared with the IATA Dangerous Goods Board[7] for its consideration.

Footnote

[7] The IATA Dangerous Goods Board reviews and determines standards and procedures necessary for the safe carriage of dangerous goods by air, and promotes the worldwide recognition, adoption of and adherence to those standards and procedures. It works closely with the ICAO Dangerous Goods Panel, which sets the international requirements for transportation of dangerous goods by air and is responsible for reviewing proposed revisions to ICAO document 9284.

Opportunity to detect the presence of Dangerous Goods in Houston

A small fuel leak observed while the helicopter was being loaded onto an aircraft for planned travel on 27 March 2017 resulted in the shipment being offloaded and returned to the cargo warehouse. This fuel leak, and the subsequent inspection of the helicopter by a mechanic and shipping agent, presented an opportunity to detect that the helicopter had not been defueled prior to transport. However, CCTV footage of the inspection shows that while the mechanic cleaned fuel residue from the shrink-wrap coating and inserted absorbent pads, he took no steps to determine the actual fuel state of the helicopter during the inspection. Despite this, the mechanic subsequently confirmed that the source of leak was residual fuel in the fuel lines and this information was communicated to the cargo operator and to the other agencies involved in the transportation of the helicopter. Based on this information, and at the request of the routing agent, Agrarflug issued a Purge Certificate, expressly stating that the helicopter had been purged of all fluids and was not considered as dangerous goods, despite not having been able to verify the actual condition of the helicopter. The Air Waybill and Air Cargo Manifest were updated accordingly and these three documents were presented to the operator. The operator did not question the fact that the Purge Certificate had been issued by the buyer in Germany, as it is not a mandatory document for items shipped under Special Provision A70. With no expectation that dangerous goods were a factor in the transportation of the helicopter, and having taken steps to address the source of the fuel leak from the helicopter, the operator accepted the helicopter for transport on its aircraft.

Escape of fuel during the flight

During the post-incident inspection at Prestwick, the helicopter battery was observed to be disconnected; therefore, none of the helicopter fuel pumps could have operated during the incident flight. The investigation considered that possible routes for fuel to escape from the helicopter could have included: via the sump drain valves, defuelling valves, the fuel vent lines or a loose connection in a fuel system interconnect line.

With the exception of the small fuel leak noticed on 27 March 2017, no fuel was observed to escape from the helicopter during the two-month period it was stored in the cargo warehouse in Houston. Nor did any fuel escape from the helicopter after refuelling in Prestwick following the incident. Furthermore, a subsequent maintenance inspection at the new owner's facility, did not reveal any defects with the fuel system which could have accounted for the fuel leak. It was therefore considered unlikely that a loose connection in a fuel line or a partially-open or stuck sump drain/defuelling valve could have contributed to the fuel escape during the flight.

When the aircraft arrived in Prestwick, the ground operations agent who first entered the aircraft observed that fuel appeared to be escaping via a vent tube on the forward right-hand side of the helicopter. Subsequent inspection of the helicopter identified that the shrink-wrap in which the helicopter had been encased had been applied such that the opening in the forward right-hand fuel vent tube was exposed, while that on the forward left-hand vent was completely sealed.

The forward vent lines serve the lower forward and lower middle cells on each side of the helicopter. Although the left and right side vent lines are not connected, each lower forward

and lower middle cell is permanently connected to its opposite side cell via the interconnect lines and fuel can pass freely from the left to right side and vice versa. The manner in which the helicopter was shrink-wrapped created a seal over the forward left vent tube; this may have prevented the pressure within the four forward fuel cells from equalising in response to aircraft cabin pressure changes during the descent into Prestwick. In the absence of any other defects which could account for the escape of fuel, the investigation considered that this wrapping of the vents may have induced a siphon-like effect, or caused the flexible fuel cells to temporarily deform, as the aircraft's cabin pressure equalised during the descent to land at Prestwick, causing fuel to be ejected via the forward right-hand vent tube.
The aircraft operator reviewed the aircraft's pressurisation profile for the incident flight and compared it with a number of flights by the same aircraft on the same route. There was nothing unusual about the pressurisation profile on the incident flight.

The helicopter manufacturer checked its occurrence database and did not find any reports of customers reporting fuel exiting out of the forward fuel vent tubes. The manufacturer commented that there is a fuel/air separator within the forward fuel vent system which is intended to allow fuel vapours to escape to the overboard vent, while any liquid fuel should drain back into the relevant fuel cell by gravity. However, the circumstances of this fuel leak are somewhat unique, and it is highly unlikely that the behaviour of the helicopter fuel system in such circumstances would have been previously considered or predicted.

The precise fuel state of the helicopter prior to its shipment by air is not known however, the post-incident weight of the helicopter pallet was some 255 kg lighter than that noted on the label attached to the pallet and the load sheet for flight CV7754. The scales used to weigh the pallet in Houston and Prestwick were both within calibration requirements. It is therefore concluded that approximately 255 kg of fuel had escaped from the helicopter during the flight, which equates to approximately 322 litres[8] of fuel.

Only the upper right fuel cell can be visually inspected on the Bell 412EP and during the post-incident inspection in Prestwick this cell was observed to be approximately half full. The fuel distribution within the remaining cells was not determined. The total indicated fuel quantity was noted as 1,440 lb, symmetrically distributed between the left and right cells. When the helicopter was refuelled, 467 litres were required to reach the fully fuelled condition. Given the helicopter's total fuel capacity of 1,587 litres, the post-incident volume of fuel was determined to have been 1,120 litres. Taking into account the approximate 322 litres which escaped, the fuel state prior to transportation of the helicopter was calculated to have been approximately 1,442 litres. At this fuel state, all the lower fuel cells would have been full.

The combined capacity of the lower forward and lower middle tanks, served by the forward vent lines, is approximately 304.7 litres, which is broadly equivalent to the quantity of fuel calculated to have escaped during the flight.

Footnote

8 Converting a weight of fuel to a volume of fuel requires the specific gravity of the fuel to be known. The specific gravity of fuel varies with temperature and can be influenced by a number of other factors. The specific gravity of Jet A1 fuel is typically 0.79 at 15°C, but can range from 0.77 to 0.83. The specific gravity of the fuel on the helicopter is not known however a specific gravity of 0.79 has been used for illustrative purposes.

Conclusions

Regardless of the exact mechanism by which the fuel escaped from the helicopter, the IATA Dangerous Goods Regulations exist to prevent the transportation of hazardous cargo representing a hazard to the safety of an aircraft. Adequate steps were not taken to correctly prepare the helicopter for transport and this situation was not identified prior to it being offered for transportation by air. The investigation identified that the dilution of responsibility among the various individuals and agencies involved meant that no one agency or individual could assure that the shipping documentation reflected the actual condition of the helicopter and was in compliance with the DGR. An inspection of the helicopter prior to travel was superficial in nature and, although no attempt was made to verify the actual fuel state of the helicopter, incorrectly concluded that the helicopter had been defuelled.

This resulted in the helicopter shipment being identified as unrestricted cargo, despite containing non-declared dangerous goods. The fuel hazard was not identified to the operator or the commander of the flight on which the helicopter travelled, and they were therefore unaware of the risk it posed. The escape of fuel from the helicopter during the flight represented a substantial hazard to the safety of the aircraft, the flight crew and those on the ground at Prestwick Airport. The containment actions taken by the RFFS at Prestwick Airport substantially reduced the possibility of a more adverse outcome.

One Safety Recommendation is made concerning procedures for the preparation of helicopters for air transportation.

> In addition, the operator has made a number of revisions to its procedures. It has also recommended that its contracted GHA take steps to raise awareness among its staff about the possibility of dangerous goods in general cargo and to improve methods for detecting of undeclared dangerous goods.

Bulletin Corrections

Following publication of the report the following two corrections were made.

Page 11:

The first sentence of the section titled '*Shipping of dangerous goods by air*' has been deleted and replaced to provide additional clarification.

Page 17:

Footnote 7 has been amended to provide additional clarification.

Further information regarding these corrections can be found on the AAIB website - https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-747-8r7f-lx-vcf and will be published in Bulletin 10/2018.

The online version of the report was amended on 15 August 2018.

Serious Incident

Aircraft Type and Registration:	Boeing 787-9 Dreamliner, G-ZBKF
No & Type of Engines:	2 Rolls-Royce Trent 1000-J2 turbofan engines
Year of Manufacture:	2016 (Serial no: 38622)
Date & Time (UTC):	29 April 2017 at 1040 hrs
Location:	En route from London Heathrow to New Delhi airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 13 Passengers - 124
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	14,200 hours (of which 1,238 were on type) Last 90 days - 175 hours Last 28 days – 48 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was on a scheduled flight from London Heathrow to New Delhi, India. The aircraft was dispatched in accordance with the Minimum Equipment List (MEL) with the left air conditioning (AC) system disabled. Shortly after reaching FL350 the crew were alerted by EICAS that the cabin altitude was increasing above normal, triggered at 8,500 feet. With no additional Environmental control system (ECS) actions available to control cabin altitude, the flight crew initiated a descent. During this descent the cabin altitude exceeded 10,000 ft and the crew completed the relevant emergency actions.

The loss of cabin pressurisation was caused by detachment of the lower right air conditioning recirculation fan duct on a sector where the left air conditioning system had been disabled before flight. As a consequence of this finding, the Aircraft Maintenance Manual has been amended to alter the process of replacing the relevant recirculation fan and maintenance procedures to react to a related Maintenance Alert Message have been altered.

The investigation also identified a software problem related to the volume of the cabin decompression pre-recorded announcement (PRA) in the passenger cabin which is being addressed by the Operator's safety action. Three Safety Recommendations are made concerning the testing of the installed performance of CVR systems.

History of the flight

Flight crew

The aircraft was scheduled to operate from London Heathrow to New Delhi, India. The aircraft flight crew, which consisted of three pilots, reported as normal at 0755 hrs for a scheduled departure time of 0925 hrs. The sector was planned under Extended-range Twin-engine Operational Performance Standards (ETOPS) rules and, due to the forecast of thunderstorms near Delhi, additional 'holding' fuel was added to the flight plan.

When the flight crew boarded the aircraft, they noted that the aircraft's electronic technical log reflected that the left AC system had been disabled, in accordance with the MEL. This was because the left No 2 (L2) CAC (Cabin Air Compressor) shaft had failed, which had subsequently damaged the left No 1 (L1) CAC. As a result of this unserviceability the aircraft no longer qualified for ETOPS[1] and a new flight plan was requested, with a maximum altitude limit of FL350 to enable the overhead crew rest areas to be used during the flight. The amended flight plan meant an additional two tonnes of fuel was added.

The aircraft took off at 1007 hrs and the climb was largely uneventful, although the crew noted a higher than usual temperature and lower than normal airflow in the cockpit. As the aircraft climbed through FL200 the third pilot left the cockpit for the flight crew rest area.

At 1032 hrs the aircraft levelled off at the planned cruise level of FL350. Two minutes later, the 'CABIN ALTITUDE PRESSURE BLOCK' was automatically[2] displayed on the EICAS display. The crew immediately responded, confirming that the cabin altitude was increasing at a rate of about 300 fpm and that both outflow valves were indicating closed. The crew then selected the 'SYSTEM STATUS' page and noted that the 'RECIRC FAN LWR R' status message was displayed.

The crew discussed remedial options and initially requested a descent to FL310 to see whether the cabin altitude would stabilise. They began a descent in flight level change (FLCH) mode, at idle power. However, the cabin altitude continued to increase and the commander asked the co-pilot to speak to the cabin service director (CSD) on the interphone, to brief her on the situation and request that the cabin service be stopped. The co-pilot initially called the first-class cabin but the CSD was not there so he spoke with another member of the cabin crew, whom he advised to stop the cabin service. The co-pilot then called the interphone in the next cabin, to locate the CSD.

As the aircraft descended through FL330, the commander advised the co-pilot that the cabin altitude was still increasing and he would be declaring a PAN, requesting a further descent. Just as the commander transmitted the PAN, the cabin altitude reached 10,000 ft and the EICAS cabin altitude warning activated. This coincided with the co-pilot speaking to the CSD, whom he advised to stop the cabin service and ensure passengers and crew were

Footnote

1 The MEL requires that the aircraft remain within 60 minutes of landing at an airfield.

2 The cabin altitude pressure block is automatically displayed on EICAS when the cabin altitude reaches 8,500 ft. It contains system information and graphics pertaining to cabin altitude, cabin altitude rate, differential pressure, landing altitude, and outflow valve position.

seated near an oxygen mask. The CSD replied, stating "ON OXYGEN MASKS OKAY", to which the co-pilot responded "NO NOT ON OXYGEN, NOT ON OXYGEN, JUST BY YOUR SEATS WITH THEM", before ending the call to don his oxygen mask. In the meantime, the commander had donned his oxygen mask. The crew completed the QRH memory items, with the cabin oxygen system being manually deployed.

Having established communications with each other, the crew declared a MAYDAY and made a rapid descent to FL100 with speedbrakes deployed. The aircraft was approximately 25 nm east of Brussels, Belgium. As the aircraft descended through FL258 the cabin altitude reached a maximum value of 10,429 ft before starting to reduce. During the descent the CSD, wearing a portable oxygen system, entered the cockpit.

After levelling at FL100, and having confirmed that the cabin altitude was at 7,000 ft and reducing, the crew removed their oxygen masks and completed the QRH checklist for 'Excessive Cabin Altitude'. The commander then asked the CSD to advise the third pilot, who had remained in the flight crew rest area on a fixed 'drop down' oxygen mask, that he could return to the cockpit and that the cabin crew and passengers could remove their oxygen masks if required.

The cabin altitude continued to reduce to about 3,700 ft, where it stabilised. Having evaluated the status of the aircraft, the crew decided to return to Heathrow. Before the CSD returned to the cabin, the commander gave her a briefing on the plan to return.

Whilst en route, approximately four tonnes of fuel was jettisoned to reduce the aircraft weight below the Maximum Landing Weight (MLW). The approach and landing at Heathrow were uneventful and the aircraft was taxied to the terminal where the passengers disembarked normally.

Cabin crew

From a cabin crew perspective, the flight progressed normally up to cruise altitude, other than that the CSD reported that she was feeling a little unwell. At cruise altitude a normal cabin service was underway. The cabin crew in the first-class cabin recalled receiving an interphone call from the co-pilot and the request to stop the cabin service and return to their seats. However, before this message could be passed on to the other cabin crew, the cabin oxygen masks deployed. The deployment of the oxygen masks is accompanied by a PRA that advises of the emergency over the cabin loudspeakers, and contains instructions to don the oxygen masks. However, while the PRA was triggered in the cabin, its volume over the speakers was so low that the content of the message could not be heard above the background cabin noise.

As a result of not hearing the PRA, and in the absence of any other serious indications of depressurisation, the cabin crew were confused as to what was happening. Many thought the oxygen masks had deployed inadvertently, possibly because of turbulence. The cabin crew did not follow their depressurisation actions but returned their cabin service carts to the galleys and took their seats there.

The passengers appeared unaware of the emergency. Some remained asleep and many did not fit their oxygen masks. Of those that did fit the masks, some fitted them incorrectly. As the cabin crews' awareness of the situation developed, they began shouting instructions to the passengers to fit their oxygen masks.

Due to the uncertainty of the situation, the CSD took a portable oxygen system and went to the cockpit to ascertain what was happening. During this period several of the cabin crew also used portable oxygen systems. Several of them reported that the systems were difficult to extract from their stowage locations and to use due to the "cumbersome" oxygen bottle. They also found it difficult to tell whether the portable oxygen systems were working.

During the return to Heathrow several of the cabin crew and passengers reported feeling unwell, although none required medical attention.

Planned Route

Figure 1

Planned route, BA143 London-Delhi 29 April 2017

Recorded information

Sources of recorded information

The aircraft was equipped with two Enhanced Airborne Flight Recorders (EAFR), one installed at the front of the aircraft and the other at the rear. The EAFR is a multifunction recorder that records 25 hours of FDR data and 120 minutes of CVR audio into a crash-protected solid-state memory.

The CVR audio record for the flight commenced at 1016 hrs, when the aircraft was climbing through FL110, and ended after the aircraft had landed. Flight data was available for the entire incident flight. Both EAFRs record the same flight data, with just over 2,200 parameters available. Parameters of significance included cabin altitude, status of cabin oxygen mask deployment, EICAS and system status display information and the speed of the air conditioning recirculation fans. System fault log information was also available from the aircraft's Central Maintenance Computing Function (CMCF) and the Aircraft Health Monitoring (AHM) ground-based software service.

Recorded data

Figure 2 shows pertinent parameters recorded during the incident. The data shown is for the period just before the aircraft reaches FL350, to shortly after the aircraft descended to FL100. Additional information not included in the earlier section 'History of the flight' is included below.

