AAIB
Air Accidents Investigation Branch

AAIB Bulletin 8/2014

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 1996.

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 14 August 2014

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

CONTENTS Cont

AAIB CORRESPONDENCE INVESTIGATIONS Cont

GENERAL AVIATION Cont

SPORT AVIATION / BALLOONS

MISCELLANEOUS

ADDENDA and CORRECTIONS

(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Special Bulletins / Interim Reports

AAIB Special Bulletins and Interim Reports

This section contains Special Bulletins and Interim Reports that have been published since the last AAIB monthly bulletin.

Farnborough House
Berkshire Copse Road
Aldershot, Hants GU11 2HH

Tel: 01252 510300
Fax: 01252 376999
www.aaib.gov.uk

AAIB
Air Accidents Investigation Branch

AAIB Bulletin S4/2014 *SPECIAL*

SERIOUS INCIDENT

Aircraft Type and registration:	B787-8, ET-AOP
No & Type of Engines:	2 General Electric GEnx-1B turbofan engines
Year of Manufacture:	2012 (MSN 34744)
Location:	London Heathrow Airport
Date & Time (UTC):	12 July 2013 at 1534 hrs
Type of Flight:	Not applicable
Persons on Board:	None
Injuries:	Not applicable
Nature of Damage:	Extensive heat damage in upper portion of rear fuselage
Information Source:	AAIB Field Investigation

Introduction

This Special Bulletin contains information on the progress of the investigation into a ground fire on an unoccupied Boeing 787-8, registration ET-AOP, at London Heathrow Airport on 12 July 2013. It follows the publication of Special Bulletin S5/2013 on 18 July 2013.

The AAIB are assisted in the investigation by Accredited Representatives from the National Transportation Safety Board (NTSB) (representing the State of Design and Manufacture), the Civil Aviation Authority of Ethiopia (representing the State of Registry and the Operator) and the Transportation Safety Board (TSB) of Canada (representing the State of component manufacture), with technical advisors from the Federal Aviation Administration (FAA), the operator and the aircraft and component manufacturers.

In Special Bulletin S5/2013, the AAIB reported the existence of extensive heat damage in the upper portion of the aircraft's rear fuselage, particularly in an area coincident with the location of the Emergency Locator Transmitter (ELT). The absence of any other aircraft systems in this area containing stored energy capable of initiating a fire, together with evidence from forensic examination of the ELT, led the investigation to conclude that the fire originated within the ELT battery.

Five Safety Recommendations are made.

Description of the ELT

The ELT is a location device, designed to notify rescue authorities of an aircraft's location in the event of an emergency. The ELT system installed on the B787-8 is a Honeywell RESCU 406AFN Automatic Fixed ELT, manufactured under contract by Instrumar Limited. The ELT transmitter unit (TU) is located in the aft fuselage crown above the passenger cabin ceiling, to the left of the aircraft centreline, and is mounted on two adjacent fuselage frames, between two thermo-acoustic insulation blankets. The ELT is activated automatically by an internal acceleration sensor, or manually by the flight crew. Unless activated it operates in 'ARMED' mode, using no power.

Examination of the ELT

CT[1] scans and a teardown examination of the ELT revealed that the internal battery pack had experienced severe disruption, exhibiting evidence of a very high-energy thermal event, consistent with having experienced a thermal runaway[2]. All five cell cases had been breached and burnt battery material had been ejected into the battery compartment and outside of the ELT case.

Significantly, the ELT battery wires were found to be improperly installed, in that they had been crossed and pinched together between the battery cover-plate and the ELT case, adjacent to one of the cover-plate fasteners (Figures 1 and 2). The cover-plate was notably bulged in this location, as the wires prevented it from sitting flush against the ELT case.

Due to the fire damage it was not possible to determine the pre-incident condition of the insulation in the area where the wires were pinched, nor the gasket which normally sits between the cover-plate and the ELT case. However, metallurgical analysis revealed strong evidence of metal-to-metal contact between the positive wire and the underside of the battery cover-plate. The surface treatment of the aluminium cover-plate had been worn away in the contact location, indicating that the integrity of the insulation may have become compromised over time, exposing the copper conductor to the cover-plate. The ELT case is electrically grounded to the aircraft Current Return Network. As such, direct

Footnote

1 Computed Tomography.

2 In the case of lithium batteries, the term 'thermal runaway' refers to a self-sustaining, uncontrollable increase in temperature and pressure. It is an exothermic reaction, releasing more heat energy during the reaction than was absorbed to initiate and maintain the reaction. Thermal runaway can culminate in a cell exhibiting violent venting of toxic or flammable gases or electrolyte, decomposition, fire and explosion. The heat released by the affected cell can also heat adjacent cells, such that the failure propagates to other cells in the battery.

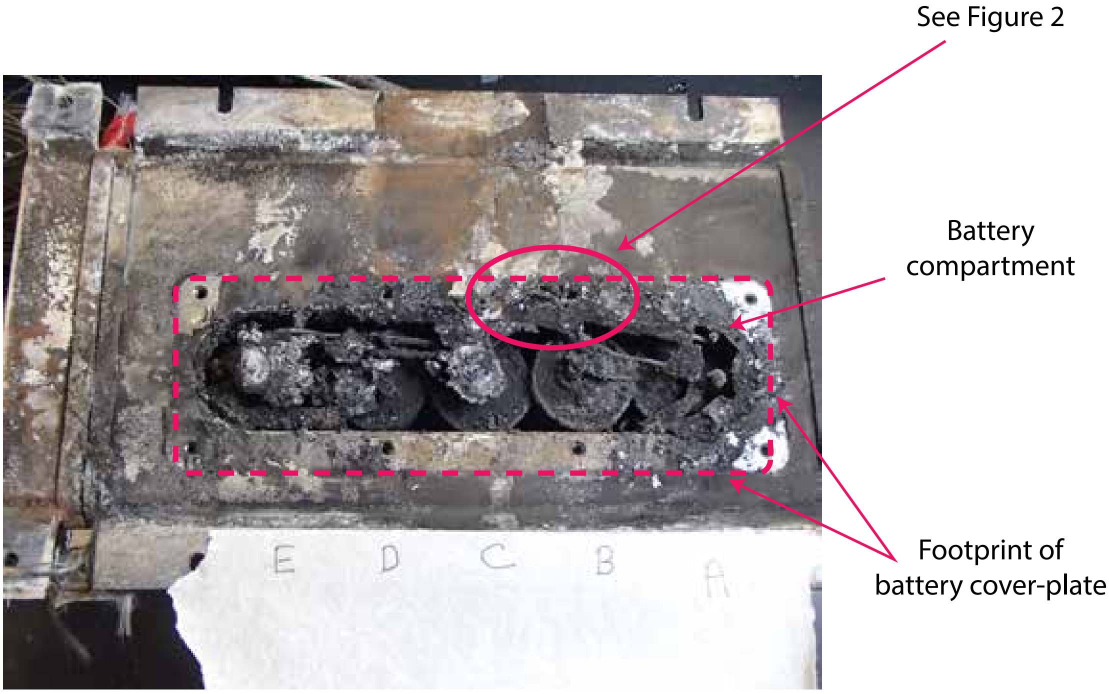

Figure 1
ELT case with battery cover-plate removed; tops of battery cells visible

Figure 2
Crossed and pinched ELT battery wires

contact between the positive conductor and the cover-plate could have provided a path for current to flow through the battery circuit to electrical ground, essentially creating a 'short-circuit' condition.

The nature of the battery failure was such that much of the battery material was consumed, and that which remained was extremely fragile. Therefore, despite extensive forensic examination and CT scanning of the battery and the individual cells, it has not been possible to determine with certainty the sequence of cell failures within the battery or the pre-failure state of the safety features in the circuit.

Description of the ELT battery

The ELT is powered by a five-cell, non-rechargeable 'lithium-metal'[3] battery, installed in the transmitter unit (Figure 3) and manufactured by Ultralife Corporation, under contract to Instrumar Limited.

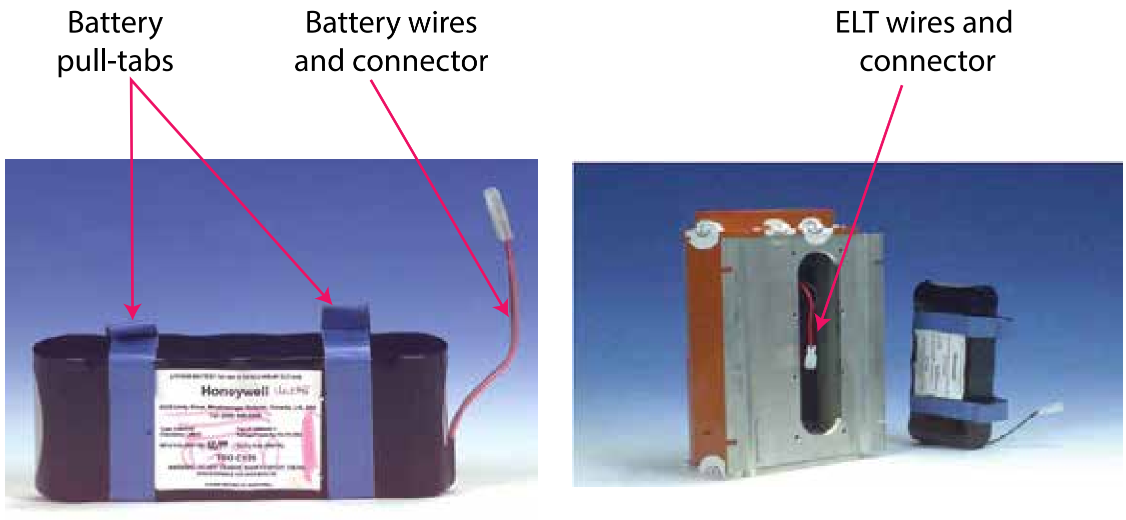

Figure 3

ELT battery pack and ELT transmitter unit, showing battery compartment

Each of the Lithium-Manganese Dioxide ($LiMnO_2$) 'D-cells'[4] has a nominal voltage of 3 V and the cells are connected in series to provide a 15 V battery, with a nominal capacity of 11.1 ampere-hours (Ah) (Figure 4). The battery is rated to a maximum continuous discharge current of 3.3 amps. Two external battery wires connect the positive and negative terminals of the battery to the ELT power supply circuit card. The chemistry in the $LiMnO_2$ cells is considerably different to that used in the rechargeable large-format lithium-ion cells used in the B787 main and APU batteries.

Footnote

[3] 'Lithium-metal' batteries, also known as 'lithium primary' batteries, are high-energy electrical storage devices that rely on electrochemical reactions to deliver energy. They are non-rechargeable batteries in which the anode is made from a layer of metallic lithium.

[4] A 'D-cell' is a cylindrical cell with a nominal diameter of 33.2 mm and a length of 61.5 mm.

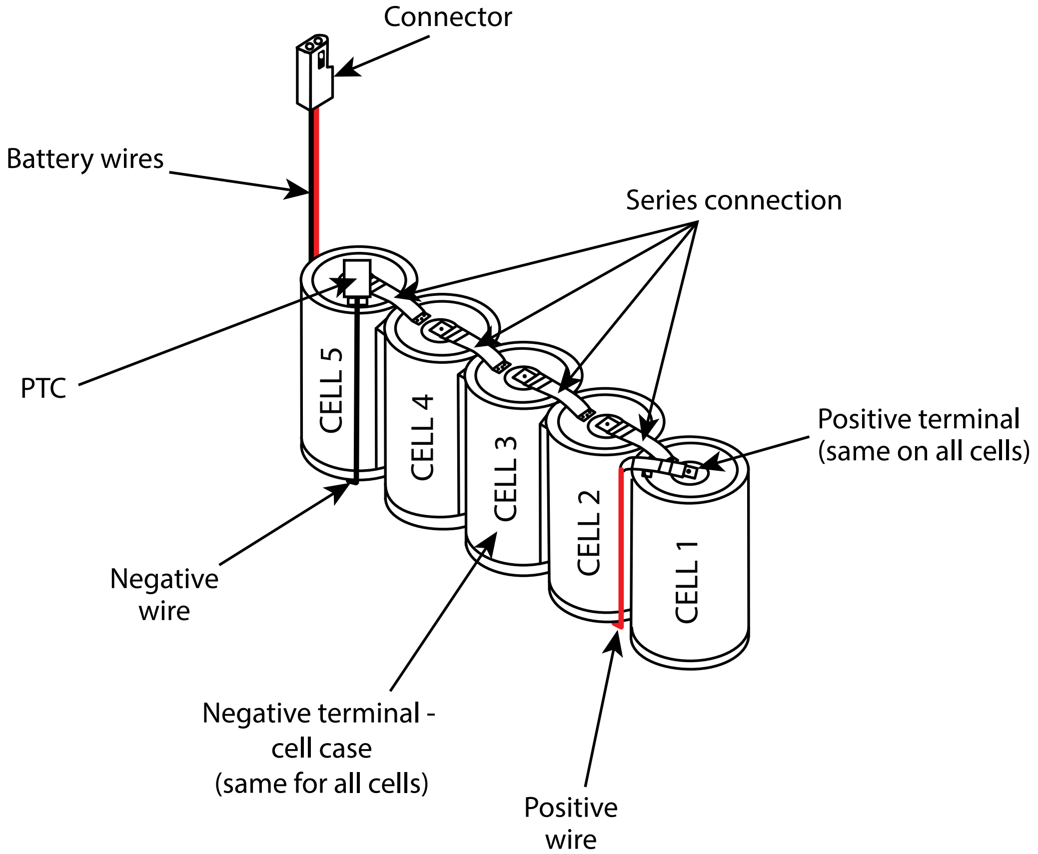

Figure 4

Battery pack illustration (outer shrink-wrap not shown for clarity)

The ELT battery circuit has a polymeric Positive Temperature Coefficient (PTC[5]) protective device installed on the negative wire. The PTC is an automatically-resettable device designed to sense temperature. It will 'trip', or transition from a low-resistance to a high-resistance state, if the temperature exceeds a specified level, either due to high current through the device or due to an increase in ambient temperature.

Each cell contains a spiral electrode winding comprised of a lithium-metal foil anode, a manganese-dioxide cathode and two layers of a separator[6] membrane. Liquid electrolyte allows electrical connection[7] between the electrodes.

Footnote

[5] The material properties of the PTC are such that its resistance increases in a non-linear manner as temperature increases. The PTC is designed to latch in the tripped condition until the fault is removed and the power to the circuit is recycled, after which it will reset. It protects the equipment in the circuit by reducing the amount of current that can flow under the fault condition, to a low steady-state level; this is known as the 'leakage current'.

[6] The separator, also known as a 'shutdown separator', is a tri-layer micro-porous polymeric membrane which acts as an insulator between the positive and negative electrode windings and the cell case to prevent internal short-circuits, while also allowing ions to move between the electrodes. The separator consists of a Polyethylene (PE) inner layer, sandwiched between two Polypropylene (PP) layers. The outer and inner layers have different threshold temperatures, above which they will become less porous and limit the number of ions which can pass through.

[7] The electrolyte allows the transport of ions between the anode and the cathode.

Design considerations and failure modes of lithium batteries

Lithium-metal is a very reactive material with a high energy density, which makes it capable of delivering high currents, long operational life and small cell sizes when used in batteries. However, because of the energetic materials used, lithium-metal batteries require proper design, test, utilisation and storage for use in aircraft applications.

In particular, lithium-metal batteries are sensitive to certain forms of thermal, electrical or mechanical abuse. Known failure modes of lithium-metal batteries include external short-circuit in the battery circuit and internal short-circuit between electrodes, both of which can lead to rapid and uncontrolled discharge, over-discharging, external heating or self-heating. Any of these conditions can elevate the temperature within a cell and if the operating temperature is exceeded by a sufficient margin, the cell pressure will increase. If the heat generated by a cell is greater than the heat it can dissipate, the cell will begin to decompose and may result in thermal runaway.

Cell and battery design therefore typically include thermal protection devices and other safety features to mitigate against the risk of thermal runaway. The cells of the ELT battery have two safety vents in the base of the cell, intended to release pressure if a thermal event occurs; the cell separator is designed to become less porous above a certain threshold temperature and shut down the electrochemical reaction within the cell. The PTC is intended to protect the battery from external short-circuits, over-current and over-temperature conditions by limiting the amount of current that can flow under the fault condition.

Root cause testing and analysis

To support the AAIB investigation, the aircraft and ELT manufacturers undertook an extensive programme of testing and analysis to identify the root cause of the ELT battery thermal event. The resulting report concluded that the most probable cause was a short-circuit caused by the improperly installed battery wires, leading to an uncontrolled discharge of the battery. It was established that this condition in isolation should not have caused a battery thermal event, if the battery short-circuit protection features had effectively limited the current to a safe level. In addition, the failure sequence would have required one of the battery cells to deplete more rapidly than the others until it reversed polarity, becoming resistive and absorbing energy from the other four cells as they discharged and ultimately resulting in thermal runaway of the depleted cell. Several tests demonstrated that when a cell failed in this manner, the heat released caused the failure to cascade to the remaining four cells.

In total, five sub-scenarios involving a combination of the above factors were identified, each of which could lead to a battery thermal runaway. The sub-scenarios took account of variation in the characteristics of the short-circuit and the different ways in which the PTC could either fail, or provide inadequate short-circuit protection to the circuit. The testing revealed a number of features of PTC operation that were not previously well understood.

The results of the test programme, the identified failure scenarios and the operation of the PTC are still under review by the AAIB and will be more fully documented in the final AAIB report.

ELT wiring anomalies

Maintenance records showed no entries relating to maintenance on the aircraft ELT (Serial No 5055) since its manufacture in December 2010. It is therefore likely that the ELT battery wires were improperly installed during production assembly of the ELT.

At the time of the incident to ET-AOP there were approximately 3,650 identical batteries in service, installed in RESCU 406AFN and the similar RESCU 406AF ELTs, fitted to numerous aircraft types. There were also approximately 2,900 similar batteries, using the same cell, installed in the Honeywell Portable ELT RESCU 406SE. Honeywell reported that they were not aware of any previous in-service thermal events involving these batteries or cells.

In February 2013 Honeywell became aware of battery wiring anomalies on a RESCU 406AFN ELT returned by an aircraft manufacturer due to a discharged battery. Inspection of the unit found the battery wires trapped under the cover-plate, cuts in the gasket and insulation damage exposing the positive conductor. There was no evidence of thermal damage to the battery.

As a result of these findings Honeywell conducted a quality review, resulting in modification of the Instrumar ELT assembly instructions, to route the wires through the battery pull-tabs, and better contain them within the battery compartment. This corrective action was introduced in April 2013 on newly manufactured ELTs. No inspections or modifications were recommended for ELTs already delivered and the findings were not communicated to customers and aircraft manufacturers.

Following the ET-AOP incident in July 2013, all in-service RESCU 406AF/AFN ELTs were subject to a mandatory one-time inspection (see 'Safety actions' section). While there is no formal means for equipment manufacturers to track compliance with such inspections, a review of Honeywell and Instrumar ELT returns data for the period July 2013 to mid-March 2014 showed that of the ELTs returned in that period, 26 exhibited trapped wires.

To date a total of 28 ELTs have been identified with trapped wires. Of these, 21 had either the positive, or both wires trapped, nine of which had the positive conductor exposed. Six of these nine units were returned with fully charged batteries, indicating that the exposed conductor had not made contact with the case to create a short-circuit. Of the remaining three units, one was the unit with the depleted battery identified in February 2013. Honeywell concluded that the exposed positive conductor created a short-circuit, but the PTC had worked as designed, resulting in benign depletion of the battery. The second unit was the ELT from the ET-AOP thermal event on 12 July 2013, and the third unit was returned without its battery installed, so the state of charge of that battery is unknown. Honeywell believe that this battery may have discharged but the unit exhibited no evidence of a thermal event, indicating that any associated battery failure was benign.

Safety actions

Responses to Safety Recommendations

On 18 July 2013 the AAIB made the following Safety Recommendations in Special Bulletin S5/2013:

Safety Recommendation 2013-016

It is recommended that the Federal Aviation Administration initiate action for making inert the Honeywell International RESCU 406AFN fixed Emergency Locator Transmitter system in Boeing 787 aircraft until appropriate airworthiness actions can be completed.

Safety Recommendation 2013-017

It is recommended that the Federal Aviation Administration, in association with other regulatory authorities, conduct a safety review of installations of Lithium-powered Emergency Locator Transmitter systems in other aircraft types and, where appropriate, initiate airworthiness action.

In response to Safety Recommendation 2013-016, the FAA issued Airworthiness Directive (AD) 2013-15-07 on 26 July 2013 requiring, within 10 days, either the removal, or inspection and corrective action as necessary, of Honeywell RESCU 406AFN ELTs installed on B787-8 aircraft[8].

Honeywell subsequently issued an Alert Service Bulletin (SB) instructing operators of all aircraft types equipped with specified RESCU 406AF/AFN ELTs, to perform an inspection of the ELT and its battery and to correct any anomalies. Embodiment of this SB was mandated by Transport Canada AD CF-2013-25 issued 15 August 2013 and FAA AD 2013-18-09 issued 18 September 2013.

On 18 April 2014 the FAA formally responded to Safety Recommendation 2013-017 as follows:

'The FAA is currently conducting a safety review of Lithium-powered ELT systems with other regulatory authorities to identify any unsafe conditions in other aircraft types. The FAA expects to provide an update on the status of the safety review by March 31 2015.'

The AAIB therefore considers the status of Safety Recommendations 2013-016 and 2013-017 as 'Adequate - Closed'.

Footnote

8 On 26 July 2013 the European Aviation Safety Agency (EASA) issued AD 2013-0168, with the same intent.

ELT redesign

As a result of the early investigation findings and feedback from the AD inspections, Honeywell modified the battery orientation within the ELT on all new production units, effective May 2014, to route the wires underneath the battery, thereby preventing the possibility of the wires becoming trapped under the battery cover-plate.

As a result of the findings from the root cause test programme Honeywell continues to review options to improve the robustness of the short-circuit protection features of the ELT battery.

Certification aspects

ELT and battery certification requirements

The B787-8 was certified in accordance with 'FAR 14 CFR Part 25'[9], however these regulations contain no specific requirements relating to ELTs. At the time of certification of the RESCU 406AFN ELT, technical standards for the performance of an ELT as a 'stand-alone' item were specified in FAA TSO[10]-C126 '*406 MHz Emergency Locator Transmitter (ELT)*' dated October 2003, and FAA TSO-C91a *'Emergency Locator Transmitter (ELT) Equipment'* dated April 1985. The RESCU 406AFN ELT held approvals in accordance with FAA TSO-C126 and TSO-C91a.

The Minimum Performance Standards[11] (MPS) for lithium cells and batteries for use in aircraft equipment were outlined in FAA TSO-C142 '*Lithium Batteries'*, dated April 2000. TSO-C142 refers to RTCA[12] document DO-227 '*Minimum Operational Performance Standards for Lithium Batteries*', dated 23 June 1995 and specifically states in paragraph 3 *'Requirements'* that batteries approved under this TSO must meet the standards described in Section 2.0 of DO-227. Appendix 1 of the TSO provides additional guidance which modifies some of the requirements of DO-227. In particular Appendix 1 recommends the inclusion of a new requirement in DO-227 dealing with '*Toxic Gas Venting Procedures,'* stating:

> *'Batteries that are capable of venting toxic gases may be installed or used in an aircraft passenger compartment if the installer shows that a safety hazard would not be created.'*

However, Appendix 1 was not specifically referenced in the '*Requirements*' paragraph of the TSO.

DO-227 contains both requirements and general guidelines for the design, test, application, handling, storage and disposal of lithium cells and batteries. Section 2.0 of DO-227

Footnote

9 US Federal Aviation Regulations Part 25 '*Airworthiness Standards: Transport Category Airplanes*'.

10 A Technical Standard Order (TSO) is a minimum performance standard for specified materials, parts and appliances used on civil aircraft. A TSO authorisation is a design and production approval for the specified equipment, but does not constitute approval to install and use the equipment on an aircraft. The TSO process is described in 14 Code of Federal Regulations, Part 21, Subpart O.

11 The minimum necessary performance to satisfy a regulatory requirement.

12 RTCA – The Radio Technical Commission for Aeronautics develops technical guidance and equipment standards for use by regulatory bodies and industry. The RTCA is an advisory body to the FAA.

describes the required 'cell-level' and 'battery-level' tests that TSO applicants must perform in order to qualify their product for use in aircraft equipment. These tests expose the cells and batteries to environmental conditions (shock loading, temperature-cycling, altitude, decompression, humidity); electrical conditions (discharge, forced discharge, external short-circuit, load profile); and design-abuse conditions (internal short-circuit and venting)[13].

Predominantly, the tests are conducted on cells and batteries in 'free air', at ambient laboratory conditions or, where a test is required to be conducted at a specific temperature, in an oven.

DO-227 paragraph 2.4.1.4, describes the external short-circuit test[14] required to be performed on individual cells (at 24ºC and 55ºC) and batteries (at 55ºC). The test requirements do not indicate to what capacity the cells or battery must be discharged under the short-circuit, or how long the condition must be maintained.

DO-227 paragraph 2.4.2.1, describes the internal short-circuit test which is only required to be completed at cell-level at 24ºC. The sample is required to be deformed between a rod and a plate, until the Open Circuit Voltage[15] (OCV) drops by at least two-thirds.

The remaining sections of DO-227 contain guidance on all aspects of cell and battery chemical composition, construction, operation and safety. Included in this guidance material is advice on integration of the battery with the equipment and the associated effects on battery performance. Specifically in respect of thermal management within batteries, DO-227 states:

> *'Thermal management within the battery itself, and when installed within equipment, must also be carefully considered in view of the heat developed within the cells or battery, by the equipment, and by the environment.'*

and:

> *'Thermal management is important in lithium batteries because lithium has a very low melting point: 180ºC. At or near this temperature lithium may react vigorously with other cell components, and the results could be catastrophic ...... Therefore, in cell and battery design, it is important to ensure that the temperature is maintained well below the melting point of lithium. Additionally, it must be recognized that under certain discharge conditions, significant heat will be generated within each cell….. Heat is dissipated by radiation, conduction and convection; therefore consideration must be given to any aspect of battery design that will influence these parameters.'*

Footnote

[13] The pass/fail criteria vary from test to test, however in general, the cells and batteries must not exhibit any leaking or venting of electrolyte, distortion, fire, rupture or a change of more than 2% in Open Circuit Voltage (OCV).

[14] The sample is held at the test temperature for 24 hours and then the short-circuit is created by connecting the positive and negative terminals with a low-resistance conductor. The sample may distort, but will fail if leaking, venting, fire or rupture occurs.

