AAIB
Air Accidents Investigation Branch

AAIB Bulletin 7/2024

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01252 512299

Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
Aldershot
Hampshire
GU11 2HH
United Kingdom

Tel: 01252 510300
Media enquiries: 01932 440015 (office hours) / 0300 777 7878 (out of hours)
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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
www.aaib.gov.uk

AAIB
Air Accidents Investigation Branch

AAIB Bulletin S1/2024 *SPECIAL*

Serious Incident

Aircraft Type and Registration:	Boeing 737-8K5, G-FDZS	
No & Type of Engines:	2 CFM56-7B27/3 turbofan engines	
Year of Manufacture:	2009 (Serial no: 35147)	
Date & Time (UTC):	4 March 2024 at 1104 hrs	
Location:	On takeoff from Bristol Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 6	Passengers - 163
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None reported	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	47 years	
Commander's Flying Experience:	14,500 hours (of which 4,500 were on type) Last 90 days - 220 hours Last 28 days - 81 hours	
Information Source:	AAIB Field Investigation	

Introduction

A Boeing 737-800 completed a takeoff from Runway 09 at Bristol Airport with insufficient thrust to meet regulated performance. The autothrottle (A/T) disengaged when the takeoff mode was selected, at the start of the takeoff roll, and subsequently the thrust manually set by the crew (84.5% N_1) was less than the required takeoff thrust (92.8% N_1). Neither pilot then noticed that the thrust was set incorrectly, and it was not picked up through the standard operating procedures (SOPs).

This Special Bulletin contains preliminary information on this serious incident, information for pilots and operators of the Boeing 737 Next Generation (737NG) about the A/T disengage occurrence in this event, and the actions the manufacturer expects crews to take should such a disengagement occur.

History of the flight

The aircraft was prepared for a flight from Bristol Airport to Las Palmas, Gran Canaria with six crew and 163 passengers. The flight was a line training sector for a new captain who was sitting in the left seat, with a training captain, acting as aircraft commander, sitting in the right seat.

Having completed their pre-flight preparation, the aircraft left the stand at Bristol to taxi to Runway 09 at 1041 hrs. The A/T arm switch on the Mode Control Panel (MCP) had been set to ARM during the before start procedures in accordance with the operator's SOPs. The aircraft taxied onto Runway 09 at 1104 hrs and was cleared for takeoff shortly afterwards. The left seat pilot handed control of the aircraft to the right seat pilot who was to be PF for the sector. The PF advanced the thrust levers to 40% N_1 and paused for the engines to stabilise before pressing the Takeoff/Go-Around switch (TOGA) which engages both the A/T in N_1 mode and the autopilot/flight director system (AFDS) in takeoff mode. At this point, the A/T disengaged with an associated warning and the A/T arm switch on the MCP was re-engaged by the PM almost immediately afterwards. At the same moment the PF advanced the thrust levers manually towards the required takeoff setting before releasing the thrust levers for the left seat occupant to control in accordance with the SOPs.

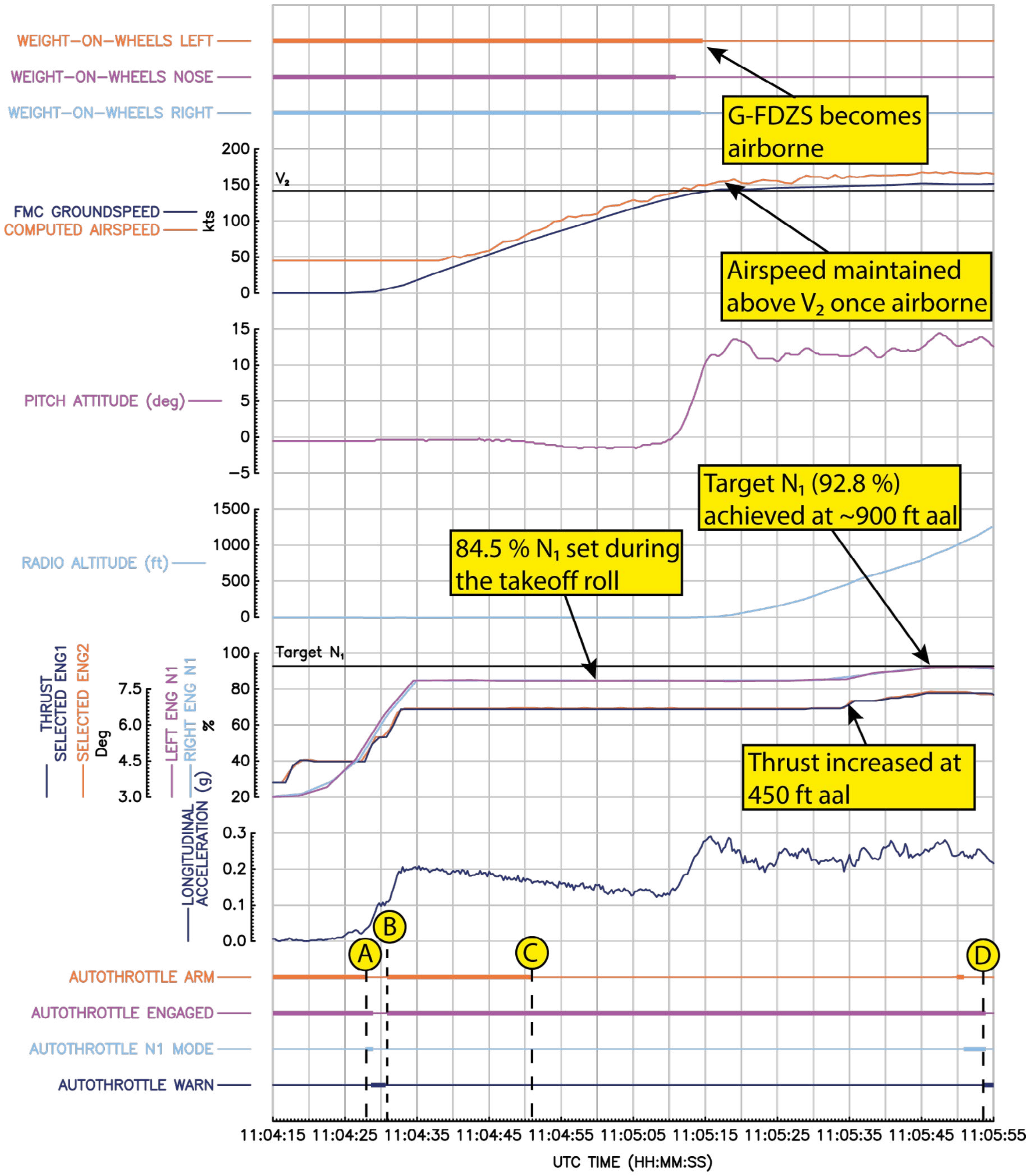
When the A/T arm switch was re-engaged on the MCP after initial A/T disengagement, it did not control the thrust lever servos as the pilots expected and instead entered an armed mode. As a result, the thrust levers did not advance to the required thrust setting and neither pilot moved them from the position the PF had set them to. Despite the SOP requiring that the thrust is set by 60 kt and checked as correct at 80 kt, the incorrect setting was missed by both pilots. This resulted in the aircraft takeoff being conducted with significantly less thrust than required, 84.5% N_1 was used instead of 92.8% N_1, with the associated reduction in aircraft performance.