The Boeing 787 AHM is a ground-based software service that collects, analyses and presents aircraft-generated data to operators to assist them in determining current and future serviceability of their aircraft. Information, which includes 'low level' faults that do not require crew action, are presented to the crew as status messages by on-board systems. When a status message is triggered, the crew are made aware on the EICAS, which displays the word 'STATUS' in blue text. Selection of the system status page 'SYS' presents the associated message on the Multifunction Display (MFD).

At 1029:54 hrs, as the aircraft was climbing through FL320, the air conditioning lower right recirculation fan stopped. The cabin altitude was 7,000 ft at this time and at 1033 hrs system status message 'RECIRC FAN LWR R' was triggered by the CMCF. This message was subsequently referred to by the crew about a minute later, after they had been alerted to the abnormal cabin pressure on EICAS.

The aircraft manufacturer later reviewed the 'RECIRC FAN LWR R' status message and its associated fault code '1031 Motor Driver Current Fault'. The manufacturer stated that the fan shut down, after which the air conditioning system attempted to restart it. After three consecutive failed attempts to restart, the status message 'RECIRC FAN LWR R' is triggered. This is a latched fault that cannot be cleared in flight. The aircraft manufacturer stated that the fault with the fan was most likely associated with it having become detached from the inner duct.

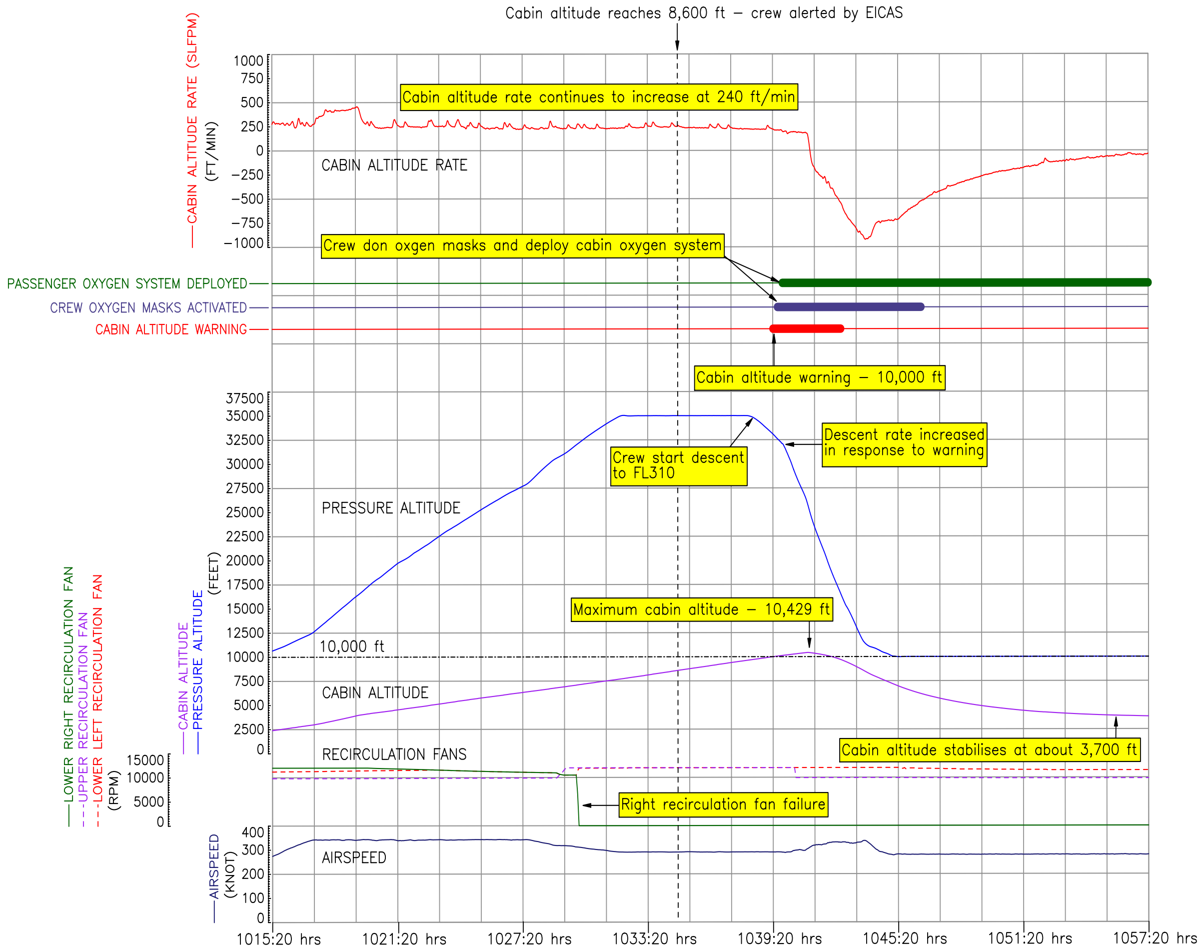

Figure 2

Descent from FL350 following cabin altitude warning

Aircraft information

Cabin pressurisation system

The cabin pressurisation system fitted to the Boeing 787 is different from earlier aircraft types, in that it does not utilise air bleeds from the engine compressors but is equipped with electrically driven centrifugal impellers, known as cabin air compressors (CACs). Four CACs are fitted, with two CACs (referred to as L1 and L2) providing compressed air to the left air conditioning unit and two CACs (R1 and R2) to the right air conditioning unit. The left and right air conditioning units can each function with only one CAC per side operating.

The system includes two recirculation fans, one each in the left and right air conditioning units. These fans are referred to as the 'left lower' and 'right lower' recirculation fans respectively. The main air conditioning unit components, including the left and right lower recirculation fans, are positioned in non-pressurised areas within the lower fuselage, just forward of the wing box structure.

The left and right lower recirculation fans are each connected by ducts to their respective left and right heat exchangers. The fan assemblies are connected to the ducts at both ends by sleeved couplings and these ducts are connected to the rest of the system by conventional 'V-band' clamps (Figure 3). Access to the right recirculation fan is more restricted, compared to the left fan, due to the left and right air conditioning systems being geometrically similar, rather than 'handed'. The right unit thus requires reaching through an extensive system of ducting and components to effect fan installation and removal.

Cabin decompression Pre-Recorded Announcement (PRA)

Manual deployment of the oxygen masks by the crew causes a cabin decompression PRA to be played over the cabin speakers by the passenger address system. This recorded announcement is intended to be heard clearly above the ambient noise in the cabin to alert passengers and cabin crew that they are to don oxygen masks.

Passenger privacy screens

The operator's business-class cabin seats fitted to its Boeing 787 fleet are installed with retractable privacy screens. Unlike other aircraft types in this operator's fleet, the privacy screens on the Boeing 787 do not automatically retract when the cabin oxygen masks are deployed, and are not required to do so.

Aircraft examination

During the flight sector into Heathrow which preceded the incident flight of 29 April 2017, the crew had reported a status message 'CABIN AIR CPRSR L2'. Engineers attended the aircraft and carried out troubleshooting in accordance with the Fault Isolation Manual (FIM), but initially could not identify the cause of the fault message. Following further investigation, it was found that the L2 CAC shaft had failed and part of it was missing. The inlet of the L1 CAC was removed for comparison and the missing material from the L2 CAC was found at the inlet with damage sustained to the blades of the L1 CAC. This was discovered shortly before the scheduled departure. It was therefore decided to dispatch the aircraft with the left AC system disabled, in accordance with the MEL.

Following the return of the aircraft to Heathrow after the incident, an examination took place monitored by the AAIB. It was found that the right-hand inner recirculation duct was disconnected from the lower right-hand recirculation fan (Figure 3). Once the duct and fan unit were removed, there was evidence that the coupling and seal joining the two had been incorrectly aligned when last assembled. The V-band clamp joining the other end of the duct to the heat exchanger was correctly fitted.

Examination of the coupling system used to connect the recirculation fan to the inner duct showed that if the coupling were not installed correctly, there was less visible evidence and a reduced tactile feel compared to that of the V-band clamp used at the opposite end of the duct. The connection of the right-hand recirculation fan is located in a position that requires reaching through an extensive system of ducting and components to install it. Viewing of the connection between the duct and fan is also restricted. Figure 3 shows the relative position of the recirculation fan and the disconnected duct.

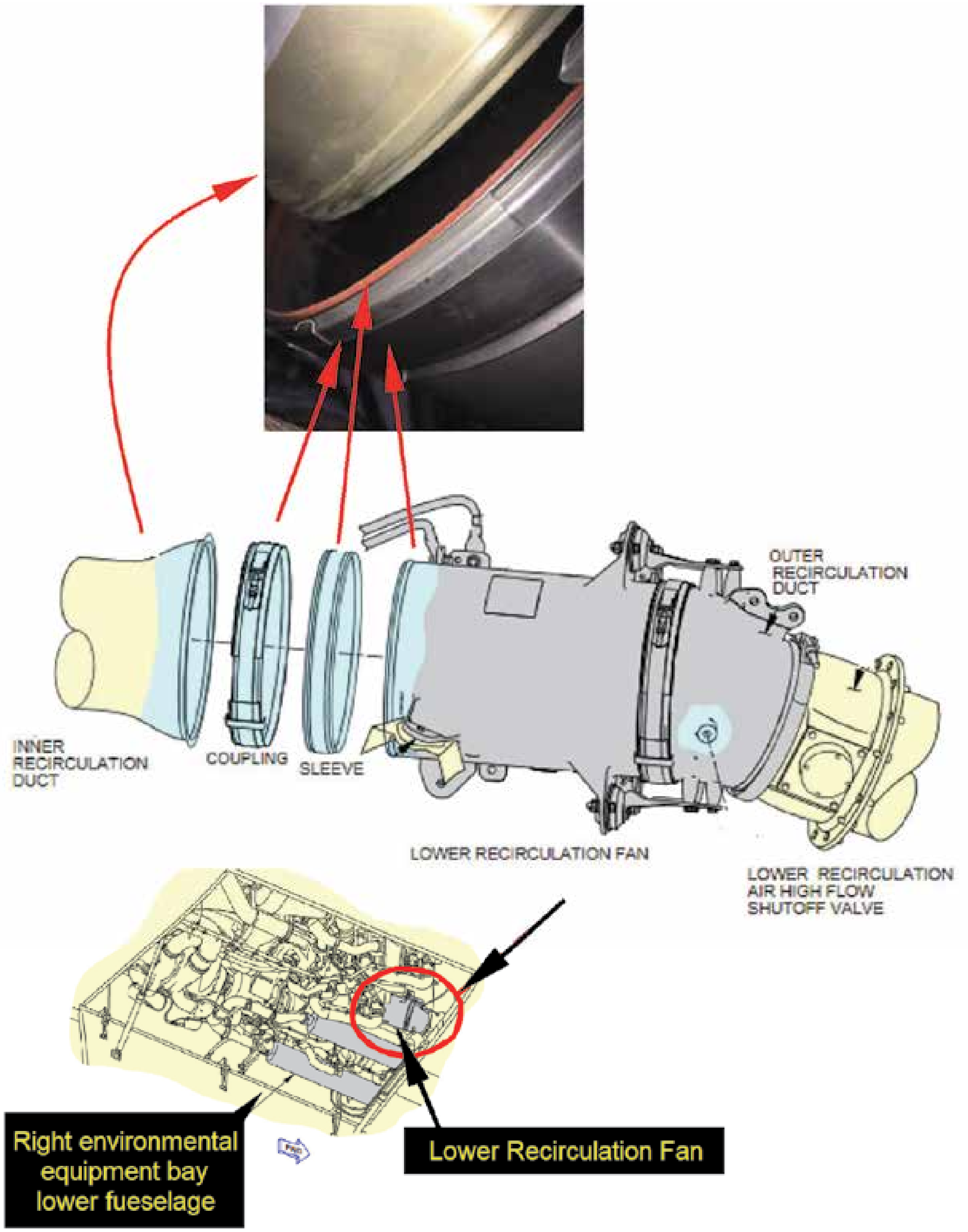

Figure 3

Position of Right Lower Recirculation Fan and photograph of disconnected duct

Previous maintenance activity

Examination of the aircraft records showed that the right-hand lower recirculation fan had been disabled on 8 April 2017 due to a fault and the fan was subsequently changed on 18 April 2017, 11 days before the incident flight. The following day, when the aircraft returned to service, the aircraft's AHM system sent Maintenance Alert Message 21-0209-C740[3] to the operator's ground-based data system, indicating that a 'high leakage/low inflow' of the cabin pressurisation system had been detected. This message is not displayed to the flight crew.

The AHM message 21-0209-C740 was assessed by the operator's engineering department and on 20 April 2017 a work request, D7 32165109 titled 'CABIN PRESSURISATION CHECKS', was raised to carry out a pressurisation leak check of the aircraft. The recent work carried out on the aircraft's right air conditioning pack (8 and 18 April) would have been available by accessing the aircraft's electronic flight log details. The end date for completion of work request D7 32165109 was set at 5 May 2017.

Thereafter, during all of the subsequent flights of G-ZBKF, of which there were 15 prior to the incident flight, Maintenance Alert Message 21-0209-C740 was sent by the aircraft to the operator's AHM ground-based data system. The end date (5 May) for the completion of work request D7 32165109 was not altered. The operator later stated that the AHM system provides just over 1,200 maintenance alerts. From experience, some maintenance alert messages are inadvertently triggered, which has led to refinements to improve the robustness of the system and reduce the level of 'nuisance' alerts. The operator had seen alert message 21-0209-C740 triggered 'intermittently' on other aircraft before and this had caused maintenance staff to question the reliability of this particular alert message.

The engineer who had disabled the left air conditioning pack on the morning of the incident had been provided with documentation that included outstanding maintenance activities. This included work request D7 32165109. The operator stated that it was not a requirement that engineers review this particular information as it was included for information purposes only.

Cabin decompression Pre-Recorded Announcement (PRA)

Under normal operation, the cabin decompression PRA is output at a peak level equivalent to the level of someone shouting. When a cabin announcement is made by the flight crew the PRA is paused and after completion of the cabin announcement the PRA continues.

Testing of the cabin audio system, and further investigation by its manufacturer[4], found that on recommencement of the cabin decompression PRA (following a cabin announcement from the flight crew), the source of the PRA announcement had reduced the amplitude of the input announcement to the passenger address system to a level just above normal conversation. The manufacturer of the passenger address system verified the system volumes were per design and operated correctly but could not produce the output at the right amplitude with the input signal reduced by the amount stated above. This caused the low level that previously stated was not intelligible. The manufacturer of the In Flight Entertainment System (IFES - which is the source of the PRA announcement) is releasing a software update to correct this deficiency of the PRA source audio levels being supplied at a lower value than specified by the manufacturer.

Footnote

[3] This fault message is triggered if the outflow valves are less than 5° open in flight.
[4] Thales: www.thalesgroup.com

Passenger privacy screens

It was found that passenger safety cards carried on the operator's fleet of Boeing 787 aircraft incorrectly indicated that privacy screens would automatically retract when the passenger oxygen masks deployed. Cabin crew training also did not reflect this difference.

EAFR CVR audio recording quality

On 21 November 2014, the National Transportation Safety Board (NTSB) of the USA published report NTSB/AIR-14/01 on an accident to a Boeing 787-8, JA829J that suffered an auxiliary power unit battery fire. During the investigation, the NTSB identified the following discrepancies with the EAFR's CVR audio recordings:

- '*only a small percentage of the dynamic range*' was used to record the crew audio channels
- The cockpit area microphone (CAM) channel had *'excessive cockpit background noise that obscured the inter-crew's conversations both during the airborne and ground portions of the flight'.*
- Superimposed on the crew channels were multiple *'full volume clicks and pops that appeared randomly throughout the recording'.*

The NTSB categorised the quality of CVR recordings using its *'CVR Quality Rating Scale'* which has five ratings: 1) unreadable 2) poor 3) fair 4) good and 5) excellent. The NTSB categorised the EAFR CVR recordings for the Boeing 787-8 registration JA829J as *'Fair'* which it defines as:

> *'The majority of the crew conversations were intelligible. The transcript that was developed may indicate passages where conversations were unintelligible or fragmented. This type of recording is usually caused by cockpit noise that obscures portions of the voice signals or by a minor electrical or mechanical failure of the CVR system that distorts or obscures the audio information.'*

The NTSB concluded that:

> *'The poor audio recording quality of the enhanced airborne flight recorder could impede future aircraft investigations because the recorded conversations and other cockpit sounds might be obscured.'*

To address this the NTSB made the following Safety Recommendation to the FAA:

> *'Require Boeing to improve the quality of (1) the enhanced airborne flight recorder radio/hot microphone channels by using the maximum available dynamic range of the individual channels and (2) the cockpit area microphone airborne recordings by increasing the crew conversation signals over the ambient background noise. (A-14-126)'*[5]

Footnote

5 The *'radio/hot microphone channels'* as stated in NTSB Safety Recommendation A-14-126 refer to the three crew audio channels.