[15] Open Circuit Voltage is the difference in electrical potential between the positive and negative terminals of a cell or battery when it is disconnected from any electrical circuit.

TSO-C142 qualification testing

The results of the TSO-C142 qualification testing[16] performed by Ultralife for the RESCU 406AFN ELT battery and cells demonstrated compliance with all the requirements of Section 2.0 of DO-227. The test reports state that the cells and the battery met all of the evaluation criteria in DO-227, and that no failure conditions were identified during the test campaign. The results for the external and internal short-circuit tests indicate conformance with the DO-227 criteria, but the maximum temperatures reached by the cells or batteries during the tests were not noted in the reports.

ELT approval process

Although not directly involved in the TSO-C142 approval process, Honeywell in co-operation with Transport Canada, reviewed the applicable DO-227 battery guidance material as part of the ELT TSO approval process. Additionally, the ELT qualification testing performed for TSO-C126 and TSO-C91a approval contained elements of abuse testing (flame, shock, impact and crush tests) on the ELT. Although not intended as battery design-abuse tests, the battery was installed in the ELT when these tests were performed. No battery failures were noted during the ELT qualification testing.

As part of the RESCU 406AFN ELT approval process for use on the B787 aircraft, Honeywell conducted a Failure Modes and Effect Analysis (FMEA)[17] for the ELT, although this was not required by TSO-C126. This document identified a number of possible failure modes for the ELT battery, attributed to an internal open-circuit or short-circuit. The effects of these failures were considered only in respect of their impact on power supply to the ELT, but the more hazardous effects of a battery fault were not captured. No failures relating to battery thermal events or thermal runaway were identified in the FMEA. Honeywell did not require Ultralife to complete a dedicated 'battery-level' FMEA and TSO-C142 contained no requirement for such a FMEA.

FAA Issue paper SE-09

The FAA published Issue Paper SE-09 '*Special Conditions: Lithium-ion battery installations*'[18], in March 2006. Although this document is not applicable to the lithium-metal batteries used in the ELT, as it is aimed at large-format lithium-ion integral aircraft batteries, both types of lithium battery share many of the same failure modes. Therefore as part of the Certification Plan for the B787 Navigation Radio System (NRS), of which the ELT is part, Boeing requested that Honeywell review the Issue Paper SE-09, to show how the concerns identified were addressed for the $LiMnO_2$ batteries used in the ELT.

Footnote

[16] Ultralife TSO-C142 Test Report for P/N U3356 cell, dated 2 May 2005 and Ultralife TSO-C142 Test Report for battery P/N S00130, dated 26 August 2005.
[17] Failure Modes and Effects Analysis (FMEA) for the RESCU 406AFN ELT, dated 29 April 2008.
[18] SE-09 was published to address known failure modes and operational characteristics of lithium-ion batteries, in advance of certification of the B787-8 main and APU large format lithium-ion batteries.

SE-09 listed nine Special Conditions (SC), of which six were of possible relevance to the ELT batteries. In particular, SC 2 stated:

> *'The batteries must be designed to preclude the occurrence of self-sustaining, uncontrolled increases in temperature in pressure.'*

Honeywell advised that the cell shutdown separator and the pressure vents would limit any uncontrolled increase of temperature and pressure. Also, SC 6 stated:

> *'Each battery installation must have provisions to prevent any hazardous effect on structure or essential systems that may be caused by the maximum amount of heat the battery can generate during a short circuit of the battery or of its individual cells.'*

Honeywell advised that the shutdown separator would limit temperature to a safe level, and that the battery was installed within a sealed compartment of the ELT transmitter unit. This information was documented in the Boeing 'ELT Certification Summary'.[19]

ELT Certification Summary

The ELT Certification Summary provides a summary of all the certification activities for the ELT, in support of the overall B787 Type Certification and documents how compliance has been achieved with all applicable certification criteria. This includes the requirements of FAR 14 CFR Part 25, the relevant TSOs and Issue Papers. Specifically in respect of compliance with FAR 14 CFR 25.1309 (d)[20], the following statement is made:

> *'The ground test and the functional failure modes for the ELT were analyzed to ensure that any failure, or combination of failures, which would prevent the continued safe flight and landing of the airplane is extremely improbable. There are no ELT failures which could reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions.'*

Current certification requirements

The ELT battery pack was granted TSO-C142 approval in November 2005. In August 2006 TSO-C142 was superseded by TSO-C142a *'Non-rechargeable lithium cells and batteries'*. Paragraph 3 '*Requirements'* of TSO-C142a requires compliance with DO-227 Section 2.0, *'as amended by Appendix 1 of this TSO'*. Appendix 1 of TSO-C142a includes all of the items previously addressed in Appendix 1 of TSO-C142, plus additional items. Of particular note, Appendix 1 of TSO-C142a introduces a new requirement '*Test Procedures for Installed Equipment Performance*,' which requires that:

Footnote

[19] Boeing document '*787 Emergency Locator Transmitter (ELT) System Certification Summary*', dated 14 December 2010.

[20] FAR 14 CFR 25.1309 *'Equipment Systems and Installations'*.

> *'Airplane and equipment manufacturers incorporating lithium cells or batteries must ensure that if there is a fire within a single cell of the battery, the equipment unit will contain the fragments and debris (but not smoke/gases/vapours) from a battery explosion or fire.'*

Additional fire safety test criteria are specified for equipment incorporating lithium cells or batteries.

TSO-C142a was an evolution of TSO-C142, updated to reflect new industry knowledge on lithium batteries. There was no regulatory requirement for the FAA retrospectively to review products previously certified to TSO-C142 standards to determine whether they would meet the new requirements of TSO-C142a.

Calorimeter testing

In March 2014 the AAIB conducted a battery discharge test in an Accelerating Rate Calorimeter (ARC), to understand how the ELT battery would behave in pure adiabatic[21] conditions. This is a highly adverse operating environment for the battery and the test was not intended to represent the battery's equipment or aircraft installation. A discharge current of 1 amp, considerably below the 3.3 amp maximum discharge capability of the battery, was chosen for the test. As it discharged, the battery temperature gradually increased from a start temperature of 20ºC over a period of 8 hours, until the PTC tripped at 96ºC. The battery then continued to self-heat until, at approximately 150ºC, one of the cells vented and decomposed under thermal runaway. The failure rapidly propagated to the neighbouring cells. The maximum cell external temperature measured during the battery failure was 454ºC. Further calorimeter testing is planned to characterise heat dissipation of the battery more fully. This will include a test with additional instrumentation to quantify the leakage current that flows through the battery when the PTC is tripped. These tests will be reported in the AAIB final report.

Discussion

Battery fire

The AAIB's findings indicate that, in the ET-AOP event at London Heathrow on 12 July 2013, all five cells in the ELT battery experienced thermal runaway. Strong physical evidence from the ELT, supported by the manufacturers' root cause testing, identified the most likely cause of the ELT fire as an external short-circuit of the battery, due to the improperly routed battery wires, most probably in combination with the early depletion of a single cell. Neither the cell-level nor battery-level safety features were able to prevent the single-cell failure, which then propagated to adjacent cells, resulting in a cascading thermal runaway, rupture of the cells and consequent release of smoke, fire and flammable electrolyte.

Footnote

[21] An adiabatic environment is one in which zero heat-loss occurs. As a battery discharges, heat is generated resulting from a combination of resistive heating from the discharge current and the chemical reactions within the cells. The Accelerating Rate Calorimeter tracks the temperature of the battery, and matches this temperature in the calorimeter chamber so that no heat transfer takes place between the battery and its surroundings.

The pinched wires prevented the battery cover-plate from forming an effective seal with the ELT case and provided a gas path for flames and ejected battery decomposition products to escape from the ELT to the surrounding aircraft structure.

Pinched wires

Sufficient slack had existed in the ELT battery wires to allow them to become trapped under the cover-plate during battery installation and this condition was not detected prior to the ELT installation on the aircraft. The possibility of pinched battery wires leading to an exposed conductor had been identified by Honeywell prior to the ET-AOP incident. The worst effect was identified as a battery short-circuit, leading the battery to deplete benignly. While these findings resulted in a change to the ELT assembly procedures in production units, they did not at that time result in inspection of in-service units. While further instances of pinched wires were found during AD compliance inspections prompted by the ET-AOP event, this was the only occurrence identified as resulting in a battery thermal event.

Following the ET-AOP incident, the mandatory one-time inspections of all in-service RESCU 406 AF/AFN ELT units, and a design modification for production units, have mitigated the possibility of further occurrences of pinched wires. Therefore no further safety action is considered necessary in this area.

Positive Temperature Coefficient device (PTC)

Although designed to protect the battery circuit from external short-circuits, over-current and over-temperature conditions by limiting the current to a safe level, the PTC did not adequately protect the battery in this event. The operational characteristics of the PTC continue to be investigated, and will be documented more fully in the AAIB final report.

Certification aspects

The use of lithium batteries in consumer and industrial applications is now commonplace and, in particular, the use of lithium batteries of all chemistries in aircraft has become considerably more prevalent. DO-227 Section 2.0 forms the basis of the technical standards (TSO-C142 and TSO-C142a) relating to lithium-metal batteries for use in aviation equipment. The guidance and requirements in DO-227, written in 1995 based on available knowledge, are now outdated and do not adequately take account of the progress in lithium battery technology and operational feedback over the intervening two decades. Therefore, in light of the findings of this investigation:

Safety Recommendation 2014-020

It is recommended that the Federal Aviation Administration develop enhanced certification requirements for the use of lithium-metal batteries in aviation equipment, to take account of current industry knowledge on the design, operational characteristics and failure modes of lithium-metal batteries.

DO-227 contains both requirements and general guidance for the design, test, application, handling, storage and disposal of lithium cells and batteries. However, TSO-C142 only explicitly requires compliance with Section 2.0 of DO-227. Therefore battery and equipment manufacturers are not obliged to comply with the guidance material, as long as they can demonstrate that their products meet the criteria defined in Section 2.0. In this case, however, Honeywell did review the guidance material as part of the overall ELT approval process.

While the test regime outlined in DO-227 is aimed at ensuring the safety, reliability and performance of cells and batteries, the associated guidance material strongly emphasises a number of equipment integration and design considerations that are not addressed by the required testing. DO-227 stresses that a battery may exhibit considerably different performance, when installed in equipment, to that which it exhibits in the uninstalled condition, particularly with respect to heat dissipation. For example, the ELT battery's ability to dissipate heat will depend on the battery materials, the ELT case, its mounting structure, the ambient temperature in the aircraft and the presence of aircraft insulation. However none of the DO-227 tests are required to be conducted with the battery installed in its parent equipment, nor with the equipment installed in the aircraft, as these tests deal only with battery-level hazards and do not take account of equipment-level or aircraft-level hazards.

The DO-227 electrical performance tests are intended to simulate the most severe effects of adverse electrical conditions to which the cells or battery may be exposed. In the ET-AOP event an external short-circuit resulted in a cascading thermal runaway of all five cells that ignited a fire and ultimately resulted in extensive fire damage to the parked aircraft. It is therefore clear that the most severe effects of an external short-circuit were not demonstrated during the DO-227 certification testing for the RESCU 406AFN ELT battery. The calorimeter test conducted by the AAIB represented worst-case heat dissipation conditions for the battery, as it was unable to dissipate any of the heat generated during a normal discharge. The 'free-air' or 'fixed-temperature' laboratory tests specified in DO-227 represent something close to best-case conditions for heat dissipation. Actual thermal performance of the battery in the ELT parent equipment and installed on the aircraft, would be between these two extremes.

In order to properly understand the most severe effects that could occur when a lithium-metal battery is exposed to adverse electrical conditions, the certification tests should take account of the battery and equipment integration. Therefore:

Safety Recommendation 2014-021

It is recommended that the Federal Aviation Administration require that electrical performance and design-abuse certification tests for lithium-metal batteries are conducted with the battery installed in the parent equipment, to take account of battery thermal performance.

The DO-227 design-abuse tests are intended to simulate the most severe effects of known failure modes for lithium-metal batteries. However DO-227 requires that the internal short-circuit test is only completed at cell-level. There is currently no requirement to conduct this test on a single cell within a battery pack, where the heat dissipation and propagation characteristics of the abused cell may differ. Further, DO-227 allows the cell-level internal short-circuit test be terminated when the cell reaches two-thirds OCV[22]. There is no requirement for the cell to be forced into thermal runaway to evaluate the potential for propagation to other cells, or the ability of the equipment to contain the resulting products of the battery failure.

The DO-227 internal short-circuit test uses a rod and plate to deform the cell. However there are many industry-accepted abuse methods used to induce a thermal runaway in lithium batteries, including nail penetration, crushing, heater mats and indentation. It is important that any certification test demonstrates the worst possible effects of a thermal runaway for a particular cell or battery design, so that battery and equipment mitigations can be effectively assessed.

The enhanced requirements of Appendix 1 of the current TSO-CA142a go some way to addressing these concerns. However, the following Safety Recommendations are made:

Safety Recommendation 2014-022

It is recommended that the Federal Aviation Administration work with industry to determine the best methods to force a lithium-metal cell into thermal runaway and develop design-abuse testing that subjects a single cell within a lithium-metal battery to thermal runaway in order to demonstrate the worst possible effects during certification testing.

and:

Safety Recommendation 2014-023

It is recommended that the Federal Aviation Administration require equipment manufacturers wishing to use lithium-metal batteries to demonstrate (using the design-abuse testing described in Safety Recommendation 2014-022) that the battery and equipment design mitigates all hazardous effects of propagation of a single-cell thermal runaway to other cells and the release of electrolyte, fire or explosive debris.

Safety Recommendations 2014-020 to 2014-023 bear similarities to recently published NTSB recommendations A-14-032 to A-14-035, arising from the NTSB investigation into a thermal event on a B787 large-format lithium–ion battery.[23] Although these two investigations are not linked and the respective batteries differ, both in their chemistry and aircraft application, the NTSB and AAIB investigations made similar findings with respect to the certification/approval process and testing requirements for lithium batteries.

TSO process

The TSO approval is a stand-alone authorisation, awarded to a specific applicant in respect of their product. In this case, the ELT battery manufacturer received TSO-C142 authorisation

Footnote

22 Open Circuit Voltage – noted earlier.
23 NTSB Safety Recommendations Letter, dated 22 May 2014, referring to the investigation of Boeing B787, registration JA8291, lithium-ion battery thermal event on 7 January 2013 at Boston.

for their battery, based on the requirements of DO-227. Although DO-227 contains useful guidance and best practice for battery/equipment integration, the TSO-C142 applicant is required only to demonstrate cell-level and battery-level safety. A battery-level technical standard cannot address all the unique aspects of a battery's operation in the parent equipment and aircraft installation. Aircraft and equipment manufacturers therefore need to evaluate whether additional requirements and testing are necessary to ensure aircraft-level safety. Although thermal runaway is a known failure mode of lithium-metal batteries, the threat of a thermal runaway within the cells of the ELT battery was not identified at any point during the certification process for the battery, the ELT, or the installation of the ELT on the aircraft. Consequently there was no consideration of the effect of a thermal runaway of the ELT battery on the safety of the aircraft. This aspect is not unique to the B787 certification process as the RESCU 406AFN, and other similar equipment using lithium-metal batteries, are installed on multiple aircraft types.

This incident has highlighted that better co-ordination is required between battery manufacturers, equipment manufacturers, aircraft manufacturers and regulators to ensure equipment-level and aircraft-level safety. Therefore:

Safety Recommendation 2014-024

It is recommended that the Federal Aviation Administration review whether the Technical Standard Order (TSO) process is the most effective means for the certification of lithium-metal batteries installed in aircraft equipment, the actual performance of which can only be verified when demonstrated in the parent equipment and the aircraft installation.

Ongoing investigation

The AAIB continue to review the results of the testing conducted by the aircraft and ELT manufacturers, to support determination of the root cause of the battery fire, and other testing conducted to understand the ability of the battery to dissipate heat when installed in the ELT. The AAIB also continue to work with the aircraft manufacturer, and others, to determine how the fire remained sustainable outside the ELT after the energy source within the batteries was exhausted. This includes the means by which the fire propagated through the aircraft structure; how the characteristics of fire initiation and propagation might differ in an in-flight scenario; and the ability of the aircraft structure to sustain flight and pressurisation loads during an in-flight fire of this type.

Published 18 June 2014

AAIB Field Investigation reports

INCIDENT

Aircraft Type and Registration:	Boeing 737-377, G-CELF
No & Type of Engines:	2 CFM56-3B1 turbofan engines
Year of Manufacture:	1988 (Serial no: 24302)
Date & Time (UTC):	2 August 2013 at 0617 hrs
Location:	On departure from Leeds Bradford Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 5 Passengers - 119
Injuries:	Crew - None Passengers - None
Nature of Damage:	Broken generator harness and over-heated battery charger
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56
Commander's Flying Experience:	8,130 hours (of which 3,300 were on type) Last 90 days - 66 hours Last 28 days - 34 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft suffered an electrical failure after departure, which led to the loss of the commander's primary flight instruments, navigation equipment and other electrical services. There was also a smell of electrical burning in the passenger cabin, so an immediate return to the airport was carried out.

The loss of power was caused by a fatigue failure of the terminal lug on the end of the No 1 generator phase 'A' ground cable. An inspection revealed a number of other lugs which had cracked in the same location, two of which were close to failing in the same manner. The lugs had probably cracked as a result of a combination of engine vibration, a rough surface finish and bending of the lug during installation.

History of the flight

The flight crew reported for duty at Leeds Bradford Airport at 0500 hrs, for a 0600 hrs departure to Schiphol Airport, Amsterdam. Pre-flight preparations and engine starting proceeded normally and the aircraft taxied for a departure from Runway 14. The co-pilot was the Pilot Flying (PF), with the commander as the Pilot Monitoring (PM). The commander was the fleet training manager and was experienced in carrying out abnormal checklist procedures in the simulator.

A reduced-thrust takeoff was carried out with the auto-throttle (AT) engaged. Shortly after lift off, the commander heard a click and noticed that the AT had disengaged. During the initial climb, the master caution and amber FLT CONT caption illuminated, indicating a failure of the Mach trim. At about the same time, the commander's electronic attitude director indicator (EADI) and electronic horizontal situation indicator (EHSI) went blank and his altimeter, vertical speed indicator, Mach ASI and radio altimeter failed, with OFF flags showing. The No 1 Transformer Rectifier Unit circuit breaker tripped and the commander attempted to reset it, but it tripped again. The flight management computer (FMC) failed and both control display units (CDUs) locked up and could not be programmed. The PF's flight instruments and displays still functioned but he was unable to display the departure track on his EHSI. The commander briefly confirmed that the standby instruments were operating correctly by comparing them with the PF's instruments.

After the aircraft's landing gear and flaps had been retracted, the after-takeoff checks were completed. The climb was stopped and the aircraft levelled at 4,000 ft. The commander used the DC and AC meter rotary selectors to check the condition of the electrical power system, which appeared normal other than a slightly higher indication on the No 2 generator. The flight crew discussed the situation and decided to return to Leeds Bradford Airport. They also identified that the yaw damper, left forward window overheat, a fuel pump and normal exhaust fan were also inoperative. In addition, the flight crew noted that the battery charger, electric hydraulic pump 'B' and normal exhaust fan circuit breakers had tripped.

The commander started the APU and called the Senior Cabin Crew (SCC) member to the flight deck and gave her a NITS[1] briefing, after which she left the flight deck and walked to the rear galley to brief her colleagues. On the way, she noticed a distinct smell of electrical burning but with no signs of smoke. When she arrived at the rear galley, her colleagues both mentioned the electrical burning smell. The SCC alerted the flight deck to the smell and pulled the circuit breakers, isolating the galley electrical systems. The commander transmitted a PAN call and requested an immediate return to the airport. He also selected the flight deck galley electrical power switch OFF.

ATC provided radar vectors for a visual approach to Runway 14, and the ILS was set on the co-pilot's instruments as a backup. The weather was good with the 0620 hrs METAR indicating: surface wind 210º/05 kt, varying between 160º and 250º, visibility 20 km, scattered cloud at 1,600 ft, OAT 18ºC, dew point 16ºC and a QNH of 1005 hPa.

The commander re-briefed the SCC that they would be landing sooner than previously stated and, whilst at that stage there was no intention to carry out an emergency evacuation, the cabin crew were briefed to be at their stations after landing, in case the situation deteriorated. Without the use of the FMC, the commander elected to use flap 40º and a V_{APP} of 140 kt, as he knew from his training role that this was a safe speed and was not runway limiting. When the aircraft was established on the final approach, the No 1 generator tripped offline. The cabin emergency lighting illuminated and then extinguished. The commander selected the APU generator to generator bus 1 and his EADI, EHSI, analogue instruments and the FMC, with the associated CDUs, were all reinstated. The commander used the FMC to establish

Footnote

1 Nature, Intentions, Timings and any Special instructions.

the V_{APP} speed, which was calculated as 127 kt. After an uneventful landing, the aircraft was taxied clear of the runway, on to Taxiway D, and brought to a stop at holding point D2. The aircraft engines were shut down and the AFRS carried out an external inspection, before the passengers were disembarked onto coaches and the aircraft was towed back to a stand.

Recorded data

The aircraft was fitted with a 25-hour FDR and a 30-minute CVR.

The FDR recording stopped 4 seconds after the aircraft lifted off the ground and re-started 3 minutes and 25 seconds before touchdown. The FDR installation is powered by phase 'A' from the 115V AC generator bus 1, which was lost after takeoff and restored 12 minutes and 41 seconds later, during the approach. There are no parameters relating to the electrical power system status or crew selections.

Limited sets of flight parameters were transmitted to ATC's radar, throughout the flight, via Mode S transponder returns. These covered a period of 26 minutes and 30 seconds. Figure 1 shows the recorded aircraft track.

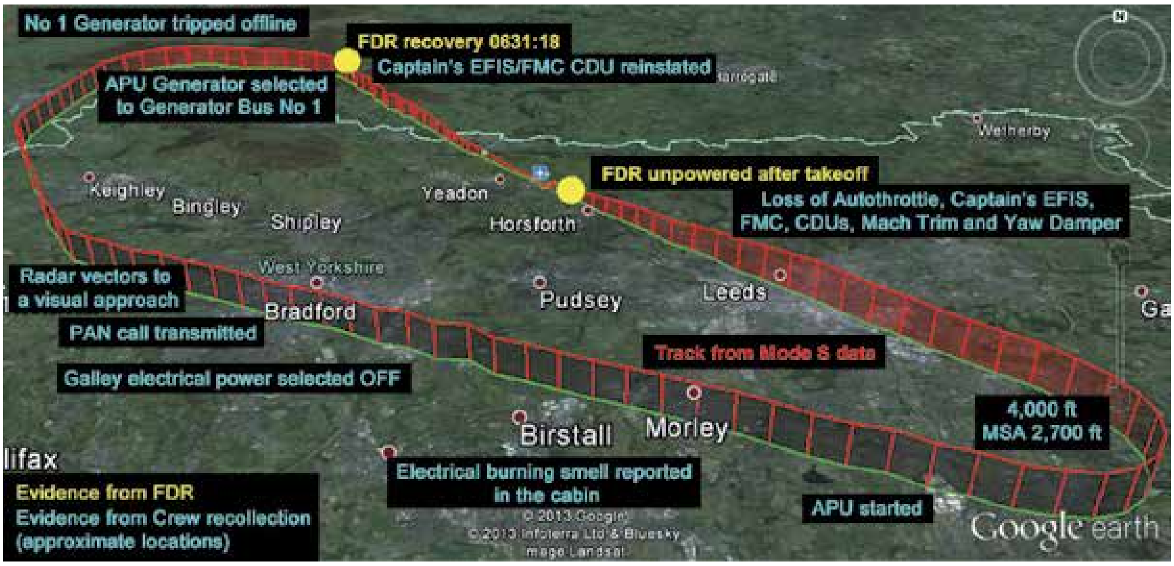

Figure 1

Aircraft track from Mode S transponder data, with approximate positions of events from crew recollections

The CVR is powered from phase 'B' of the No 1 generator and it continued to operate during the period when FDR power was lost. However, it also continued recording after the aircraft had landed and the pertinent evidence from the incident was not preserved.

Aircraft examination

Examination of the aircraft's electrical system revealed that the red phase 'A' ground cable from the No 1 generator had separated from the T191 stud on the side of the No 1 engine (Figure 2). This cable had separated due to a failure of its terminal lug (Figure 3). Further examination of the generator harness revealed a cracked terminal lug on the blue phase 'C' ground cable at the T191 stud (also shown in Figure 2) and a further cracked terminal lug at the firewall end of the grey ground cable (opposite end of grey cable shown in Figure 2). The crack on the blue phase 'C' lug was only visible after the heatshrink insulation was removed.

Figure 2

Location of separated red phase 'A' generator cable, and cracked blue phase 'C' lug at T191 stud on G-CELF's No 1 engine

The red phase 'A' cable had a tight bend radius but it was within limits for a cable in a restricted area.

The battery charger in the avionics bay was removed because it smelt of burnt material. Internal examination revealed that a coil had burnt – this coil was connected in three-phase to the internal transformer.

The following circuit breakers in the flight deck were found to have tripped: Transformer Rectifier (TR) Unit No 1, Battery Charger, Electric Hydraulic Pump System B, and Normal Exhaust Fan Power.

Following replacement of the No 1 generator harness and the battery charger, functional tests and a flight test revealed no faults or smell of electrical burning.

Figure 3

Failed terminal lug on the end of the phase 'A' generator ground cable

Electrical system description

On the Boeing 737-300, primary electrical power is provided by two engine-driven generators which supply three-phase 115 V 400 Hz alternating current. Each generator supplies its own bus system (Figure 4) in normal operation and can also supply power to the transfer bus of the opposite side; this is accomplished automatically via the Bus Transfer (XFR) relay if one generator fails or is disconnected. The APU drives a generator that can supply power to one of the AC Generator busses in flight. The system design does not allow parallel operation of two generators on one bus, so prior to a different generator being connected to a bus, the existing generator is disconnected. Transformer rectifier (TR) units and a battery supply DC power. The battery also provides backup power for the AC and DC standby systems.