The rotation point was 260 m from the end of the runway and the aircraft crossed the end of the runway at a height of approximately 10 ft. Both pilots had noted how close to the end of the runway they were. The flight to Las Palmas was uneventful apart from several attempts to re-engage the A/T and subsequent disengagements.

Recorded data

Flight recorders

G-FDZS was fitted with both an FDR and a CVR. The CVR fitted to G-FDZS was not removed from the aircraft as it continually overwrites itself, retaining only the last two hours of audio. As such, the recording of the takeoff would have been overwritten during the flight to Las Palmas. However, the FDR was removed and downloaded. Data from the FDR is shown below in Figure 1.



G-FDZS becomes airborne

Airspeed maintained above V_2 once airborne

Target N_1 (92.8 %) achieved at ~900 ft aal

84.5 % N_1 set during the takeoff roll

Thrust increased at 450 ft aal

Ⓐ	A/T transitions from ARM to N1 mode on TOGA selection, disconnects almost immediately with a warning
Ⓑ	A/T re-armed within five seconds but no active mode selected
Ⓒ	A/T transistions to ARM HOLD mode, as per design, at 84 kt
Ⓓ	A/T transitions from ARM to N1 mode, but disconnects with a warning almost immediately (2nd uncommanded disconnect)

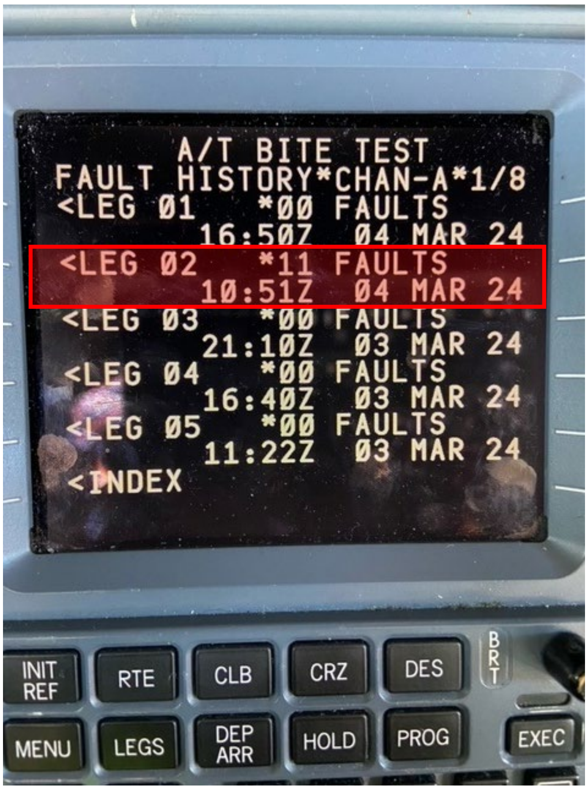
Figure 1

FDR data for the takeoff

The data shows that 84.5% N_1 was set for the takeoff instead of 92.8% N_1 and, although the thrust setting was increased from 450 ft aal, the required takeoff thrust setting was not attained until passing approximately 900 ft aal. As a result, G-FDZS became airborne 260 m from the end of Runway 09 and the runway end was overflown at a height of approximately 10 ft. Further, as the correct thrust setting was not set until passing approximately 900 ft aal, the A38 road, adjacent to the boundary of Bristol Airport, was overflown at less than 100 ft.

Multipurpose Control and Display Unit (MCDU) Fault data

The MCDU allows maintenance personnel to interrogate the health of several aircraft subsystems, including the A/T, and to investigate any logged faults. The fault history for the A/T, (Figure 2), shows that 11 faults were logged for the incident flight to Las Palmas - LEG 02 - but no faults were logged on the return flight to the UK, or on the preceding day.



```
       A/T BITE TEST
FAULT HISTORY*CHAN-A*1/8
<LEG 01     *00 FAULTS
        16:50Z  04 MAR 24
<LEG 02     *11 FAULTS
        10:51Z  04 MAR 24
<LEG 03     *00 FAULTS
        21:10Z  03 MAR 24
<LEG 04     *00 FAULTS
        16:40Z  03 MAR 24
<LEG 05     *00 FAULTS
        11:22Z  03 MAR 24
<INDEX
```

Figure 2

A/T fault history for the incident flight and the preceding day

Five of the 11 logged faults related to uncommanded A/T disconnections. The first of these fault records, is shown in Figure 3, and occurred at 1104 hrs when, from the FDR data, G-FDZS was on the runway at the beginning of the takeoff roll.

```
      A/T BITE TEST
LEG02 *A/T DISC   * 11/11
CHAN-A *ARM      *ARM HOLD
   RATE MONITOR
*SUSPECT LRU(S)
   ASM 1

FLT --------  MSG22-31687
11:04Z          04 MAR 24
ALT    616FT    A/S   45KT
<INDEX
```

Figure 3

Detailed fault record for the initial uncommanded A/T disconnection, showing the suspected cause as ASM 1

The fault record indicates the suspected cause of the uncommanded A/T disconnection as ASM 1, the A/T servo motor for the number 1 engine throttle lever. A further four uncommanded A/T disconnections occurred during the flight to Las Palmas, two during the initial climb to altitude and two during the cruise. A series of other fault messages were logged, after the initial A/T disconnection, as G-FDZS accelerated for takeoff. These were generated passing 90 kt airspeed and all related to the mis-set thrust, indicating that the correct takeoff thrust had not yet been set.

Flight data monitoring (FDM)

The AAIB has investigated numerous other takeoff performance events and made several safety recommendations. One of these safety recommendations, Safety Recommendation 2022-019, relates to the use of FDM data to identify takeoff events that may otherwise go unnoticed and unreported.

Safety Recommendation 2022-019

It is recommended that the UK Civil Aviation Authority encourage all UK Air Operator Certificate holders to implement into their flight data monitoring programme algorithms to detect the precursors relevant to the monitoring of takeoff performance detailed in the European Operators Flight Data Monitoring Document, Guidance for the implementation of flight data monitoring precursors.

Although this event was reported, the operator conducted a retrospective analysis using a simple statistical measure of other 737 takeoffs from Bristol and produced the plot shown in Figure 4. The X-axis represents the peak longitudinal acceleration at around 80 kt groundspeed and the Y-axis the number of takeoffs that are represented by each bar. The incident takeoff is shown by the red arrow in Figure 4, far to the left of the bulk of the data, whereas for a normal distribution of data 99.7% of all takeoffs would be expected to lie within the region marked by the two vertical red lines.