As of April 2018, NTSB Safety Recommendation A-14-126 remains 'OPEN', awaiting a final response from the FAA.

When both EAFRs fitted to G-ZBKF were replayed by the AAIB, the CVR recordings exhibited the same characteristics to those previously identified by the NTSB, with approximately 10% of the available dynamic recording range used when the crew headset microphones were in use. Subsequently the AAIB became aware that the Australian Transport Safety Bureau (ATSB) and the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) of France had also experienced the same issues when reviewing CVR recordings from Boeing 787 aircraft.

Further to the previous findings of the NTSB, the AAIB also identified that when the flight crew of G-ZBKF had used their oxygen masks, the full dynamic recording range of the crew CVR channels was used, with occasional clipping of the signal. Figure 4 reflects the difference in dynamic recording range when the flight crew used the headset and oxygen mask microphones.

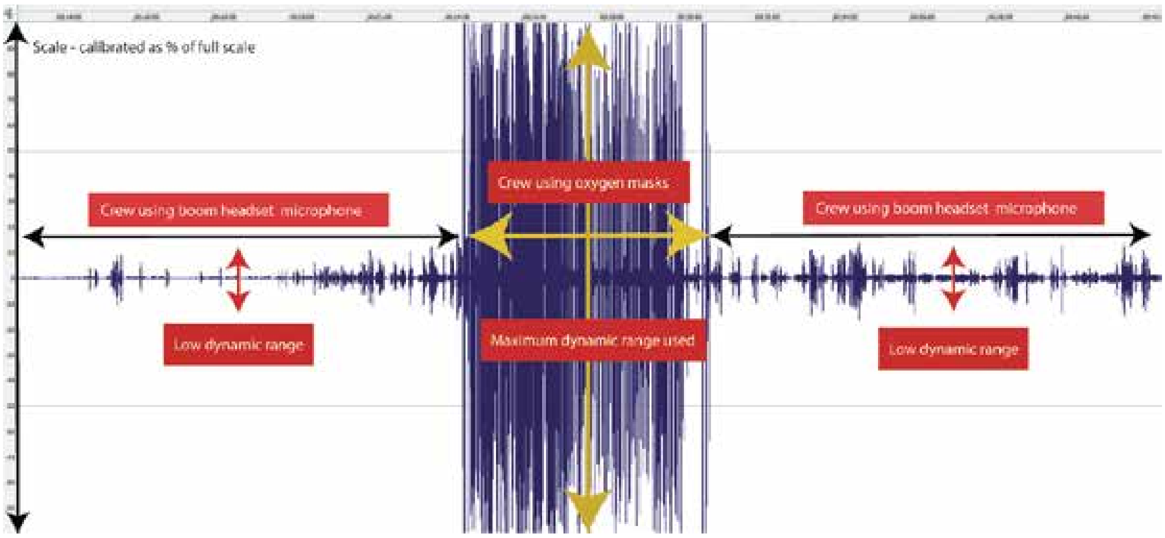

Figure 4

G-ZBKF – CVR waveform of crew channel showing difference in use of available dynamic recording range between headset and oxygen mask microphone signals

EAFR operation and readout

The aircraft is fitted with three audio control panels (ACPs), one for each crew position (commander, co-pilot and observer). Each ACP digitises the respective crew member's communications and transmits this as digital audio data packets over the aircraft's Avionics Full Duplex Switched Ethernet (AFDX) network to the EAFR. The data packets include a 'time stamp' that is acquired from an integral time reference source within each ACP. The CAM signal is provided as an analogue voltage, which the EAFRs digitise prior to recording.

Due to transport latencies of the AFDX network, and 'drift' between the ACPs internal time reference sources, corrections are required to ensure that the crew and CAM audio channels are synchronised[6] during replay. The EAFR CVR readout is made using a ground-based software utility called the Integrated Ground Software (IGS), which is produced by the manufacturer of the EAFR. IGS is used by the AAIB, other safety investigation authorities and operators.

The AAIB initially replayed the EAFRs fitted to G-ZBKF using IGS software version 2.11. Analysis of the audio found that each crew channel contained erroneous '*full volume clicks and pops'*. The AAIB subsequently contacted the manufacturer of IGS for assistance, who provided IGS version 2.14, advising that this included several refinements to the alignment process applied to the crew and CAM channel. The recordings from G-ZBKF were reprocessed and the '*full volume clicks and pops'* were no longer present. The IGS manufacturer subsequently confirmed that version 2.11 and earlier versions of IGS had inadvertently incorporated '*full volume clicks and pops'* into the audio.

The AAIB has notified the NTSB, other safety investigation authorities, and the operator of G-ZBKF of these findings. The IGS manufacturer is also considering notifying other operators of the need to update the IGS software to resolve this anomaly.

Certification of Boeing 787 EAFR CVR system

The certification of the Boeing 787 EAFR CVR system consisted of two distinct parts. The first related to the certification of the EAFR itself, which was certified by its manufacturer as meeting the requirements of FAA Technical Standard Order (TSO) C123B, 'Cockpit Voice Recorder Equipment'. The second part of the certification process related to the CVR system fitted to the aircraft, which was certified by the aircraft manufacturer as meeting the FAA operating rules contained in Title 14 of the Code of Federal Regulations (14 CFR) PART 25, Subpart F, 25.1457 – Cockpit Voice Recorders.

TSO-C123B required that the EAFR met the minimum performance standard as defined in the European Organization for Civil Aviation Equipment (EUROCAE) document ED-112[7] which includes aspects such as the minimum crash survivability of the recorder. ED-112 also included Chapter I-6 that provided requirements for verifying the installed performance of the CVR system. This included:

- *'For each newly installed system, the quality of the recording shall be established by analysis of information recorded on the ground and in flight.*
- *Position the microphone for recording general cockpit sounds, voice communications originating at the pilot and co-pilot stations, voice communications of other flight crew members in the cockpit when directed to those stations…..*

Footnote

[6] IGS calculates time synchronisation adjustments using a combination of the recorded arrival time of each ACP audio data packet at the EAFR, and the time that each data packet was transmitted from the ACPs. IGS then adds or removes audio samples from the three crew channels so that they align with the CAM channel, which is used as the master time source.

[7] ED-112 - Minimum Operational Performance Specification for Crash-Protected Airborne Recording Systems.

- *In general, the proper recording level will be confirmed using the oscilloscope to show that the full recording dynamic range has been achieved without excessive clipping of peak signals. A check should be made to confirm that adequate signal to noise ratios exist for all significant input signals*[8]
- *The presence of cockpit sounds, crew speech and audible warnings should be confirmed on the area microphone channel.'*

However, in TSO-C123B, the FAA permitted a number of exemptions, including the requirement to meet the performance standards in ED-112 Chapter I-6. The FAA advised that the rationale for the exception was that TSOs normally relate to the specification and performance of equipment as 'standalone' units, and that guidance on the installed performance of systems is typically provided in an Advisory Circular (AC)[9]. When the Boeing 787 CVR system was certified, AC 25.1457-1A dated 1969 was applicable to the CVR system. This provided guidance on the position of the CAM relative to the cockpit loud speakers, but it did not provide guidance on how to verify the installed performance of the CVR system.

As a result of the exception to comply with ED-112 Chapter I-6, and a lack of guidance in AC 25.1457-1A, there was no requirement for the aircraft manufacturer to demonstrate that the performance of the Boeing 787 CVR system met any industry approved guidance or standard.

Following the NTSB's findings on the performance of the CVR system fitted to aircraft registration JA829J, it made this Safety Recommendation to the FAA:

'Either remove the current exception to European Organization for Civil Aviation Equipment ED-112A, "Minimum Operational Performance Specification for Crash Protected Airborne Recording Systems" chapter I-6 in Technical Standard Order 123B, "Cockpit Voice Recorder Equipment," or provide installers and certifiers with specific guidance to determine whether a cockpit voice recorder installation would be acceptable. (A-14-127)'

The FAA responded to NTSB Safety Recommendation A-14-127 by publishing AC 20-186. This provides guidance on determining that CVR and FDR systems '*perform as intended*' and defines the test requirements as those specified in ED-112A Chapter I-6 (CVR) and Chapter 2-5 (FDR). However, AC 20-186 is not applicable to the CVR system fitted to the Boeing 787 as the EAFR was certified prior to the applicability of the AC.

Footnote

8 In this context, the dynamic range of the audio recording is the ratio between the largest and smallest recorded signals. A non-optimised use of the dynamic range can affect the overall 'quality' of a digital recording due to a low signal to noise ratio and quantisation noise.

9 An AC is not mandatory or a regulation, but can provide information on an acceptable means of compliance when applying for certification.

On 15 November 2016, the NTSB responded to the FAA, stating:

> *'We believe that the AC [20-186] contains good guidance, and that, if the guidance were applied to the Boeing 787 CVR installation, the installation would fail in multiple ways.'*

However, the NTSB concluded that AC 20-186 met the intent of the Safety Recommendation and classified it as '*CLOSED-ACCEPTABLE ACTION*'.

In August 2017, the AAIB and NTSB met with the aircraft manufacturer and FAA to discuss the certification process applied to the Boeing 787 CVR system. The FAA advised that the evaluation of the system performance was delegated to the aircraft manufacturer, who carried out a series of ground tests and a 'scripted' flight test (based on that provided in ED-112, which was applicable at the time). The recordings from these tests were evaluated by an Authorized Representative (AR)[10] who had worked on previous CVR certification programmes with the manufacturer.

The acceptance criteria applied by the AR focused on the intelligibility of 'voice communications', in accordance with the regulation[11] that states '*voice communications of flight crewmembers'* shall be recorded. Aural alerts, such as those generated by TAWS, were also confirmed as being recorded. The AR subsequently provided confirmation that the system performance was acceptable and the FAA granted approval.

The aircraft manufacturer further commented that the evaluation process applied to CVR systems is 'subjective' as it considered that ED-112 and the updated version ED-112A, lacked detail in providing 'objective' measurements.

Dynamic recording range of crew channels

The aircraft manufacturer stated that it had been aware of the difference between the recorded dynamic ranges of the boom headset and oxygen mask signals prior to certification of the Boeing 787. The manufacturer advised that the reason for this difference is that in normal operation the output signal from the headset microphone is about 0.1 volt, whereas, the output signal from the oxygen mask microphone is much higher, at about 2.0 volt. The ACP microphone input is designed[12] to accept an analogue voltage range of between 0 volt and 2.1 volt (peak-to-peak) and therefore when digitised, the boom headset microphone signal is at a much lower level than the oxygen mask signal.

The Boeing 787 audio system combines the crew headset/oxygen mask microphone signals with the sidetone[13] signal. The aircraft manufacturer advised that during the system design

Footnote

[10] An AR is a qualified individual who may act, for certain functions, on behalf of the regulator (FAA).
[11] (14 CFR) PART 25, Subpart F, 25.1457.
[12] RTCA DO-214 'audio systems characteristics and minimum operational performance standards for aircraft audio systems and equipment'.
[13] The sidetone signal is the audio reproduced through the headsets speakers consisting of sound of the pilots own voice, RTF and interphone communications. It may also include other background sounds picked up by the headset microphone.

it had aimed to comply with the requirement in ED-112 that stated '*at the summing point, the microphone signal exceeds the level of its corresponding sidetone signal on a high percentage of occasions*'. This was to ensure that crew speech would not be inadvertently masked by higher amplitude RTF signals, such as ATC transmissions.

During development, the aircraft manufacturer found that the sidetone signal level exceeded the crew headset microphone signal when combined. The manufacturer resolved this by attenuating the sidetone signal, which resulted in the signal using about 5% of the available recordable dynamic range.

Analysis of the G-ZBKF incident recording shows that when the sidetone signal is combined with the oxygen mask microphone signal, the sidetone is predominantly masked by the much higher amplitude oxygen mask signal.

Certification process used in Europe by the EASA

For aircraft certified by the EASA, the performance of CVR systems is to be measured against the requirements currently specified in ED-112A[14]. For aircraft manufactured in France, the BEA participate informally in the approval process by reviewing pre-certification CVR recordings, and providing feedback on areas that the manufacturer may consider improving upon. The review process is 'subjective' in nature.

European certification guidance material

EASA has advised that as part of Rule Making Task (RMT).0249 it intends to update its guidance material on demonstrating that the quality of the CVR recording complies with the corresponding certification standards. The update is based on EASA Certification Memorandum (CM)-AS-001, which is to be consolidated with views provided by the European Flight Recorder Partnership Group (EFRPG)[15].

Review of CVR recordings from B787 and other aircraft types

The AAIB performed a comparative review of the Boeing 787 EAFR CVR recordings against a range of other turbofan powered aircraft, which included the Boeing 747-400, 777, 767, 737-800, 737-300, Airbus A380, A340, A330, A320 and Embraer 190. These recordings were all from solid-state CVRs, meaning that the relative use of the dynamic recording ranges were directly comparable.

The results of the review indicate significant variation between aircraft types of the 1) recorded dynamic range of the crew channels and 2) ambient background noise levels compared to crew speech recorded on the CAM channel. Figure 5 and 6 show the difference between the crew and CAM channels of nine different aircraft types.

Of the recordings, the lowest recorded dynamic range when the headset microphone was in use was the Boeing 787 and the highest was the Boeing 757. For the CAM channel, the

Footnote

[14] or '*any later equivalent standard produced by EUROCAE*'
[15] The EFRPG is an independent voluntary group of European flight recorder experts represented by manufacturers, national aviation authorities and safety investigation authorities.

Boeing 787 and Airbus A380 had the highest levels of background ambient noise which, depending on the phase[16] of flight, could mask crew conversation. The Airbus A320 CVR system provided a reasonable balance of the use of the dynamic recording ranges and level of ambient noise on the CAM channel that meant that the majority of sounds and communications could be readily transcribed.

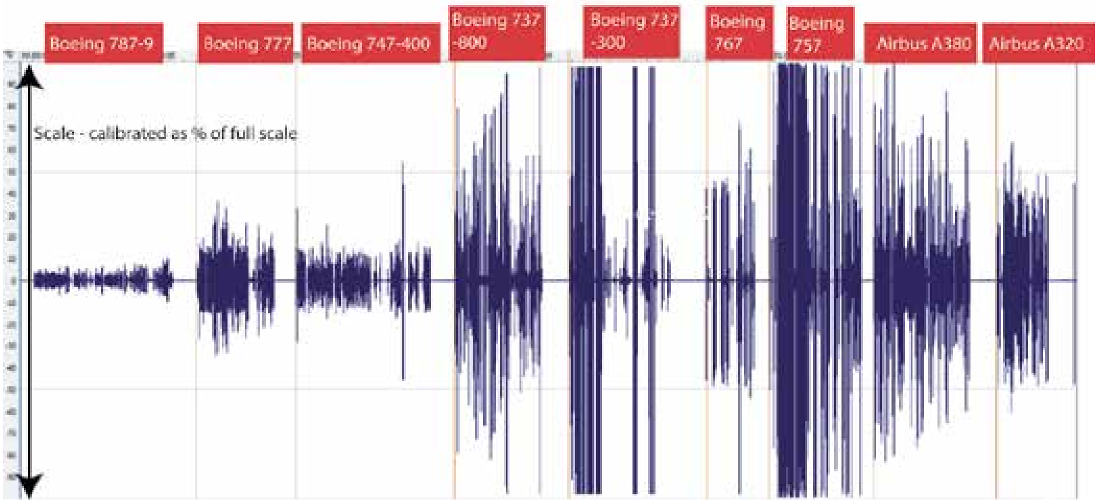

Figure 5

Nine aircraft types - differences in dynamic range used for recording of crew channels

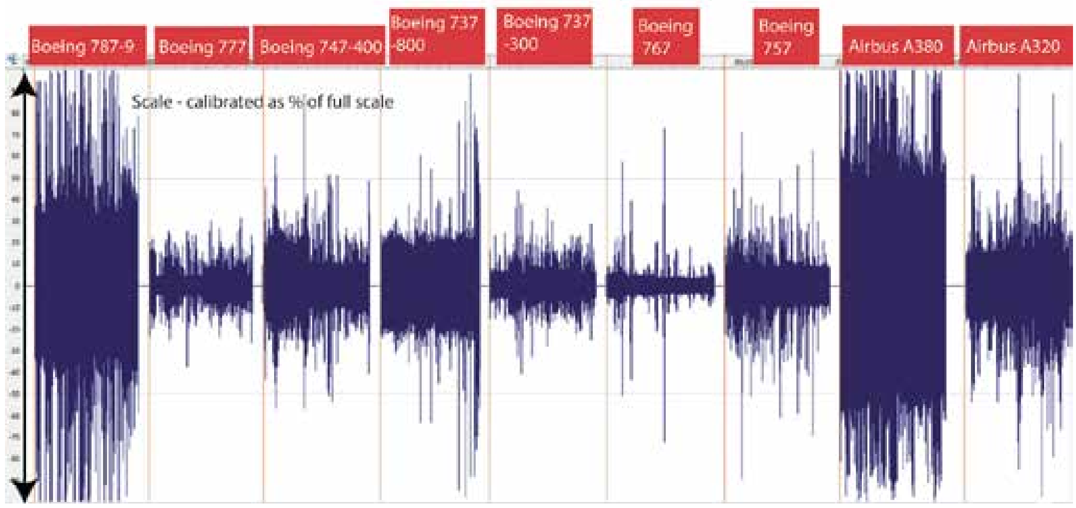

Figure 6

Nine aircraft types - differences in dynamic range used for recording of CAM channel

Footnote

16 Background sound levels were significantly increased during takeoff, when the aircraft was configured for landing and when high engine power settings were used in conjunction with reverse thrust.