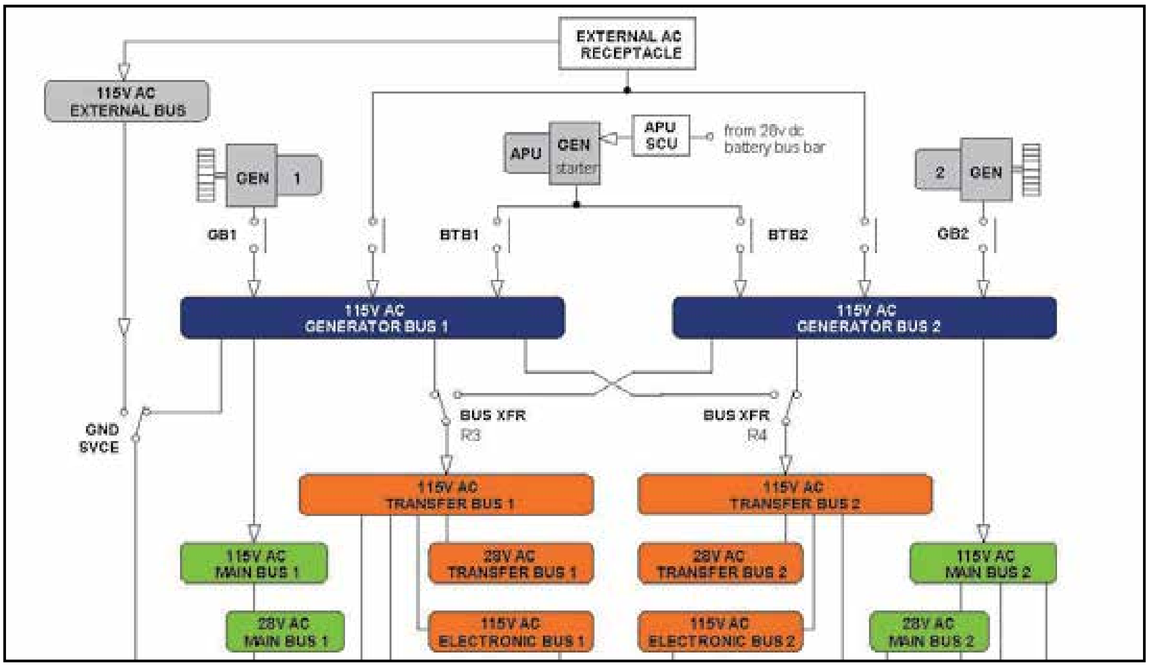

Figure 4

Top level electrical system schematic for the Boeing 737-300
(orange denotes busses carrying essential loads and green denotes busses carrying non-essential loads; schematic courtesy of B737MRG)

Effect of a loss of phase

There are a number of electrical components on the aircraft that require 3-phase power for operation, such as hydraulic pumps, fuel pumps and transformers. Other lower power components, such as the EFIS screens, instruments and auto-throttle operate using single-phase power. When the phase 'A' generator cable broke at the T191 stud, there would have been a drop in voltage in the phase 'A' line. However, the voltage on phase 'A' would not have dropped to zero because the 3-phase loads, still powered by phases 'B' and 'C', would have induced current and voltage on phase 'A'. This occurs because 3-phase loads are connected across the phases rather than from each phase to ground. This effect is illustrated in Figure 5. There is no current flow in the phase 'A' line between ground and the generator bus, so the current transformers at the generator and generator bus measure the same current and therefore the differential current protection is not tripped. On the Boeing 737-300 there is no measurement of differential current between phases. Inside the generator bus there is current flow in the phase 'A' line due to the voltage induced from the 3-phase components.

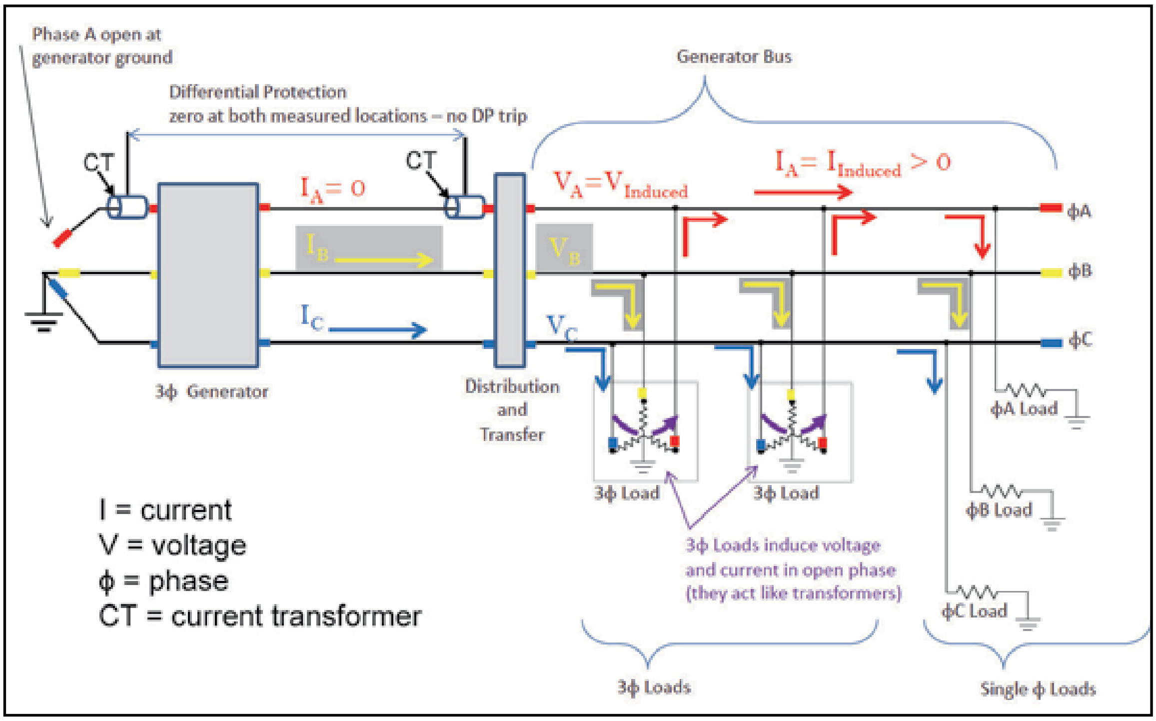

Figure 5

Operation of a 3-phase system with phase 'A' open circuit at the generator ground

Under-voltage protection trips off the generator when the average voltage across all 3-phases drops below a certain value[2]. Using the aircraft manufacturer's estimate for the induced voltage on phase 'A' at the beginning of this incident, the calculated average across all three phases was high enough to prevent the under-voltage protection being

Footnote

[2] This value is proprietary information so cannot be published although it was shared with the investigation team.

triggered. Thus, the No 1 generator did not trip offline when the terminal lug failed. The single-phase equipment is designed to operate at 115 V, but the aircraft manufacturer stated that some equipment might still operate at the lower voltage induced on phase 'A'. This explains why the single-phase equipment using phase 'A' did not fail simultaneously.

The following single-phase AC components that failed in the incident all operate from phase 'A': Auto-throttle, Captain EFIS displays, Captain's Airspeed Indicator (ASI), Captain's Altimeter, Captain's Vertical Speed Indicator (VSI), FMC, Mach Trim, Yaw Damper and the Flight Data Recorder (FDR). This aircraft was equipped with only one FMC, and without an FMC the CDUs lock up.

The loss of phase 'A' to the 3-phase devices, such as the pumps and transformers, results in the remaining phases 'B' and 'C' drawing more current. This excessive current draw eventually results in the thermal circuit breakers (C/Bs) for these devices tripping. This explains why the C/Bs for the electric hydraulic pump B, the normal exhaust fan, TR1 and the battery charger[3] eventually tripped. The excessive current draw also caused the coil inside the battery charger to overheat.

As each C/B for a 3-phase device tripped, the induced voltage on phase 'A' reduced. Eventually, once enough 3-phase devices had tripped offline, the phase 'A' induced voltage probably dropped sufficiently that the under-voltage protection tripped off the generator during the final approach. Figure 6 shows an expanded diagram of the No 1 Generator Bus system, highlighting the components which are fed from the different busses, and the C/Bs which tripped in the incident.

Consequently, once the No 1 generator tripped offline, the Bus Transfer (XFR) relay automatically switched to the Alternate position, causing the No 2 generator bus to power the No 1 transfer bus. This restored power to the essential single-phase AC equipment operating on phase 'A'. This explains why the captain's instruments were restored after the No 1 generator tripped offline. The captain also manually selected the APU to feed the No 1 generator bus at about the same time, which restored power to all loads powered by Generator Bus 1. The TR1 C/B remained tripped but a closed TR3 disconnect relay[4] (Figure 6) allowed the No 2 side to feed the No 1 DC busses.

Findings from operator's fleet inspection

Following the incident the operator carried out an unscheduled visual inspection of the generator harness terminal lugs on their fleet of 32 Boeing 737-300 aircraft. This consisted of a detailed visual inspection of the lugs without magnification, and it was reported that the engineers removed the lugs from the T191 stud to inspect them. However, the heatshrink insulation was not removed. On one aircraft, G-GDFB, on the No 2 engine, the terminal lug from the ground cable at the T191 stud was found to have cracked (Figure 7). There were differences in how the heatshrink insulation had been applied to the lug ends of the cables,

Footnote

3 The battery charger contains a 3-phase transformer.

4 The TR3 disconnect relay would have opened if Glideslope (GS) mode had been engaged on the autopilot or flight director, but this mode was not engaged during the approach.

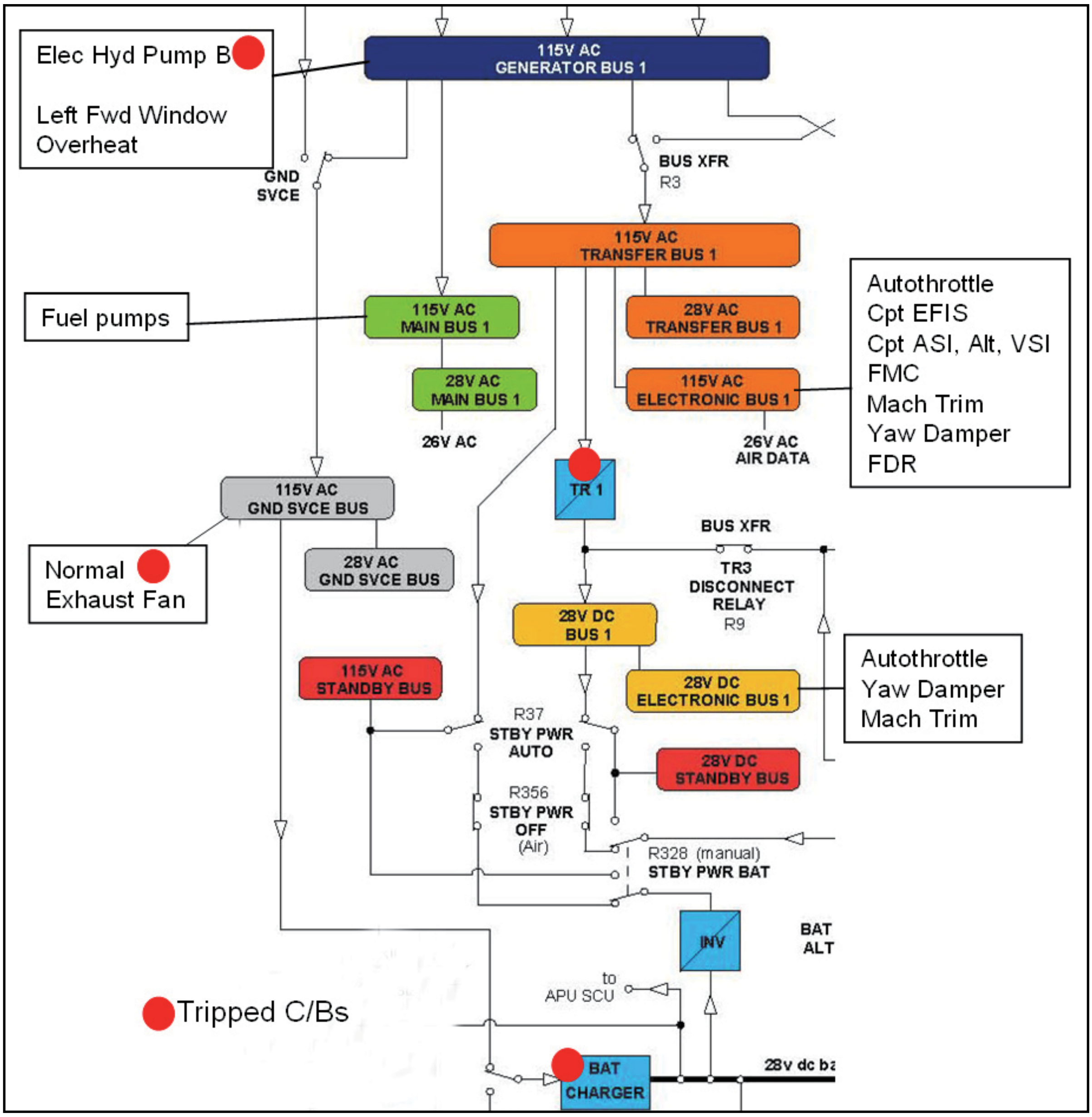

Figure 6

Electrical system schematic detail for Generator Bus 1
(red dots denote equipment with tripped circuit breakers;
schematic courtesy of B737MRG)

and the vulnerable bend area of the blue phase 'C' lug was not visible. The cracked lug was removed and bent open which revealed that it had cracked through half its thickness (Figure 8).

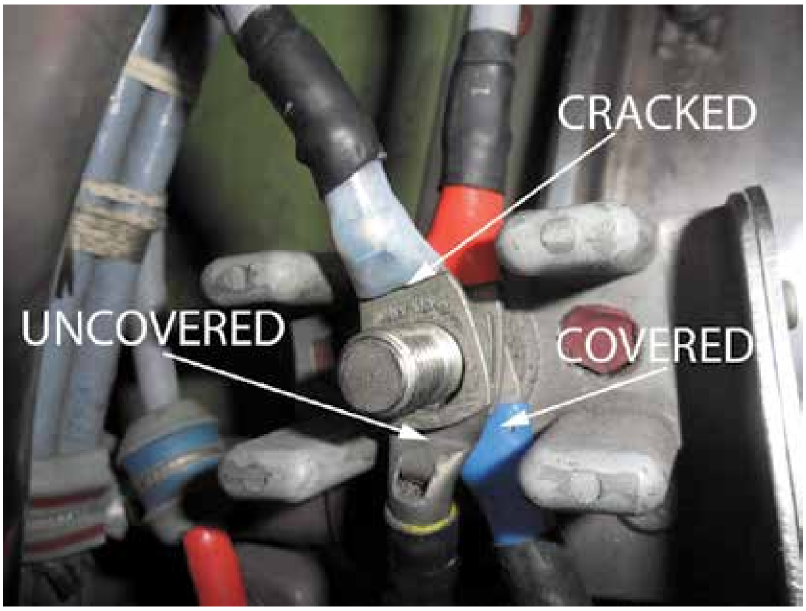

Figure 7

Cracked terminal lug from ground cable at T191 stud on G-GDFB's No 2 engine

Figure 8

Close-up of cracked terminal lug from ground cable on G-GDFB's No 2 engine

The fleet inspection also revealed two terminal lugs with cracked coatings on another aircraft, G-CELI.

Maintenance history

According to the aircraft operator, no removal or maintenance of the No 1 generator harness on G-CELF had been carried out since the engine's last overhaul in March 2008. According to the engine overhaul records the harness had been removed from another engine and installed on engine s/n 722273 which was later fitted to G-CELF. According to these records the harness was:

> *'only visual inspected for external damages in accordance with Standard Wiring Practices Manual [SWPM] D6-54446 Rev. 39 and is in serviceable condition.'*

The harness is not a tracked part with a serial number and therefore it was not possible to determine the age of the harness or the cables and lugs within it.

On 13 July 2013 the flight crew of G-CELF reported high vibration on the No 1 engine. The vibration level had reached a maximum of 2.5 units, which was within permissible limits, although normal vibration levels are below 1 unit. The operator elected to install a new set of fan blades on 30 July 2013 which resolved the vibration issue.

There had been no incidents of high vibration on the No 2 engine from G-GDFB since the operator took ownership in May 2010. The last recorded maintenance on the harness was during the engine's last overhaul in 2008.

Maintenance requirements

In the aircraft manufacturer's Maintenance Planning Data (MPD) there is a requirement to '*Perform a detailed inspection of the generator power feeders and connected EWIS*[5] *on Engine No.1*'[6]. The same requirement exists for Engine No 2 and these are to be carried out at the 1C interval which is every 4,000 hours. The EWIS includes termination devices such as the terminal lugs. The definition of 'detailed inspection' in the MPD is:

> *'An intensive examination of a specific item, installation or assembly to detect damage, failure or irregularity. Available lighting is normally supplemented with a direct source of good lighting at an intensity deemed appropriate. Inspection aids such as mirrors, magnifying lenses, etc. may be necessary. Surface cleaning and elaborate access procedures may be required.'*

There are no removal instructions as part of this inspection and to examine both sides of all the terminal lugs at the T191 stud would require the cables to be removed from the stud. Some terminal lugs have the bend area covered by heatshrink insulation and cannot be inspected without removing the insulation. The specification for the terminal lugs states that the heatshrink must be 1/4 inch ± 1/16 inch clear of the rear edge of the hole, and because of the tolerances on the distance from the rear edge of the hole to the bend, the bend area could be covered or uncovered. According to the operator this inspection was carried

Footnote

[5] EWIS is the Electrical Wiring Interconnection System.
[6] Task B20-60-03-6A-8 in 737-300/400/500 Maintenance Planning Data D6-38278, Sep 2013.

out during G-CELF's last 1C check in March 2012 and during G-GDFB's last 1C check in May 2012. However, the operator stated that this was an inspection of many components and would not necessarily pick up cracked terminal lugs, and the inspection would not involve removing the cables or the heatshrink insulation.

According to the aircraft manufacturer the same detailed inspection called for during the 1C check should be carried out during engine overhaul. The engine overhaul organisation that overhauled G-CELF's No 1 engine in 2008 had since closed down so it was not possible to obtain any further information on what their visual inspection of the harness entailed.

The records for the overhaul of G-GDFB's No 2 engine state that a '*visual inspection'* and a *'continuity and insulation test*[7]*'* were carried out on the generator harness in-situ on the engine. The overhaul organisation stated that the inspection was carried out in accordance with the aircraft manufacturer's SWPM. This manual does not detail any specific inspections, but in a section on '*Permitted Bends in a Terminal'* it states '*Make sure that there are no cracks in the bend area*'. They also stated that the heatshrink insulation would not be removed if it was covering the bend area of the terminal lug. However, they also reported finding cracked terminal lugs in about 1 in 100 harnesses.

The engine overhaul period is based on the component with the most limiting cycles remaining. The shortest lifed item on an overhauled engine usually has at least 12,000 cycles remaining. For the operator of G-CELF with an average annual utilisation of 1,000 cycles, this would equate to an overhaul every 12 years.

Manufacture of terminal lugs

The failed and cracked terminal lugs from G-CELF and G-GDFB had part number YAV6CL2NK[8] (AN6). The lugs with the cracked coating from G-CELI, part number YAV4CL2NK[9] (AN4), were slightly larger. Both types of lugs are manufactured in the same way by the same manufacturer, using an automated machine to flatten the end of a copper tube to form the tongue. A hole is then punched into the tongue and the lugs are annealed to a maximum hardness of Rockwell F50, as measured at the barrel[10]. The lugs are then coated with nickel plating. The composition of the copper tube is 99.9% minimum copper and the nickel plating is 99.9% minimum nickel. The lug manufacturer reported that the lugs had been manufactured in the same location since 1978 and there had not been any recorded design or manufacturing changes since then.

The lugs meet the Boeing specification BACT12M which does not require fatigue testing. However, the lug manufacturer conducted fatigue testing on tin plated versions of the lugs to SAE standards[11].
The aircraft manufacturer's SWPM specifies that the lug of a BACT12M standard connector

Footnote

[7] A continuity and insulation test will check for short-circuits but will not detect, and is not intended to detect, cracked terminal lugs.
[8] Boeing part number BACT12M6-4.
[9] Boeing part number BACT12M4-4.
[10] The lug manufacturer does not specify a maximum hardness for the tongue.
[11] They were tested to SAE-AS20659 in accordance with SAE-AS7928.

may be bent once only, through a maximum of 30º, in either the up or down direction, and that this bending must be performed with a tool before installation. Crazing of the nickel plating is permitted after bending, provided there is no exposed copper. The lug manufacturer's specification does not state whether the lugs can or cannot be bent although the lug manufacturer stated to the AAIB after the investigation that they do not support bending of the lugs by customers.

Metallurgical examinations

Detailed metallurgical analysis was carried out on the lugs from G-CELF, G-GDFB and G-CELI. The fracture surfaces of the failed lug on the end of the phase 'A' generator ground cable (G-CELF) are shown in Figure 9. This revealed that fatigue cracks had initiated at multiple sites on the lug's upper surface and then coalesced after a short distance to form a single crack front which propagated downwards to the centre of the lug, and then curved round the edges. The crack tips then propagated towards each other, along the lower wall, until they reached a point where the remaining section failed in overload. The large surface area of fatigue crack growth, compared with that of the final separation, indicated that the cyclic loading was of low magnitude, repeated for a large number of cycles.

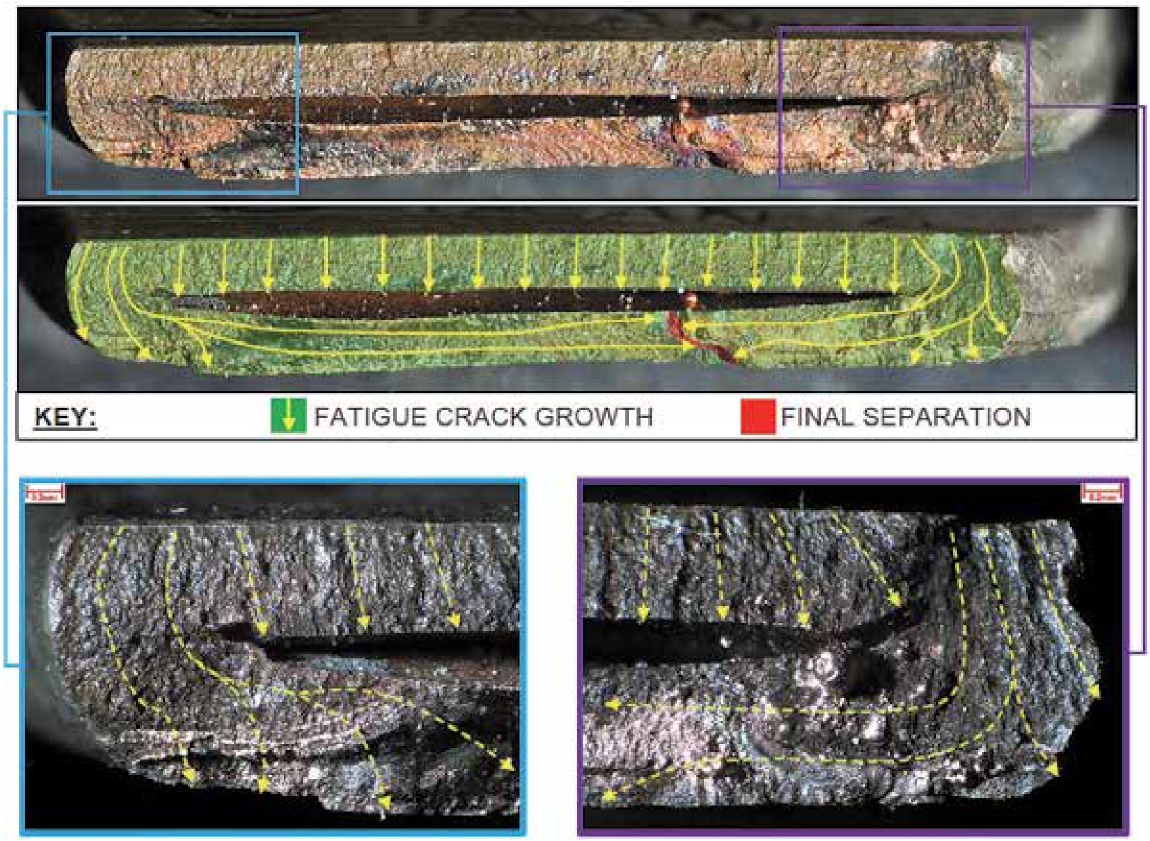

Figure 9

Fracture surfaces of failed terminal lug on the end of the phase 'A' generator ground cable (G-CELF)

Examination of the lug's upper surface revealed a series of parallel grooves that had been formed by the flattening tool used to make the lug. The fatigue cracks had initiated within one of these grooves.

Examination of the fracture surfaces under SEM[12] revealed regions of both transgranular and intergranular crack propagation, which was consistent with corrosion fatigue. Transgranular crack growth would have dominated during periods when the cyclic stress was relatively high and/or the severity of the corrosive environment was low. Intergranular crack growth would have dominated when the converse was true. Fatigue striations were evident in both the transgranular and intergranular regions and their fine spacing was consistent with a load spectrum of high frequency vibrations.

In order to examine the fracture surfaces on the two cracked lugs from G-CELF and the cracked lug from G-GDFB, the lugs were forced open until they failed. The fracture surfaces of all three lugs displayed the same downward fatigue crack growth from multiple initiation sites from within one of the parallel grooves formed by the flattening tool. The fatigue crack on the blue phase 'C' lug from G-CELF had propagated through half its thickness but had not yet propagated around the corners. A secondary fatigue crack had initiated on the lower surface and propagated upwards (Figure 10). The presence of this crack indicated that there had been a degree of reversal in the cyclic bending loads exerted on the lug. The fatigue crack on the ground lug from G-CELF was at an early stage of development and had propagated through less than a quarter of the lug's thickness. The fatigue crack growth on the lug from G-GDFB was similar to that of the phase 'C' lug from G-CELF, and had propagated through over half of the lug's thickness.