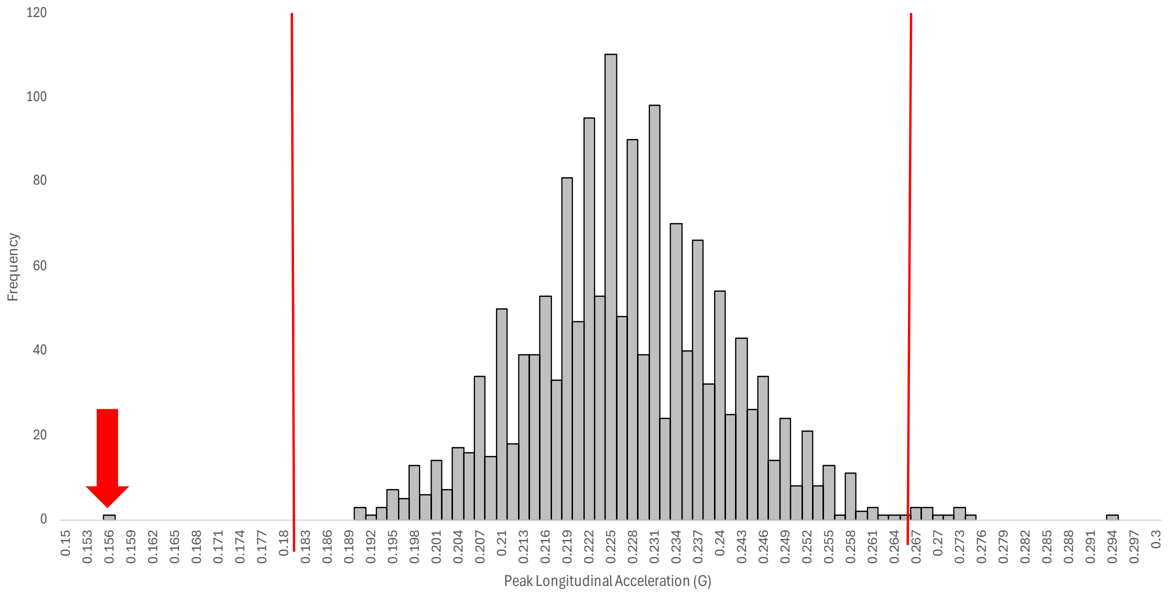


Figure 4

Histogram of 737 takeoffs at Bristol,
showing the normal spread of peak accelerations and the incident takeoff

Autothrottle system

The 737NG A/T system can control the thrust from takeoff to landing. Limiting N_1 values are normally provided by the FMC. Each thrust lever is moved with an independent autothrottle servo motor (ASM). The thrust levers can be moved manually or, if the A/T is engaged and active, the servo motors will position the thrust levers to comply with computed thrust requirements.

The A/T system is armed as part of the before start procedures after the performance figures have been entered into the FMC. Once the takeoff begins, the pilot advances the thrust levers manually to 40% N_1 and waits for the engine power to stabilise before pressing the TOGA switch. Pressing this switch moves the A/T from ARM mode to N_1 mode and the ASMs will automatically advance the thrust levers to the FMC takeoff thrust figure. At 84 kt IAS the A/T mode changes to throttle hold and the ASMs are isolated from the thrust levers. This is to prevent any uncommanded movement of the thrust levers during the rest of the takeoff roll and initial climb. The A/T returns to ARM mode at 800 ft above airfield elevation. The A/T becomes active again when the pilot selects N_1 mode at thrust reduction altitude to set climb thrust. The A/T will automatically disengage when a system fault is detected.

The manufacturer described the A/T system on the 737NG as having a long history of nuisance disconnects during takeoff mode engagements. When the fault history of the A/T is checked they often show fault messages for the autothrottle servo motor (ASM) for either throttle lever 1 or 2. Usually, subsequent functionality checks on the system find no faults. Investigations by the aircraft manufacturer together with the manufacturer of the ASM found that an earlier model of the motor was more susceptible to power on or power transfer events which can cause the ASM to shut down internally and cause a disconnect of the A/T when the TOGA switch is pressed.

A newer model of the ASM is more robust to the power quality issues associated with power on and power transfer events and the manufacturer recommends that any operators of the 737NG who are affected by these disconnects should retrofit their aircraft with the newer model of ASM and associated Flight Control Computer software. The manufacturer released a Fleet Team Digest in October 2021 detailing the issue and the available service bulletin (SB) for replacement. At the time of this event G-FDZS was fitted with the earlier model of ASMs.

Information for pilots

The manufacturer's Quick Reference Handbook (QRH) covers actions to be taken by the crew when there is an emergency or system failure on the aircraft. The QRH lists the reason that crew should reject the takeoff and this list includes system failure(s) as one of the reasons to reject below 80 kt. The manufacturer includes the disconnection of the A/T when the TOGA switch is pressed as a systems failure and expects the crews to stop as a result. This allows the crew time to assess the failure and decide on their actions rather than potentially continuing the takeoff roll without a functional A/T system. The crew in this event continued their takeoff using manual thrust, at a setting below that calculated for takeoff performance.

The Flight Crew Training Manual (FCTM) applicable to the 737NG and 737 MAX contains details on the operation of the aircraft type. The section on takeoff details the actions the crew should take when using derated or reduced thrust for takeoff if additional thrust is required to complete the takeoff after V_1. With both reduced thrust and derated thrust, the FCTM recommends the selection of full rated thrust if required after V_1. This was a change introduced in 2022 to the previous policy which suggested that crews should increase thrust no more than the full derated thrust setting.

It is well known that humans are poor at detecting acceleration rates and recognising that their takeoff run is not matching the calculated performance. Performance issues can be insidious and invisible to the crew until very late in the takeoff roll. A previous report from the AAIB covered the reasons for this in detail[1]. However, it is very unlikely that any crew will recognise there is an issue until they approach the end of the runway, and few crews then select an increase in power to try and mitigate their performance issues.

Footnote

[1] https://www.gov.uk/aaib-reports/aircraft-accident-report-aar-2-2018-c-fwgh-21july-2017 [Accessed April 2024].

Analysis

The aircraft took off from Runway 09 with a thrust setting significantly below that required to achieve the correct takeoff performance. Rotation for the takeoff occurred only 260 m before the end of the runway and the aircraft passed over the end at a height of approximately 10 ft. The N_1 required to achieve the required takeoff performance was 92.8% but, following an A/T disconnect when the crew selected TOGA, 84.5% was manually set instead. Despite an SOP requirement to check the thrust setting on takeoff, the crew did not realise that the thrust was not set correctly until after the takeoff although they had noted how close to the end of the runway they were.

The A/T had disconnected when the TOGA switch was pressed due to a fault with the ASM associated with the thrust lever for engine 1. This disconnect was a known issue with the older type ASMs fitted to the aircraft type. The manufacturer has issued a Fleet Team Digest for operators detailing the issue and the SB for replacing the ASMs with a newer model.