During the meeting in August 2017 (between the AAIB, NTSB, aircraft manufacturer and FAA), several CVR recordings[17] were replayed, which included the Boeing 787-8 EAFR CVR flight test recording. It was noted that the intelligibility of the crew communications recorded on the CAM channel during the flight test appeared 'clearer' compared to the CAM recording from a 'routine flight'.

The difference between the two recordings may have been due to the 'scripted' nature of the flight test, resulting in the crew speaking louder and placing more emphasis on clarity than normal. However, evaluation of the Boeing 787 recordings also showed that when the aircraft equipment cooling system was turned 'off' after flight, there was a notable reduction in the ambient noise recorded on the CAM channel. This indicates that airflow from the equipment cooling system in the cockpit was contributing significantly to the 'high' ambient noise on the CAM. It was also commented that the CAM recording gave the impression that the cockpit environment was noisy and did not truly represent the actual ambient sound if a human observer were listening in the cockpit.

Speech Transmission Index (STI) analysis

There are several types of objective analysis technique that can be applied to audio to ensure that a minimum standard of speech intelligibility is achieved. One such technique is the STI, which uses a combination of test tones that are recorded and analysed to provide an index score. An index of one represents perfect speech intelligibility and zero is unintelligible.

ED-112, and the later ED-112A[18], both specify that an STI test is performed on the CVR unit, with the crew channels and CAM channel requiring a minimum index score of 0.75 (good to excellent) and 0.85 (excellent) respectively. However, this STI test is not applicable to the installed performance of the CVR system.

Analysis

Operations

The flight crew were appraised of issues related to the cabin pressurisation system during their ground briefing before the incident flight on 29 April and discussed those relating to temperature control again during the climb. Shortly after establishing the aircraft in the cruise, the crew were alerted to a higher than normal cabin altitude by the EICAS. They quickly recognised the relevance of this and promptly took action to avoid a cabin altitude exceedance by requesting a descent to FL310. The passenger oxygen was manually deployed. The cabin altitude continued to increase and as it reached 10,000 ft, the commander initiated an emergency descent to FL100. The cabin reached a maximum altitude of 10,429 ft.

When the pressurisation warning occurred, the crew carried out the appropriate QRH drills in a timely and comprehensive manner. The emergency descent was conducted in accordance with SOPs and was well co-ordinated with ATC.

Footnote

17 Recordings from routine flights, not from safety events.
18 Chapter I-3 'minimum performance specification under standard test conditions'.

In the cabin, the cabin decompression PRA was reported as not being audible. Whilst the passenger oxygen masks deployed, the lack of an apparent accompanying PRA caused confusion amongst the cabin crew as to the exact nature of the situation. Accordingly, the initial response by the cabin crew was uncoordinated and ineffective, with the majority of the cabin crew reacting by returning their service carts to the galleys. The unstructured response of the cabin crew meant the reaction of the passengers was not effective and some passengers did not don their oxygen masks.

The relatively low altitude exceedance of just over 10,400 ft, which lasted for only a short duration due to prompt flight crew action, reduced the possibility of medical effects on cabin crew and passengers. However, had the cabin altitude continued to climb the effects of not donning oxygen masks would have been more serious.

The CSD recognised that the situation was confused and took the initiative to enter the cockpit to clarify with the flight crew. She was, however, unable to return to the cabin until the aircraft levelled at FL100, so the situation in the cabin was not resolved until after the conclusion of the emergency descent.

Engineering

The loss of cabin pressure was due to a compromised ECS. This was because of a number of factors:

1. The incorrect fitment of the sleeve and coupling joining the replaced lower recirculation fan to the inner recirculation duct in the right air conditioning (AC) system allowing a leak of cabin air.
2. The maintenance organisation did not identify that the continuing air leakage, which persisted as a consequence of this incorrect fitment of the sleeve on the right AC system, would affect the pressurisation system performance if the aircraft were flown with the left AC unit disabled.
3. Fracture of a component (tie-rod) within the L2 CAC of the left air conditioning system, resulting from a manufacturing quality control shortfall.
4. Damage to the L1 CAC of the left AC system as a result of ingestion of a liberated part of the failed L2 CAC tie-rod and its nut, leading to the disabling of the left AC system before flight.

It is not known whether further physical movement of the components of the incorrectly fitted coupling, on the right AC unit, occurred during the incident flight, when the right unit was called upon to pressurise the aircraft on its own.

The incorrect fitment of the coupling and sleeve was partly a consequence of the inaccessibility of those components in the right AC unit and the lack of tactile feel enabling an incorrectly assembled coupling to be easily identified. The resulting leakage from the recently assembled coupling was identified by the AHM Customised Alert and analysed by the operator's Technical Support department. It was decided that, as the aircraft was operating satisfactorily with the leakage present, there were no other abnormal indications and a planned maintenance input was scheduled for the near future, investigation of the leak could be aligned with that input. This decision in turn appears to have been influenced by the perception of the high frequency of data and messages received by AHM on the 787 fleet.

The manufacturing quality shortfall in the L2 CAC has been identified by the component supplier as a batch problem and the location of components from that batch established. The potential for damage to the L1 CAC resulting from the ingestion of the failed part of the L2 CAC was not explicitly considered during the original system Fault Mode Effects Analysis (FMEA) carried out by the manufacturer. However, other system-level failures that can cause loss of both CACs in one pack had been considered and accounted for at the design stage and the manufacturer is not aware of any other event where the failure of a CAC has resulted in damage to, or failure of, the second CAC on the same AC pack.

The decision to dispatch the aircraft

The decision to dispatch the aircraft with the left AC system disabled did not take account of the unresolved leakage problem on the right AC system. Procedures of the operator, common within the industry and consistent with the approved MEL, permitted dispatch of the aircraft with one AC unit disabled provided certain flight routing constraints were observed. In this instance the procedures did not ensure that the operating system would continue to function, with the normal level of reliability. Although the individual who authorised the dispatch with one AC system disabled was provided with information, including details of the status of the right system, that individual was not aware of the incorrect fitment of the sleeve and coupling or its influence on the performance of the pressurisation system.

CVR performance

The full volume clicks and pops that appeared randomly throughout the recording on the crew channels on the incident flight was later confirmed as being introduced by the EAFR manufacture's ground-based replay software, IGS. A later version of the software, version 2.14, resolved this anomaly.

The review of CAM recordings for the Boeing 787 indicated that airflow in the cockpit from the equipment cooling system appeared to contribute to the high level of ambient background noise, as a significant reduction in background noise is apparent on the CAM recording when the system was turned off. Discussions further indicated that the level of ambient background noise recorded by the CAM may not truly represent that experienced by a human observer in the cockpit. This indicates that the CAM installation is not optimised.

The NTSB has previously made Safety Recommendation A-14-126 to address the performance of the CAM recording on the Boeing 787. As of April 2018 this Safety Recommendation remains 'OPEN', awaiting a final response from the FAA. Therefore, although issues were found in this incident that are similar to those that caused the NTSB to issue Safety Recommendation A-14-126, the AAIB considers that it is not necessary to make a further Safety Recommendation on this subject.

However, this AAIB investigation has highlighted an additional issue with the Boeing 787 CVR performance. A significant difference exists between the recorded dynamic range when the headset and oxygen mask microphones are used. The aircraft manufacturer attenuated the sidetone signal so that ATC communications did not inadvertently mask the crew speech when using the headset microphone. However, when the oxygen masks are used, the sidetone signal can be easily obscured due to the much higher signal level of the oxygen mask microphone. The aircraft manufacturer was aware of this during certification, but considered that it was acceptable.

Although audio processing techniques may be applied to reduce the effect of the issues identified with the CVR recordings of the crew and CAM channels, it is not always possible to recover quieter background sounds and speech. Consequently, information that may be of significance to an investigation may be lost. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2018-008

It is recommended that the Federal Aviation Administration require Boeing to modify the audio system fitted to the Boeing 787, so that sidetone signals recorded on the cockpit voice recorder crew channels are not masked when flight crew oxygen mask microphones are in use.

The review of CVR systems from different aircraft types, including the Boeing 787, has highlighted the significant variation in the installed performance of these systems, with differences in the use of the available dynamic recording range and levels of background noise on the CAM channel that can affect the intelligibility of the recordings.

The CVR unit is subject to qualitative performance testing in ED-112A that includes an 'objective' measurement in the form of an STI index test. However, the installed performance of CVR systems is currently evaluated using a 'subjective' process. Therefore, differences in opinion can exist as to whether the performance of the CVR system is acceptable.

If an 'objective' analysis measurement, such as the STI index, could be applied to the testing of the installed performance of the CVR system, this would enable the setting of a minimum standard of performance that manufacturers could demonstrate. However, it is not known whether such qualitative measurements can be successfully applied to CVR system recordings. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2018-009

It is recommended that the European Aviation Safety Agency initiate a review to consider whether a repeatable and objective analysis technique can be applied to audio recordings to establish consistent installed performance of cockpit voice recorder systems.

If this review shows that a qualitative measurement can be successfully applied, the EUROCAE document ED-112 (currently ED-112A) should be updated to include this information. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2018-010

It is recommended that the European Organization for Civil Aviation Equipment (EUROCAE) amend their document '*Mininimum Operational Performance specification for Crash Protected Airborne Recorder Systems*' (currently ED-112A) to include a repeatable and objective analysis technique to establish consistent installed performance of cockpit voice recorder systems.

Conclusions

Loss of cabin pressure

The inability of the aircraft to maintain normal cabin pressure was found to be have been caused by the right lower recirculation fan becoming detached from the inner duct, which allowed air from the AC unit to leak to atmosphere rather than provide the required cabin pressure on a sector where the left air conditioning system had been disabled before flight.

When the aircraft was operated during the incident flight with only the right air conditioning system available, the system did not have sufficient capacity to overcome the effect of the leak. It was concluded that the lower right recirculation fan had not been correctly attached to the inner duct when the fan had been installed on 18 April 2017.

Cabin PRA

The deployment of the oxygen masks in the cabin was accompanied by the cabin decompression PRA. However, the level of the PRA was reported as not being audible. The apparent lack of an accompanying PRA caused confusion amongst the cabin crew as to the exact nature of the situation and the initial response by the cabin crew was uncoordinated, with some passengers not donning their oxygen masks.

The cause of the low volume of the PRA was subsequently identified as a software issue in the cabin audio system, whereby the volume of the announcement was attenuated following use of the cabin address system from the cockpit.

CVR performance

Digital 'spikes' evident in the crew channels, as identified by the NTSB during the readout of the EAFRs fitted to accident aircraft registration JA829J, has been subsequently confirmed as being introduced by the EAFR manufacturers ground replay software, IGS. This issue has now been resolved and the AAIB has communicated this to other accident investigation laboratories.

The NTSB has previously identified deficiencies in the quality of the CVR recordings on the Boeing 787 and issued Safety Recommendation A-14-126 to address these. The AAIB has further identified that ATC communications can be masked when the flight crew are using the oxygen masks, due to the disparity in the recorded dynamic range of the sidetone and oxygen mask signals. A Safety Recommendation has been made to address this.

Testing of the installed performance of CVR systems is currently largely subjective, which has led to variation in their performance. Three Safety Recommendations are made to address this.

Safety actions

Following the serious incident to G-ZBKF on 29 April 2017 a number of safety actions have been taken:

- The aircraft manufacturer has revised the Aircraft Maintenance Manual (AMM) installation procedure for the lower recirculation fans.
- The aircraft manufacturer has made changes to its Fault Isolation Manual for Maintenance Message 21-34127, the message triggered by Maintenance Alert Message 21-0209-C740 from the AHM. This includes checking for recent maintenance activity on the cabin pressurisation system, including the lower recirculation fans.
- The aircraft manufacturer has made an update to the AHM 'maintenance alert' logic for message 21-0209-C740. This logic helps to filter out only those instances that are deemed valid and should be presented to the airline.
- The operator of G-ZBKF has revised its process for dealing with AHM 'maintenance alert' message 21-0209-C740.
- The operator of G-ZBKF is updating the audio system software fitted to its fleet of Boeing 787 to prevent the volume of the cabin decompression PRA from being attenuated.

ACCIDENT

Aircraft Type and Registration:	1) North American P-51D, Mustang, G-SHWN 2) North American P-51D-20 (Modified), Mustang, G-BIXL
No & Type of Engines:	1) 1 Rolls-Royce V-1650-7 piston engine 2) 1 Packard Motor Car Co Merlin V-1650-7 piston engine
Year of Manufacture:	1) 1944 (Serial no: 122-40417) 2) 1944 (Serial no: 38675)
Date & Time (UTC):	23 September 2017 at 1530 hrs
Location:	Near Duxford Airfield, Cambridgeshire
Type of Flight:	1) Private 2) Private
Persons on Board:	1) Crew - 1 Passengers - None 2) Crew - 1 Passengers - None
Injuries:	1) Crew - None Passengers - N/A 2) Crew - None Passengers - N/A
Nature of Damage:	1) Propeller 2) Horizontal stabiliser
Commander's Licence:	1) Airline Transport Pilot Licence 2) Airline Transport Pilot Licence
Commander's Age:	1) 52 years 2) 53 years
Commander's Flying Experience:	1) 18,000 hours (of which 600 were on type) Last 90 days - 9 hours Last 28 days - 5 hours 2) 19,000 hours (of which 87 were on type) Last 90 days - 119 hours Last 28 days - 37 hours
Information Source:	AAIB Field Investigation

Synopsis

Two P-51 Mustangs were taking part in a display sequence at the *Battle of Britain Air Show* at Duxford, Cambridgeshire. The accident occurred as they were joining formation with a Boeing B-17G in preparation for the next part of the display. The pilots had briefed and agreed that the lead P-51 would join on the B-17's right side and the other on its left side. However, during the display both pilots tried to join on the B-17's right, resulting in the two P-51s colliding. They landed without further incident.

A number of human factors were contributory to the accident. Most significantly, although the P-51 pilots had performed a 'walk through' of their display, they did not include the

part involving the B-17. The CAA has added some additional guidance to Edition 15 of CAP 403, *Flying Displays and Special Events: Safety and Administrative Requirements and Guidance,* with regards to performing walk throughs of displays prior to flight.

History of the flight

Introduction

The two P-51s were part of a formation flypast that included a B-17. The B-17 had already completed a flypast with a Douglas DC3 and a Douglas C47 and the next part of the sequence involved the P-51s joining the B-17 once the DC-3 and C-47 had departed. After the formation flypast with the B-17, the P-51s planned to separate from the B-17 and perform formation aerobatics. G-SHWN was the lead P-51, with G-BIXL following.

Background

The P-51 pilots had arrived at Duxford the day before the airshow. That evening they discussed the formation aerobatics they planned to fly. This was to be the same sequence they had flown together at Prestwick Airshow, three weeks earlier, where the pilot of G-SHWN had led the display.

The pilots attended the main pilots' mass airshow briefing by the Flying Display Director at Duxford the following morning. Afterwards, the pilots of the DC-3, C-47, B17 and P-51s were given an additional formation briefing by the leader of their part of the display; the DC-3 pilot. In addition to the verbal briefing, the DC-3 pilot/formation leader gave the pilots a written brief which he had produced.

The pilot of G-BIXL read this handout during the verbal brief, then drew a pictorial representation of the display with aircraft symbols, as he preferred to use this form of aide memoire (Figure 1). When discussing how the P-51s would join the B-17, the lead P-51 (G-SHWN) pilot stated that, after taking off separately from the B-17, DC-3 and C47, the P51s would initially practice some formation aerobatics away from the airfield, with G-BIXL positioned on the right. After the DC-3 and C-47 had completed their flypast with the B-17, the P-51s would join the B-17 for their flypast. He said G-SHWN would join on the B17's right with G-BIXL joining on its left; G-BIXL's pilot agreed with this. They then discussed what they would do during the formation aerobatics. At this time, G-BIXL's pilot's focus was on the formation aerobatics, as the flypast with the B-17 was "bread and butter flying"; he having flown many of these before, albeit in and with various types of aircraft.