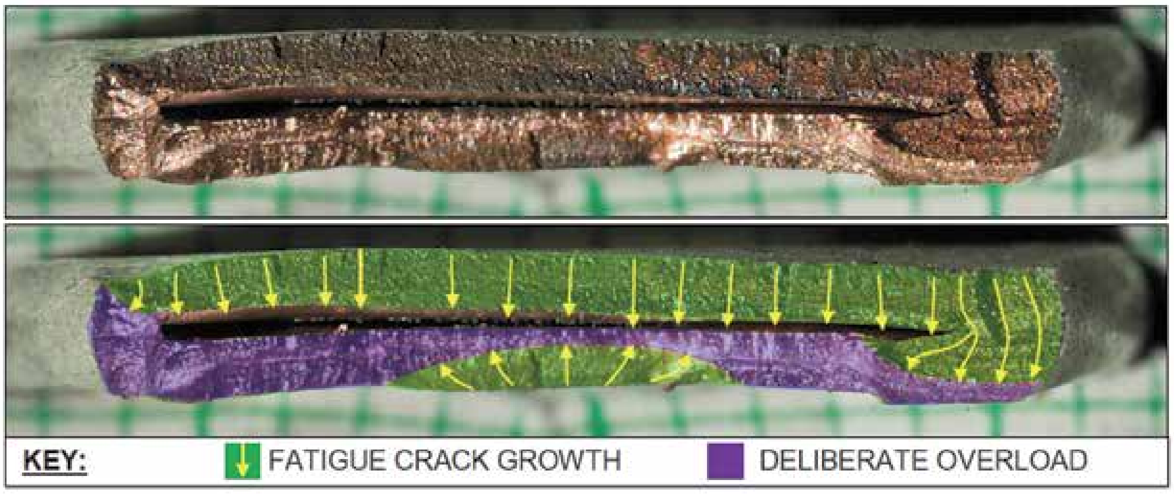

Figure 10

Fracture surface of cracked terminal lug on the end of the phase 'C' generator ground cable (G-CELF)

Footnote

12 Scanning Electron Microscope.

Detailed examination of the pattern of the parallel grooves from which the cracks had initiated revealed that they were the same, indicating that these four lugs had probably been flattened by the same tool. The grooves did not disturb the lettering stamped on the lugs, which indicated that the grooves were made either before or at the same time as the lettering. A sample of new terminal lugs had much shallower grooving (Figure 11). The lug manufacturer stated that lug inspection checks are performed on a sample basis with the naked eye, and that these checks had not noted any grooves of the extent shown in the left and middle images of Figure 11.

Figure 11

Comparison of the parallel grooves on the G-CELF lugs and a new unused lug (right)

The two lugs from G-CELI had an array of parallel cracks that appeared to extend through the nickel plating and not the underlying copper; one of these lugs had significant flaking of the nickel at the bend line exposing the underlying copper.

Material composition

Analysis of the cracked lugs by Energy Dispersive X-Ray Spectroscopy revealed that they were composed of 100% copper with a measurement accuracy of 0.1%, which was within specification for the lug. Microhardness testing revealed that the failed G-CELF lug and the cracked G-GDFB lug had hardness levels remote from the cracked or bent locations of 83 and 70 HV[13] respectively, where 65 HV would be equivalent to 50 HRF in a Rockwell hardness test. These figures are above the maximum hardness specified by the manufacturer, although they were measured at the tongue instead of the barrel, so this might account for some difference. However, it might also indicate that the annealing of the lugs after flattening was not fully effective.

Footnote

[13] HV is the unit measurement of hardness using the Vickers hardness test.

Microsections of the crack surfaces did not reveal any evidence of hydrogen embrittlement and there was no evidence of any microstructural anomalies at the fatigue initiation sites. The thickness of the lugs was also measured and found to be within specification.

Lug bending

The failed red phase 'A' lug from G-CELF appeared to have minimal bending, although it could have been previously bent and re-flattened. The blue phase 'C' lug from G-CELF was bent downwards by 12º, and the ground lug from G-CELF was bent upwards by about 30º (Figure 12). The cracked lug from G-GDFB was bent downwards by 10º[14], and both connectors from G-CELI were bent upwards by 15º.

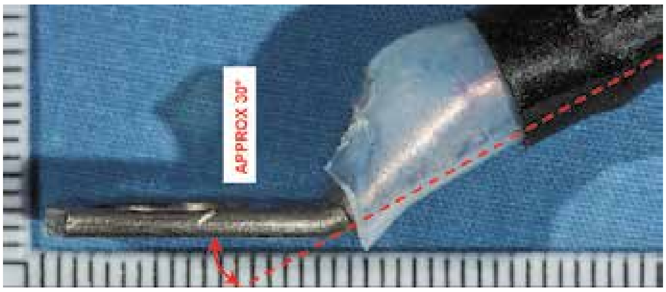

Figure 12

30º upwards bend of cracked G-CELF ground lug

As part of the investigation, bend testing was carried out on a sample of five AN6 and five AN4 terminal lugs. Bending of the AN4 lugs through 30º caused flaking of the nickel plating in one case, and an array of parallel cracking in another – this flaking and cracking was similar to that present on the AN4 connectors from G-CELI. However, the flaking had not exposed the underlying copper, while the cracking had exposed the copper.

Bending of the AN6 lugs once through 30º caused an array of shallow, parallel cracks to form. They were just detectable with the unaided eye, but easily visible with x10 magnification, and the underlying copper was exposed. Bending the lugs once through 15º caused cracks in the nickel plating which were just detectable with x10 magnification. Bending the lugs more than once caused the extent and severity of the cracking to increase. Bending the lugs upwards by 15º and then down by 15º twice produced cracking which was easily detectable and extended through the plating into the copper. If the final bend was up, then this had the effect of closing the cracks making them more difficult to detect.

Previous instances of cracked lugs

The aircraft manufacturer reviewed operator reports of open phase events on the Boeing 737 Classic[15] fleet for the period 1983 to 2004. There were 11 reports of open phase events, of which one in June 1998 was traced to a damaged ground lug. There was

Footnote

[14] This downwards bend had been made by the operator to expose the crack after removal. The pre-removal angle was not recorded.

[15] The term 'Classic' refers to the 737--300, -400 and -500 series of aircraft.

an additional report of a fractured lug in 1990 in which the operator had not reported the symptom of 'open phase event'. However, there is no requirement for these failure events to be reported to the manufacturer.

The lug manufacturer reviewed their customer complaint log dating back to 2004 and this did not contain any reports of cracked lugs.

Two organisations that overhaul CFM engines were contacted to determine the rate of cracked lugs found during their visual inspections. One organisation estimated that their rejection rate of harnesses due to cracked lugs was 1 in 100. The other organisation reviewed its data and found two instances of harnesses with cracked terminal lugs between 2008 and 2013. Both of these harnesses had been on engines that had had been subjected to heavy vibration caused by bird strikes.

Electrical system on the Boeing 737NG[16]

On the Boeing 737NG aircraft the electrical system incorporates under-voltage protection that monitors each phase separately. If the voltage of a single phase drops below a specified threshold for a specific number of seconds[17], the affected generator will trip offline and automatic bus transfer will occur. Therefore, if the G-CELF failure event had occurred on a 737NG, power to the Captain's instruments and other phase 'A' systems would have only been lost for a few seconds. The 737NG electrical system also incorporates 'Unbalanced Phase' protection which can detect a single loss of phase and will trip the generator offline after a 19-second time delay. When this system activates it will prevent bus transfer.

Analysis

Operations

The initial loss of the AT was recognised by the commander who was aware that it was not a 'no go' item in the Minimum Equipment List (MEL) and expected to continue the flight. As his instruments and other services failed, he realised that there had been a significant electrical failure although he did not recognise the situation as one which was covered in the abnormal checklist. The PF continued to fly the aircraft, using his instruments, and ATC were notified of the situation. The crew agreed that there was no abnormal procedure for their circumstances and that they should return to Leeds Bradford Airport. At that stage, there was no urgency to return and the Standard Operating Procedures (SOPs) regarding briefing the cabin crew were carried out as normal.

When the SSC made the commander aware of the burning smell, the flight crew decided to expedite their return and transmitted a PAN call. From his training background, the commander knew that 140 kt was a safe approach speed and would not be runway limiting. When the No 1 generator tripped offline, the commander carried out the abnormal procedure and the FMC became available, enabling the appropriate approach speed to be obtained.

Footnote

[16] 737NG refers to the 'Next Generation' models consisting of the 737-600, -700, -800 and -900.
[17] This value is much less than a minute. The exact number of seconds is proprietary information.

System failure

The electrical failure symptoms experienced by the flight crew could all be explained by the failure of the red phase 'A' generator ground cable lug end. The electrical burning smell could be explained by the overheated coil inside the battery charger which occurred as a result of excessive current draw in the remaining 'B' and 'C' phases. The Boeing 737-300 and the other 737 Classic aircraft do not have systems that can detect a single loss of phase so there was no clear annunciation to the crew as to the failure condition or what action to take. If the flight crew had turned off the No 1 generator, then the No 2 generator bus would have powered the No 1 transfer busses automatically and this would have restored the EFIS, Auto-throttle, FMC and the other phase 'A' systems. However, there was no checklist instructing them to do this. The aircraft manufacturer stated that writing a checklist for this situation would be difficult because the electrical failure symptoms would be different depending upon which phase was lost. They also considered that instructing the crew to turn off a generator in this situation could result in the wrong generator being turned off, resulting in the loss of instruments on both sides.

It took just over 12 minutes from the initial failure event until the No 1 generator automatically tripped offline which allowed power to all instruments and essential systems to be restored. This was probably triggered by the under-voltage protection which monitors the three-phase average voltage.

Lug failures

The red phase 'A' ground cable terminal lug failed due to corrosion fatigue under the influence of loads consistent with high frequency vibrations. The blue phase 'C' terminal lug and the grey ground terminal lug had started to crack in the same manner and would probably have failed eventually as well. This engine had been subject to higher than normal vibration in the month preceding the failures, which was probably a contributory factor. However, this level of vibration was not unusual and given the large size of the worldwide 737 Classic fleet and the low reported incidents of cracked lugs, it is unlikely that high vibration alone caused the lugs to crack. The terminal lug on G-GDFB had cracked through almost half its thickness without any reported high vibrations in the engine's previous 3 years of service. However, it was possible that this engine had suffered from high vibration prior to 2010 when the operator had taken ownership of it.

Another factor which probably contributed to the cracks was the rough surface finish on the upper surface of the lugs. All the cracks on the G-CELF and G-GDFB lugs had initiated within one of the parallel grooves at the bend. These grooves were visibly deeper than those compared to a small batch of new lugs. It was probable that these lugs had been flattened using the same tool which was more rough than usual. It could not be established how common rough grooving was on these lugs and there was no surface finish specification in BACT12M, and therefore the grooving was considered a contributory factor rather than a sole causal factor.

A third factor which probably contributed to the cracks was the effect of bending. Bending tests revealed that cracks in the nickel plating would form when the bending was within the limits of the SWPM. If bending exceeded these limits, cracks could develop in the underlying copper. The cracked lugs from C-CELF and G-GDFB were bent to varying degrees and it was not possible to establish how much prior bending they had had. Since generator harnesses are 'on-condition' items and can be re-used many times on different engines it is possible that the lugs had been bent more than once, although such a practice is not approved in the SWPM. Even if the lugs had only been bent once, the resulting cracking in the nickel plating combined with the grooving and the higher than normal vibration could explain the failures.

A fourth possible contributory factor was that the hardness of the G-GDFB lug and failed G-CELF lug was higher than the manufacturer's specification. Harder materials are more brittle and therefore more susceptible to cracking.

The red phase A cable had a tight bend radius but it was within the limits specified by the SWPM for a cable in a restricted area, and none of the other cracked lugs were on cables with a tight bend radius, so this was probably not a significant factor.

The cracking of the nickel plating present on the two larger AN4 connectors from G-CELI was consistent with the effect of bending alone. These cracks had exposed the underlying copper which was not permitted by the BACT12M specification but there was no evidence that fatigue cracks had initiated from them.

In the lug manufacturer's view, the fatigue cracks are not the result of the manufacturing process but are due to the installation and bending processes used during maintenance, and in-service vibration.

Lug inspections

The aircraft manufacturer's maintenance requirements do not include a specific inspection of the terminal lugs on the generator harness. They stated that the detailed inspection of the EWIS that is required at every 1C check should suffice. However, this inspection does not require removal of the lugs from the T191 stud or removal of any heatshrink insulation covering the susceptible bend area. Due to the stacking of the lugs at the T191 stud and the possibility that the lugs can be installed upside down[18], it is not possible to inspect the susceptible bend area on all the lugs without removing them from the stud and without removing any covering insulation.

It was not clear what level of visual inspection had been carried out on the generator harness terminal lugs when the G-CELF and G-GDFB engines were overhauled. However, it was clear that the organisation which overhauled the G-GDFB engine was detecting cracked lugs at a frequency of about 1 in 100 harnesses, so there was a degree of effectiveness in their procedures despite them not removing the heatshrink insulation.

The operator of G-CELF intends to carry out a special detailed inspection of the terminal lugs at the T191 stud at every future 1C check. This is because a phase A lug failure

Footnote

[18] 'Inverted' installation of the cables with the bend area face down is permitted by the SWPM.

causes a system failure that is not detected by the electrical system, has no checklist, and is likely to generate an electrical burning smell from the battery charger. These effects have significant consequences for the workload of the crew.

The effect of a phase 'B' or phase 'C' lug failure might be less serious than failure of the phase 'A' lug due to the systems they affect but further detailed analysis would be required to confirm this. Failure of the grey ground lug at either the T191 lug or at the engine firewall would not result in a loss of power because the phase loadings would remain balanced.

Failure of any of the generator harness terminal lugs on a Boeing 737NG would have minimal effect for the flight crew, because the system would detect the fault and the power to the instruments would be interrupted for much less than a minute.

The current inspection requirements as detailed in the MPD would miss some lugs that had started to crack because the bend area of the lug is not visible on some lugs without removing the cable or removing the insulation.

The aircraft manufacturer stated:

> *'The possibility of modifying the inspection requirements to require removal of the generator lugs for a more complete inspection was considered. It was noted, however that additional inspections requiring removal of the lugs will introduce the possibility of damage caused by the disassembly as well as the potential for assembly errors that degrade overall reliability. Given the current low rate of ground lug fractures leading to open phase failures, such additional inspection actions would likely present a greater risk of open phase failure than currently exists.'*

The aircraft manufacturer re-iterated that it considered bending of the lugs in the field acceptable but that the preferred option would be to use lugs that had been pre-bent by the lug manufacturer. The aircraft manufacturer is moving towards using only pre-bent lugs on new designs and will be considering the use of pre-bent lugs as replacements for lugs on aircraft currently in service.

ACCIDENT

Aircraft Type and Registration:	Europa XS, G-GBXS
No & Type of Engines:	1 Rotax 914-UL piston engine
Year of Manufacture:	1998 (Serial no: PFA 247-13196)
Date & Time (UTC):	21 August 2013 at 1317 hrs
Location:	Airstrip at Common Farm, Wymeswold, Leicestershire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passengers - 1 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Light Aircraft Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	About 460 hours (of which 104 were on type) Last 90 days - 20 hours Last 28 days - 1 hour
Information Source:	AAIB Field Investigation

Synopsis

The evidence suggested that the pilot was performing a low-level circuit to land back at the farm strip from which he had just departed, most likely in response to an engine problem. Control was lost during the base turn and the aircraft struck the ground in a steep nose-down attitude, fatally injuring the pilot and passenger.

History of the flight

The pilot and passenger arrived at the airstrip, where the aircraft was based, on the morning of the accident. At about 1230 hrs another locally-based pilot (Witness A) arrived and had a short discussion with them. The accident pilot told him he intended to land away at an airfield in East Anglia. The relative merits of various airfields were then discussed, but no definite destination was established.

G-GBXS was approved to use Mogas and the pilot was seen refuelling the aircraft from jerrycans using an electric pump. It is not known how much fuel was added, but the pilot was heard commenting to his passenger that they would add all the available fuel so that they would not have to refuel again that day.

The pilot then conducted a pre-flight inspection on the aircraft. While Witness A closed and locked the hangar, the pilot and passenger boarded the aircraft and the engine was started. The engine was running when Witness A came outside and he watched the pilot conduct the power checks outside the hangar. The aircraft then taxied to the south-east end of the runway to take off in a north-westerly direction[1].

Having seen the aircraft taxi away from the hangar, Witness A then drove to the airfield gate, about 150 m down a short slope beyond the departure end of the runway, and watched the takeoff. He considered that the takeoff and initial climb looked and sounded normal but as the aircraft made a left turn crosswind, it rolled abruptly to the left by about 70º. The witness believes he saw large elevator and aileron inputs as the aircraft recovered to an approximately wings-level attitude. It then proceeded on a downwind heading. He continued to watch the aircraft, which now appeared to be operating normally, until it passed from his view on the downwind leg. He then left the airstrip.

At about 1900 hrs, the wreckage of the aircraft was found in a field adjacent to the south-eastern end of the airstrip.

Wreckage site

The wreckage was located in a field of stubble adjacent to the airstrip.

The propeller and most of the reduction drive unit had detached from the engine. There were two almost parallel ground marks, each 4 m long either side of the propeller, consistent with the leading edges of both wings striking the ground. The majority of the wreckage, comprising the fuselage, engine, both wings and empennage, was located approximately 7 m from the propeller.

The tip of the propeller spinner was buried 35 cm below the surface of the ground. The orientation of the propeller hub plate indicated that the aircraft's impact attitude was 25º left-wing-low and 80º nose-down. There was a small cut mark in the ground under one of the propeller blades, possibly indicative of engine rotation but there was no significant evidence of rotation on the fracture surfaces of the reduction drive unit. It was concluded that the engine was probably turning, but it was not possible to assess the engine power at impact.

Both wings were largely intact but had significant leading edge damage. The left wing leading edge was more damaged than the right. The fuselage was severed just aft of the wing trailing edge and just ahead of the horizontal tailplane. There was no evidence of fire.

The fuel tank was intact, but the fuel lines were broken, allowing fuel to drain onto the ground. There was a smell of fuel on the ground around the wreckage. It was not possible to determine how much fuel had been on board the aircraft.

The engine coolant and oil systems, both of which had a radiator and reservoir, were damaged so it was not possible to determine the coolant and oil quantities before the accident. There was evidence of staining on the lower fuselage; this included a thin streak of brown fluid that extended to halfway between the wing trailing edge and the tailplane leading edge.

Footnote

[1] Common Farm has a single grass runway oriented SE-NW.

Pilot information

The pilot held an EASA Light Aircraft Pilot's Licence (LAPL) with a Single Engine Piston Rating. His medical certificate was not located, but CAA records show that he held a valid EASA LAPL medical, issued on 15 July 2013.

The pilot's last flight with an instructor was in October 2011, within the 24 months required by the LAPL recency requirements. He also routinely flew a Renegade microlight aircraft and his flying logbook contained 323 hours of microlight flying.

The pilot was familiar with the airstrip at Common Farm, having operated from there on numerous occasions.

Aircraft information

The aircraft was a Europa XS with a retractable monowheel undercarriage. The flaps and undercarriage were activated simultaneously by a mechanical lever, such that the flaps and gear were either both up or both down. G-GBXS was built in 1998 and had flown 1,328 hrs at the time of the accident. The aircraft was issued with a Permit to Fly on 13 August 2012.

The aircraft was equipped with a stall warner, consisting of a tube mounted in the wing leading edge, a pressure switch and an electric buzzer.

Results of flight tests conducted on G-GBXS for the purpose of renewal of its Permit to Fly gave a clean stall speed of 54 kt and a flaps-down stall speed of about 46 kt. The stall warner activated approximately 7 kt above the clean stall speed and 11 kt above the flaps-down stall speed.

The aircraft was fitted with a four-cylinder, turbocharged Rotax 914 UL engine. The fuel air mixture was fed from a manifold to the twin carburettors. A balance pipe between the two carburettors ensured they were fed with a similar mixture. The balance pipe had a tapping for the manifold pressure gauge. An Airmaster propeller was fitted, along with a constant speed controller. In normal operations the propeller operated at a constant speed, depending on which of the four settings (TAKEOFF, CLIMB, CRUISE and HOLD) was selected on the controller unit in the cockpit. A manifold pressure gauge in the cockpit provided indication of engine power.

The aircraft was equipped with a FLYdat engine monitoring system, which measures eight engine parameters including: engine speed, Cylinder Head Temperature (CHT), oil pressure and oil temperature. All eight parameters are output to a LCD display in the cockpit. Each parameter has warning and alarm thresholds. If the warning threshold for a parameter is exceeded, the corresponding parameter on the LCD display flashes and a red warning light on the instrument panel next to the FLYdat unit flashes. If the alarm threshold for a parameter is exceeded, the corresponding parameter on the LCD display flashes and the red warning light next to the FLYdat illuminates continuously. The FLYdat records, in non-volatile memory, the highest value measured for each parameter for each six-minute period of engine operation. However, for the last period of each flight, the highest value for each parameter measured is recorded for an unspecified period of between 1 second and 5 minutes and 59 seconds.

The FLYdat unit was configured so that the engine speed thresholds were 5,800 rpm for a warning and 6,000 rpm for an alarm, and the CHT thresholds were 135ºC for a warning and 150ºC for an alarm.

Recorded information

GPS

Recorded information was available from a GPS[2] recovered from the aircraft, the FLYdat recovered from the aircraft and a wind turbine located about 1 km north of the accident site. The GPS contained a track log of the accident flight, with GPS-derived aircraft position, track, altitude and groundspeed. The record commenced at 1309 hrs with the aircraft parked near the hangar and ended at 1317:53 hrs. Information from the GPS is shown in Figures 1 and 2. Wind data recovered, with the assistance of the operator of the wind turbine, included wind direction as well as minimum, maximum and average wind speed for ten-minute periods. The data was acquired by an anemometer located on the turbine hub, 180 ft agl.

At 1314 hrs, G-GBXS taxied from the hangar area to the threshold of the north-westerly runway, where it remained for about a minute. At 1316 hrs the aircraft commenced the takeoff roll. As it passed the departure end of the runway, its groundspeed was 62 kt and it had climbed to an altitude of about 430 ft (120 ft agl). The aircraft continued climbing along the runway track to about 200 ft agl (Figures 1 and 2, Point A). It then made a 180º left turn[3], during which it descended at an average rate of 384 ft/min over 12 seconds, to approximately 140 ft agl (Point B).

Having completed the left turn, the aircraft was established on a downwind track parallel to, and 210 m laterally displaced from, the runway. As it flew downwind, it climbed slowly at an average rate of about 70 ft/min, whilst its groundspeed remained at about 53 kt (based on a wind from 166º at 12 kt, the aircraft's airspeed would have been about 63 kt). The rate of climb was such that the aircraft maintained a relatively constant height of about 160 ft. When the aircraft was almost abeam the threshold of the north-westerly runway, it turned left towards the runway. At this point the aircraft's lateral distance from the runway was about 240 m. The final data point (Point C) was recorded with the aircraft at a height of about 100 ft (470 ft amsl) and a groundspeed of 58 kt. The corresponding airspeed would have been approximately 54 kt. The position of the final data point was 89 m from the wreckage site and 170 m from the threshold of the north-westerly runway.

Previous flights

The GPS record contained eight of the pilot's previous flights dating back to 30 April 2013. Six of the flights had departed from the north-westerly runway at Common Farm. Comparison of the accident flight and these previous takeoffs indicates that the acceleration profiles of the aircraft whilst on the runway were similar, with the accident flight having the third highest

Footnote

2 Garmin manufactured unit, model 296.

3 The average rate of turn during the 180° turn was 15°/sec and the average groundspeed was 55 kt. In a level turn, this would equate to an average bank angle of approximately 38°.

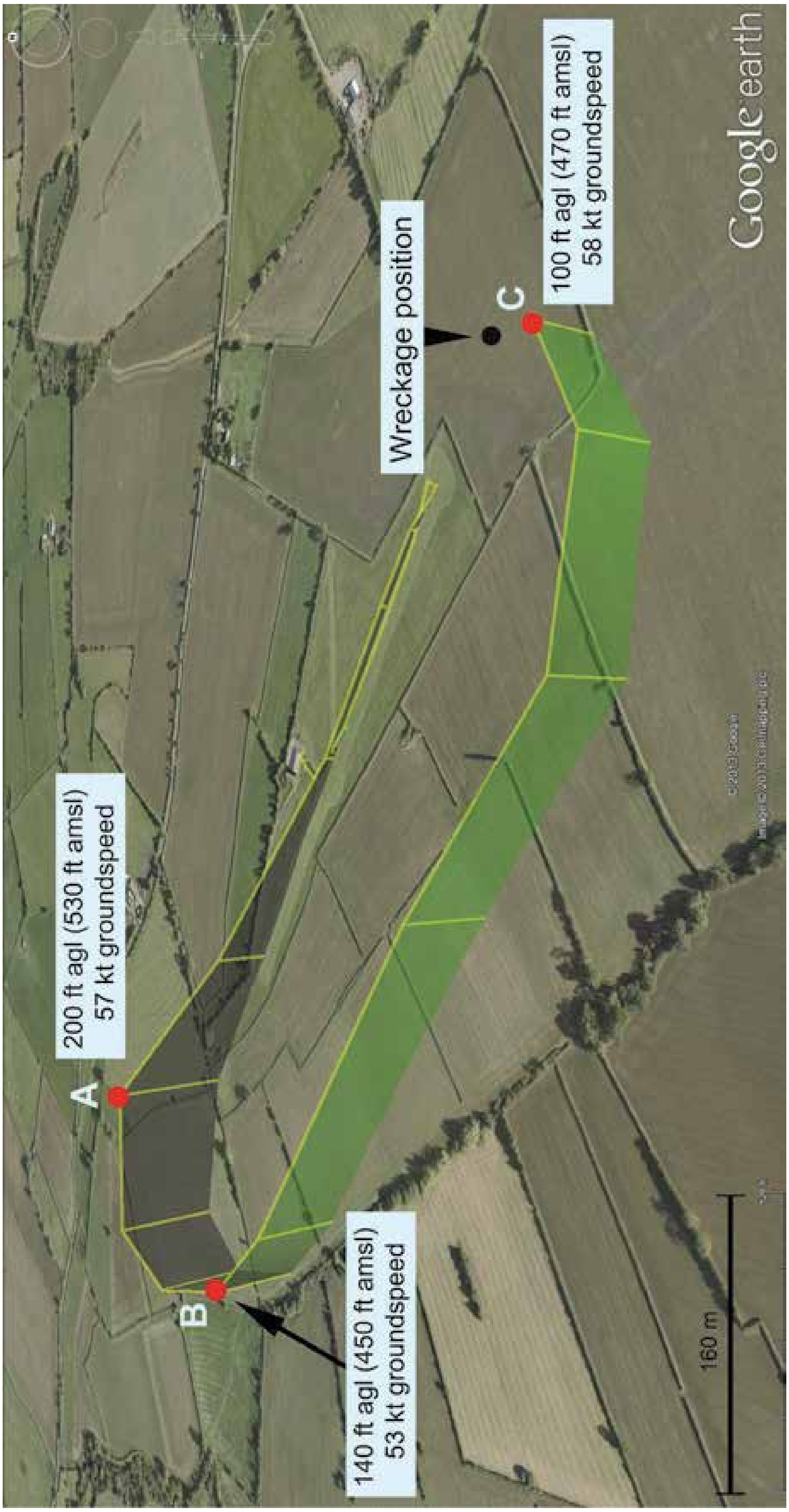

Figure 1
Overview of G-GBXS GPS track

acceleration. Factors affecting aircraft acceleration such as weight, air temperature and condition of the grass runway during each of the previous flights could not be established. However, the data is indicative that the aircraft's performance during the accident flight takeoff was not unusual.