Further investigation

The investigation continues to examine all pertinent factors associated with this serious incident and a final report will be issued in due course.

Published: 30 May 2024.

AAIB Field Investigation Reports

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

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

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

Serious Incident

Aircraft Type and Registration:	ATR 72-202, G-NPTF	
No & Type of Engines:	2 Pratt & Whitney Canada PW121 turboprop engines	
Year of Manufacture:	1990 (Serial no: 192)	
Date & Time (UTC):	17 January 2023 at 0425 hrs	
Location:	East Midlands Airport	
Type of Flight:	Commercial Air Transport (Cargo)	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	37 years	
Commander's Flying Experience:	5,264 hours (of which 583 were on type) Last 90 days - 74 hours Last 28 days - 28 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During the latter stages of a CAT II automatic approach to East Midlands Airport, the aircraft suffered a significant electrical malfunction. This caused the loss of the co-pilot's flight instrument displays and triggered a number of warnings and cautions. The crew executed a go-around and diverted to Birmingham International Airport. A wiring defect, probably caused by incorrect use of mechanical wire stripping tools at a third-party organisation, was the cause of the electrical malfunction. Action has been proposed by the equipment manufacturer and has been taken by the third-party maintenance organisation to promote the use of alternative tooling to prevent a reoccurrence.

History of the flight

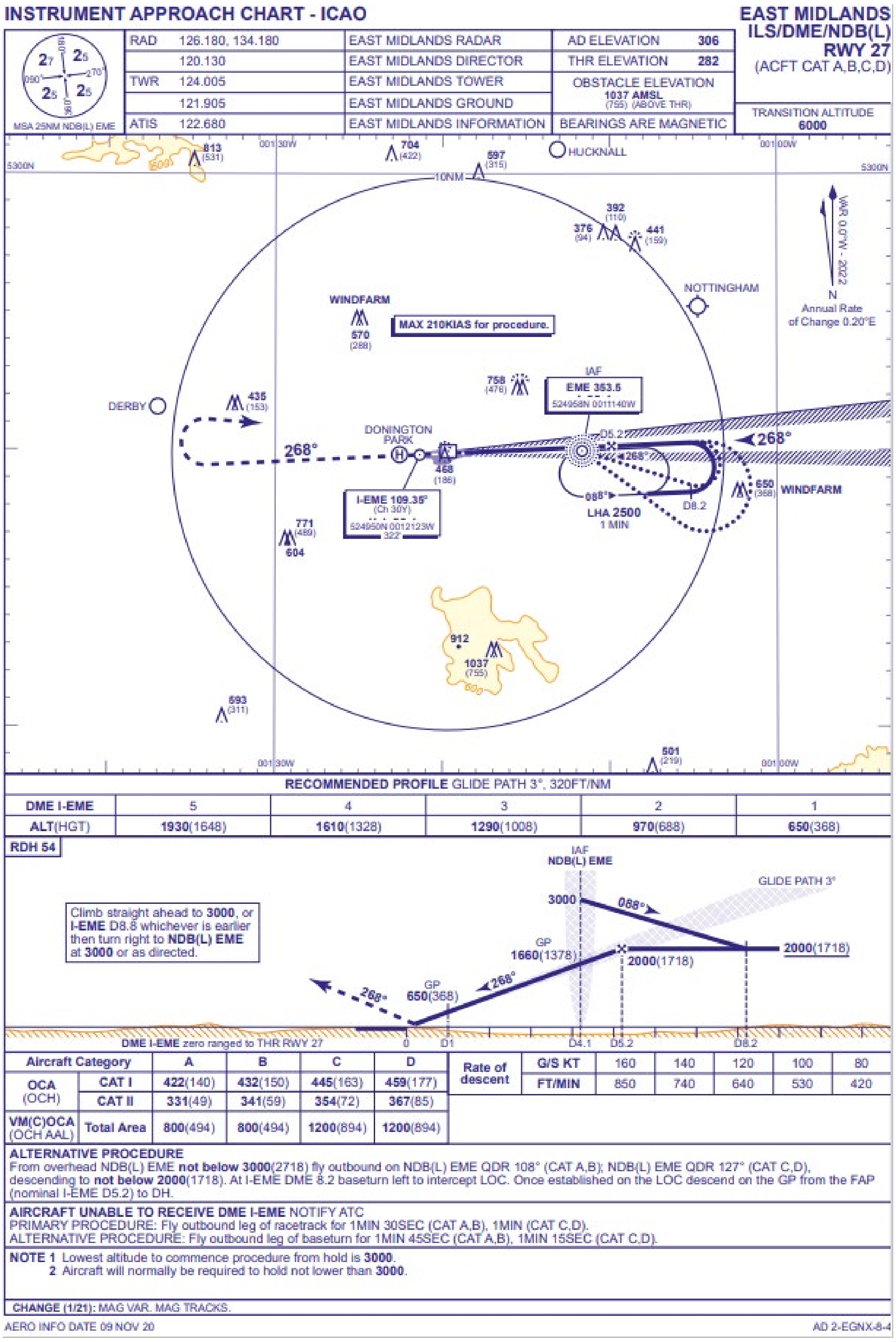
The crew reported for duty at 2320 hrs at East Midlands Airport (EMA). The aircraft's tech log contained an entry for an Acceptable Deferred Defect to the TCAS system but there were no other technical issues. The aircraft was de-iced due to frost conditions at EMA, and it departed at 0030 hrs. The flight to Belfast International (BFS) was without incident and the aircraft arrived at 0150 hrs. The crew conducted a routine turnaround and, due to low temperatures and active frost in BFS, the aircraft was again de-iced before its departure at 0310 hrs.

The departure from BFS and the cruise toward EMA were uneventful. Due to a forecast of freezing fog at EMA the crew prepared and briefed for a CAT II approach with the commander as PF. As they approached EMA, they were told to expect to hold due to delays caused by the Low Visibility Procedures in force at EMA. The aircraft entered the hold as directed and after approximately 10 minutes ATC gave radar vectors to intercept the ILS for Runway 27 at EMA.

The initial stages of the CAT II approach on the ILS proceeded normally. The aircraft achieved stable approach conditions at 1,300 ft amsl and, at 1,000 ft radio altitude, the crew saw the correct dual autopilot indications on the aircraft displays. At approximately 500 ft radio altitude the aircraft entered cloud. Shortly after that the ELEC caution on the Centralised Crew Alerting System (CCAS) illuminated. This indication directed the crew to check the electrical indications on the overhead panel where they noted that the DC GEN2 FAULT amber light was flashing. The co-pilot's Electronic Attitude and Direction Indicator (EADI) and Electronic Horizontal Situation Indicator (EHSI) were also flashing in time with the ELEC and DC GEN2 captions. The autopilot (AP) disconnect horn sounded and the flight director (FD) modes on the EADI disappeared, although the FD guidance bars remained visible and appeared to give sensible indications. The crew decided to go around.