About 30 minutes before takeoff, the P-51 pilots met at their aircraft and discussed the display again. The focus was on the formation aerobatics, which they walked through together. This was something they had done before all their previous displays together. While the pilot of G-BIXL waited in the cockpit to start, he went through the formation aerobatics in his head with his eyes closed; he did not go through the join with the B-17.

Accident flight

The P-51s' start up, takeoff from Runway 24R and departure from Duxford were uneventful. At the time, the weather was clear and the wind was from the south-south-west at 6 to 7 kt.

Having completed the practice formation aerobatics with G-BIXL on the right of G-SHWN, the pilot of G-SHWN became visual with the B-17. It was flying about 500 ft agl, tracking south-west away from Duxford. The P-51s then flew towards it to commence the join.

After the B-17 commenced a right turn back towards the airfield, the P-51s passed below and through its 6 o'clock in a left turn, before reversing the turn. Once in the right turn, G-BIXL's pilot flew through the B-17's 6 o'clock to join on its right. As he did, he looked at G-SHWN, which he was moving away from and believed it was going to join on the B-17's left. Thinking that both P-51s were now on their nominated sides of the B-17, he looked inside the cockpit to check the instruments. At this point he believed that the airspace to the B-17's right was only for his aircraft and he thus had "carte blanche" to fly into position for their flypast. He briefly looked in his 9 o'clock and saw nothing, but was not concerned that he could not see G-SHWN, as they were both at low level and it may not have been easily visible against the ground due to its camouflaged paint scheme (Figure 2). He also believed the pilot would have been doing the same as him, flying low and fast before climbing into position with the B-17.

G-BIXL's pilot's next recollection was that the aircraft nosed down slightly and started to shake moderately. He checked the engine instruments, which were indicating normally, and believed something had detached from the aircraft. As the shaking increased, he turned towards Duxford. He transmitted a MAYDAY declaring he would land on Runway 06L (grass), as the wind was relatively light from the south-west. The landing was uneventful.

The pilot of G-SHWN stated that as the B-17 was in its right turn, the P-51s passed through its 6 o'clock in a left turn and below it, before reversing the turn. Just before the right turn reversal he looked over his right shoulder and saw G-BIXL. This did not concern him as they had briefed to do a "loose formation join". G-BIXL next appeared descending from above right and its tailplane passed through his propeller disk as he was about to move up and into position on the B-17. He did not see G-BIXL prior to this as he was predominately concentrating on the B-17 that was in his 11 o'clock. He felt a very slight knock which made him realise they had collided. G-BIXL initially disappeared under his aircraft's nose and then re-appeared out to its left, whereupon he observed the damage to its left tailplane.

Having heard the pilot of G-BIXL transmit a MAYDAY, the pilot of G-SHWN initially followed the B-17. Once G-BIXL had landed, he separated from the B-17 and landed on Runway 24 (asphalt) without event.

G-BIXL's pilot's comments

G-BIXL's pilot stated that when he draws a diagram of a formation display he usually annotates an aircraft symbol with *'ME'* to indicate which aircraft is his in the formation. On this occasion he annotated '*P51*' against both symbols representing the P-51s (Figure 1). He is "fairly sure" that had he differentiated between the two symbols, he would not have joined the B-17 on the right. He stated that he would ensure that he always does so in future.

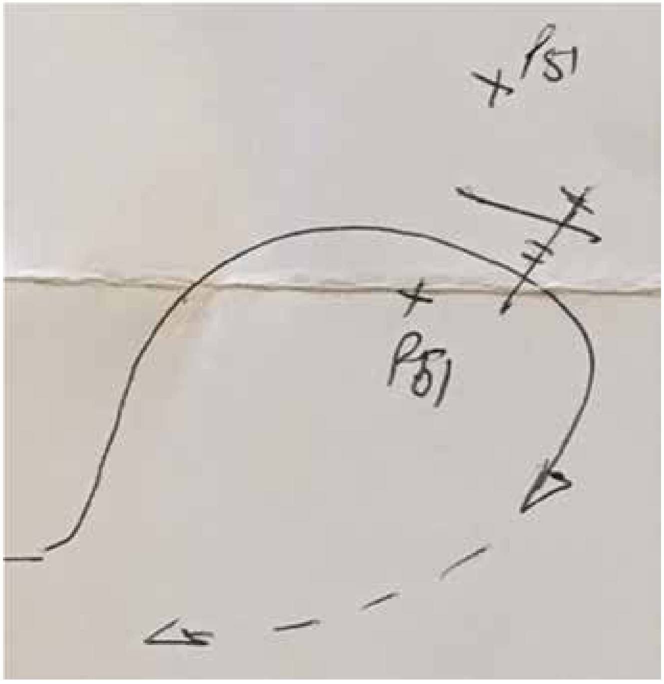

Figure 1
Part of G-BIXL's pilot's annotated diagram

Also, had all the pilots walked through the display on the ground, as is generally the norm, and had he flown the whole display through in his mind during his pre-flight preparation, he stated he was almost certain his misunderstanding would have been noticed and corrected before takeoff. He added that they only walked through the formation aerobatics as the join and flypast with the B-17 was considered a "standard piece of flying" that they had flown recently at Prestwick, albeit with a different lead aircraft. He believed he was likely to have suffered from "risky shift[1]" as a result of having done similar joins "hundreds of times".

He stated that in future he would keep the lead aircraft visual until it is established in formation with the flypast's lead aircraft before moving to his briefed side. Had he believed G-SHWN was on the incorrect side he would have sought clarity over the radio.

Footnote

1 Risky shift is a tendency for individuals to make more daring decisions when they are in groups, than when they are alone.

CAP 403 - *Flying Displays and Special Events: Safety and Administrative Requirements and Guidance*

Edition 14 of the CAA's CAP 403 was extant at the time of the accident. Whilst evidence from the pilot interviews suggested it was generally the norm for display pilots to do walk throughs as part of their preparation prior for a display, there was no mention of this in CAP 403.

Aircraft information

The North American P-51D Mustang is a single-pilot World War Two era long range fighter aircraft. It has an all metal airframe construction, with a hydraulically retractable main landing gear and tailwheel arrangement. The fuselage is 32 ft long, it has a wingspan of 37 ft and a horizontal stabiliser span of 13 ft. The single V-1650 engine drives a Hamilton Standard four blade propeller, which has a diameter of 11 ft 2 in. The accident aircraft are depicted in Figure 2.

Figure 2

P-51D Mustang aircraft involved in the accident.
(G-BIXL on the left and G-SHWN on the right)

Aircraft examination

Damage was present on both aircraft from contact between the propeller blades of G-SHWN with the left horizontal stabiliser of G-BIXL (Figures 3 and 4). The blade strike on the horizontal stabiliser was within a few centimetres of the control cables for the elevator trim system, but resulted in structural damage only. The propeller blades all exhibited scuffing to the paint, but no visible structural damage.

Figure 3

Damage to horizontal stabiliser of G-BIXL

Figure 4

Damage to rear face of G-SHWN propeller blade

Recorded data

The collision between the aircraft was recorded by two cameras; one being operated by a witness on the ground and another fixed to the B-17, looking rearward from one of the observation windows and recording autonomously. A still from the latter is shown in Figure 5.

Figure 5
Video still showing the collision

Analysis

The P-51 pilots had flown many formation flypasts together before, in different types of aircraft. They had also practised the formation aerobatics part of the display three weeks prior to the accident.

At the briefing, the pilots of the DC-3, C-47, B-17 and P-51s were given a written description of the flypast by the leader. During the briefing, G-BIXL's pilot drew a diagram of the flypast with aircraft symbols. While he would normally annotate such a diagram with '*ME*' against the symbol depicting his aircraft, in this case he annotated '*P51*' for both the symbols that represented the P51s. Having done this, he was not subsequently able to identify from the sketch which side he was briefed to join the B-17. However, he added that had he been in any doubt, he would have sought clarity over the radio.

The pilot of G-BIXL agreed and acknowledged at the briefing that his P-51 would formate on the left side of the B-17. However, having planned and practised the formation aerobatics in echelon right he may have had some confirmation bias to support his belief that being on the right of the B-17 for the flypast was correct.

The P-51 pilots' concentration was predominantly focused on the formation aerobatics during the briefing and walk through, rather than the whole display. This resulted in G-BIXL's pilot incorrectly recalling the brief and attempting to join on the B-17's right, as opposed to the left. Had they widened their attention to the whole display, the pilot of G-BIXL believed the accident may have been avoided.

As the pilot of G-BIXL closed into position on the B-17's right he briefly looked in the aircraft's 9 o'clock and did not see G-SHWN. Had he remained visual with G-SHWN and monitored its position while it joined on the B-17's right, this may have caused him to either remember that he was briefed to formate on the B-17's left, or to make an appropriate radio call to confirm the intentions of G-SHWN's pilot.

Conclusion

The two P-51s collided due to a combination of human factors. The pilot of G-BIXL did not annotate his diagram of the display sequence to show which was his aircraft. This removed one of the possible means of confirming which side he had been briefed to join the B-17. There appears to have been omissions, possibly resulting from a degree of complacency, during the briefings and subsequent walk through, where the join and flypast with the B-17 were not considered. Best practice would have been for the pilot of G-BIXL to have remained visual with G-SHWN until it was in the final formation position.

It was only providence that prevented this accident from resulting in a catastrophic outcome.

Safety action

Given that most display pilots conduct walk throughs and G-BIXL's pilot commented that he believed the accident would have been avoided had they done a walk through of the whole display, the CAA has made the following addition to Appendix C of Edition 15 of CAP 403, *Flying Displays and Special Events: Safety and Administrative Requirements and Guidance*, that was published in March 2018:

*'**Useful guidance for display pilots***

…

Briefings and walk throughs

C3 It is essential that in addition to the FDD's written and verbal briefings that all display items consisting of formations are thoroughly briefed. It is vital that every member of the formation has a clear picture of the objectives of the formation as a whole and of their individual positioning and responsibilities within it. ***Walk throughs are an integral part of this briefing process and it is strongly recommended that they are adopted as a standard part of all formation briefings*** *[AAIB bold].*

C4 Walk throughs are not exclusive to formation briefs and can also be of benefit to the solo display pilot.'

AAIB Correspondence Reports

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

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

The accuracy of the information provided cannot be assured.

ACCIDENT

Aircraft Type and Registration:	Cessna 208B Grand Caravan, G-BZAH	
No & Type of Engines:	1 Pratt & Whitney Canada PT6A-114A turboprop engine	
Year of Manufacture:	2000 (Serial no: 208B0811)	
Date & Time (UTC):	21 February 2018 at 1630 hrs	
Location:	Netheravon Airfield, Wiltshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Nose gear drag link spring failure	
Commander's Licence:	Commercial Pilots Licence	
Commander's Age:	36 years	
Commander's Flying Experience:	3,000 hours (of which 2,100 were on type) Last 90 days - 150 hours Last 28 days - 40 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further work comissioned by the operator	

The pilot reported that during the landing roll, following a normal landing, he heard a loud bang, after which the aircraft nose appeared to be lower than normal. He stopped the aircraft and shut it down to carry out an inspection. This identified that the nose landing gear drag link spring had failed (Figure 1).

A detailed analysis of the failed part, carried out on behalf of the operator, indicated that the failure was most likely due to damage to the protective coating which had allowed the high-strength steel material to be exposed to moisture. A corrosion fatigue mechanism then led to the crack which resulted in the failure.

The failure is being dealt with through normal continued airworthiness processes.

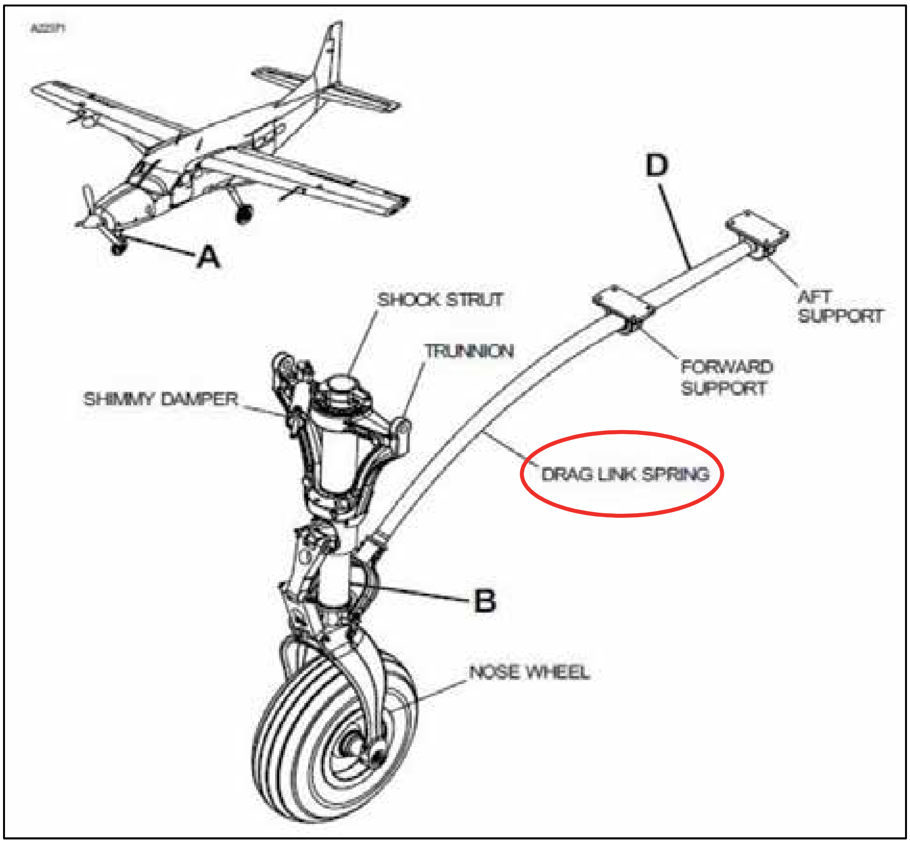

Figure 1
General arrangement of nose landing gear

ACCIDENT

Aircraft Type and Registration:	Jetstream 4100, G-MAJC
No & Type of Engines:	2 Garrett Airesearch TPE331-14GR-807H turboprop engines
Year of Manufacture:	1992 (Serial no: 41005)
Date & Time (UTC):	16 October 2017 at 0835 hrs
Location:	Hawarden Airport, Chester
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 9
Injuries:	Crew - None Passengers - 1 (Minor)
Nature of Damage:	Damage to right propeller and right overwing emergency escape hatch
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	5,000 hours (of which 450 were on type) Last 90 days - 150 hours Last 28 days - 52 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and addtiional enquiries by the AAIB

Synopsis

During a descent into Hawarden Airport, at around FL150, the flight crew noticed a burning smell. Oxygen masks were donned, a MAYDAY was declared and an expedited approach was carried out to land on Runway 22. The crew experienced some difficulty in communication, both internal and external, while using their oxygen masks. After landing the aircraft was taxied clear of the runway, brought to a stop, and an emergency evacuation was carried out.

The burning smell was as a result of smoke and dust carried in the atmosphere from North Africa and Iberia.

The report highlights safety action taken by the operator in relation to its procedures, and other agencies in relation to the promulgation of information in unusual meteorological circumstances such as these.

History of the flight

The flight crew reported for duty at 0600 hrs at Leeds Bradford Airport. When they reported they were advised that their original schedule had been changed. Another company aircraft was unavailable due to a technical problem so the crew were to position their aircraft to Bristol International Airport and then operate a sector to Hawarden with passengers.

The aircraft had been parked overnight on the apron at Leeds. The commander reviewed the technical log and noted there were no open entries; however, when he went through the pre-flight checklist, he noticed that the standby battery charge was low. An engineer was called to the aircraft to assist, he advised that after a period with ground power attached the battery would re-charge. The crew continued to prepare the aircraft for flight. The commander reported afterwards that he had felt rushed and that there had not been time to complete a pre-flight briefing with the cabin crew member.

The co-pilot was the pilot flying (PF) for the sector to Bristol. The flight was uneventful and the aircraft landed and was shut down on the apron. The commander requested a ground power unit be connected to the aircraft, but none was available. The passengers boarded and the aircraft departed at 0800 hrs, approximately 30 minutes behind the normal schedule. The commander was the PF.