The downwind positions and heights recorded were somewhat variable, but were in the order of 1,000 to 1,500 m lateral spacing from the runway and 600 to 1,000 ft agl.

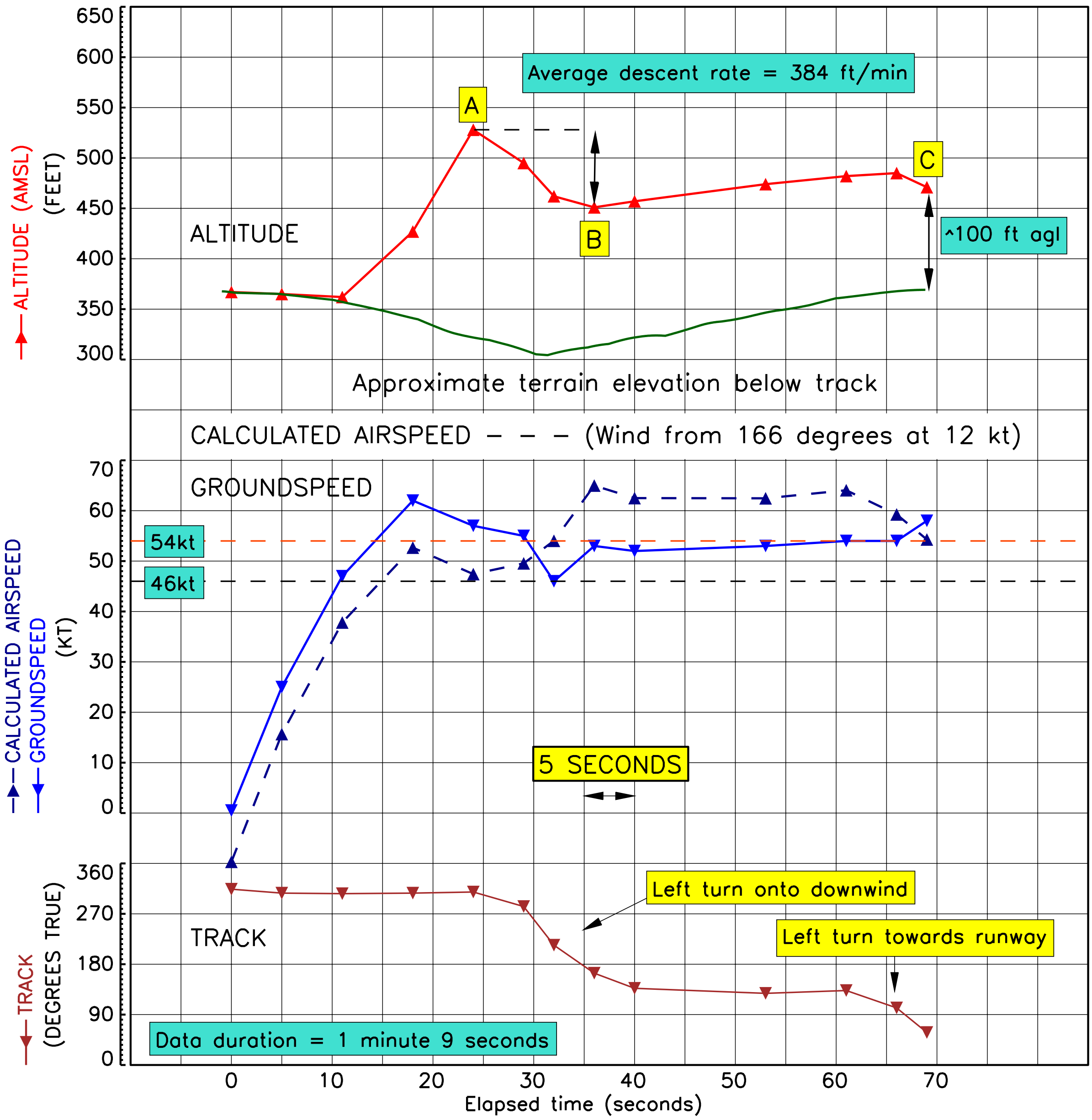

Figure 2

Time series plot of GPS data

FLYdat

The FLYdat unit was successfully downloaded. The engine speed and CHT for all three recorded periods for the accident flight were as follows:

Time after engine start	Engine rpm	CHT (°C)
0 to 5 min 59 s	2,660	84
6 min to 11 min 59 s	4,130	143 (warning)
12 min to end of recording	5,830 (warning)	198 (alarm)

The six-minute time intervals make precise assessment of the data difficult. The parameters for the first time interval are consistent with engine start up, and power checks at around 4,000 rpm appear to have been made during the second time interval. It was not possible to determine the duration of the final time interval which very probably contained most, if not all, of the 69 seconds from the start of the takeoff run to last recorded GPS position.

Information from earlier flights was also recorded on the FLYdat. The previous three flights had maximum recorded engine speeds of 5,960, 5,950 and 5,930 rpm, all of which had registered a warning on the FLYdat. However, for the accident flight a CHT warning was triggered before the engine speed warning was reached, possibly whilst the aircraft was still on the ground. Some time after the CHT warning occurred, an engine speed warning and a CHT alarm were recorded by the FLYdat, although it was not possible to determine which had occurred first.

The CHT sensor for the FLYdat has an operating range of -20ºC to 204ºC. The sensor was tested with another similar sensor and found to read the correct temperature over a range of temperatures from room temperature up to 200ºC. The red FLYdat warning light was tested and illuminated satisfactorily.

Maintenance activity

The pilot had carried out maintenance on the aircraft the day before the accident. The entry in the engine logbook was as follows:

> *'Oil leak traced to hose into radiator*
> *Tightened hose clip after lowering both radiators. Tested O.K.'*

The propeller was fitted with new blades in June 2011.

Detailed examination of the wreckage

The engine was stripped with the assistance of the UK distributor. There was no evidence of any thermal distress or mechanical failure. The damage to the engine and engine area was such that it was possible to recover only a small quantity of fluid from the coolant system. This was subsequently chemically analysed. Whilst not definitive, it was concluded that the fluid in the coolant system was most likely a 50:50 glycol/water mix.

The filler cap for the coolant system was found detached from the expansion tank and the pressure relief valve had detached from the cap. There were no compelling marks on the cap to suggest that it had been forced off when the aircraft struck the ground so the filler cap becoming detached during the flight could not be ruled out.

Swabs of the brown streak along the lower fuselage were taken and chemically analysed. It was concluded that the brown streak was engine oil and not engine coolant. This streak could have been made some time before the accident.

The tube linking the manifold balance pipe to the manifold pressure gauge in the cockpit was examined. There were two pieces of tubing of different diameters, joined by a length of metal tubing. According to the engine installation manual, a condensate trap should be installed in the balance pipe. The manifold pressure gauge was badly damaged and it was not possible to carry out a functional test. The absence of the condensate trap exposed the pressure gauge to possible damage from fuel vapour.

The mainwheel was found in the retracted position. Although there were some witness marks around the landing gear/flap lever 'DOWN' detent, these could have been produced during the complex impact sequence. The level of damage was such that it was not possible to determine the gear and flap position when the aircraft struck the ground.

The flying controls were examined and no evidence of a control problem was found.

An inspection of the propeller revealed significant damage to the hub unit. The propeller blades appeared to be towards the fine pitch end of the range; this was consistent with the selector knob in the cockpit which was in the TAKEOFF position.

The buzzer and the pressure switch in the stall warner were tested and operated satisfactorily. The airspeed indicator calibration was tested and was found to be within 3 to 4 kt in the speed range from 40 to 70 kt.

Pathology

Post-mortem and toxicological examinations were conducted on both the occupants on behalf of the Coroner. The reports were reviewed by a specialist aviation pathologist. He reported that there was no evidence of natural disease which could have had any bearing on the cause of the accident. The toxicology tests on the pilot detected an over-the-counter drug which '*had the rare potential to cause drowsiness*'; however, it was thought '*unlikely to have played a role in this accident*'.

Regarding injury the pathologist reported that:

> *'The pilot exhibited injuries to the palm of his left hand, suggestive of having grasped something at the time of the crash; the most likely thing would be the control column. This finding strongly suggests that the pilot was conscious at the time of the crash.'*

and:

> *'Overall the pattern of injury between the two occupants was similar and consistent with a nose-down impact with the ground. The crash forces were beyond the range of human tolerance.'*

Increase in stalling speed during turns

The stalling speed of an aircraft increases in a turn due to the increase in the load factor.

In order to make a final approach from the downwind leg an aircraft has to be turned though about 180º. From its position on the downwind leg, for G-GBXS to avoid significantly overshooting the runway centreline, this turn would have to be accomplished in a lateral distance of around 240 m. Assuming an entry airspeed of 59 kt, this would have required an average angle of bank of 38º. The result of applying this bank angle would be a load factor of 1.14, resulting in an increase in the aircraft's clean stalling speed from 54 kt to 61.6 kt, and an increase in the flaps-down stalling speed from 46 kt to 52 kt.

Forced landing options

The fields surrounding the airstrip were generally level or gently sloping with, in a majority of cases, short stubble on a hard soil base. Available ground runs ranged from 300 m to over 1,000 m, depending on approach direction.

Analysis

The evidence shows that, after becoming airborne, the pilot decided to abandon the flight and return to the airstrip.

It is impossible to be certain why the flight was abandoned, but, if the FLYdat system was generating a CHT alarm, it would have been prudent to land as soon as possible. Whilst some anomalies were identified during the wreckage examination, these should not have prevented the engine from producing sufficient power to complete a circuit successfully. The fact that the aircraft was able to maintain height and airspeed supports this.

The aircraft's position on the downwind leg was closer to the runway and at a lower height than on other flights recorded on the GPS. It was not possible to determine why the aircraft did not accelerate or climb to a greater height, but this may be indicative that, either by choice or circumstance, the pilot did not or could not use all of the available engine power.

The sudden roll excursion observed by Witness A was consistent with a low-speed stall during the crosswind turn, from which the pilot was able to recover.

The GPS data show that the airspeed was approximately 10 kt above the clean stall speed during the downwind leg but during the base turn the airspeed decreased significantly. Given the increased stalling speed in the turn due to the load factor, it is likely that the reducing airspeed caused the aircraft to stall during the turn, leading to a loss of control from which the pilot was unable to recover.

The Europa's landing performance and the condition of the fields surrounding the accident site were such that the prospects of a successful off-airfield landing were good. On the other hand, given that the aircraft was able to maintain height and speed on the downwind leg, the pilot may have considered that a landing back on the strip was an achievable and preferable option. However, the aircraft's low height and positioning close in to the runway would have made successful completion of the circuit highly challenging.

It is likely that the pilot would have been looking out during the base turn and concentrating on aligning the aircraft with the runway. The aircraft's proximity to the runway meant that there was less distance and hence less time available than usual to complete the manoeuvre. In addition, the wind, although light, was from a direction that would have pushed the aircraft through the turn, increasing the possibility of it overshooting the runway centreline. If the pilot's attention was focussed on looking out and successfully completing the turn, he may not have been aware of the decreasing airspeed and the risk that this posed.

This, and previous similar accidents, show that a loss of control at low level has a very high probability of serious or fatal injury.

The increased load factor and resultant increase in the stalling speed in a turn mean that it is critical to maintain a sufficient margin of airspeed above the stall, particularly when manoeuvring at low altitudes where there may be insufficient height available to recover.

Conclusion

The evidence suggests that the pilot had abandoned the planned flight and was flying a low-level circuit to land back on the airstrip, probably as a result of an engine problem. The aircraft was at a low height and close to the runway during the downwind leg.

The airspeed decreased during the turn onto the base leg, probably resulting in a stall and subsequent loss of control. There was insufficient height to effect a recovery and the aircraft impacted the ground in a steep nose-down attitude, causing fatal injuries to both occupants.

BULLETIN CORRECTION

In the section entitled **Aircraft information** the date that the Permit to Fly was issued is incorrect. The correct date is **13 August 2013**, and not 12 August 2012.

The online version of the report was corrected prior to publication, on 14 August 2014.

ACCIDENT

Aircraft Type and Registration:	Socata TB10 Tobago, G-CFME
No & Type of Engines:	1 Lycoming O-360-A1AD piston engine
Year of Manufacture:	1996 (Serial No: 1795)
Date & Time (UTC):	30 September 2013 at 1051 hrs
Location:	11 nm south-east of Bristol International Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	66 years
Commander's Flying Experience:	332 hours (of which 34 were on type) Last 90 days - 9.5 hours Last 28 days - 3 hours
Information Source:	AAIB Field Investigation

Synopsis

The accident occurred during a flight from a private airstrip back to the aircraft's home base at Henlow. Poor weather conditions were forecast along the planned route, with low cloud and poor visibility. The pilot obtained only minimal meteorological information beforehand, which led him to believe that conditions were suitable for the proposed flight. When the aircraft encountered the poor weather, it started circling and descended to a very low level. It came within close proximity of a tower, forcing the pilot to carry out an avoiding manoeuvre. This placed the aircraft in an unusual attitude at low height and in very poor visibility, a situation the pilot had neither the training nor experience from which to recover.

Background to the flight

The accident occurred during a flight from a private farm airstrip near Taunton in Somerset to the aircraft's home base at Henlow Airfield, near Luton. The pilot made the outbound journey on Friday 27 September 2013 and planned to return to Henlow on the Sunday, having spent the weekend staying with his friends, the farm owner and his wife. However, the pilot's activities on the Sunday delayed his return to the farm, so he postponed his return flight until the following morning, Monday 30 September.

Outbound flight of 27 September 2013

Excellent flying conditions existed on 27 September for the outbound flight to the farm strip. The pilot had not previously flown there, although he had visited on several occasions by road. Some time after taking off, the pilot made an unexpected return to Henlow. On entering the club house, he made comment to the effect that both his GPS units had stopped working (the pilot was referring to the tablet computers which he routinely used for this purpose but he mainly referred to the larger one). When others examined it, the tablet was still functioning but the GPS position was in error. This appeared to be resolved by turning the unit off and on again. According to the pilot's family, this was not the first occasion he had experienced technical problems with the tablet.

Radar data showed that, after taking off on the easterly runway, the aircraft turned left and established briefly on an appropriate south-westerly track, but then made a left turn on to a southerly track which took the aircraft into the Luton Airport control zone. It penetrated the zone by about 1 nm before turning right and returning eventually to Henlow.

Luton Airport ATC filed a safety report on the incident, which occurred at a time of high numbers of arriving aircraft and necessitated the Luton zone controller imposing a temporary restriction on departing flights. The pilot contacted Farnborough ATC (who provided a service outside controlled airspace in that area) and was given navigational assistance to avoid the control zone and return to Henlow.

Prior to his second departure, the pilot was advised by an acquaintance and part-time instructor to organise his departure such that he flew out to the east while ensuring the tablet's GPS was working correctly, before returning to overfly the airfield, so as to have a known starting point for navigation purposes. He also asked the pilot if he had a conventional chart with the route navigation information plotted on it in case of further problems, and the pilot said that he did. As described later it was subsequently established that, although the pilot carried an aviation chart, it had no more on it than an indistinct route line drawn between Henlow and the farm strip.

The accident flight

As Henlow Airfield was normally closed on Mondays, the pilot telephoned on the Sunday and arranged for a club member to be present on the airfield for his return the next day. It was agreed that he would return between 1100 hrs and 1300 hrs, with an ETA of 1130 hrs. The pilot also telephoned his wife. During their conversation, he mentioned that he was prepared to leave the aircraft at the airstrip if the weather was poor, and travel home by train. At the farm, the pilot mentioned that the weather for his return flight would be fine, but it was not known from where he may have obtained this information.

The pilot spent the evening before the flight relaxing with his friends and retired at about 2215 hrs. The following morning, at 0723 hrs, he telephoned an instructor (the same instructor that the pilot had spoken to prior to his outbound flight) to enquire about the weather conditions in the Henlow area. The instructor, who was at his normal place of work, asked the pilot to wait whilst he accessed an on-line weather report for Luton Airport (9 nm south of Henlow). He read this out to the pilot, who appeared content and did not ask for any further information (the content of the weather report is described later in this report, but conditions at Luton were generally favourable). Following this call, the pilot made a similar comment to the farm owner as he would later make to his wife, that conditions were clear for his return route.

The pilot was seen by the farm owner and his wife over the breakfast and early morning period. He appeared rested and in good spirits. He had with him two tablet computers, a larger one with a 250 mm screen and a smaller one. Although the pilot had used the larger one earlier in the weekend to show his friends details of the outbound flight, he was not seen carrying out any activity on either tablet during the morning period, although there were periods when he may have done so unobserved. He made no request to access the Wi-Fi facility at the farm or to use a separate computer there.

At about 1000 hrs on the day of the accident, the pilot was driven the short distance to his aircraft by the farm owner's wife. Although she was not directly concerned about the weather, she saw it was rather grey and asked the pilot if it was suitable for his flight. In replying, the pilot referred to the earlier phone call, and said that his route back to Henlow would be clear up to 6,000 ft. The pilot did not appear hurried or concerned, and took time during his pre-flight inspections to explain some of the aircraft features and related paperwork, although he mentioned that he needed to be back at Henlow by 1300 hrs. The farm owner's wife left the pilot to his preparations and saw the aircraft take off at 1023 hrs. She watched it make an orbit of the airfield before setting off eastwards.

Shortly after takeoff, the pilot attempted twice to make radio contact with ATC at Bristol Airport. The Bristol controller replied, but no further transmissions were received from the pilot. Other airfields and ATC units were contacted during the investigation, but there were no records of the pilot having contacted any of them during the accident flight.

Recorded radar data, together with GPS position information downloaded from the pilot's tablet computer, showed that the aircraft proceeded on an approximate track for Henlow, although with significant deviations as described later in this report. It passed over the low ground of the Somerset Levels, heading towards the Mendip Hills, where terrain rises to about 1,000 ft amsl. As it did so, the aircraft headed towards an area of poorer weather conditions, with low cloud, reduced visibility and rain.

Witnesses in the area of Stratton-on-the-Fosse, on the north-eastern side of the Mendip Hills, described the low cloud lying as mist or fog. Some heard an aircraft in the area some minutes before the accident, while others were not aware of it until very late. Those witnesses who heard the aircraft beforehand described varying engine sounds, as if the aircraft was manoeuvring or circling, although it remained hidden from view by the low cloud. Two witnesses closest to the eventual accident site described the aircraft passing over their property on more than one occasion and seemed to be getting lower, although they could not see it. The last time it passed over, the aircraft was extremely low and they were alarmed. The witnesses thought the aircraft may have been climbing from that point but, when the aircraft was at about the furthest point of its orbit from them, the engine noise reduced, suggesting to them that it may have been preparing to land. There was then a sudden increase in engine noise which continued until the sound of an impact a short while after.

A number of witnesses were working on the roof of Downside Abbey, a neo-Gothic structure with a tower reaching 166 ft agl. These witnesses described the aircraft appearing close by in a wings-level attitude but at very low height, immediately to the north of the Abbey and on a track directly towards it. Almost as soon as they saw the aircraft, it began an avoiding manoeuvre in which it pitched nose-up and rolled to the right, accompanied by a change in engine note to what sounded like full power. The aircraft was reportedly well below the height of the tower, and witnesses believed it avoided the tower by about 30 m. A unanimous view was that the aircraft would have struck the tower had the pilot not taken avoiding action.

No-one saw the aircraft after the avoiding manoeuvre, either because it became lost from view behind the building or due to the poor visibility. However, many heard the sound of an impact soon afterwards.

The aircraft crashed in a partially wooded area within the grounds of the Abbey. Several people hurried to where the sound of the impact had come from. The first 999 call was made at 1052 hrs by the witnesses closest to the accident site, immediately on hearing the sound of impact. Several witnesses reported a strong smell of fuel at the site. An ambulance arrived on scene at 1109 hrs and it was established that the pilot had suffered fatal injuries. The elevation of the accident site was 630 ft amsl.

Engineering

Examination of the accident site indicated that the aircraft had impacted in a lightly wooded area, in such a way that only a single large tree and a small area of ground were affected. The wing structure was severely broken up as a result of a sequence of impacts with the boughs of the tree and aircraft debris was scattered over a limited distance from the ground impact point. It was concluded from the overall evidence that the aircraft had been descending at a very steep angle when impact occurred.

Examination also confirmed that the aircraft had been structurally complete at the impact.

The propeller was found to have separated as a result of a largely torsional failure of the forward end of the engine crankshaft. This failure, viewed in conjunction with the nature of the damage to the two blades, was consistent with the engine having been delivering power at impact. A detailed examination of the engine did not reveal any evidence of internal failure that was not associated with impact forces.

The flying control system was examined and found to be free from any evidence of pre-impact failure. Examination of the flap actuator confirmed that the flaps were fully retracted at the time of the impact. The vacuum pump, the power source for the primary gyro instruments, was found to be fully serviceable and correctly installed such that it would have been capable of creating the appropriate airflow velocity to enable the Attitude Indicator (AI) and the Horizontal Situation Indicator (HSI) to function correctly during engine operation.

The pilot initially planned to make a local flight on the Sunday, and to refuel at a local airfield. However, because of his other activities on the Sunday, this did not happen. A fuel consumption calculation showed that the aircraft would have landed at the farm with approximately 60-65% fuel remaining, after starting the day with full tanks. This would have been sufficient for about 90 minutes flying, including a suitable reserve. Assuming no more than light headwinds for the return flight, it would have been expected to take about 70 minutes.

Pathological and medical information

The pilot held a valid EASA Class 2 medical certificate. A post-mortem examination was carried out by an aviation pathologist. Toxicological tests revealed no evidence of drugs or alcohol, and no evidence of exposure to carbon monoxide. No natural disease was identified which could have contributed to the pilot's death or to the cause of the accident. It was established that the pilot had suffered multiple injuries which were all consistent with having been caused at the time of the accident, and that no additional or alternative personal safety equipment would have altered the fatal outcome.

Meteorological information

The Met Office provided a report on the meteorological situation that existed on the day of the accident flight.

General situation

Surface analysis charts indicated that the accident area was subject to a light to moderate east to south-easterly airflow, with a weakening warm front moving north-east across the area during the morning. Infra-red and visible satellite images showed thick frontal cloud over southern Wales and central southern England. Figure 1 shows a visible spectrum satellite image taken about the time of the accident.

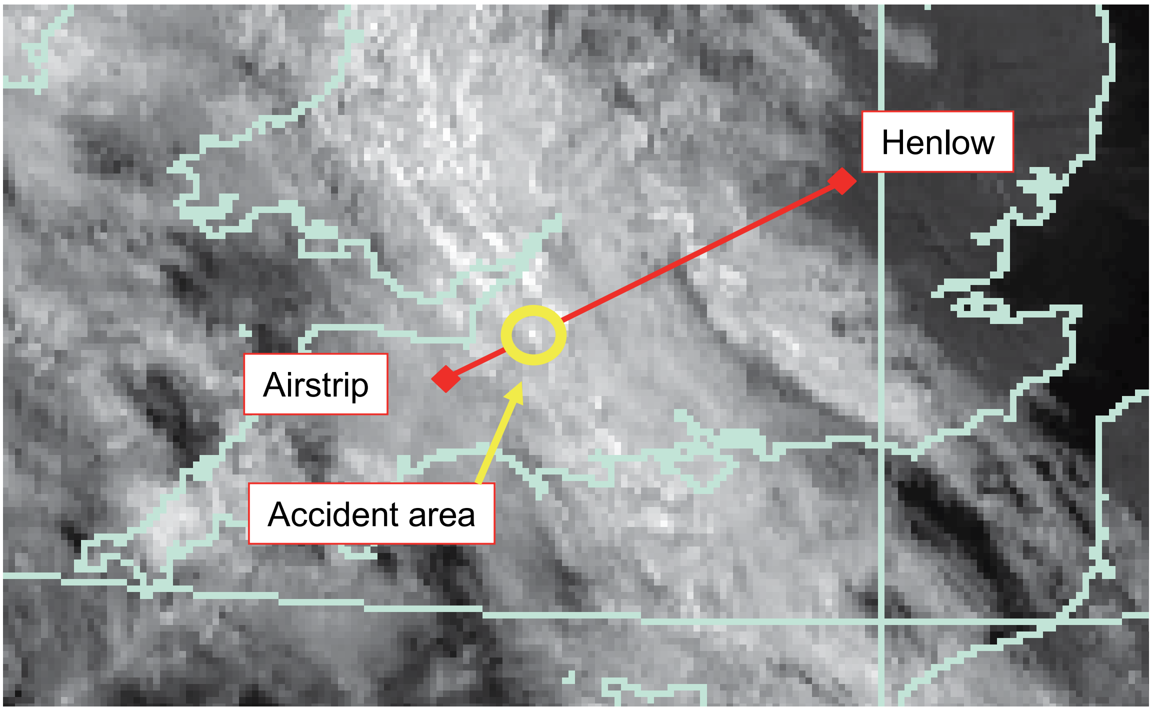

Figure 1

High Resolution Visible Spectrum Satellite Image
30 September 2013 at 1100 hrs UTC

Surface observations in the accident area for the hour before the accident showed visibilities reducing to between 1,300 m and 2,000 m generally, with some areas down to about 800 m. Similarly, cloud bases reduced to below 1,000 ft, and as low as 200 ft in places. There was also a slow moving band of moderate rain associated with the weather front, with lighter and patchier rain or drizzle elsewhere.

Further east, towards the planned destination, conditions were more favourable. Visibilities improved through the morning from around 8 km to around 20 km by midday, while cloud dissipated and cloud bases rose from around 1,000 ft to 2,500 ft.

Forecast information

Met Office Form 215 detailed weather conditions for flights below 10,000 ft over the UK and very near continent. The Form 215 issued at 0257 hrs on 30 September 2013 showed the forecast meteorological situation for 1200 hrs. This showed the slow moving weather front across the accident area with better conditions to the east. The text described isolated or occasional areas of reduced visibility in the accident area, with occasional hill fog (implying visibility of less than 200 m). Cloud bases immediately to the south-west of the front (the area the aircraft would be approaching from) were forecast to be down to between 500 ft and 1,000 ft on occasions, with cloud locally on the surface as fog.

The 0501 hrs forecast for Bristol Airport (30 nm north-east of the takeoff airstrip and 11 nm north-west of the accident site) included temporary reductions in visibility to 7,000 m in rain, and broken cloud at 1,200 ft. There was a 30% probability of 3,000 m visibility in rain and mist with broken cloud at 400 ft.