As power was applied for the go-around there were numerous audio and visual warnings including Enhanced Ground Proximity Warning System (EGPWS) warnings for "TERRAIN AHEAD" and "TOO LOW GEAR". The co-pilot's EADI and EHSI continued to flash, and his ASI was cycling from maximum to minimum speed. The co-pilot made a positive rate of climb call and then, on the commander's order, retracted the landing gear. The commander's EADI and EHSI went blank for a few seconds but then recovered before blanking again for a few seconds approximately one minute later. The standby instruments continued to work normally.

During the climb, both pilots recalled hearing sounds that they believed were electrical relays cycling. The Autopilot Display Unit (ADU) was also flashing, and the crew were unable to reselect the AP. In the climb, the crew realised that the flap setting had remained at 30 and they retracted the flaps; flaps limiting speed was not exceeded. They carried out the published go-around procedure, levelled at 3,000 ft amsl and turned right toward the EME NDB (Figure 1).



INSTRUMENT APPROACH CHART - ICAO

EAST MIDLANDS
ILS/DME/NDB(L)
RWY 27
(ACFT CAT A,B,C,D)

RAD	126.180, 134.180	EAST MIDLANDS RADAR	AD ELEVATION	306
	120.130	EAST MIDLANDS DIRECTOR	THR ELEVATION	282
TWR	124.005	EAST MIDLANDS TOWER	OBSTACLE ELEVATION 1037 AMSL (755) (ABOVE THR)	
	121.905	EAST MIDLANDS GROUND		
ATIS	122.680	EAST MIDLANDS INFORMATION	BEARINGS ARE MAGNETIC	

TRANSITION ALTITUDE
6000

RECOMMENDED PROFILE GLIDE PATH 3°, 320FT/NM

DME I-EME	5	4	3	2	1
ALT(HGT)	**1930**(1648)	**1610**(1328)	**1290**(1008)	**970**(688)	**650**(368)

Climb straight ahead to **3000**, or **I-EME** D8.8 whichever is earlier then turn right to **NDB(L) EME** at **3000** or as directed.

DME I-EME zero ranged to THR RWY 27

Aircraft Category		A	B	C	D
OCA (OCH)	CAT I	**422**(140)	**432**(150)	**445**(163)	**459**(177)
	CAT II	**331**(49)	**341**(59)	**354**(72)	**367**(85)
VM(C)OCA (OCH AAL)	Total Area	**800**(494)	**800**(494)	**1200**(894)	**1200**(894)

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

ALTERNATIVE PROCEDURE
From overhead NDB(L) EME **not below 3000**(2718) fly outbound on NDB(L) EME QDR 108° (CAT A,B); NDB(L) EME QDR 127° (CAT C,D), descending to **not below 2000**(1718). At I-EME DME 8.2 baseturn left to intercept LOC. Once established on the LOC descend on the GP from the FAP (nominal I-EME D5.2) to DH.

AIRCRAFT UNABLE TO RECEIVE DME I-EME NOTIFY ATC
PRIMARY PROCEDURE: Fly outbound leg of racetrack for 1MIN 30SEC (CAT A,B), 1MIN (CAT C,D).
ALTERNATIVE PROCEDURE: Fly outbound leg of baseturn for 1MIN 45SEC (CAT A,B), 1MIN 15SEC (CAT C,D).

NOTE 1 Lowest altitude to commence procedure from hold is **3000**.
2 Aircraft will normally be required to hold not lower than **3000**.

CHANGE (1/21): MAG VAR. MAG TRACKS.

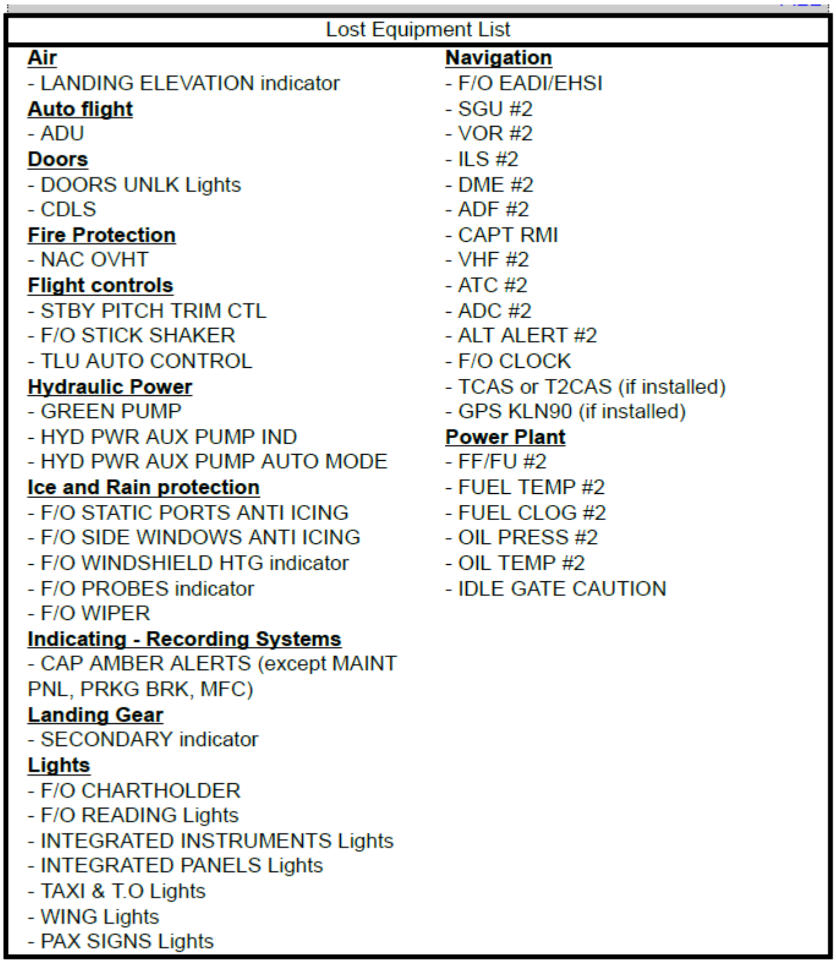
AERO INFO DATE 09 NOV 20 AD 2-EGNX-8-4

Figure 1

EMA approach and go-around procedure

Once level, the crew made a PAN call to ATC but heard no response. They then tried to contact ATC on the distress frequency 121.5 MHz but still received no response. They reselected the EMA Tower frequency, selected 7600 on the transponder, then broadcast a MAYDAY. Amidst audio conditions that the crew described as severe "static", the pilots heard a faint message from ATC to contact EMA Radar. They changed to the appropriate frequency and from that point communications were restored. The crew requested radar vectors for a diversion to Birmingham International Airport (BHX).