The 0820 hrs METAR at Hawarden was: surface wind from 150° at 12 kt, visibility 6,000 m, showers in the vicinity, cloud broken at 900 ft, temperature 16°C dewpoint 15°C and pressure 1008 hPa.

The descent checks and approach briefing for Runway 22 had been completed and the aircraft was descending through FL150 to the south of Hawarden when the flight crew started to notice a burning smell. It appeared to them that the smell was coming from the air vents on the flight deck. They donned their oxygen masks and attempted to verify communication between themselves, but found it difficult because of high noise levels coming through the cockpit speakers.

The co-pilot declared a MAYDAY to ATC, advising of a burning smell and their intention to continue to land at Hawarden. The commander contacted the cabin crew member on the interphone. She was hardly able to hear his message but understood that they were carrying out an emergency descent and went to check and secure the cabin. When he contacted her again she could not hear any of the message so she entered the flight deck. The commander gave her an emergency briefing, using the 'NITS' mnemonic (Nature, Intentions, Time, Special instructions), advising her that the aircraft would be landing in 10 minutes and to standby for instructions after landing. The noise levels through the cockpit speaker remained high and when the commander spoke or attempted a transmission there was a strong feedback signal.

The approach and landing on Runway 22 was completed and the commander taxied the aircraft clear of the runway, turning north onto adjacent Taxiway 'D', and brought it to a stop. He did not know if he could contact the cabin crew member and was uncertain of the conditions in the passenger cabin, so he decided an emergency evacuation should be carried out. He shut down the engines and made a PA announcement to the cabin to initiate the emergency evacuation.

After the commander made the evacuation announcement to the cabin, the engines continued to operate at idle power for 8 seconds before they started to run down; the propellers continued turning for a further 40 seconds. The forward cabin door and the two mid-cabin over wing emergency exits were opened by the passengers. The right over wing exit door was dropped to the ground behind the wing and blown forwards by the wind into the still rotating right propeller. The aft cabin exit door was opened by the cabin crew member; it fell to the ground and was blown rearwards by the propeller wash from the right engine (Figure 1).

Figure 1
Aircraft evacuation

The passengers exited the aircraft and, once they had checked the cabin was clear, the crew followed. The RFFS were in attendance and assisted with the passenger management. There was one minor injury. A timeline of the evacuation is provided at Table 1.

Time (s)	Event
00	Aircraft turns onto Taxiway 'D'
15	Aircraft stopped
22	Over wing exits opened
49	All passengers off aircraft
63	Propellers stop turning
73	All crew off aircraft

Table 1
Evacuation timeline

Recorded information

The CVR was replayed at the AAIB and contained a record of the event. The recording indicated that both pilots were wearing their oxygen masks and had their interphones selected, which caused high noise levels during intake and exhalation of breath. Feedback whistle was also evident when the commander adjusted or removed his mask and when he attempted some transmissions.

Video recordings of the outside of the aircraft during the passenger evacuation were available for the investigation.

Aircraft information

Communication

Selection and control of audio received and transmitted by each pilot is through on-side Audio Control Panels (ACP). VHF, interphone and passenger address selections are made by means of push button switches which deselect the previous selection. To select the oxygen mask microphone a MIC-MASK switch on the Audio Control Panel (ACP) is selected to MASK. When an ACP is selected to MASK audio to the cockpit speaker is activated and cannot be turned off.

A switch on each control column can be selected to TX, OFF or IC. After pressing TX the switch will spring back to OFF, whereas if 'IC' is pressed it will remain selected until a different selection is made.

Engine shut down procedures

For a normal engine shut down at the end of a flight the engine STOP buttons are pressed. This operates the fuel purging system and, when the rpm reduces to 50%, the power levers are moved to the REVERSE position.

In an emergency evacuation the engines are shut down by moving the Condition Levers to the FEATHER/FUEL SHUTOFF position, see Emergency Evacuation Checklist (Figure 2).

EMERGENCY EVACUATION

WARNING: If there is a fire or signs of a fire, only the door or the escape hatch away from the fire should be used

Aircraft...STOP
Parking/Emergency brake.......................................ON
Condition levers.......................................FEATHER/SHUT OFF
Fuel and Hydraulic LP valve captions.......................CONFIRM SHUT

IF FUEL AND HYDRAULIC VALVE CAPTIONS DO NOT INDICATE SHUT

Fuel and Hydraulic LP valve switches...........MANUALLY SELECT SHUT

Cabin crew...ALERT/BRIEF

"STATE EMERGENCY EXITS TO BE USED"

CONFIRM PROPELLORS HAVE STOPPED ROTATING

Call on PA.."EVACUATE AIRCRAFT"

Emergency lights...ON
L & R Fire extinguisher switches (if required).........SHOT 1 & SHOT 2

ADVISE ATC

END OF CHECKLIST

Figure 2

Emergency Evacuation Checklist

The aircraft manufacturer was not able to provide details of the time differential between the two methods for engine shut down to be achieved.

Emergency evacuation procedures

The Jetstream 41 aircraft has a single cabin entry door with integral airstairs located on the forward left side of the fuselage. Two over-wing emergency escape doors are located either side of the cabin and there is a single service door on the aft right side of the fuselage. All these can be used as exits in the event of an emergency evacuation.

The Operator's Operations Manual (OM) guidance for emergency evacuation advised that the Emergency Evacuation Checklist (Figure 2) should be performed as a memory action, the OM included the additional information:

> *'It is essential to have the engines shut down prior to the start of an evacuation. Consequently, the call on the PA to evacuate must only be made when it is considered safe to commence the procedure.'*

Aircraft examination

The aircraft was inspected at the Operator's maintenance facility and damage was found to three separate areas. The right-hand overwing emergency exit door had been struck by the right-hand propeller, causing damage to both. The right hand rear emergency exit door was damaged by contact with the taxiway surface.

Meteorology

On 13 October 2017 the UK Met Office Environment Monitoring and Response Centre (EMARC) noted on satellite imagery a quantity of dust which had lifted from the Sahara Desert and was tracking towards the UK, carried by strong southerly winds on the eastern side of ex-hurricane Ophelia. This air also picked up and carried quantities of smoke from a series of forest fires on the Iberian Peninsula. By 16 October this air reached the UK and was concentrated into a denser layer by the cold front associated with Ophelia. The Met Office forecasts for 0900 hrs 16 October 2017, separately for dust and biomass burning, are reproduced at Figures 3a and 3b.

Other information

Multiple events of smoke and fumes

During 16 and 17 October the AAIB received 32 notifications of Smoke/Fume events affecting aircraft in UK airspace and the UK CAA received in excess of 60 Mandatory Occurrence Reports (MOR). Of the 32 events reported to the AAIB, smoke/fumes were initially detected by flight and cabin crew members at altitudes from between 2,000 ft and FL200. The earliest event appears to have been around 0622 hrs on 16 October in the vicinity of Liverpool at FL130; the aircraft returned to land at Liverpool. Subsequently there were clusters of affected aircraft in the Channel Islands, Liverpool/ Manchester area and, in the afternoon of 16 October, around London Heathrow. During the afternoon of 16 October London Heathrow appended a message to their ATIS, alerting arriving and departing crews of the possibility of their encountering smoke while airborne.

The majority of the aircraft affected either returned to land at the point of departure or expedited their existing approaches, although two aircraft continued en route after initially reporting a

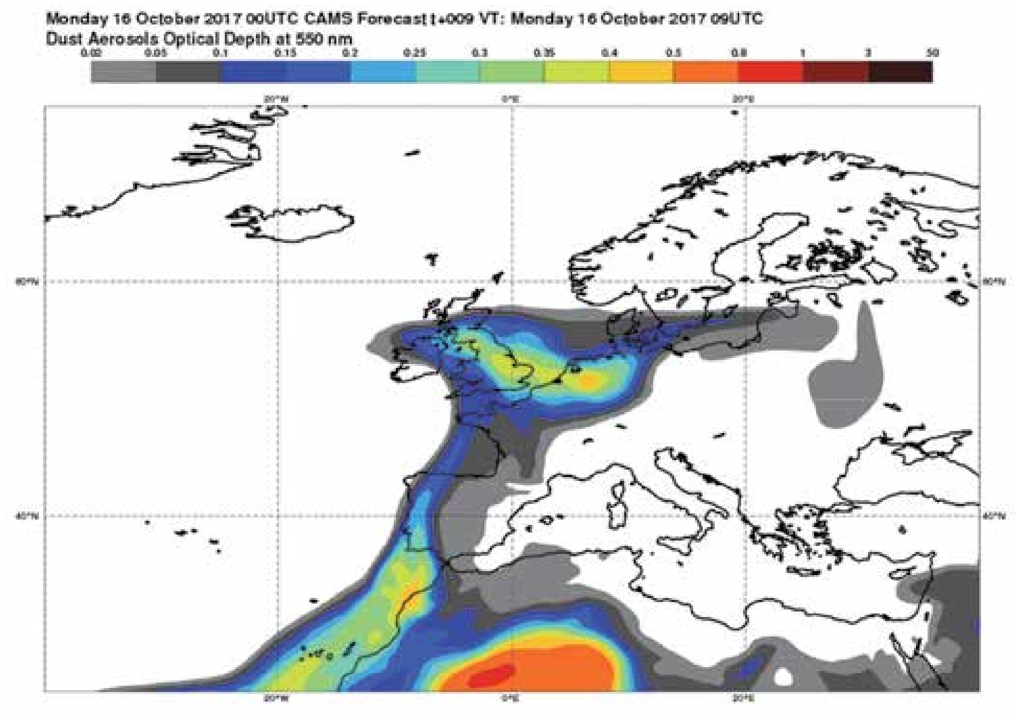

Figure 3a

16 October 2017 forecast Dust Aerosols for 0900 hrs

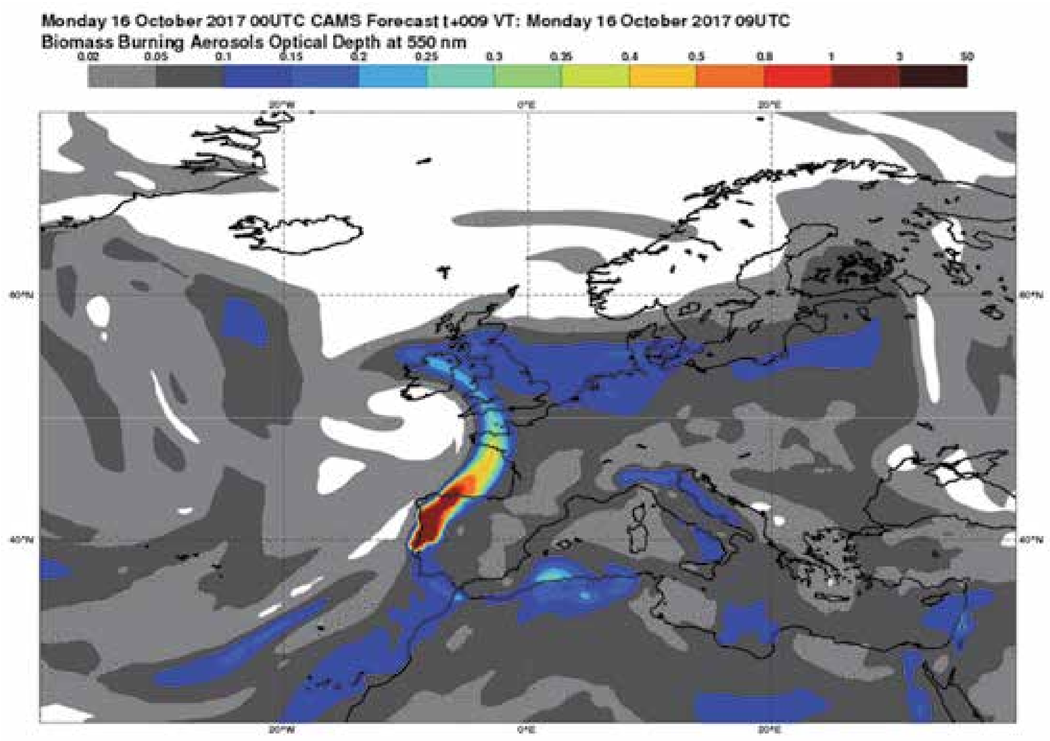

Figure 3b

16 October 2017 forecast Biomass Burning Aerosols for 0900 hrs

problem. Nearly all flight crews declared either PAN or MAYDAY and most used oxygen masks. Of these several reported experiencing difficulty when using the on board masks/goggles, some with vision through the goggles and some with interphone and radio communications.

On 16 October, different Air Navigation Service Provider (ANSP) units received multiple reports of fumes on the flight deck and of aircraft making precautionary or emergency landings. A Met Office meteorologist, based at National Air Traffic Services (NATS) headquarters, was contacted by NATS personnel when they became aware that smoke and fumes were affecting numbers of aircraft. The enquiry was passed on to the Met Office and initially a general, but not aviation specific, press report was issued. Later the report was undated to include information about the altitudes at which smoke/dust was present.

Analysis

Meteorological situation

The smoke/fume event took place on G-MAJC early on the morning of 16 October 2017, and before it was recognised that other aircraft were similarly affected. However, later in the day when there was evidence of significant numbers of aircraft reporting smoke and fumes, there was no co-ordinated dissemination of this information. Smoke and fumes on an aircraft create a high level of stress for the flight crew and any additional information is likely to be beneficial. Flight crews experiencing a smoke/fumes event would still be required to complete the abnormal procedures, but with the benefit of an understanding of the likely cause.

Communication

The flight crew had difficulty in communicating between themselves and with the cabin crew member because of high levels of breathing noise and occasional feedback whistle. This created a distraction, increased their workload and meant that the commander did not feel well informed about the conditions in the passenger cabin.

The reason for the breathing noise was the sustained selection of interphone. The reason for the feedback whistle was not determined but it appeared to be generated from the commander's side and be associated with times when he removed or adjusted his mask or attempted transmissions.

Evacuation procedure

The commander's lack of information as to the conditions prevailing in the passenger cabin led him to initiate an emergency evacuation as soon as the aircraft came to a stop. During the emergency it is likely that the flight crew were operating under high levels of stress and, as a result, the evacuation procedure was rushed and checklist actions not completed. This led to the passengers evacuating the aircraft unescorted while the propellers were still turning, with an associated risk to themselves.

Three of the four emergency exits are behind the wing and thus the possibility of walking into a propeller is reduced. However, the forward exit presents a high risk to personnel, especially when there is no crew member in attendance. The operator recognises this by requiring the engines to be shut down and the propellers confirmed to have stopped rotation before an evacuation is initiated. The combined rundown time for the engine and the propellers, as demonstrated in this case, may be in excess of 40 seconds.

Safety action

In December 2017 a review of the smoke and fume events on 16 and 17 October was held by the UK CAA together with representatives from NATS and the Met Office.

The Met Office advised that accurate forecasting of such phenomena is problematic because it is hard to forecast the extent and height at which the smoke is likely to be present due to the difficulty in accurately locating the fires.

Met Office systems allow a SIGMET to be issued that contains smoke related information and, although it is not compliant with the ICAO format or existing templates, a test showed that it was compatible with NATS's systems. In future a SIGMET will be issued when NATS informs the Met Office there is significant smoke in the atmosphere that is affecting aircraft operations.

ANSPs are responsible for notifying the Met Office of any pilot reports of unusual phenomena affecting flight, but not at present for notifying the UK CAA.

Work is being undertaken to see whether a 'Securité' message broadcast on 121.500 MHz could be used to promulgate a safety message concerning smoke in the UK FIR.

The participants agreed to ensure that suitable escalation and inter-agency coordination procedures are put in place to improve the promulgation of such unusual events in the future.

The operator conducted its own internal investigation into the event and identified safety recommendations and actions. The operator decided to:

> Provide enhanced training on use of oxygen masks including a video of mask donning procedures.
>
> Provide a list of approved headset types shown to be compatible with the aircraft communication systems.
>
> Review and amend the passenger emergency briefing to include a warning about the danger of rotating propellers.
>
> Incorporate a similar type of event into the company training programme.

Bulletin Correction

The third and fifth items from the above safety actions section (commencing 'Met Office systems' and 'Work is being undertaken') were omitted from the original report prior to printing.

The items were added to the online version of the report prior to publication on 12 July 2018.

ACCIDENT

Aircraft Type and Registration:	Cessna 152, G-BOLW
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1977 (Serial no: 152-80589)
Date & Time (UTC):	29 March 2018 at 1100 hrs
Location:	Beccles Airfield, Suffolk
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose landing gear and propeller; possible shock-loading of engine
Commander's Licence:	Private Pilot's Licence
Commander's Age:	71 years
Commander's Flying Experience:	350 hours (of which 257 were on type) Last 90 days - 3 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

While landing, the aircraft bounced and then contacted the ground in a nose-down attitude, causing damage to the nose landing gear and propeller.