The 0805 hrs forecast for RNAS Yeovilton (23 nm east of the departure airstrip and about 16 nm south-west of the accident site) included temporary reductions in visibility to 5,000 m in light rain, and broken cloud at 800 ft. Later in the morning (from 1100 hrs on) temporary conditions were forecast to worsen to 3,500 m visibility in rain showers with scattered cloud at 600 ft and broken towering cumulus cloud at 1,500 ft.

The most recent forecast for Luton Airport before the pilot's phone call at 0723 hrs gave a light north-easterly wind and small amounts of cloud at 3,500 ft. Visibility was forecast to be in excess of 10 km, with a 30% chance of dropping to 6,000 m during the first part of the morning. Observations timed at 0650 hrs and 0720 hrs reported a visibility of 9,000 m and no significant cloud.

Airfield actual weather reports[1]

Bristol Airport reported increasing cloud amounts and reducing visibility through the morning, reaching 2,000 m visibility and overcast cloud at 400 ft by the 1020 hrs observation. By 1050 hrs (the time of the accident), visibility was 1,400 m in mist, with overcast cloud at 300 ft. Conditions worsened for a time afterwards, with visibility dropping to 700 m in fog.

Footnote

[1] All times are UTC (Greenwich Mean Time). The aircraft took off at 1030 hrs UTC.

RNAS Yeovilton reported light easterly or north-easterly winds through the morning. By 0850 hrs the station was reporting 7,000 m visibility in light drizzle, with scattered cloud at 900 ft and overcast cloud at 1,400 ft. By 0950 hrs, the conditions had deteriorated further, to 1,800 m visibility in light rain and drizzle with broken cloud at 400 ft and overcast cloud at 800 ft. By the time of the accident, Yeovilton was reporting a lowest cloud base of 200 ft.

Video footage

A member of the public provided footage from an in-car video system, reportedly showing conditions a short while before the accident. The footage was taken on a journey which terminated 400 m from the accident site. Assessments of visibility were made at several stages within 1 nm of the accident site, based on identifiable features. Conditions were misty with occasional light rain. Visibility was assessed to be 700 to 800 m.

Pilot's meteorological planning

The pilot's family described how he routinely used the home computer or his tablet computer to access weather information and to plan flights. He would, with a suitable internet connection, have been able to download meteorological and NOTAM[2] information using the flight planning application on his tablet. However, the meteorological information he would have been able to obtain this way would have been limited to actual and forecast airfield weather reports and wind conditions; synoptic charts or other graphical presentations that would show the presence of frontal systems and other meteorological features would not have been available. For this he would have needed to access an online aviation briefing service.

The pilot did have an online account with the Met Office's aviation briefing service, but last accessed this service on 30 June 2012. There was no record on the pilot's mobile telephone of a call to any other aviation weather briefing provider over the few days before the accident flight. It was found that the tablet had not downloaded meteorological data since 20 September 2013, which was the last occasion the pilot flew prior to the outbound flight of 27 September. Thus, the only confirmed source of meteorological information for the pilot was the phone call he made on the morning of the accident.

It was reported that the pilot had briefly discussed the weather for his planned trip on the previous Thursday, both with his son and with the co-owner of the aircraft. His son had observed that, although the weather was presently fine, poorer weather was due to arrive in the coming days. The pilot had responded by saying, as he did to his wife on the Sunday, that he was prepared to leave the aircraft at the farm strip if the conditions deteriorated. To the co-owner, the pilot said he would not make the trip if the weather was not going to be suitable. During the investigation, the pilot's family observed that he had no pending business engagements and should not have been under undue pressure to make the return flight.

Footnote

2 Notices to Airmen.

Pilot's tablet computer

Data recovered from the tablet computer's memory consisted of files used by the flight planning and navigation application. These contained data related to meteorological reports, stored routes, the planned route at the time of the accident and recorded GPS data from the accident flight and earlier flights. As described earlier, the meteorological files contained no recent information.

Planned route

At the time of the accident, a route (termed here the 'planned route') was stored in the flight planning and navigation application, which would have provided the pilot with a graphical presentation on his tablet. This was the route that would have been displayed on the tablet at the time of the accident.

The planned route was from Henlow to the farm strip, ie applicable to the outbound flight. The application allowed the planned route to be reversed by the user, thus generating navigation data relevant to the return flight to Henlow. However, this had not been done (otherwise the route would have been modified to reflect the change). The route would still have been depicted on the tablet's display and could have been followed by the pilot, although associated navigation data (time and distance to destination) would have been inaccurate. The route contained an anomaly in that it did not go direct to the farm strip, but to a waypoint 1.7 nm south of it, over the town of Wellington. This manually-entered waypoint was labelled with the name of the farm, but its position appears to have been input incorrectly. Part of the planned route is shown in Figure 2.

GPS data – 27 September 2013

GPS data for both the outbound flight of 27 September 2013 and the accident flight were recorded in memory. The frequency with which the data points were logged by the GPS unit was dynamically controlled by algorithms in the unit's controlling software, based on rates of change of height, track, and ground speed.

The pilot's second departure from Henlow on 27 September followed an almost identical initial track to the earlier one that resulted in the infringement of Luton's control zone, except that it stabilised on a path appropriate to the planned route. About 5 nm of the last waypoint, the aircraft routed towards the farm strip for landing. GPS altitude for the majority of the route was approximately 2,000 ft.

GPS data – accident flight

The aircraft took off at 1023 hrs. Instead of converging on the planned route after takeoff as would be expected, the observed track continued to deviate northwards from it until the aircraft was about 8 nm from the farm strip (Figure 2). At range 10 nm, the aircraft turned right through about 150º before flying across the planned route and reversing course again to follow its direction, this time to the south of it. The aircraft then entered a 'figure of eight' manoeuvre before turning to establish on the planned route. There were further deviations from the route but, within 5 nm of the accident site, the position remained within 0.5 nm of it.

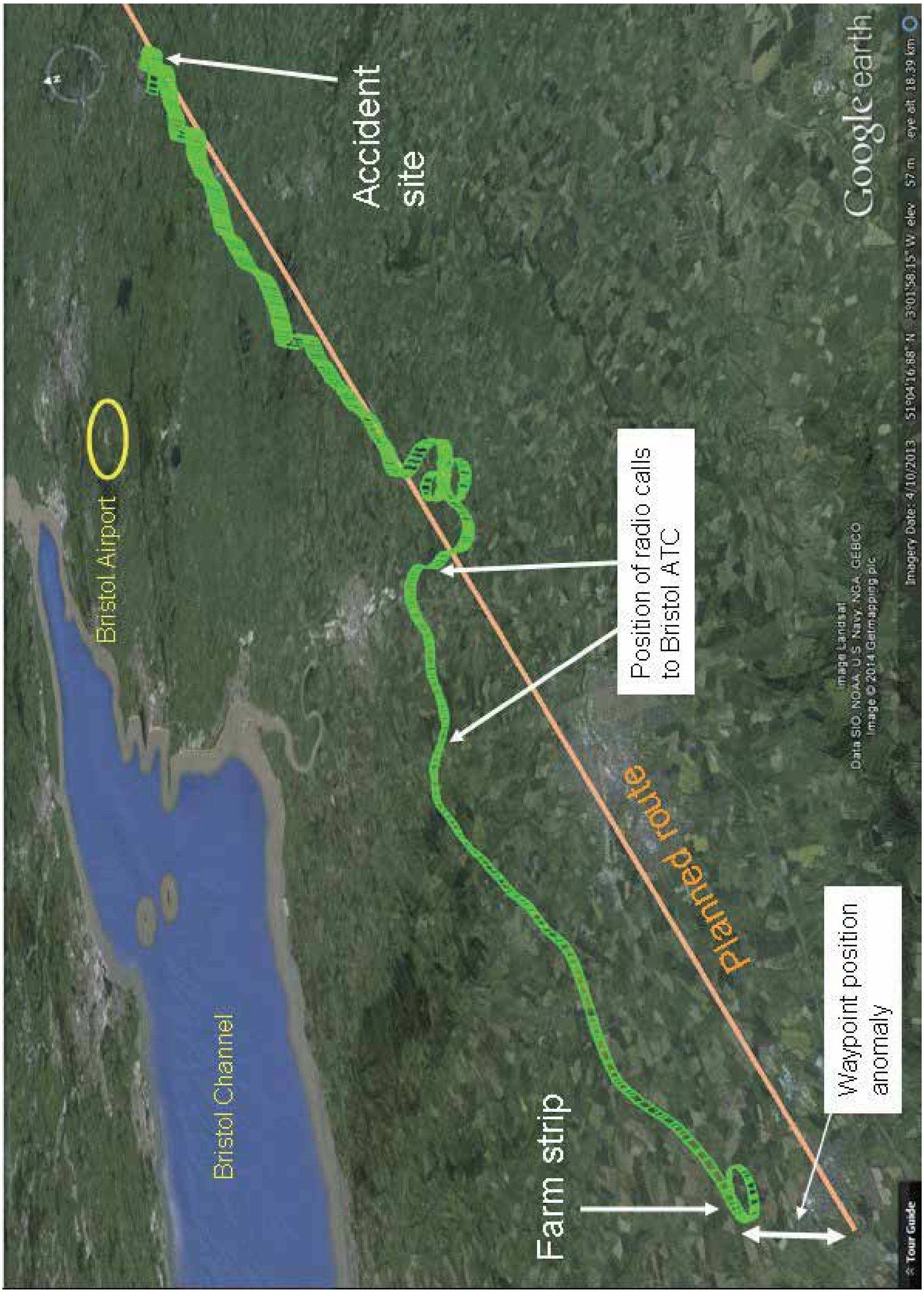

Figure 2

Planned route line and GPS track (oblique view)

GPS altitude data showed that the aircraft climbed to 1,000 ft (about 800 ft agl) over the farm strip before departing en-route. It maintained approximately this height until the point at which it turned across the planned route, when it climbed noticeably to between 1,300 ft and 1,400 ft. During the turn to the right at the start of its figure of eight manoeuvre, the GPS altitude reduced to about 700 ft agl. However, at this stage, the recorded positions suggest a degrading GPS function (possibly through signal blanking) so the associated altitude data may not be accurate. As the aircraft continued into a left hand orbit, the recorded GPS positions recovered and altitude values increased. As the aircraft turned towards its active route, it showed a sustained climb to about 1,800 ft altitude which continued until, as it passed over the city of Wells in Somerset, the GPS altitude indicated 3,100 ft (about 3,000 ft agl). After this point, altitude remained reasonably constant, while the ground beneath the aircraft steadily rose towards about 750 ft. Given the forecast winds, recorded groundspeeds were generally consistent with an IAS of 110 -120 kt.

Radar information

Recorded radar data was obtained from the long range radars at Clee Hill in Shropshire and Burrington in North Devon. The data from both heads commenced simultaneously as the aircraft climbed into radar coverage and showed a close correlation with the GPS data. No Mode C altitude data was received so the GPS altitude could not be verified. The aircraft's transponder controls were extensively damaged and it was not possible to establish whether Mode C had been selected by the pilot.

Final manoeuvres

Figure 3 shows a combination of the GPS position data and radar derived data. Also shown are the times of the last position points, the direction the aircraft was travelling before it took action to avoid the tower, and the accident site. The discrepancy between the tracks is due to the radar positional accuracy, recording rate and the low level coverage.

The aircraft started a right turn in the accident area, and started to descend. After about 270º of turn, it had descended to about 2,300 ft (about 1,700 ft agl). From this point, the GPS appears to have suffered from signal blanking again, as the recorded position began to deviate from the radar data and became unreasonable. Radar data shows the aircraft continued in its right turn, eventually turning through about 450º before radar returns ceased at 1050:31 hrs, 500 m from the aircraft's last observed position. The GPS data ends with 12 data points which occur at short intervals over a 12 second period, ending at 1050:51 hrs. The positions of these data points are unreliable, but all occur within 170 m of the last position reported by eyewitnesses.

Pilot information

Flying training

The pilot started flying training in 2004. He gained his PPL(A) in late 2011, by which time he had flown 287 hours, 267 of which were with an instructor. The extended training period was attributed in part to the pilot's business and other interests, which sometimes prevented the amount and quality of pre-flight preparation necessary for training flights. It was noted

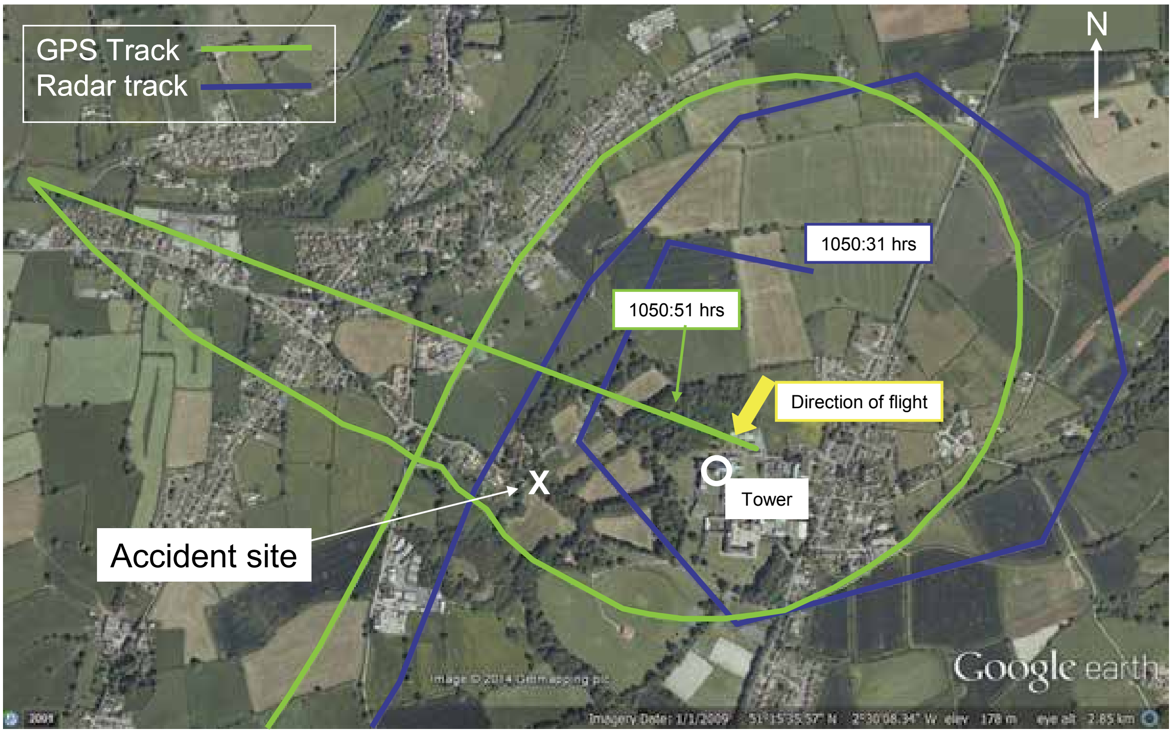

Figure 3

GPS and radar tracks for the final stages of the flight

that the pilot appeared content to fly dual for extended periods and did not regard gaining his pilot's licence as a goal in its own right.

A senior flying instructor, who had flown frequently with the pilot since 2008 (most recently, in May 2013), assisted the investigation with information concerning the pilot's strengths and weaknesses and general approach to flying. Although pre-flight readiness and preparation remained a weaker area, the pilot was described as being unlikely to embark on a flight which he knew might be beyond his experience or ability to deal with. While the pilot's handling skills were reported as generally good, it was felt that his airborne decision making ability could be degraded relatively easily if faced with demanding or unexpected situations. He had completed elementary instrument flying practice as part of his training but was not otherwise experienced in this skill[3]. It was considered unlikely that he would knowingly fly when bad weather was forecast, a view shared by the pilot's family.

With regard to contingencies occurring on navigation exercises such as poor weather or becoming lost, the pilot would have been trained in the correct contingency procedures and had demonstrated this knowledge during training.

Footnote

[3] Basic instrument flying techniques are taught during flying training as a contingency procedure in case of an inadvertent encounter with poor visual conditions. This training does not qualify a pilot to plan to fly by sole reference to the aircraft's instruments.

Experience in G-CFME

In early 2009 the pilot became joint owner of a Cessna 150, which he flew for most of the remainder of his flying training. He continued to fly the aircraft after gaining his PPL(A) until he became a joint owner of G-CFME in early 2012. From that time, all the pilot's recorded flying hours were in G-CFME. At the time of the accident, he had flown 34 hours in the aircraft.

Flight planning and navigation

During training, the pilot used conventional aviation charts and flight planning techniques to plan navigation exercises. According to his family, about six months before the accident he started using a flight planning application on his tablet computer for both flight planning and airborne navigation. The tablet used by the pilot used an internet connection (both Wi-Fi and mobile network connectivity) which provided the capability of carrying out planning functions, including displaying warnings to navigation and both current and forecast airfield weather conditions. It also had an in-built GPS receiver, enabling a continuous graphical presentation of current position. However, when used in an aircraft, such a unit is known to have particular limitations, such as signal blanking. The Civil Aviation Authority's Safety Sense Leaflet 25 states:

> *'Parts of the aircraft structure may get in the way, for example the outside wing in a turn. If this blanks the signal momentarily, the navigation capability may be degraded or lost, requiring several seconds of straight and level flight to re-establish navigation information. These problems are particularly prevalent in hand-held units with internal aerials.'*

A 1:500,000 scale aeronautical chart was recovered from the aircraft after the accident. The chart was marked only with an indistinct and broken route line between Henlow and the farm strip, applied with a chinagraph or grease pencil. There was no other navigational information marked on the chart. Advice by the Civil Aviation Authority is that stand-alone GPS equipment of the type used by the pilot was only ever to be used as an aid to other forms of navigation, typically correctly marked aviation charts and navigation logs.

'Landaway' experience[4]

A detailed analysis of the pilot's flying logbook and the aircraft's journey log was made, in order to establish the extent of the pilot's experience relative to the flights he planned for the weekend of the accident. Only flights made after the pilot gained his PPL were considered, as before that he would have been flying under the supervision of an instructor. It was found that all the pilot's experience of landing away at other airfields involved flights made there and back on the same day. The majority of airfields he visited were in his local flying area and none were further west or south-west than RAF Brize Norton in Oxfordshire.

Footnote

4 'Landaway' here refers to a flight from the pilot's home airfield to one or more other airfields where the aircraft lands before making a return flight.

With one exception, all the pilot's landaway flights were made in very good flying conditions. The single exception was when he flew with another pilot to a neighbouring airfield to collect G-CFME and then flew it back to Henlow, a distance of 14 nm. The outbound flight on 27 September was also made in excellent weather conditions.

Applicable regulations

Pre-flight duties of the aircraft commander

The Air Navigation Order 2009, which was applicable to the accident flight, listed in Article 86 the pre-flight duties of an aircraft commander. It included the following:

> *'A commander must, before taking off on a private flight, an aerial work flight or a public transport flight, take all reasonable steps so as to be satisfied (that) … the flight can safely be made, taking into account the latest information available as to the route and aerodrome to be used, the weather reports and forecasts available and any alternative course of action which can be adopted in case the flight cannot be completed as planned.'*

Visual Flight Rules (VFR)

The pilot was required to conduct his flight in accordance with the Visual Flight Rules (VFR). The rules applicable in any situation are dependant upon the aircraft's altitude, airspeed and airspace in which it is flying. In relation to the accident flight, when flying at or below 3,000 ft amsl, the pilot was required to remain clear of cloud with the surface of the ground in sight, and with a minimum visibility of 1,500 m. For flight above 3,000 ft amsl, the minimum visibility permissible is 5 km.

Analysis

The physical examination of the aircraft wreckage revealed no fault, malfunction or failure which may have contributed to the accident. The aircraft was assessed to be capable of normal flight and the engine was delivering power at the moment of impact. These conclusions were supported by eyewitness accounts that the aircraft made a sudden manoeuvre that appeared to be a deliberate action by the pilot to avoid the tower. Coincident with this was the sound of the engine going rapidly to what sounded like full power.

Recorded data showed the aircraft flying what appeared to be a continuous, controlled turn before the accident. This, along with the pathologist's report, the apparently deliberate avoiding manoeuvre flown by the pilot, and accounts of those who saw the pilot on the day of the accident, make pilot incapacitation an unlikely initiating factor in the accident.

From the recorded data and witness accounts, it is clear that the aircraft descended in a more or less continuous right hand turn to a very low height in poor weather. The pilot would have been aware of the considerable risk such a manoeuvre entailed, so it must have been for a reason which the pilot felt would have made any other course of action impossible or highly inadvisable. Considering the circumstances and the pilot's experience, the investigation considered that either navigation problems or the poor weather itself (or a combination of the two) were the most likely reasons.

Even though he had no experience of flight on the planned route, the pilot had no proper chart or navigation log prepared for the flight and was therefore dependant on his tablet computer. Even in fine weather, his ability to navigate without the computer and no chart as back-up was uncertain, as the airspace infringement incident of 27 September illustrated, so a failure in poor weather conditions in an unfamiliar area would have presented a major challenge. It is very unlikely that the pilot would have embarked on the flight or continued eastwards without continued position information, and the recovered data showed that the GPS was providing accurate position information for the great majority of the flight. It was therefore concluded that, although there was the capability for it to present a distraction in the final stages of the flight, a loss of GPS position data was not the reason that the pilot stopped following his intended route.

An obvious aspect of the accident was the extremely poor low level weather in the accident area, and the investigation considered this to be the probable reason that the pilot deviated from his intended route and descended. He would have encountered generally poor conditions soon after takeoff, which would have worsened as the aircraft approached the frontal system lying across the route. The GPS track from takeoff showed significant deviations and changes in altitude. These were not features of the outbound flight, which was flown in good conditions. Considering the weather and the need to get back to Henlow in reasonable time, it is unlikely that the pilot would have made these manoeuvres had he not deemed them necessary. Consequently, the manoeuvres were almost certainly weather-related. It is possible that the pilot was attempting to seek weather information from Bristol, but the responses were not acknowledged, and so presumably went unheard, by the pilot.

The investigation sought to explain why the pilot embarked on the flight when the poor weather conditions had been forecast. There was time available before the flight for the pilot to obtain the latest weather forecast and reports from airfields near his route, and he had the knowledge to be able to do so. He probably regarded his tablet computer as his main source of weather information, but he did not download any weather pertinent to the accident flight. The farm owner had a Wi-Fi system, but the pilot did not ask for access to it, nor to use the farm's own computer to access an online aviation weather briefing service. The apparent lack of other navigation planning is also notable, such as the planned route on the tablet computer, which remained unchanged since the outbound flight and still subject to the waypoint location error. In fact, there was no evidence to suggest that the pilot had carried out any pre-flight preparation at all, other than the telephone call to enquire about the Luton weather.

From the comments the pilot made to his friends at the farm strip, he clearly believed that the weather for the route was suitable. Had he been aware of any relevant weather information other than the Luton weather that he obtained by telephone (and there is no evidence that he did), then the pilot would have been unlikely to have held this view. Indeed, had the pilot been able to access weather information by other means, he would not have needed to make the call at all. It was concluded that the pilot based his assessment of the en-route weather conditions entirely on the conditions at the farm and the Luton reports, which would have led him to believe that weather conditions would improve the further east he flew. In fact, for the first part of the flight, the opposite was true.

As his return had been delayed, there would have been some pressure on the pilot to make the flight. However, the pilot had discussed a poor weather contingency with his family and it was felt he would have left the aircraft at the farm strip and travelled home by train if need by, as he had stated. The fact that he did not further supports the supposition that the pilot was not aware of the probable weather conditions affecting his planned flight.

Once airborne, the pilot was probably faced with critical decisions for which his experience to date and lack of pre-flight planning had not prepared him. The GPS track shows that the pilot was, at various stages, unable to make progress along his desired route, and he may even have started to turn back. However, his belief that conditions would improve the further east he flew may have been the reason he continued towards his destination. The aircraft climbed to around 3,000 ft altitude which, based on his outbound flight, was higher than the pilot probably intended to fly and is likely to have been above the lowest cloud. Whilst the in-flight conditions presumably improved with this change of altitude for a time, it is probable that the pilot had only intermittent ground contact and that this would have reduced as he flew towards the worst weather.

Eventually, the pilot appears to have been forced into an alternative course of action. The right turn may have been an attempt to turn back, but the aircraft continued to circle. It is possible that the weather conditions, which may have been steadily worsening for some time, made it impossible for him to identify a clear route out of the weather. With only basic instrument flying training and no recent practice, it is unlikely that the pilot would have been able to fly and navigate out of the situation using instruments alone. It is therefore probable that he started the descent with marginal ground references in an attempt to gain better conditions below the cloud, while probably being unaware at that time that the poor visibility extended to ground level.

From the description of witnesses, radar recordings and timings of recorded GPS positions, it is probable that the aircraft flew about a further 270º of turn from the point that the GPS position started to degrade. Although the actual track cannot be known, a reducing radius turn is indicated. While this could have been the result of pilot disorientation leading to an increasingly tight turn, the appearance of the aircraft when it became visible does not suggest this occurred. A more likely explanation is that the aircraft was reducing speed in the later stages, probably because of the poor visibility or even as a precursor to a possible landing. However, as the flaps were found to be fully retracted, an intention to land is considered to be less likely.

Final accident sequence

The apparent avoiding action described by witnesses would have been an instinctive reaction by the pilot when faced with a possible collision. It is therefore likely to have been quite a violent manoeuvre, causing the aircraft to enter a dynamic pitching and rolling manoeuvre with an upward vector. There would have been two significant consequences of this. In the poor conditions, it would have removed any ground references the pilot had, leaving him completely dependant upon his flight instruments for orientation. Furthermore, as the pilot was not prepared for the manoeuvre, it would have been disorientating and possibly even incapacitating in the short term. The pilot had neither the training nor experience to recover from such a situation in the little height available. The proximity of the accident site to the tower and the nature of the accident site itself, suggests that the aircraft entered a climbing, rolling manoeuvre which resulted in the aircraft's nose dropping before it entered a steep final descent.

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:	Aero L-29 Delfin, G-BYCT	
No & Type of Engines:	1 Motorlet M701C-500 turbojet engine	
Year of Manufacture:	1973 (Serial no: 395142)	
Date & Time (UTC):	20 May 2014 at 1300 hrs	
Location:	Near Cranfield Airfield, Bedfordshire	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Front canopy detached in flight	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	62 years	
Commander's Flying Experience:	13,000 hours (of which 30 were on type) Last 90 days - 30 hours Last 28 days - 13 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot reported that following a normal takeoff, and while climbing through a height of 500 ft, the front right side of the canopy lifted by approximately one inch. As he attempted to pull the canopy down it detached from the airframe. The aircraft was undamaged and landed normally.