As the DC GEN2 FAULT amber light was flashing, the crew carried out QRH actions for a DC GEN2 fault, which involves selecting that generator to OFF. Approximately seven minutes elapsed from the start of the event until the crew deselected DC Gen 2. When the DC generator 2 was switched off the audio and visual warnings stopped, the co-pilot's screens stopped flashing and went blank, and a number of caution lights remained illuminated in the overhead panel. The commander recalled that the "Bus Tie Contactor (BTC) did not close" as would have been expected so the DC Bus 2 was unpowered. The crew consulted the QRH loss of equipment list for DC Bus 2 off (Figure 2).



Lost Equipment List

Air
- LANDING ELEVATION indicator

Auto flight
- ADU

Doors
- DOORS UNLK Lights
- CDLS

Fire Protection
- NAC OVHT

Flight controls
- STBY PITCH TRIM CTL
- F/O STICK SHAKER
- TLU AUTO CONTROL

Hydraulic Power
- GREEN PUMP
- HYD PWR AUX PUMP IND
- HYD PWR AUX PUMP AUTO MODE

Ice and Rain protection
- F/O STATIC PORTS ANTI ICING
- F/O SIDE WINDOWS ANTI ICING
- F/O WINDSHIELD HTG indicator
- F/O PROBES indicator
- F/O WIPER

Indicating - Recording Systems
- CAP AMBER ALERTS (except MAINT PNL, PRKG BRK, MFC)

Landing Gear
- SECONDARY indicator

Lights
- F/O CHARTHOLDER
- F/O READING Lights
- INTEGRATED INSTRUMENTS Lights
- INTEGRATED PANELS Lights
- TAXI & T.O Lights
- WING Lights
- PAX SIGNS Lights

Navigation
- F/O EADI/EHSI
- SGU #2
- VOR #2
- ILS #2
- DME #2
- ADF #2
- CAPT RMI
- VHF #2
- ATC #2
- ADC #2
- ALT ALERT #2
- F/O CLOCK
- TCAS or T2CAS (if installed)
- GPS KLN90 (if installed)

Power Plant
- FF/FU #2
- FUEL TEMP #2
- FUEL CLOG #2
- OIL PRESS #2
- OIL TEMP #2
- IDLE GATE CAUTION

Figure 2
DC Bus 2 Lost Equipment List

In addition to the items on the Lost Equipment list, the commander also stated that there remained additional electrical failures to those on the list such as the loss of the environmental control system recirculation fan and the Aircraft Performance Monitoring System.

The crew recognised that the main battery was discharging and the Green hydraulic system which lowers the landing gear was unpowered. The commander was concerned for further electrical failures should the aircraft remain airborne for longer than the published 30-minute life of the main battery. The crew did the performance calculations for landing at BHX and used the Blue hydraulic system to pressurise the Green hydraulics to allow the landing gear to be lowered.

The left navigation receiver could be tuned to the ILS for Runway 33 at BHX, but all automatic flight functions remained unavailable. The commander flew a manual raw data ILS approach to Runway 33 and the aircraft landed without further incident and taxied to stand. The aircraft was taken out of service for detailed troubleshooting on the cause of the electrical issues experienced by the crew.

Meteorology

The weather report for EMA at 0350 hrs gave the following conditions: wind 270° at 8 kt, visibility 400 m in freezing fog, cloud broken at 100 ft and the temperature and dewpoint both -2°C. This was as forecast, and the crew had prepared for such conditions.

The weather at BHX at 0350 hrs was wind 230° at 1 kt, CAVOK, temperature -5°C and dewpoint -6°C.

Recorded information

The aircraft's flight data recorder (FDR), cockpit voice recorder (CVR) and EGPWS were downloaded for analysis of the recorded information, together with ground radar data from Clee Hill and Claxby. Relevant information from the CVR recording is included in the history of the flight.

The recorded radar track data for the approach to EMA and diversion to BHX are shown in Figure 3. The radar returns for the approach to EMA included pressure altitude from the aircraft's Mode S transponder. However, from 0418:51 hrs, with the aircraft within a nautical mile of the runway at about 400 ft aal, the transponder transmissions stopped, and the aircraft continued to be tracked only by primary radar for the remainder of the flight.

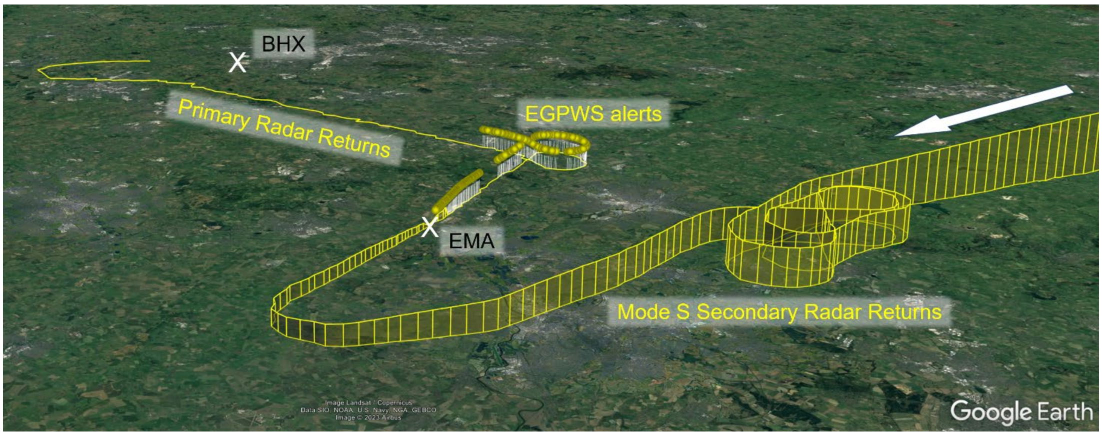


Figure 3

Radar ground track

Data from the aircraft's FDR show that just after 0418 hrs the master warning alert was triggered together with spurious VHF 2 transmission indications and radio altimeter heights (Figure 4). The spurious heights were intermittent over a period of seven minutes and ten seconds and were sufficiently low to trigger 31 EGPWS alerts (2x "PULL UP", 6x "TERRAIN, TERRAIN", 6x "TOO LOW TERRAIN", 12x "TOO LOW GEAR" and 5x "BANK ANGLE, BANK ANGLE") – see Figure 3 for the location of the aircraft during these EGPWS alerts. Note that some of the alerts coincided with others so not all were heard on the CVR.

The spurious VHF 2 transmission indications continued for the remainder of the flight as did the master warning alert.