History of the flight

Following a flight from Southend Airport, the pilot approached the concrete Runway 27 at Beccles Airfield, Suffolk, in good weather conditions and with a light crosswind from the left. Once established on final approach, the pilot realised the aircraft was too high, so he went around and re-positioned the aircraft for a second approach. He achieved a better approach angle at the second attempt, but was still higher than he should have been, and elected to steepen the approach by making a late selection of full flaps.

It is probable the aircraft's rate of descent then increased, because it landed heavily and bounced, before contacting the runway a second time, in a nose-down attitude. This caused the nose landing gear to partially collapse while both propeller blades struck the surface (Figure 1), before the aircraft came to rest in soft ground to the right of the runway. After turning the fuel and electrics off, the pilot opened the passenger door and vacated.

The pilot assessed that he mis-judged both approaches but, on the second attempt, he became over-confident and continued, rather than initiating another go-around. Due to the late selection of full flap, the aircraft's rate of descent probably increased but the pilot was unaware of this while flaring to land.

Figure 1

G-BOLW with the nose landing gear angled rearwards and the propeller tips bent

One contributory factor noted by the pilot, was that he had not gained any recent practice of recovering from a bounced landing, while accompanied by an instructor. Indeed he had been unable to fly for several months and, although he regained his recency as a pilot by flying with an instructor, this took place at Southend, which has a large runway equipped with approach lighting. In hindsight, he ought to have completed some circuits at an airfield with smaller runways, such as Beccles, while flying with an instructor.

ACCIDENT

Aircraft Type and Registration:	Diamond DA 42 M Twin Star, G-DOSB
No & Type of Engines:	2 Thielert TAE 125-02-99 piston engines
Year of Manufacture:	2008 (Serial no: 42.328)
Date & Time (UTC):	6 April 2018 at 0743 hrs
Location:	Bournemouth Airport, Dorset
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propellers, engine gearboxes, lower engine cowlings and various underside panels
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	9,000 hours (of which 4,000 were on type) Last 90 days - 100 hours Last 28 days - 27 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB

Synopsis

Whilst downwind to land, the student pilot and his instructor were distracted while ensuring they had visual contact with an aircraft flying ahead of them in the circuit. Then, on base leg, when the student believed that he had lowered the landing gear, the instructor noticed the parking brake had been inadvertently applied and, although they rectified this, the instructor continued to consider the issue. He then realised they were on final approach, and overlooked a check of the aircraft's landing configuration, while coaching the student towards the runway. After touchdown it became apparent that the landing gear was UP and damage was incurred as the aircraft slid to a halt on the runway.

History of the flight

As part of a preparatory flight for a multi-engine class rating test, the student pilot re-joined the airfield circuit and made an approach, with the flaps configured normally. He encountered some difficulty maintaining the approach centreline and the correct speed, due to the "challenging" conditions; there was turbulence and an estimated crosswind of 14 kt. Nevertheless, a satisfactory touch-and-go landing was achieved and the aircraft then manoeuvred onto the downwind leg, for an approach to land, without the use of flaps.

While downwind, the student actioned the '*Pre Landing*' checklist, which includes confirmation that the parking brake is selected '*Off*'. He then commenced the '*Final Descent*' checklist and believes he said “gear down”, before reducing power and commencing a turn onto base leg. However, the instructor recalled that the student placed one hand on the landing gear control lever and was about to turn onto the base leg, when it became apparent that neither of them could see a preceding aircraft. Because of this, the instructor asked the student to continue downwind but, after a short time, they spotted the aircraft ahead and then began the turn onto the base leg.

Once on the base leg, the instructor noticed the parking brake was on and pointed this out, but the student responded that he thought the parking brake lever was off. They then discussed the fact that the aft positions of the two adjacent heating controls are labelled OFF, whereas the parking brake lever functions in the opposite sense; its aft position is labelled LOCK and the checklists refer to this as ‘*On*’. Consequently, the student released the parking brake, by moving the lever forward to the ‘*Off*’ position (labelled RELEASE), but the instructor remained distracted for several seconds, contemplating why the parking brake lever had been erroneously set.

The aircraft was established on short final approach, but offset from the centreline, before the instructor switched his attention away from the issue of the lever positions and markings. He considered instigating a go-around but decided instead to coach the student back towards the centreline. While he did this, the student made large power changes, to try and control the airspeed, which was tending to increase. Because he was fully occupied monitoring the student’s actions, the instructor overlooked a required check that the aircraft was stable and in a landing configuration at 100 ft aal.

As they passed over the runway threshold, the student gradually reduced power and the aircraft made a gentle touchdown on the asphalt runway, without any initial indication of abnormality. However, unusual noises were then heard and it became apparent that the landing gear was UP and that the propellers were striking the surface as the aircraft slid to a halt, with the underside of the engine cowlings and the fuselage in contact with the runway. The instructor then shut the aircraft systems down, before he and the student opened the canopy and vacated. They observed that the landing gear lever was in the UP position but noticed that the gear doors appeared to have opened and that the tyres had become partially visible (Figure 1).

Crew comments

Following the accident, the instructor stated that he and the student overlooked checking the landing gear indications for three reasons. Firstly they were distracted by looking for the traffic ahead of them in the circuit, secondly there was some confusion due to the mis-selection of the parking brake and, thirdly they continued an unstable approach, which led to the instructor coaching the student and forgetting to check the aircraft was stable and in the landing configuration at 100 ft.

The student reflected that he might have been distracted, either by the other traffic or by the parking brake position, and that it is possible he did not move the landing gear lever. He observed that earlier in the flight, and also on previous flights, he had been asked to respond to simulated emergencies using ‘touch drills’ only; touching the relevant levers or switches but not activating them. He said it was possible, because of his high workload, that he inadvertently touched the landing gear lever but did not move it.

Figure 1

G-DOSB prior to an attempt to raise it using airbags.
The nose landing gear doors are open and the nosewheel appears to rest on the runway

During the latter stages of the approach, the student remembered that the airspeed kept increasing. He had assumed this was due to the additional power he applied to compensate for the strong crosswind, or because it was a flapless approach. However, he realised after the accident that, because the landing gear was UP, the aircraft had created less drag than normal and therefore less thrust was required.

The aircraft operator stipulates an '*Approach Gate*' at 400 ft aal when on a visual approach and, at this point, the student should have called '*400 stable*' or '*400 not stable, go-around*'. One of the parameters which has to be checked before calling '*400 stable*' is that the landing gear is DOWN, with three green indicators lit. Neither crew member recalled this being said and the student suspected that he either forgot it, because he was working hard to manage the approach, or that he made it without actually looking at the position of the landing gear lever. His recollection was, that at 100 ft aal, he did state '*100 landing*', which suggests he had convinced himself the landing gear was down. However, he noted that most of his previous experience had been on types with fixed landing gear and this could have influenced his decision making process at a time of high workload.

Earlier in the flight, while practising an engine fire drill, the student recalled hearing an intermittent aural warning from a remote cockpit speaker, which indicated the landing gear was UP and one power lever was positioned at 17% of its range, or less. Neither pilot recalled hearing this aural warning prior to the aircraft's final touchdown.

Operator's report

The aircraft operator's initial report suggested that the parking brake may have been selected '*On*' instead of the gear lever being set to DOWN. When this was noticed, it led to distraction and some confusion, partly due to the different directions in which the parking brake lever and the adjacent heating controls operate. This distraction prevented the instructor from effectively monitoring the student, who was working at high capacity during the approach.

It is possible that the landing gear was either fully or partially deployed for the landing but it retracted after touchdown, so checks will be made on the serviceability of the landing gear and its aural warning system when the aircraft is repaired. The aircraft operator also plans to review the operating parameters and the adequacy of the aural warning system, and to consider incorporating the labelled positions for the parking brake lever in the aircraft checklists.

Other recommendations from the aircraft operator's internal report included:

- Crews be reminded of the necessity for carrying out entire checklists correctly and without interruption. In addition, there should be an internal review of the manner in which checklists are completed, and guidance provided on the actions required if a checklists is interrupted.

- Crews be reminded of the importance of the 'Approach Gate' checks, with instructors reminded also of the prime importance of monitoring students' actions, especially at crucial stages of flight.

- Crews be reminded that a go-around is often the best and safest course of action if an approach becomes unstable or is rushed. Any unresolved or unusual aircraft situations should be dealt with at a safe altitude, when time and available capacity allow the best opportunity for problem solving.

ACCIDENT

Aircraft Type and Registration:	Europa XS, G-JAGY	
No & Type of Engines:	1 Rotax 914-UL piston engine	
Year of Manufacture:	2000 (Serial no: A094)	
Date & Time (UTC):	4 February 2018 at 1429 hrs	
Location:	Compton Verney, Wellesbourne, Warwickshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Aircraft extensively damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	61 years	
Commander's Flying Experience:	263 hours (of which 7 were on type) Last 90 days - 9 hours Last 28 days - 0 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

During a local flight from Wellesbourne Mountford airfield the aircraft's engine abruptly stopped and could not be restarted, resulting in a forced landing in a field. The aircraft nosed-over during the forced landing, causing damage to the aircraft and minor injuries to the pilot. An inspection of the aircraft after the accident did not establish the cause of the engine failure.

History of the flight

The pilot was making a local flight from Wellesbourne Mountford airfield to gain experience with the aircraft that he had recently purchased and imported from the USA. There was sufficient fuel for the flight and the fuel level sight gauge showed ¾ full. Approximately fifteen minutes into the flight, whilst 3 nm east-north-east of Wellesbourne Mountford airfield at an altitude of 1,400 ft, the engine abruptly stopped. The pilot did not consider that he had sufficient height to glide back to the airfield and turned onto a southerly heading to avoid a village. The pilot made a MAYDAY call to Wellesbourne Information and attempted to restart the engine by engaging the starter motor, without success.

The pilot selected a large field to land in that was downwind, with slight downslope in the selected landing area. The aircraft touched down in the field on the main landing gear, before the nose landing gear leg dug in, causing the aircraft to nose-over and come to rest inverted (Figure 1). The pilot reported that the field was soft due to recent wet weather.

He sustained minor injuries and stated that he found egress from the aircraft difficult due to damage to the upper fuselage and the broken canopy. He recalled hearing the sound of at least one of the aircraft's electric fuel pumps running whilst he was in the aircraft, prior to his egress, and stated that all of the aircraft's switches were in the normal positions for flight.

Figure 1
Accident site

Aircraft examination

Following the importation of the aircraft from the USA, as part of the initial LAA Permit to Fly inspection, the pilot and an LAA Inspector had replaced the fuel pressure regulator, fuel filters, turbo control unit and both carburettors. The aircraft had flown for approximately 10 hours since the LAA Permit to Fly was issued, with no problems identified with the engine or the aircraft's fuel system.

The aircraft was examined by the LAA following the accident, however this examination did not determine the reason for the engine failure. The engine's crankshaft turned normally by hand, with compression on all four cylinders, and no abnormalities were evident with the aircraft's spark plugs. The aircraft's two electric fuel pumps[1] were tested and functioned normally when supplied with electrical power, and the fuel filters were not clogged.

Footnote

1 The Rotax 914 piston engine fitted to G-JAGY does not have a mechanical engine-driven fuel pump. Fuel pressure is supplied by two independent electric fuel pumps; one primary fuel pump and one secondary fuel pump.

The LAA aircraft examination identified that the aircraft's instrument panel featured switches to control electrical power to each of the aircraft's electric fuel pumps (Figure 2).

Figure 2

Fuel pump switches

This arrangement is contrary to the Europa XS build manual, which requires that the primary electric fuel pump is powered directly from the engine's alternator with overload protection provided by a 5 amp circuit breaker. This design ensures that the primary fuel pump is powered whenever the engine is running.

The initial LAA Permit to Fly inspection following the aircraft's importation from the USA did not detect the non-standard fuel pump switching arrangement in G-JAGY. The LAA publishes guidance on the inspection of imported homebuilt aircraft in Technical Leaflet TL 1.06[2], which includes the need to check that the imported aircraft complies with the LAA-approved design standard. Despite this variation in the aircraft's fuel system configuration, there was no evidence to show that it had been the cause of the engine failure and the pilot recalled hearing at least one of the aircraft's fuel pumps running following the accident.

Footnote

2 http://www.lightaircraftassociation.co.uk/engineering/TechnicalLeaflets/Building,%20Buying%20or%20Importing/TL%201.06%20Imported%20Aircraft.pdf

Conclusion

The aircraft's engine abruptly stopped during a local flight and with the aircraft in a position with insufficient height to glide back to Wellesbourne Mountford airfield. During the resulting forced landing in a field the aircraft nosed-over, coming to rest inverted, and the pilot received minor injuries. The cause of the engine failure was not established.

ACCIDENT

Aircraft Type and Registration:	Gulfstream AA-5B Tiger, G-BJAJ
No & Type of Engines:	1 Lycoming O-360-A4K piston engine
Year of Manufacture:	1979 (Serial no: AA5B-1177)
Date & Time (UTC):	19 April 2018 at 1200 hrs
Location:	Thruxton Airfield, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nose leg bent; propeller damaged and engine possibly shock-loaded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	375 hours (of which 231 were on type) Last 90 days - 4 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot's intention was to gain experience flying the aircraft from the right seat, so that he could later accompany a newly qualified member of the pilot-owners' syndicate. For his first flight in the right seat, another experienced pilot occupied the left seat and they took off from Lower Upham Airfield, Wiltshire and flew towards Thruxton. The pilot later commented that it seemed "strange" flying from this seat but he felt capable of continuing and knew he could have asked the other pilot to assist if necessary.

On the final approach to Runway 25 at Thruxton, both occupants considered the flightpath was correct. However, the pilot was distracted by manipulating the control column with his right hand, rather than his left, and he experienced difficulty monitoring the airspeed indicator. As they crossed the threshold, he realised he was slow, so he lowered the nose and increased power, but the nosewheel and the propeller unexpectedly struck the runway. The aircraft bounced before the pilot regained control. He completed the landing and then taxied to the apron (Figure 1).

As a result of the accident, the pilot realised that he should have sought assistance from a qualified instructor before flying the aircraft from the right seat.

Figure 1

G-BJAJ with damage to the propeller and the nose leg

ACCIDENT

Aircraft Type and Registration:	Jabiru J400, G-REAF
No & Type of Engines:	1 Jabiru 3300A piston engine
Year of Manufacture:	2010 (Serial no: PFA 325-14502)
Date & Time (UTC):	23 February 2018 at 1635 hrs
Location:	Peterborough (Conington) Airport, Cambridgeshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Nose leg collapsed causing distortion to firewall and cockpit floor; propeller damaged and engine shock-loaded
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	68 years
Commander's Flying Experience:	10,560 hours (of which 5 were on type) Last 90 days - 68 hours Last 28 days - 40 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After purchasing this homebuilt aircraft, the owner was receiving familiarisation training from an instructor who had little previous experience on type. At approximately 50 ft aal, while making an approach to land, power was reduced and the aircraft pitched nose-down. It landed heavily on the nose landing gear, which collapsed, and the propeller struck the runway.

History of the flight

The aircraft had been acquired by a pilot who had gained a Private Pilot's Licence a few months previously and had 90 hours' flying experience, mostly in Cessna 152s. The pilot was receiving type familiarisation training from a flight instructor, and they had already flown the aircraft together for 3 hours, although for the preceding flights one of the rear seats had been occupied. Some years previously, the instructor had flown a Jabiru J430, which has a different wing design, but he had not flown a Jabiru J400 until he began giving familiarisation training to the owner and to another pilot.

After flying one circuit to the asphalt Runway 10, at Peterborough (Conington), the owner flew a normal approach and maintained 70 KIAS until, at approximately 50 ft aal, she reduced power with the aim of decelerating to 60 KIAS. The instructor suggested that additional power was needed at this stage, but the aircraft "abruptly" pitched nose-down, causing the descent rate to increase and, before the instructor could intervene, the aircraft landed heavily in a nose-down attitude. Consequently, as the aircraft slowed to a halt on the runway, the nose leg collapsed and the propeller struck the ground. The crew members made a radio call to report their situation, switched off the fuel and electrics and vacated the aircraft without difficulty.

Commander's comments

Following the accident, the flight instructor stated that, before the owner decided which aircraft type she would purchase, he had provided her with some training in a microlight type that he was more familiar with, and which she wished to consider. When she decided instead to buy G-REAF, he agreed to provide familiarisation training to her and to another pilot. He received advice from the aircraft's builder, the previous owner, but he did not fly the aircraft until he commenced the familiarisation training. Prior to the accident flight, he had gained 5 hours experience in the aircraft, but this was with three persons on board, as one of the other two pilots occupied a rear seat for the preceding flights.