The canopy is mounted on the airframe by two hinges fitted to the right side of the canopy and is secured to the airframe by four latches, two on each side. The pilot reported that it is difficult to check that the hooks are engaged in the latches, so after closing and locking the canopy he pushed upwards on the left side to check that it was secure. The pilot believes that the hinges might have been binding slightly which prevented the hooks on the right side from engaging in the latches.

BULLETIN CORRECTION

The pilot had provided the AAIB with the incorrect flying hours for the last 90 days, which had then been published in the AAIB monthly report. The flying hours for the last 90 days, which have been incorrectly stated as 3 hours, should be corrected to read 30 hours.

The online version of this report was corrected on 10 September 2014.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 757-2Y0, G-FCLK
No & Type of Engines:	2 Rolls-Royce RB211-535E4-37 turbofan engines
Year of Manufacture:	1994 (Serial no: 26161)
Date & Time (UTC):	23 August 2013 at 1713 hrs
Location:	Gatwick Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 8 Passengers - 220
Injuries:	Crew - None Passengers - 5 (Minor)
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	13,470 hours (of which 9,250 were on type) Last 90 days - 86 hours Last 28 days - 230 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and other AAIB enquiries

Synopsis

The commander ordered passengers to disembark after observing smoke from hydraulic fluid leaking onto the aircraft's brakes. The intent of the order was not understood by all, and some passengers vacated the aircraft using an emergency exit slide.

History of the occurrence

The passengers had boarded another aircraft at London Stansted some hours earlier, for a direct flight to Tenerife, but the aircraft developed a technical problem before departure and could not be flown. The passengers were accommodated in the terminal at Stansted for several hours while an alternative aircraft was sought. When the replacement aircraft arrived at Stansted, the crew members' allowable duty hours were insufficient for them to operate to Tenerife and back, so plans were made for them to operate the aircraft to Gatwick, where a replacement crew was to take over. The departure from Stansted was approximately six hours behind its scheduled time.

The flight to Gatwick was uneventful. After landing, the aircraft taxied to Stand 38 where a jet-bridge was attached to the door just aft of the flight deck on the left hand side (door 1L[1]). The crew going off duty began handing the aircraft over to their on-coming colleagues. The

Footnote

[1] Doors are numbered from the front of the aircraft and identified as on the left or right side of the aircraft.

passengers remained in the cabin, mostly seated, though some moved around and made use of the aircraft's facilities.

The on-coming commander began his external inspection of the aircraft, during which his attention was drawn to a hydraulic leak above the left main landing gear. He re-boarded the aircraft and informed the cabin manager and co-pilot of the leak, before returning outside to the ramp. The cabin manager used the interphone to inform cabin crew at the rear of the aircraft of the problem. Evidence suggested that this news did not reach all the cabin crew. He saw that the leaking hydraulic fluid was falling onto the brakes, which were warm following the aircraft's landing, and smoke was being produced.

In brief discussion with an engineer, the commander decided it was appropriate to disembark the passengers and crew rapidly. He returned to the aircraft cabin's forward vestibule and made an announcement on the public address system which he later recalled as being "Ladies and gentlemen, we need to clear the aircraft immediately; there is smoke on the left hand side". He stated that the passengers did not react to this announcement, so he made a further announcement saying "Move, come this way!". Shortly afterwards, a member of the cabin crew informed him by interphone that the door 3R emergency exit had been opened and the slide had deployed.

A male and a female passenger who were seated together adjacent to door R3, which is the emergency exit immediately aft of the right wing, were interviewed several weeks after the incident[2]. They explained that their view forward was restricted by lavatories on both sides of the cabin immediately in front of their seat row; their view aft was less restricted.

The male passenger recalled being in his seat by the emergency exit aft of the wing on the right hand side of the aircraft (door 3R), when he heard an announcement on the public address system: "smoke on the left side, get out, get out, get out!". He recalled not being certain that the announcement had been made by a member of crew, and wondering whether a passenger had made the announcement. He looked to the left side of the aircraft but his view was restricted and it was not possible to see whether anything was amiss. He recalled making an assessment of the situation and contemplating how long it would take to disembark via the normal exit. He examined the instructions on the emergency exit, and as he did this he heard another passenger addressing him and saying "do it, do it".

He opened the emergency exit and the slide deployed. He assisted some passengers onto the slide before going down it himself.

His partner, seated next to him, remembered hearing an announcement: "we have smoke on the left hand side, get out"; she commented when interviewed that the announcement was not preceded with an introduction from the person speaking (for example: 'this is the captain').

Footnote

[2] Enquiries into the passengers' identities and contact details took time.

She recalled that another passenger then addressed her partner, saying words to the effect of "Open the exit… you've got to open it". After this, her partner opened the emergency exit, and the slide fitted to it deployed. She left the aircraft via the slide, without difficulty, and then assisted other passengers coming down behind her.

Cabin crew reports

Reports submitted by the cabin crew to the operator's safety department were forwarded to the AAIB. The reports suggested that the commander's initial announcement may have included an introduction ('this is the captain…'), although some reports suggested no introduction was made, and that his announcement included instructions that passengers should leave their belongings on board. The report by the cabin crew member nearest door 3R stated that when the emergency exit was opened, he was not certain whether an evacuation had been commanded or not, but that on observing cabin crew members (from the off-going crew) helping passengers at the bottom of the slide, he continued to direct passengers to the emergency exit and down the slide, until it became apparent that cabin crew in the forward part of the aircraft were directing passengers to door 1L.

Statements of other cabin crew members suggested that public address announcements had been made by the cabin manager, "along the lines of 'don't panic, leave your bags, move to the forward door on the left hand side of the aircraft'".

After the evacuation

Airline and airport staff, and then the fire and rescue service personnel, assisted passengers on the ramp. Five passengers suffered minor injuries[3] and were treated at the scene; none were hospitalised.

The passengers who had exited via the slide were escorted into the terminal building. The passengers were then accommodated overnight in a nearby hotel. They were flown to Tenerife the next day.

Estimates of the number of passengers who used the slide varied between 10 and 100; it was not possible to determine the number with certainty, though several witnesses mentioned numbers around 20 or 30.

Flight recorders

The aircraft was fitted with a cockpit voice recorder (CVR) and flight data recorder (FDR). The CVR was downloaded at the AAIB's facilities, but the recording did not contain either relevant dialogue or the commander's public address announcement, because conversations had taken place out of the range of the cockpit area microphone, and the public address system was not recorded. The FDR did not contain relevant data and was not downloaded.

Footnote

[3] Reliable details of the injuries could not be obtained.

Standard operating procedures

Cabin crew at doors

Ten days before the incident, the operator published a *'Safety and Survival Bulletin'* which contained the following article:

> *'Unattended doors on the ground*
>
> *Crew are repeatedly leaving doors unattended on the ground with passengers on board.*
>
> *At least one crew member must remain 'in the vicinity' of each pair of doors when passengers are onboard and the aircraft is on the ground (B1 Manual: 2.10.2 Door Cover.)*
>
> *It was only at the end of last year that a B757 had to be evacuated whilst on stand so the importance of following this procedure cannot be stressed (sic).'*

Procedures for rapid disembarkation

The operator had published procedures for rapid disembarkation, alongside procedures for evacuation of the aircraft using emergency exits, which included the forms of words to be used during public address announcements:

> ***'Rapid Disembarkation***
>
> *In the event passengers need to leave the aircraft quickly using steps/airbridge.*
>
> *Flight Crew PA:*
>
> > ***"Attention Cabin Crew, clear the aircraft immediately".***
>
> *This should be followed by a PA from the Cabin Crew:*
>
> > ***"Attention, this is an emergency announcement, will all passengers follow Cabin Crew instructions and get off the aircraft immediately. Leave everything behind".***
>
> *In the event a rapid disembarkation is necessary during passenger boarding, the Cabin Crew must be alert to the situation and reverse the flow of passengers as quickly as possible to disembark the aircraft.'*

However, whilst the AAIB investigation was ongoing, the operator revised their procedures to bring airlines within their commercial group into line with each other. The revised instructions stated:

'***CONTROLLED DISEMBARKATION***

In situations where an evacuation using slides is not necessary but the passengers should leave the aircraft as a precaution (e.g. specific bomb threat, unpleasant odour in the cabin), this is called a ***controlled disembarkation****.*

In a controlled disembarkation steps, airbridge one or more slides, or a combination of methods, can be used. It requires a prompt passenger response but is not a time-critical situation requiring an immediate 'full' evacuation. Depending on the situation the Flight Crew will decide:

- *at which aircraft doors the steps/airbridge are fitted, unless they are already in place*

and/or

- *which doors slides should be deployed*

and then inform the SCCM.

The Captain then gives the instruction:

"Controlled disembarkation by the steps/airbridge/slide(s) at door/doors ...!"'

No form of words to be used in addressing the passengers was prescribed.

Engineering

The aircraft operator's engineers identified that hydraulic fluid had leaked from the left hand main landing gear retract actuator. The actuator was transferred to an overhaul contractor for strip-down, examination and repair. The examination revealed corrosion on a number of items with damage and failure of associated o-ring seals leading to the fluid leakage from the component. The extent and nature of the damage made the item beyond economic repair. This is the only main landing gear actuator failure held on record by the operator. The component is not subject to a specific overhaul life policy set by the original equipment manufacturer.

The actuator was replaced and the aircraft returned to service.

Analysis

Engineering

The hydraulic leak on the main landing gear actuator appeared to have resulted from corrosion and failure of o-ring seals within the unit. Although no overhaul life was set for the item, and thus it would remain installed for the life of the aircraft, unless it failed or inspection revealed deficiencies, the absence of evidence of previous failures of the component suggested that the probability of failure was slight. Following replacement of the actuator, no recurrence of the leak was reported.

Operations

The commander's decision to order a rapid disembarkation reflected a concern that the smoke produced by the hydraulic fluid falling on the brakes constituted a hazard and that it was desirable to remove persons from the aircraft.

The SOP for rapid disembarkation called for a member of flight crew to make one announcement, then for the cabin crew to instruct the passengers as follows: *'Attention, this is an emergency announcement, will all passengers follow cabin crew instructions and get off the aircraft immediately'*. In this instance, the commander did not follow the procedure, but made a similar announcement to the one prescribed for the cabin crew to deliver, while standing in the forward cabin vestibule. This reportedly had no effect. It was not possible to determine why the passengers did not react.

The investigation could not establish the precise wording of the announcement made, or whether it was preceded by words such as 'this is the captain…', but the prescribed announcement did not begin with an introduction by the person making it. It is notable that the words laid down in the SOP, by which the cabin crew would instruct passengers to disembark, also had potential to be misinterpreted as an instruction to evacuate, because no reference was made to the manner in which passengers were to leave the aircraft, and it contained the words *'an emergency announcement'*. In particular, the phrase did not specify that passengers must not use the emergency exits. For a passenger seated at the rear of an aircraft, adjacent to an emergency exit, and aware that the only open door is at the very front of the cabin, '…*get off the aircraft immediately'* might be construed to mean that the emergency exits should be used. (Although the form of words applicable to a rapid disembarkation or evacuation would be recognisable to the crew, passengers would not be aware of the distinct phrases and would have to interpret the words they heard, in context.)

The company's revised procedures did not prescribe a form of words for a rapid disembarkation announcement to the passengers, and crew members choosing their words might bear this incident in mind when composing announcements.

When the passengers did not react to his first announcement, the commander made a second one, after which passengers in the forward part of the aircraft began making their way to door L1.

Aft of the lavatories, passengers did not have the clear view up the cabin which those further forward enjoyed. The passengers seated near to door 3R had, therefore, heard an emergency announcement and understood that the passengers were being disembarked; they had also heard reference to 'smoke'. The male passenger's action in examining the emergency exit instructions was an understandable reaction to the circumstances. It was not possible to determine whether he would have activated the exit in the absence of encouragement from the passenger nearby to open it.

The opening of the exit could have been avoided had a member of cabin crew, aware of the intention to carry out a rapid disembarkation, been positioned at the exit. The operations manual required cabin crew to be in the vicinity of doors while on the ground, and a reminder of the procedure had been issued to crew only ten days before the incident. This incident serves as a further reminder of the benefits of having cabin crew close to doors while on the ground.

Although the cabin crew had been made aware of the hydraulic leak, they were not informed of the intention to carry out a rapid disembarkation until the commander made his PA announcement; procedures did not require this. It would have taken little time to inform the cabin crew, by interphone, of the planned rapid disembarkation, and instruct them to take positions by the exits. This action would both have prevented an undesirable opening of an emergency exit, and placed cabin crew appropriately to deal with any escalation of the situation calling for an evacuation via the slides to be carried out.

The operator, whose safety department investigated the event, does not plan to alter the revised procedures implemented during the AAIB investigation.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 757-200, N605AA
No & Type of Engines:	2 Rolls-Royce RB211-535E4 turbofan engines
Year of Manufacture:	1995 (Serial no: 27056)
Date & Time (UTC):	22 October 2013 at 1430 hrs
Location:	100 nm south-east of Providenciales, Turks and Caicos Islands
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 169
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	Not known
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was en route to Miami when smoke started to fill the cockpit. The crew actioned the '*Smoke, Fumes and Fire'*, and the '*Smoke Removal*' checklists and diverted to Providenciales without further incident. The smoke was attributed to a seal in a Low Pressure Fuel Pump that had failed, allowing fuel to enter the oil system and then the bleed air system. The engine manufacturer is conducting a detailed inspection of the fuel pump to determine the specific cause of failure, in accordance with its established continued airworthiness procedures.

History of the flight

The aircraft, which was en route to Miami, was 100 nm south-east of Providenciales when smoke started to fill the cockpit. The flight crew donned their oxygen masks and goggles, and actioned the QRH checklist. They requested an emergency descent from Miami ATC and initiated a diversion to Providenciales. A flight attendant informed the crew that smoke was coming from the left engine, but there was no sign of fire. The crew completed the '*Smoke, Fumes and Fire'*, and the '*Smoke Removal*' checklist. Passing through 10,000 ft, the smoke had dissipated enough to allow them to remove their masks and goggles.

The aircraft landed at Providenciales Airport without further incident. Fluid was later observed to be leaking from the left engine.

Engine inspection

The left engine was removed from the aircraft and inspected. The oil level was found to be low and there was a strong smell of fuel in the oil system. A significant amount of debris was found on the magnetic chip detectors (MCD), particularly the high-speed gearbox MCD. Subsequent investigation revealed that a seal on the Low Pressure (LP) fuel pump was leaking, allowing fuel to enter the high-speed gearbox and thence the oil system. The seal was found to be heavily damaged.

The fuel pump has a recommended maintenance interval of 12,000 hours. The failed pump had operated for 11,600 hours.

Source of the smoke

Engine pneumatic bleed air is taken from two locations on the engine: the HP2 and the HP6 ports. The probable path of the smoke was from the main bearing seal in the Intermediate Pressure (IP) compressor section of the engine into the HP2 port, and then into the left air conditioning pack and air conditioning ducts.

Discussion

This is believed to be the fifth occasion on this engine type of a fuel pump fault that has resulted in smoke entering the bleed air system. The engine manufacturer is conducting a detailed inspection of the fuel pump to determine the cause of failure, in accordance with its established continued airworthiness procedures.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 757-256, G-ZAPX
No & Type of Engines:	2 Rolls-Royce RB211-535E4-37 turbofan engines
Year of Manufacture:	2000 (Serial no: 29309)
Date & Time (UTC):	13 December 2013 at 1720 hrs UTC
Location:	On approach to Freetown-Lungi Airport, Sierra Leone
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 7 Passengers - 145
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	5,300 hours (of which 700 were on type) Last 90 days - 100 hours Last 28 days - 40 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further investigations by the AAIB

Synopsis

The aircraft commenced a VOR approach from above the nominal glidepath and with excess speed. The pilots attempted to establish the aircraft on the correct path but, at 500 ft, the approach was unstable and EGPWS "SINK RATE" and "PULL UP" warnings were generated. The aircraft landed from the approach.

History of the flight

The aircraft was on a passenger flight from London Gatwick Airport to Freetown Lungi Airport in Sierra Leone, and was cleared to intercept the final approach track on the VOR approach for Runway 30. The pilot reported that he had to request descent on more than one occasion before being cleared to descend to 2,000 ft[1] to commence the approach. As the aircraft turned onto the final approach track, it was above the ideal profile and above the correct approach speed, and consequently had significant excess energy. The crew saw the runway and assessed that the aircraft was high so the pilot extended the landing gear at 185 kt, disconnected the autopilot and commenced a descent with a high rate of descent in an attempt to regain the correct profile. The crew selected flap when the speed

Footnote

[1] Altitudes were obtained from the Quick Access Recorder (QAR) data that was made available to the investigation. The altitudes are corrected for QNH and therefore represent the assessed readings on the pilots' altimeters. The airport elevation at Freetown is 84 ft.

allowed. They selected partial speed brake at 1,450 ft and fully deployed it at 1,000 ft. Below 1,000 ft the average rate of descent was approximately 1,500 ft per min.

At 500 ft, an EGPWS "SINK RATE" alert sounded, followed at 350 ft by an EGPWS "PULL UP" alert that lasted for 6 seconds. The pilot stated that, at the time of the "PULL UP" alert, the aircraft was close to the normal profile so he elected to continue the approach to land. At 500 ft, the aircraft CAS was 155 kt (22 kt above V_{REF}[2]) and the rate of descent was approximately 1,900 feet per minute. The landing flap selection was made at 290 ft and the aircraft speed reduced to 148 kt at touchdown with full speed brake still deployed. The rate of descent was in excess of 1,000 ft per min until the aircraft was below approximately 150 ft.

The commander stated that it was clear that the approach was unstable and that he should have flown a go-around.

Safety action

As a result of this incident, the operator has amended its procedures to include a call by the pilot monitoring (PM) at 500 ft radio altitude. If the approach is stable then the PM will call "500 stable" and the approach may continue. If the PM assesses that the approach is not stable, a call of "500 Go-Around" is made and the PF must execute this manoeuvre immediately.

Footnote

2 Reference landing speed.

SERIOUS INCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8, G-JECJ
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2005 (Serial no: 4110)
Date & Time (UTC):	12 February 2014 at 1940 hrs
Location:	Belfast City Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 47
Injuries:	Crew - None Passengers - None
Nature of Damage:	None reported
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	8,304 hours (of which 1,871 were on type) Last 90 days - 96 hours Last 28 days - 13 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During the landing flare, in gusty conditions, the commander's prosthetic arm became detached, control was lost, and a heavy landing resulted.

History of the flight

The aircraft was on a scheduled commercial air transport flight from Birmingham to Belfast City, with the commander, in the left flight deck seat, as pilot flying. It was night, and although there was no low cloud affecting the airport, the wind at Belfast was a strong west-south-westerly, gusting up to 48 kt. Before the approach, the commander checked that his prosthetic lower left arm was securely attached to the yoke clamp which he used to fly the aircraft, with the latching device in place.

Although gusts over the crosswind limit for the aircraft were reported, the final wind report from ATC was within the limit, and the approach continued. The commander disconnected the autopilot and flew the aircraft manually. As he made the flare manoeuvre, with somewhat more than flight idle torque still applied, his prosthetic limb became detached from the yoke clamp, depriving him of control of the aircraft. He made a rapid assessment of the situation and considered alerting the co-pilot and instructing him to take control. However, because the co-pilot would have had little time to assimilate the information necessary to take over in the challenging conditions, the commander concluded that his best course of action was to move his right hand from the power levers onto the yoke to regain control. He did this, but with power still applied, and possibly a gust affecting the aircraft, a normal touchdown was followed by a bounce, from which the aircraft landed heavily.

Safety action

The commander commented that he would in future be more cautious about checking the attachment on his prosthesis, as his check may have dislodged the latching mechanism; that he would brief his co-pilots about the possibility of a similar event; and that they should be ready to take control at any time.

ACCIDENT

Aircraft Type and Registration:	CEA DR400/2+2, Dauphin, G-BBCH
No & Type of Engines:	1 Lycoming O-235-H2C piston engine
Year of Manufacture:	1973 (Serial no: 850)
Date & Time (UTC):	21 February 2014 at 1604 hrs
Location:	Sandhurst Village, Gloucestershire
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:	59 years
Commander's Flying Experience:	906 hours (of which 714 were on type) Last 90 days - 4 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

While on a local VFR flight the engine lost power, probably as a result of carburettor icing. During the subsequent forced landing the aircraft came to rest in a hedge and was severely damaged.

History of the flight

The pilot was on a local VFR flight from Gloucestershire Airport. The pilot flew between 1,500 ft and 2,000 ft amsl to remain VMC below cloud.

Approximately 15 nm west of Gloucestershire Airport, the pilot applied carburettor heat for "about 10 seconds", before heading back to the airport. Approximately 10 nm from the airport, at about 1,500 ft amsl, the pilot noticed a severe reduction in engine power. He applied carburettor heat for about 10 seconds, turned the fuel pump ON and confirmed the magnetos were on BOTH. He informed ATC that he had an engine problem and that he was making a forced landing.

During the forced landing the aircraft's rate of descent increased just before touchdown. The aircraft then hit and came to rest in a hedge in the undershoot of the field in which the pilot intended to land. He vacated the aircraft uninjured. Emergency services arrived soon after.

The aircraft suffered extensive damage to its nose landing gear leg, wings and propeller. Approximately 70 litres of fuel were recovered from the aircraft.

Pilot's comments

The pilot commented that during his pre-flight preparation he did not believe there to be a serious risk of carburettor icing. He could not recall using the carburettor heat regularly during the flight.

Having subsequently noted in '*Safety Sense Leaflet 14 - Piston Engine Icing*', published by the CAA, that the conditions may have been conducive to a "moderate to severe risk" of carburettor icing, the pilot believed that this was the cause of the power reduction. He added that in retrospect he should have used the carburettor heat for longer and more frequently.

ACCIDENT

Aircraft Type and Registration:	Cessna 182T, N2231F
No & Type of Engines:	1 Lycoming IO-540-A1A5 piston engine
Year of Manufacture:	2007 (Serial no: 18281925)
Date & Time (UTC):	23 May 2014 at 1015 hrs
Location:	Tiree Airport, Isle of Tiree
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to nosewheel, engine and propeller, boundary fence
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	190 hours (of which 190 were on type) Last 90 days - 4 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The accident occurred at the end of a flight from Perth Aerodrome to Tiree Airport. The weather was fine with a forecast surface wind of 21 kt from 030º. On first contacting Tiree ATC, the pilot was given an actual surface wind of 20 kt from 020º and he elected to land on Runway 05. The aircraft joined the circuit downwind and flew a normal approach.

As the pilot completed his flare, the aircraft yawed right through about 45º. The pilot was unable to correct the swing and decided to fly a go-around. The aircraft started to gain height, but by now was diverging to the right of the runway centreline and its nose landing gear struck a boundary fence which partially detached from its supports. With the fence still attached to the nose landing gear, the aircraft landed on uneven ground beyond the fence line and pitched forward onto its nose. There was minor damage to the cabin area but neither occupant was injured.

ACCIDENT

Aircraft Type and Registration:	Denney Kitfox Mk 2, G-BSCG
No & Type of Engines:	1 Rotax 582 piston engine
Year of Manufacture:	1992 (Serial no: PFA 172-11620)
Date & Time (UTC):	13 June 2014 at 1240 hrs
Location:	Private strip, Blackshawhead, West Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Right wing and leading edge tube bent. Fuselage, engine cowling and propeller were all damaged
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	66 years
Commander's Flying Experience:	520 hours (of which 76 were on type) Last 90 days - 0 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot reported that the aircraft had not flown for several months during which the fuel tanks had been drained and left empty. Approximately two weeks prior to the accident the aircraft had been refuelled with fresh fuel to enable engine ground runs to be carried out to check the performance of a new propeller. The engine performed satisfactorily. No defects were reported during the annual inspection for the revalidation of the Permit to Fly, which was carried out the day prior to the accident.

On the day of the accident the wind was described as light, the temperature and dew point were reported as 20ºC and 15ºC and the grass runway was damp. The aircraft was refuelled and a sample of fuel taken from the aircraft fuel strainer appeared to be normal. The engine power checks were satisfactory.

The aircraft accelerated normally along the runway and reached a height of approximately 9 ft when the engine suddenly lost power. The pilot reported that the aircraft immediately stalled and the right wing struck the ground pitching the aircraft onto its nose. The pilot who was wearing a four-point harness was uninjured. The cause of the loss of power was not established.

The pilot flew on average 20 hours a year and had last flown approximately six months prior to the accident flight.

ACCIDENT

Aircraft Type and Registration:	Europa, G-TAGR
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2004 (Serial no: PFA 247-13061)
Date & Time (UTC):	19 April 2014 at 1605 hrs
Location:	About 1 nm north of Branscombe Airfield, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to propeller, nosewheel and engine cowling
Commander's Licence:	Private Pilot's Licence
Commander's Age:	71 years
Commander's Flying Experience:	1,021 hours (of which 17 were on type) Last 90 days - 23 hours Last 28 days - 12 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft's engine began misfiring during flight. The pilot made two attempts to land at a nearby airstrip but on each occasion the aircraft was high and had to go around. After the second go-around, the engine stopped and the pilot made a forced landing in a ploughed field. The nosewheel dug into the surface, causing damage to the aircraft.

History of the flight

The aircraft was flying in fine weather conditions between Perranporth in Cornwall and Bournemouth. About 35 minutes into the flight, at a height of 3,000 ft, the engine started to misfire. The pilot switched on the fuel pump and, after about 10 minutes of normal running, switched it off again. A few minutes later the engine again started misfiring and the pilot again switched on the fuel pump. This produced normal running for a few more minutes but then the engine began to misfire, even with the fuel pump selected on.

The pilot made a MAYDAY call to Exeter ATC, who informed him he was about 3 nm east of Branscombe Airfield. The pilot turned towards the airfield, assisted by radar vectors from ATC. The airfield had a grass airstrip orientated 01/28 but the pilot did not see it until flying overhead. With an easterly wind, he turned to approach the airstrip from the west, but as the aircraft was too high for a direct approach he flew a go-around.

During the second approach, the engine was producing inconsistent power. The aircraft was again high and touched down with about one third of the available distance remaining. The pilot did not think that he would be able to stop before a hedge and trees at the end of the strip, so applied full power to go around again. Initially the engine responded normally but started to misfire again as the aircraft climbed through about 200 ft. The pilot started a left turn back towards the airstrip but the engine stopped. There was a ploughed field ahead, and the pilot landed the aircraft in it. Touchdown was on the main wheels, but after a ground roll of 30 or 40 ft, the nose wheel dug into the ground and the aircraft came to a stop.

The pilot reported that a blocked fuel filter may have been the cause of the engine misfire and eventual stoppage.