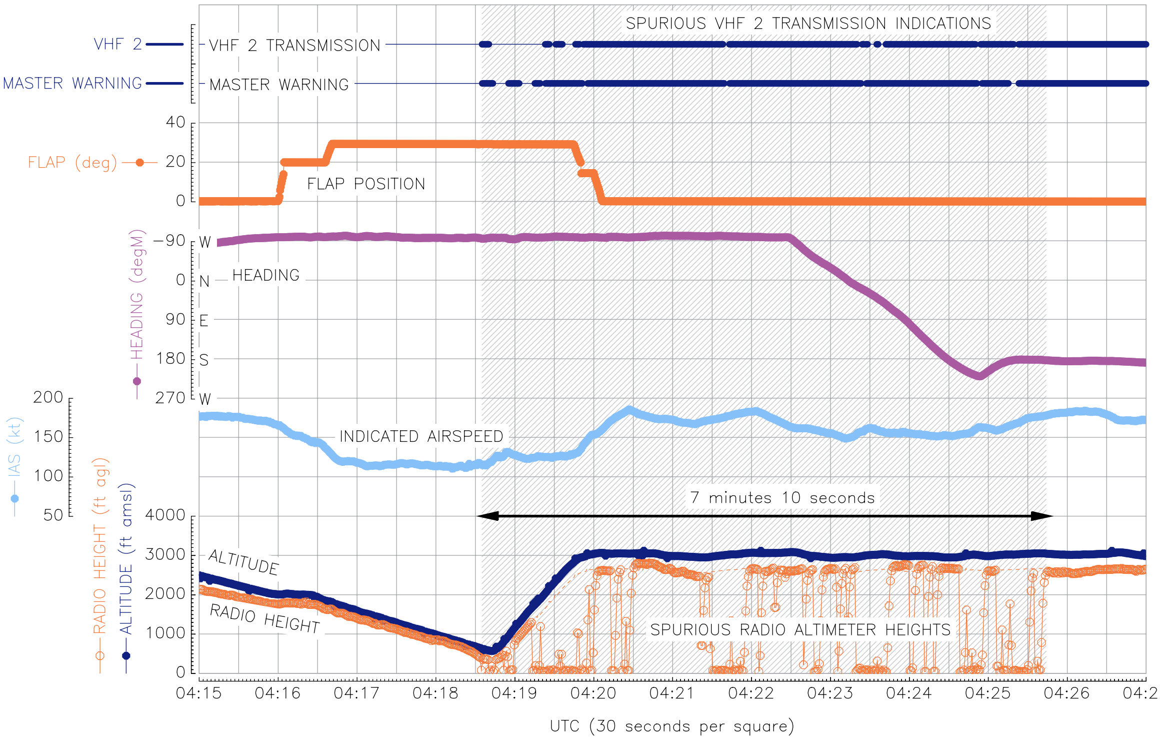


Figure 4

FDR data

Aircraft information

The ATR 72-202 is a twin turboprop regional aircraft. G-NPTF was manufactured in 1990, held a valid ARC and was being operated as a cargo variant. G-NPTF joined the operator's fleet in May 2022.

Category II (CAT II) operations

For a CAT II ILS approach, the aircraft's single autopilot is automatically coupled to both Horizontal Situation Indicators by 1,200 ft radio altitude and confirmed by the presence of dual CPL (couple) indications on the ADU. If the dual indications are not present by 1,000 ft radio altitude, then the approach may not be continued below 200 ft aal.

The minimum RVR for the aircraft to conduct a CAT II approach is as follows:

- Touchdown 300 m
- Mid-Point 125 m
- Stop-End 75 m

The operator's operations manual Part B states '*Any failure that is not completely 'treated' (ATR terminology) before 1000 ft AAL, or that occurs below 1000 ft AAL, shall lead to a go around.*'

Maintenance history

Routine scheduled maintenance had been completed on G-NPTF two days before the accident flight. During the check, the No 2 engine DC starter-generator (DC Gen 2) brushes were found worn to their service limit, so it was replaced with an overhauled unit. The replacement starter-generator had been overhauled and bench tested in accordance with the manufacturer's Component Maintenance Manual (CMM) six months previously and was supplied with a valid EASA Form 1 Authorised Release Certificate.

Electrical systems

During flight, the ATR 72-202's electrical power is provided by the following sources:

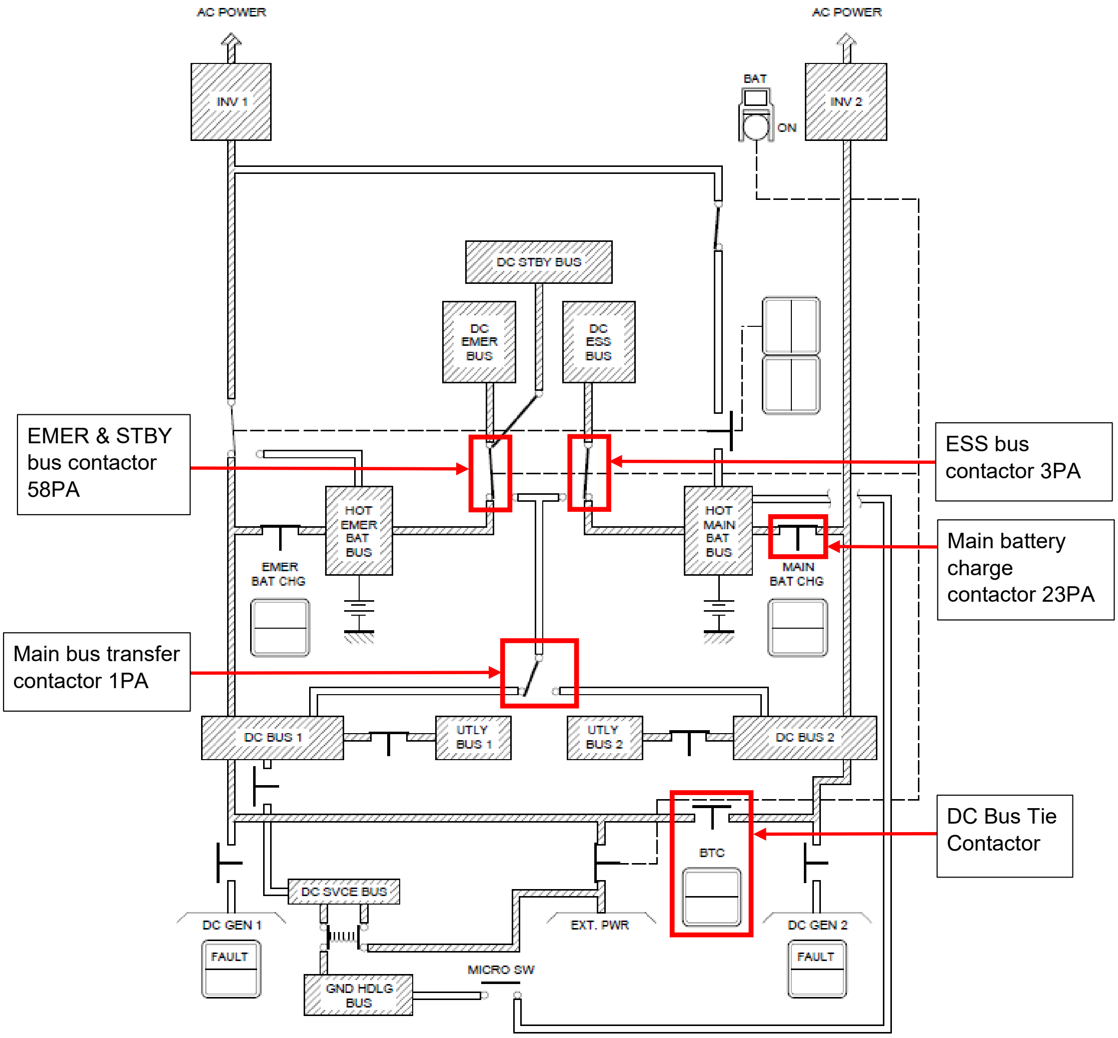
- Two engine-driven 28V DC starter-generators, one on each engine (DC Gen 1, DC Gen 2).
- Two DC-supplied static inverters, providing constant frequency 26V and 115V AC power.
- Main and Emergency 24V DC batteries.
- Two propeller-driven AC frequency wild generators providing 115V AC.