The instructor knew that 65 KIAS is the recommended approach speed for the type, but the aircraft's builder had offered verbal advice to target 70 KIAS and to keep the power above idle while landing, because with the engine idling the reduced propeller wash could reduce the elevator's authority. He also stressed that variations in the payload could significantly affect the Centre of Gravity (CG), which would move well forward with only the front seats occupied. The instructor reported that he studied the aircraft's weight and balance schedule with the new owner and they calculated that, when only the front seats were occupied, the CG was acceptable without any need for ballast to be carried.

The aircraft's builder provided written notes for operation of the aircraft and, for the approach to land, these recommended:

'
- *Trim full aft*
- *Late final speed 65kts*
- *Speed is critical – tendency to lose lift fast if speed drops*
- *Keep a little power on during round-out to give elevator authority*'

From his past experience, the instructor believed that pilots who learn on microlights often transition easily to heavier aircraft, but pilots, such as the new owner, who learn on conventional general aviation trainers can take longer for the transition to lighter machines. He therefore anticipated that the owner could experience difficulty adjusting to the reduced momentum and quicker response of this light aircraft but, nevertheless, he was taken by surprise when the owner reduced power towards idle and the aircraft pitched nose-down "abruptly". He considered it possible that the airspeed indicator (ASI) was over-reading and the aircraft had stalled; he understood the documented stall speed in the landing configuration to be 45 KIAS.

One outcome of this accident is that it has bolstered the instructor's belief that newly qualified pilots should build experience flying the class of aircraft they have learnt on, ideally within a flying club atmosphere. The instructor also elected to join the Light Aircraft Association (LAA) in order to benefit from this organisation's knowledge and guidance.

LAA assessment

This home-built aircraft was operating on a Permit to Fly administered by the LAA, which offered several observations about this accident.

The Type Acceptance Data Sheet (TADS) for the Jabiru J400 states:

> *'Note that the handling of the aeroplane is significantly affected by the loading, especially the rear seat loading. Check weight and balance carefully before flight to ensure the aircraft is within the permitted weight and balance envelope.'*

Prior to this flight, the instructor and the owner had only flown the aircraft with three people on board. Having checked the CG, the instructor should have appreciated how far forward it moved with only the two front seats occupied, and that this would accentuate the aircraft's tendency to pitch nose-down when the power was reduced. However, it was the first time the instructor had flown the aircraft in this configuration and he was surprised when the aircraft pitched "abruptly" nose-down. The LAA does not believe it likely that the aircraft stalled, but acknowledges that the accuracy of the ASIs fitted to this class of aircraft is variable and intends to ensure the ASI in this aircraft is re-calibrated during rebuild.

The LAA encourages flight instructors to be conversant with the aircraft they provide training in and, if they are inexperienced on type, to fly with an experienced pilot before they train others. If the instructor was unable to arrange this, he could still have investigated the aircraft's handling characteristics himself prior to providing the familiarisation training. Slow speed flight and stalls in the landing configuration could have been evaluated at a safe altitude, with the ASI cross-checked against the stall warner and perhaps against GPS data.

There are 25 Jabiru J400s administered by the LAA and, because they have all been assembled from kits, their build quality, especially the wing form, can vary. As there may be slight differences in handling characteristics from one aircraft to another, pilots are advised to gain familiarity with individual machines.

Finally the LAA observed that light aircraft such as this, where the payload can account for a large percentage of the total weight, tend to have handling characteristics akin to a microlight type when lightly loaded, but they tend to handle more like conventional general aviation types when heavier. Moreover, the nose landing gear systems of aircraft in this class are unlikely to be as robust as those fitted to classical training types such as Piper PA-28s or Cessna 152s.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-JKAT	
No & Type of Engines:	1 Lycoming O-320-B2C piston engine	
Year of Manufacture:	1986 (Serial no: 566)	
Date & Time (UTC):	20 April 2018 at 1500 hrs	
Location:	Shobdon Aerodrome, Herefordshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Airframe buckled	
Commander's Licence:	Student	
Commander's Age:	50 years	
Commander's Flying Experience:	59 hours (of which 59 were on type) Last 90 days - 11 hours Last 28 days - 11 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and eyewitness account	

The student pilot, on the first leg of a qualifying cross-country flight, was cleared for an approach to Runway 26 and directed to land on the grass strip to the north. Once on final, he chose a landing spot directly ahead and about a third of the way along the grass runway.

As he came to a high hover at an estimated height of 7 to 10 ft, he felt a slight judder. He judged that he was not slowing to a full hover and was concerned he might be entering vortex ring effect. He decided he was too low to lower the nose and translate forward, so he remained level and pulled more power to try to hover but the helicopter descended and turned through 90°, contacting the ground heavily.

The pilot reported that the runway was changed to Runway 08, 20 to 30 minutes later. It is possible there was a light tailwind during the landing attempt. The AFISO who observed the arrival reported that the hover appeared to take place at a greater height than that perceived by the pilot.

ACCIDENT

Aircraft Type and Registration:	Tecnam P2008-JC, G-HRLE	
No & Type of Engines:	1 Rotax 912-S2 piston engine	
Year of Manufacture:	2015 (Serial no: 1052)	
Date & Time (UTC):	19 April 2018 at 1010 hrs	
Location:	Fishburn Airfield, Durham	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damaged beyond economic repair	
Commander's Licence:	Light Aircraft Pilot's Licence	
Commander's Age:	63 years	
Commander's Flying Experience:	196 hours (of which 41 were on type) Last 90 days - 6 hours Last 28 days - 2 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

Immediately after takeoff, the aircraft suffered a loss of power and landed heavily in a field of rapeseed, adjacent to the airfield.

History of the flight

In good weather conditions, the pilot taxied the aircraft, which had not been flown for three weeks, to the refuelling facility at Fishburn Airfield. After adding fuel, to an indicated level of approximately 50% in the left tank and 75% in the right, the pilot re-started the engine and completed the pre-takeoff checks, without encountering any difficulty.

The grass Runway 08 was used for takeoff and all was normal until approximately 150 ft agl, when the engine "spluttered" and lost power, forcing the pilot to land ahead in an adjacent field of rapeseed. The aircraft touched down heavily, causing the landing gear to collapse and damaging the wings, but it came to rest upright and the pilot was able to turn off the electrics and vacate out his door.

A witness, who is an aircraft engineer, observed the aircraft lose power as it climbed, and he reached the aircraft quickly and established that the pilot was un-injured. Upon seeing smoke and then flames appear from the left side of the engine, the witness opened the right engine cowling and successfully used the aircraft's extinguisher to put out a small fire.

Figure 1

G-HRLE after the accident, with the airfield background left

The engine was subsequently inspected by an engineering organisation. The engine turned freely and had not seized, however the fire had damaged several components, including the fuel system, and it was not possible to determine the reason for the loss of power.

ACCIDENT

Aircraft Type and Registration:	Zenair Ch 601ULA Zodiac, G-CIWS	
No & Type of Engines:	1 Rotax 912ULS piston engine	
Year of Manufacture:	1995 (Serial no: 6-8027)	
Date & Time (UTC):	13 May 2018 at 1245 hrs	
Location:	North Moor Airfield, near Scunthorpe, Lincolnshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damaged beyond economic repair	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	73 years	
Commander's Flying Experience:	1,417 hours (of which 26 were on type) Last 90 days - 27 hours Last 28 days - 20 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot was returning to North Moor, his home airfield and, because it was a warm day and the atmosphere was thermally active, he expected turbulence near the airfield. He positioned the aircraft on final approach for the grass Runway 27 and estimated the wind was from 300º at a maximum of 9 kt. Because there are power lines approximately 225 m from the airfield boundary, the pilot flew above them, before steepening his approach and aiming to land near the runway threshold. However, the aircraft sank unexpectedly and, despite adding power, the pilot could not prevent it colliding with a hedge at the eastern airfield boundary. After penetrating the hedge, the aircraft passed close to a parked vehicle and the nose landing gear collapsed before it came to rest near the runway threshold (Figure 1). The pilot opened the canopy and evacuated without injury.

There are hangars and other buildings to the north of the runway threshold and the pilot thinks that the north-westerly wind may have curled over these buildings, creating a strong downdraught which he encountered. In hindsight, and considering the wind direction, he believes he might have avoided the worst of the downdraught had he stayed a little higher on final approach and landed slightly further down the runway than normal.

Figure 1

G-CIWS near the vehicle that it missed and with the hedge visible behind

ACCIDENT

Aircraft Type and Registration:	Hummerchute, G-CKTA
No & Type of Engines:	1 Rotax 582 piston engine
Year of Manufacture:	2017/(Serial no: 482)
Date & Time (UTC):	14 April 2018 at 1330 hrs
Location:	Luffenham Aerodrome, Rutland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	Rear landing gear axle and propellor damaged
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	487 hours (of which 470 were on type) Last 90 days - 10 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

On becoming airborne on its maiden flight, the newly assembled powered parachute aircraft pitched steeply nose-up before falling backwards to the ground. A number of the lines securing the canopy to the 'trike' (accommodating the wheels, occupants and engine) were found to be of the wrong length. This caused the canopy to 'fly' in a different longitudinal position and attitude from normal, leading to loss of control of the aircraft.

The aircraft manufacturer has taken the safety actions of improving its quality checks during manufacture and flight testing aircraft prior to releasing them from the factory.

History of the flight

The pilot reported that he carried out a normal takeoff for a newly rigged aircraft of this type. This consisted of an extended taxi during which the canopy inflated and rose above the trike whilst he observed the rigging from the cockpit. After seeing that it appeared to be rigged correctly, he applied full power. The canopy then oscillated from side to side. The pilot retained control, assuming that it had encountered a thermal and continued the takeoff run. Immediately after becoming airborne, the canopy seemed to lose all forward speed whilst the trike continued forward, swinging upwards before falling backwards onto the ground. The impact broke the rear axle and propeller as well as inflicting minor injuries to the two occupants.

Aircraft information

The Hummerchute is a powered parachute, manufactured by Aerochute Pty Industries in Australia.

In flight, the occupants are seated side-by-side on a three-wheeled unit (the trike) suspended beneath the parachute canopy. The trike also accommodates the engine, positioned behind the occupants, driving a pusher propeller. The parachute lines are attached at four points on the structure of the trike behind the occupants. The shape of the parachute when in flight is affected by the layout and lengths of the numerous attachment lines.

The type is imported to the UK from Australia by the pilot involved in this accident. This was the first flight of this example. Following the accident, the pilot became aware that the Permit to Fly issued for the aircraft had expired shortly before the accident. He also became aware that, when valid, the Permit required such a flight to be carried out solo.

Aircraft examination

Following the accident, the parachute rigging was checked and appeared to be correct. The canopy was then compared with another which was known to have flown satisfactorily. It was established that a group of lines (known as D lines) were of similar length to another group (known as C lines). On the reference canopy, the D lines were of a different length from the C lines. It thus became clear that the parachute of the accident aircraft had been incorrectly manufactured.

Effect of manufacturing error

As a consequence of the incorrect lengths of some of the rigging lines, it appears that once airborne the parachute took up a position slightly behind, rather than directly above the trike.

It thus provided a significant braking effect, rather than just a lifting effect on the trike. This upset the longitudinal trim of the combination, leading to a loss of control.

Safety actions

On establishing the nature of the problem, the pilot immediately informed the owner/customer of a Hummerchute he had recently supplied and had inspected at the same time as G-CKTA. He advised the customer not to attempt a flight. The customer confirmed shortly afterwards that the D lines on his parachute were about 8 inches shorter than those on the reference parachute. The parachute manufacturer was contacted and subsequently confirmed that they had identified a batch which had been manufactured with incorrect length D lines. They reported that only two of them had left the factory and both had been supplied to the UK.

The manufacturer has informed the importer that all future parachutes will come with a full factory trim check and will also be check flown prior to shipping to the UK.

ACCIDENT

Aircraft Type and Registration:	Ikarus C42 FB80, G-CICG
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2013 (Serial no: 1304-7259)
Date & Time (UTC):	18 April 2018 at 1345 hrs
Location:	Popham Airfield, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Right main landing gear leg detached
Commander's Licence:	Private Pilot's Licence
Commander's Age:	74 years
Commander's Flying Experience:	1,507 hours (of which 238 were on type) Last 90 days - 13 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries made by the AAIB

Synopsis

The aircraft struck a traffic cone when the pilot mistakenly tried to land on an area of rough ground at Chilbolton Airfield. After aborting the landing, the pilot proceeded to Popham Airfield, but the right main landing gear detached on touchdown and the aircraft ground-looped.

History of the flight

The pilot made an approach to the grass Runway 24 at Chilbolton, which is an un-manned airfield, after noting that the windsock indicated a strong crosswind from the east-southeast[1]. He adopted a 'crabbed' final approach, with the aircraft pointing to the left of the runway, and he focussed on maintaining the correct airspeed, monitoring the windsock and remaining clear of power lines situated close to the airfield boundary. While flaring to land, the pilot noticed a row of traffic cones on the grass ahead, so he aborted his landing and increased power but, as he did so he heard a "thump". He climbed away, assuming the aircraft had hit a cone which was intended to indicate the runway was unavailable, and he then diverted to Popham, his home airfield.

Footnote

[1] At 1345 hrs the surface wind recorded at Middle Wallop Airfield, situated approximately 5 nm west of Chilbolton, was from 130° at 14 kt.

Runway 21 was in use at Popham and the aircraft touched down on the left mainwheel first, due to a crosswind component of approximately 11 kt from the left. However, when the right mainwheel touched down, the gear leg separated at its airframe attachment points and the aircraft ground looped to the right, before coming to rest with the right wingtip touching the grass. After the pilot had shut down and vacated the aircraft, he realised that the main landing gear leg had detached, due to damage sustained when it struck the traffic cone at Chilbolton.

Following subsequent enquiries, the pilot discovered that the aircraft had hit and destroyed one of several traffic cones, placed to deter pilots from using a strip of rough ground to the left of Runway 24 at Chilbolton. The pilot regarded himself as familiar with Chilbolton, although he had not landed there for eight months, and he knew there was likely to be a contrast in colour between the runway and the rough ground to the side. Unfortunately, due to the ambient conditions, he was distracted, and he did not see the white markings by the runway threshold and misidentified the darker coloured strip of rough ground to be the runway.

Airfield information

Chilbolton is an unlicensed airfield but the operator tries to alert pilots to the presence of the adjacent rough ground in flight guides and on its website. The pilot was aware of the website but had not referred to it prior to this flight and he had not seen a photograph, recently added and labelled, to show pilots what to look for when landing on Runway 24[2] (Figure 1).

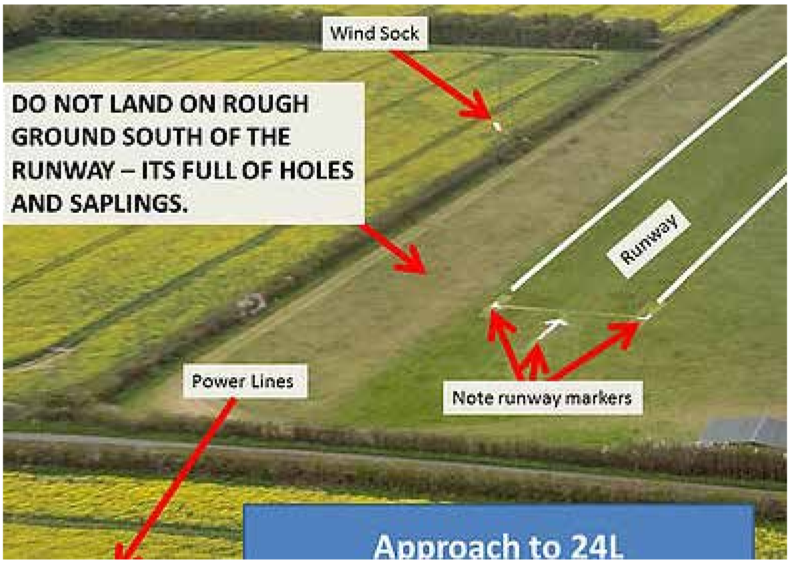

Figure 1

Illustration from the on-line brief for Chilbolton Airfield, highlighting the rough ground beside the runway. The illustrated white parallel lines do not represent ground markings

Footnote

2 The airfield's operator referred to Runway 24 as '*24L*', indicating that a left-hand circuit was required, to avoid noise sensitive areas. The operator has stated an intention to review its guidance material, having learnt that this designation infers there are parallel runways such as Runway 24 Left and Runway 24 Right.

Miscellaneous

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

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

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

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

Published February 2014.

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

Published June 2014.

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

Published September 2014.

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

Published July 2015.

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

Published August 2015.

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

Published October 2015.

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

Published March 2016.

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

Published September 2016.

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

Published March 2017.

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

Published March 2018.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

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

Air Accidents Investigation Branch