ACCIDENT

Aircraft Type and Registration:	FLS Aerospace Sprint 160, G-SCLX
No & Type of Engines:	1 Lycoming AEIO-320-D1B piston engine
Year of Manufacture:	1994 (Serial no: 002)
Date & Time (UTC):	10 April 2014 at 1015 hrs
Location:	Kirdford, West Sussex
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to tail surfaces, left elevator detached
Commander's Licence:	Private Pilot's Licence
Commander's Age:	23 years
Commander's Flying Experience:	103 hours (of which 56 were on type) Last 90 days - 0 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft lifted off from a private grass airstrip but failed to climb away. Its tail struck a wire fence at the end of the strip and the aircraft was bought to a stop in the field beyond. The aircraft, which was taking off in calm conditions with an increased flap setting, appeared to have encountered conditions which exceeded its performance capabilities.

History of the flight

The pilot's PPL had lapsed, and the purpose of the flight was for him to conduct training in preparation for a Licence Skills Test for licence renewal. His flying instructor held a CPL and had 7,762 flying hours.

The pilot reported that conditions were fine for the flight, with a calm wind. The intention was to carry out a local flight with his instructor from a private grass airstrip. The airstrip, which was 400 m long and orientated north-south, was assessed by the pilot as soft but useable over its length. There was a slightly softer region about one-third distance from the start of takeoff, identified by a higher than usual power required when crossing at taxi speed. Taking off in a southerly direction, the airstrip had a gradual up slope for about two thirds of its length, before sloping downwards to its end. A wire fence crossed the southern field boundary.

Aircraft checks were completed normally. The pilot reported that he had frequently and successfully used two stages of flap for takeoff, in order to minimise the ground roll, and so selected two stages of flap on this occasion. With full power achieved during a static run-up, he released the brakes. The aircraft appeared to accelerate normally and lift off speed was achieved before the highest part of the strip. The pilot's impression was that the aircraft lifted off but did not climb away, and this was confirmed by eyewitnesses at the airstrip. The aircraft then sank back towards the ground and gave no further indication of climbing.

With the end of the airstrip approaching, the pilot selected a nose-high attitude in an attempt to minimise cockpit or propeller damage. The rear of the aircraft contacted the ground and then struck the wire fence at the end of the airstrip. The elevator control lost effectiveness and the aircraft touched down in the field beyond. Brakes were applied and the aircraft came to a stop before the instructor shut down the engine. The aircraft was then secured and both occupants vacated normally.

The pilot thought that the aircraft's acceleration may have been adversely affected by the soft ground, although he had not thought so at the time. The flying instructor commented that the pilot had appeared very competent and knowledgeable in matters of aircraft operating techniques. He also thought that the acceleration appeared normal. He noted that the aircraft failed to accelerate after lift off, and thought it was possibly due to the selection of full flap, even though the pilot had reportedly used it before to good effect.

AAIB comment

When an aircraft is just above the ground during takeoff, it benefits from the advantage of 'ground effect' which impedes the development of vortices associated with high-lift conditions, and therefore the induced drag which results. However, if the aircraft is flown out of ground effect without first accelerating, induced drag increases markedly as these vortices develop. If the aircraft does not have sufficient power, it may be unable to climb further, or may fail to clear obstacles under the takeoff flight path. This scenario is normally associated with tailwheel aircraft because of their natural tail-low configuration, but is a potential risk area for all aircraft.

In this case, it is possible that the aircraft became airborne in a high drag configuration at a relatively slow airspeed (which was the reason for increasing the flap setting) and experienced a significant increase in power required as it transitioned through ground effect, exceeding the aircraft's capabilities.

The surface winds at Gatwick Airport (17 nm away) around the accident time showed light winds of between 2 and 5 kt, generally from just north of west but variable in direction from between 210º and 030º. With calm wind at the surface at the airstrip, the possibility of encountering a tailwind component soon after lift off must also be considered.

ACCIDENT

Aircraft Type and Registration:	Isaacs Fury II Fury, G-AYJY
No & Type of Engines:	1 Continental Motors Corp C90-12F piston engine
Year of Manufacture:	1975 (Serial no: PFA 1373)
Date & Time (UTC):	12 April 2014 at 1729 hrs
Location:	Exeter Airport, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to left wheel, propeller and wingtips
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	25 years
Commander's Flying Experience:	1,500 hours (of which 3 were on type) Last 90 days - 90 hours Last 28 days - 30 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries by the AAIB

The pilot was attempting to land on asphalt Runway 26 at Exeter after two previous aborted attempts. The control tower informed him that the wind was 10 kt from between 260º and 330º. Upon touchdown, with both mainwheels on the ground, the right wing started to rise as the pilot closed the throttle and so he applied power to go around. He did not maintain directional control and the aircraft veered to the right onto the grass. The left wheel dug into the grass, causing the aircraft to rotate about it as it pitched onto its nose. It came to rest with the right upper and left lower wing leading edges also in contact with the ground.

After shutting down the fuel and electrics, the pilot evacuated the aircraft. He stated that he felt that insufficient right aileron was applied on landing, leading to a loss of directional control.

ACCIDENT

Aircraft Type and Registration:	Rand KR-2, G-BVIA
No & Type of Engines:	1 Volkswagen 1834 piston engine
Year of Manufacture:	2003 (Serial no: PFA 129-11004)
Date & Time (UTC):	3 May 2014 at 1730 hrs
Location:	Temple Bruer Airfield, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Considerable damage
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	81 years
Commander's Flying Experience:	841 hours (of which 792 were on type) Last 90 days - 1 hour Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot had taken off in fine weather to conduct a test flight. The aircraft had been refuelled to full prior to flight, but after takeoff the pilot noticed the fuel gauge was reading less than half-full. He decided to make an immediate return to the airfield but, on approach to land, the engine stopped. The pilot attempted to make the runway but the mainwheels caught a hedge before the threshold and the aircraft overturned. The pilot, who was wearing a full safety harness, sustained only minor injury.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna F152, G-BHEC
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1979 (Serial no: 1676)
Date & Time (UTC):	1 March 2014 at 1605 hrs
Location:	Stapleford Aerodrome, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller, engine shock-loaded, nose landing gear, engine mounting frame, skin and bulkhead around nose broken
Commander's Licence:	Student
Commander's Age:	25 years
Commander's Flying Experience:	19 hours (of which 19 were on type) Last 90 days - 8 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

While back-tracking Runway 22, with another aircraft on final approach to land, the pilot began to taxi more quickly, intending to vacate the runway before the approaching aircraft was forced to go around. As she prepared to turn off the runway, she could not slow the aircraft sufficiently and it ran into a hedge at the end of the runway.

The pilot stated that she became anxious to vacate the runway and applied too much power. The high taxi speed, combined with the down-sloping runway, meant she was unable to stop.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna F172N, G-LTEE
No & Type of Engines:	1 Lycoming O-320-H2AD piston engine
Year of Manufacture:	1978 (Serial no: 1772)
Date & Time (UTC):	5 May 2014 at 1339 hrs
Location:	Fairoaks Airport, Surrey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	Damage to left wing spar, wing and body panels, tail, propeller and windscreen
Commander's Licence:	Private Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	113 hours (of which 7 were on type) Last 90 days - 10 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

After a normal touchdown the aircraft started drifting to the right with a crosswind from the left. The pilot applied left rudder but the aircraft departed the runway surface to the right and flipped inverted as it came to rest. The pilot assessed that he may not have been holding sufficient into-wind left aileron after touchdown.

History of the flight

The pilot had trained on the Cessna 152 and had flown Piper PA-28s since gaining his licence in 2012. He had recently converted to the Cessna 172. During a cross-country flight from Dunkeswell to Fairoaks he noticed that he needed to hold a constant left aileron input to maintain wings level. This was a known problem with this aircraft and the rudder trim had been set almost full left by previous pilots in an attempt to relieve the amount of left aileron required.

On arriving at Fairoaks the wind was reported as 12 kt from 180°. The pilot carried out an overhead join, selected two stages of flap and turned onto final for Runway 24. He then realised he was too high and initiated a go-around. On the pilot's second approach he was also too high so carried out another go-around. During the third approach he extended his downwind leg to allow himself more time on final. Because of the crosswind he decided to leave the flaps up and approach at about 85 kt. The aircraft touched down normally on the centreline and the pilot initially allowed the aircraft to decelerate without touching the brakes. At about 320 m from the runway threshold, the aircraft started to drift to the right[1] (Figure 1); this was possibly coincident with initial brake application. The pilot applied left rudder but the aircraft continued to drift to the right and departed the runway surface at about 30 kt. The ground was soft and boggy causing the aircraft to decelerate quickly as the nosewheel ploughed the ground to a depth of about 30 cm. Just as the aircraft was about to stop it pitched forwards onto its back. The pilot and his passenger were left hanging upside down but were able to release their harnesses and exit through the doors.

Figure 1

Aircraft ground track from GPS data (*image ©Google Earth*)

Pilot's assessment of the cause

The pilot could not recall if he had into-wind left aileron applied after touchdown, but he suspected that he did not have sufficient left aileron applied. He thought the wind had lifted the left wing slightly, and this combined with the braking caused the right brake to be more effective than the left, causing the right turn. He also considered that whatever was causing the right roll in-flight may have also contributed to the left wing lifting.

Footnote

[1] The aircraft's GPS track and groundspeed had been recorded on the pilot's tablet device using Skydemon software.

ACCIDENT

Aircraft Type and Registration:	Vans RV-7, HB-YLM
No & Type of Engines:	1 Lycoming O-320 piston engine
Year of Manufacture:	2005 (Serial no: 70795)
Date & Time (UTC):	11 June 2014 at 1026 hrs
Location:	Airstrip near Fort Augustus, Inverness-shire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Both wings, cowling and propeller; boundary fence
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	2,537 hours (of which 1,382 were on type) Last 90 days - 139 hours Last 28 days - 13 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft was flying in fine, calm conditions at 2,000 ft over Loch Ness when its engine began to run roughly. On his GPS navigation display, the pilot identified a farm airstrip near the town of Fort Augustus. He flew over the airstrip to inspect it and decided to carry out a precautionary landing there, which he did successfully. After landing, the pilot checked the fuel and carburation systems, and found no faults. A fuel sample was clear. Engine runs at up to full throttle were normal, so the pilot prepared to takeoff again.

During the subsequent takeoff, the aircraft drifted to the left side of the airstrip, on what the pilot described as damp grass. He attempted to correct the deviation with rudder input but this was not effective, so he reduced to idle power to abandon the takeoff. The left wing struck a fence post, causing the aircraft to yaw left and pass through the fence line. The right wing also struck a fence post before the aircraft came to a stop.

ACCIDENT

Aircraft Type and Registration:	Yak-52, G-CBMD	
No & Type of Engines:	1 Ivchenko Vedeneyev M-14P piston engine	
Year of Manufacture:	1982 (Serial no: 822710)	
Date & Time (UTC):	3 May 2014 at 1425 hrs	
Location:	Rochester Airport, Kent	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Slight damage to left wingtip and aileron	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	55 years	
Commander's Flying Experience:	503 hours (of which 385 were on type) Last 90 days - 1 hour Last 28 days - 0 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The aircraft landed on Runway 02 at Rochester after a local flight. As the aircraft was taxiing towards the runway exit, the pilot intended to retract the wing flaps but inadvertently selected the landing gear. The rear of the aircraft and the left wingtip then slowly sank to the grass surface as the landing gear partially retracted, causing slight damage.

The pilot attributed the accident to human error. A significant contributory factor was his lack of recent flying on type: he had flown only once since December 2013, that flight being in a PA-28 aircraft in April 2014.

ACCIDENT

Aircraft Type and Registration:	Zenair CH 601X1 Zodiac, G-RWMW
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2006 (Serial no: PFA 162B-14231)
Date & Time (UTC):	14 May 2014 at 1445 hrs
Location:	Private airstrip near Ayr, Ayrshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	Severe
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	70 years
Commander's Flying Experience:	3,020 hours (of which 229 were on type) Last 90 days - 13 hours Last 28 days - 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was returning to the airstrip after a flight to Bute, about 28 nm away. A weather report, obtained from Prestwick ATC, gave a surface wind of 11 kt from 240º with scattered cloud and good visibility. The temperature was 13ºC.

The airstrip was orientated 06/24 and located in a farm field, such that the longest landing distance available was about 300 m. It was situated amongst gently undulating terrain. The aircraft was approaching to land in a south-westerly direction when the accident occurred. When the aircraft was on short finals at an estimated height of 70 ft, it experienced a sudden onset of turbulence, of a severity the pilot had not previously encountered. The aircraft lost airspeed and, from the pilot's report, appeared to have stalled, pitching to about 40º down and striking the ground approximately 100 m from the beginning of the airstrip.

The pilot and his passenger, who were both wearing full harnesses, sustained minor injuries. The pilot reported that the cockpit had maintained its internal volume, and that the impact forces had been absorbed by crumpling of the fuselage structure from the firewall aft.

ACCIDENT

Aircraft Type and Registration:	Dynamic WT9 UK, G-JFDI
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2007 (Serial no: DY192)
Date & Time (UTC):	8 June 2014 at 1230 hrs
Location:	Haddenham, Thame, Oxfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to nose gear and propeller
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	213 hours (of which 213 were on type) Last 90 days - 3 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

On the downwind leg at Haddenham the pilot was distracted by a person in the vicinity of the runway. The aircraft became low on the approach and touched some corn crop short of the runway threshold, causing the nosewheel to detach. The pilot applied power, went around, and subsequently landed at Oakley without injury.

History of the flight

Whilst on the downwind leg to land at Haddenham, the pilot noticed a person walking along the middle of the grass runway. He made a blind call to Haddenham Traffic to request his removal, and extended his downwind leg. As the aircraft turned onto final the person had moved and was now standing to the right of the runway, near the threshold.

The pilot reported that his approach was a little low due to the long final leg, but considered that he would land only about 10 m short of the threshold. He was mindful that the person was still standing next to the threshold and recalled the noise of the landing gear touching some corn, followed by a loud "thump". He applied power and went around, and a radio call informed him that the nosewheel had detached. He elected to return to his departure airfield of Oakley where the runway was concrete and there was less risk of the nose leg digging in. He landed at Oakley, where the wind was down the runway, holding the nose leg off the runway for as long as possible during the landing.

Pilot's comments

The pilot assessed the cause of the accident as being distracted by the person on the runway, which led him to him landing short after an extended downwind leg. In retrospect he felt he should have aborted the landing at Haddenham and gone around.

Although the aircraft was equipped with a ballistic recovery system, the pilot elected not to use it as he believed there was a high probability of completing a successful landing.

ACCIDENT

Aircraft Type and Registration:	Murphy Maverick 430, G-ONFL
No & Type of Engines:	1 Rotax 503 piston engine
Year of Manufacture:	1995 (Serial no: PFA 259-12750)
Date & Time (UTC):	24 March 2014 at 1445 hrs
Location:	North Coates Airfield, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller, left landing gear, cowling and firewall
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	1,423 hours (of which 2 were on type) Last 90 days - 11 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft landed in a brisk crosswind and the pilot had difficulty turning the aircraft out of wind as it slowed. Application of power to energise the rudder was not successful and only prolonged the landing run. The aircraft overran the side of the runway into a dyke.

History of the flight

The pilot had agreed to deliver G-ONFL from Fenland Airfield to North Coates. Other commitments meant that it was the last day on which he would be able to make the flight before going abroad for a month.

The pilot flew to North Coates in company with another aircraft, in which he was to travel back. Once en route, G-ONFL's radio was found to be not working. The flight to North Coates was completed uneventfully in good visibility but some turbulence. The surface wind at North Coates appeared, from the windsock, to favour Runway 23; it was later estimated to be from 160º at 10 kt gusting to 18 kt, thus representing a significant crosswind.

As far as he was able, the pilot landed diagonally across the grass manoeuvring area and runway. The touchdown was normal but, as the aircraft slowed after landing, the pilot was unable to turn right (out of the wind) towards the parking area. He attempted to energise the rudder with an application of power, but this merely prolonged the landing run. With insufficient space in which to take off again, the aircraft overran the left hand edge of the runway and went into a dyke which ran alongside.

The pilot was not aware that the runway had been re-aligned since his last visit, to run directly alongside the dyke. With no accurate local wind information and a crosswind that was stronger than expected, he considered a better course of action would have been to divert to a more favourable airfield.

ACCIDENT

Aircraft Type and Registration:	Pegasus Quik, G-CCPC	
No & Type of Engines:	1 Rotax 912ULS piston engine	
Year of Manufacture:	2003 (Serial no: 7994)	
Date & Time (UTC):	6 June 2014 at 1530 hrs	
Location:	East Fortune Airfield, East Lothian	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Trike, propeller and wing structure damaged.	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	62 years	
Commander's Flying Experience:	158 hours (of which 42 were on type) Last 90 days - 15 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot was flying in the circuit at East Fortune Airfield, East Lothian and using Runway 11. The wind was initially from 110° at about 11-12 kt, but had changed direction and was now from 90°. The initial touchdown was on an area of grass immediately before the start of the concrete runway. As the aircraft reached the concrete section it bounced into the air. The pilot applied full power to go around, but the left wing was caught by the wind causing the aircraft to veer to the right. The rear wheels of the trike caught a fence that encircled a cattle field adjacent to the runway. The aircraft then came to rest in the field causing damage to the trike, wing and propeller; the pilot suffered minor injuries.

ACCIDENT

Aircraft Type and Registration:	Team Minimax, G-MYRG
No & Type of Engines:	1 Rotax 447 piston engine
Year of Manufacture:	1998 (Serial no: PFA 186-11891)
Date & Time (UTC):	1 March 2014 at 1440 hrs
Location:	Easterton Airfield, Elgin, Moray, Scotland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to tyres, wheel rims, engine cowling, propeller and brake attachments
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	66 years
Commander's Flying Experience:	406 hours (of which 35 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was being flown by one of its new owners. This was the first flight since a damaged elevator had been repaired. Upon becoming airborne, the pilot felt that the stick forces in pitch were abnormal and returned to the airfield for a landing. The subsequent touchdown was very heavy and the aircraft was damaged. It was found that the fixed elevator trim tab, which had been removed as part of the repair, had been refitted upside down.

History of the flight

The aircraft was being flown for the first time by one of its new owners. The ground roll had been normal but the pilot found that it required an unexpectedly large amount of back pressure on the control column to rotate the aircraft and lift off. As he climbed away at about 60 mph, he had to maintain significant back pressure. On levelling out, he described the aircraft as "possible to fly with one hand but more comfortable with two" and it was difficult to achieve well-balanced turns.

After 15 minutes flight in the vicinity of the airfield to get used to handling the aircraft, the pilot radioed the airfield and advised them that he was downwind to land and that they could expect a "very bad landing" as he was having elevator trouble. Setting up for an extended final approach at 60 mph, he found that it was difficult to control airspeed and believes he may have been fast when he flared prior to touchdown. This, coupled with the abnormal stick forces, meant that the aircraft landed very heavily.

It was subsequently found that the fixed trim tab on the elevator had been fitted upside down. After the aircraft had been collected on a trailer by the new owners, the elevator had been damaged in transit and a repair had been carried out which required removal of the tab. Upon completion of the repair, the tab had been refitted incorrectly as could clearly be seen from photographs taken prior to the repair. The tab should have had a noticeable downward deflection but instead had an upwards bend.

The Light Aircraft Association advise that they intend to highlight this occurrence in a forthcoming edition of their magazine *Light Aviation.*

ACCIDENT

Aircraft Type and Registration:	Thruster T600T, G-MZKT
No & Type of Engines:	1 Rotax 582 UL-DCDI piston engine
Year of Manufacture:	1998 (Serial no: 9038-T600T-023)
Date & Time (UTC):	29 March 2014 at 1515 hrs
Location:	Great Thorns Farm, Swaffham, Norfolk
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller, fuselage pod, windscreen, main landing gear and both wings
Commander's Licence:	Private Pilot's Licence
Commander's Age:	65 years
Commander's Flying Experience:	1,470 hours (of which 81 were on type) Last 90 days - 6 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft took off from Runway 07 with the reported wind from 100º at 10 kt. After a normal circuit, the pilot was approaching to land back on the same runway using the 'crab' method to compensate for the crosswind from the right. As the aircraft crossed the threshold, he changed to a right-wing-low technique and touched down on the right mainwheel first. He closed the throttle and the tailwheel settled on the ground. At that moment, a gust of wind lifted the right wing. The pilot was not able to correct using the ailerons and applied power to go around. The aircraft then veered to the left and the left mainwheel struck the raised, ploughed edge of the runway. As it left the runway and entered a rough grass field, the aircraft tipped onto its nose and left wingtip, rotating through about 180º before coming to rest in an upright attitude.

The pilot stated that his failure to anticipate the gust of wind coupled with his decision to go around - he believes the aircraft would otherwise have probably stopped on the runway - were the major factors in the accident.

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).

BULLETIN CORRECTION

This report was originally published in AAIB Bulletin 7/2014, page 67. However, following reassessment and prior to publication on 10 July 2014, the report has been corrected for a factual error on the number of circuits flown. The original version of the report appears in the hard copy version of Bulletin 7/2014, but the online version has been corrected. The corrected version follows:

ACCIDENT

Aircraft Type and Registration:	Cessna 152, G-BIDH	
No & Type of Engines:	1 Lycoming O-235-L2C piston engine	
Year of Manufacture:	1981 (Serial no: 152-80546)	
Date & Time (UTC):	11 April 2014 at 1715 hrs	
Location:	Beverley (Linley Hill) Aerodrome, Yorkshire	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Nose leg collapse and bending damage to propeller tips, engine frame, cowling and firewall	
Commander's Licence:	Student Pilot's licence	
Commander's Age:	42 years	
Commander's Flying Experience:	23 hours (of which all were on type) Last 90 days - 9 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB	

Synopsis

During a solo circuit the student pilot made an approach and was observed to flare the aircraft high. The aircraft descended and bounced on touchdown. The nose then dropped and the nose landing gear collapsed on impact with the ground. The aircraft came to a stop resting on the underside of the engine cowl, having sustained damage to the airframe, propeller and nose landing gear. The pilot was uninjured and vacated the aircraft without further incident. The accident was caused by mishandling after the bounce on touchdown.

History of the flight

The weather conditions on the day of the incident were good, with a 9-10 kt wind directly down the runway and clear visibility. The pilot had performed two satisfactory circuits under dual instruction with no intervention. He was then sent to perform a pair of solo circuits, consisting of a touch-and-go followed by a full-stop landing, and then to repeat the exercise. He completed the first pair of solo circuits satisfactorily.

On the first of the second pair of solo circuits his instructor watched him fly the correct circuit pattern before the student made an RTF call to confirm which flap setting he should use. The instructor advised him to select either 20º or 30º according to his judgement. On approach the pilot flared the aircraft slightly higher than normal and bounced on touchdown. The nose then dropped, the aircraft descended and on impact with the ground the nose landing gear collapsed. The aircraft came to a stop resting on the underside of the engine cowl with the nose gear still attached but bent and twisted beneath the aircraft. The propeller tips were distorted and the aircraft had sustained structural damage to the engine frame and firewall. The pilot vacated the aircraft uninjured.

Pilot's observations and discussion

The pilot's previous solo flights and landings had all gone very well so on this occasion he was disappointed in his performance. Afterwards he carried out his own analysis of the accident:

> After his RTF call he had selected what he believed to be 20º of flap; the aircraft was actually set at 30º of flap. This flap setting, along with wind speed and direction on the day, may have contributed to the high flare on approach as he compensated for the nose-down attitude caused by this flap setting. He also considered he had not recognised that he had flared high and, because he not previously experienced a poor landing, was unable to identify the deteriorating situation.

He also discussed the outcome with his instructor and concluded that after the first bounce he had felt he was losing control and thus did not attempt a go-around, as he had been taught. As a result he had opted for a more determined attempt to land the aircraft by lowering the nose, which created an excessive rate of descent onto the nose landing gear.

BULLETIN CORRECTION

Aircraft Type and Registration: Eurocopter EC155B1, OY-HJJ

Date & Time (UTC): 6 November 2013 at 2023 hrs

Location: Clipper South Gas Field, North Sea

Information Source: AAIB Field Investigation

AAIB Bulletin No 7/2014 , page 38 refers

The report incorrectly classified the occurrence as an INCIDENT. The occurrence was in fact classified as a **SERIOUS INCIDENT**.

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

3/2010 Cessna Citation 500, VP-BGE
2 nm NNE of Biggin Hill Airport
on 30 March 2008.

Published May 2010.

4/2010 Boeing 777-236, G-VIIR
at Robert L Bradshaw Int Airport
St Kitts, West Indies
on 26 September 2009.

Published September 2010.

5/2010 Grob G115E (Tutor), G-BYXR
and Standard Cirrus Glider, G-CKHT
Drayton, Oxfordshire
on 14 June 2009.

Published September 2010.

6/2010 Grob G115E Tutor, G-BYUT
and Grob G115E Tutor, G-BYVN
near Porthcawl, South Wales
on 11 February 2009.

Published November 2010.

7/2010 Aerospatiale (Eurocopter) AS 332L
Super Puma, G-PUMI
at Aberdeen Airport, Scotland
on 13 October 2006.

Published November 2010.

8/2010 Cessna 402C, G-EYES and
Rand KR-2, G-BOLZ
near Coventry Airport
on 17 August 2008.

Published December 2010.

1/2011 Eurocopter EC225 LP Super
Puma, G-REDU
near the Eastern Trough Area
Project Central Production Facility
Platform in the North Sea
on 18 February 2009.

Published September 2011.

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

Published November 2011.

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

Published February 2014.

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

Published June 2014.

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 System
ATPL	Airline Transport Pilot's Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot's Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitoring
EGPWS	Enhanced GPWS
EGT	Exhaust Gas Temperature
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure Ratio
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FAA	Federal Aviation Administration (USA)
FIR	Flight Information Region
FL	Flight Level
ft	feet
ft/min	feet per minute
g	acceleration due to Earth's gravity
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 1200 hrs)
HP	high pressure
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IP	Intermediate Pressure
IR	Instrument Rating
ISA	International Standard Atmosphere
kg	kilogram(s)
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
KTAS	knots true airspeed
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LP	low pressure
LAA	Light Aircraft Association
LDA	Landing Distance Available
LPC	Licence Proficiency Check
m	metre(s)
mb	millibar(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
min	minutes
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
N	Newtons
N_R	Main rotor rotation speed (rotorcraft)
N_g	Gas generator rotation speed (rotorcraft)
N_1	engine fan or LP compressor speed
NDB	Non-Directional radio Beacon
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OPC	Operator Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIC	Pilot in Command
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
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

AAIB
Air Accidents Investigation Branch