Two separate electrical networks, No 1 (left side) and No 2 (right side) for both DC and constant frequency AC power operate independently. In case of failure of one network, each side of the DC or AC network can be connected to its respective DC or AC opposite side, using the DC BTC or the AC Bus Tie Relay (BTR).

The 115V AC wild network is standalone from the DC and constant frequency AC networks.

Each electrical network powers a series of buses, which in turn distribute power to equipment and services that are shared amongst the networks to provide system redundancy.

The DC network is shown in Figure 5.



EMER & STBY bus contactor 58PA

ESS bus contactor 3PA

Main battery charge contactor 23PA

Main bus transfer contactor 1PA

DC Bus Tie Contactor

Figure 5

DC network schematic

The DC 1 and DC 2 networks supply power to corresponding static inverters, each providing constant frequency AC output on AC 1 and AC 2 networks (Figure 6). Each inverter has a 26 V and a 115 V 400 Hz output.

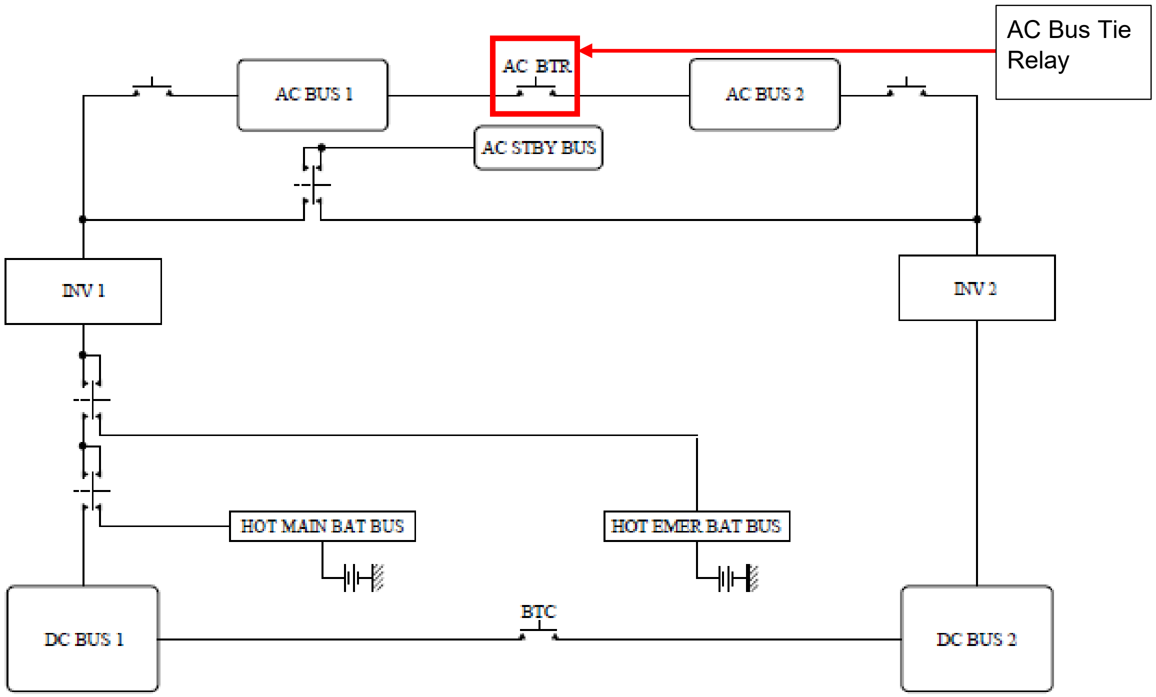


Figure 6

Constant frequency AC network

Emergency network power distribution

Cross supply and redundancy between the buses is provided by a series of contactors and switches including, among others, the BTC, BTR and main bus transfer contactor 1PA. Their operating logic is managed by Bus Power Control Units (BPCU) and Multi-Function Computers (MFC) to provide automatic reconfiguration in case of one DC Generator loss.

If one of the DC generators fails, its dedicated GCU isolates the affected DC network and the BPCU closes the BTC so that the other DC generator can provide power to both DC main buses. The BTC can also be isolated (ISOL) via a pushbutton switch on the flight deck overhead panel, preventing the main DC 1 and DC 2 buses being linked. The 1PA contactor further allows DC Bus 1 or DC Bus 2 to power the ESS, STBY and EMER Buses, if either or both of the 3PA and 58PA contactors are unable to be controlled by the MFCs.

Constant frequency AC 1 and AC 2 are linked by the BTR that operates in a similar manner to connect both AC networks together in case of a single inverter failure. If the BTC is automatically closed by the BPCU, the BTR will be closed by MFC 1 after a 10 second delay. If the BTC pushbutton switch is manually set to ISOL, the BTR is also isolated, preventing AC 1 and AC 2 from being linked.

If both DC generators fail, critical flight systems and equipment on the DC Emergency (EMER), Standby (STBY) and Essential (ESS) buses are powered by the main and emergency batteries. On G-NPTF, this gives up to 30 minutes of flight time to land the aircraft.

DC starter-generator

There are two DC starter-generators fitted to the aircraft, one to each engine. The generators are numbered by which engine they are fitted to: DC Gen 1 and DC Gen 2. Each generator separately supplies DC Bus 1 and DC Bus 2.

The starter-generator operates in two modes. Firstly, as a starter during the engine start sequence, when it uses an external power source[1] to rotate the engine up to its self-sustaining speed of 45% NH[2]. At this point, the unit stops providing starting torque. When NH then reaches 61.5%, the unit begins to operate as a DC generator, providing power to its respective DC Bus network.

NH is measured by a magnetic speed sensor within the starter-generator. The speed sensor assembly consists of a conical metal speed disc with equally spaced holes around its face, that is attached to the unit's rotating shaft, and a magnetic sensing unit positioned above the disc (Figure 7). As the disc rotates, the holes pass the sensor. The change in air gap detected as the holes pass creates an output voltage from the magnetic sensor which is translated into the NH measurement.

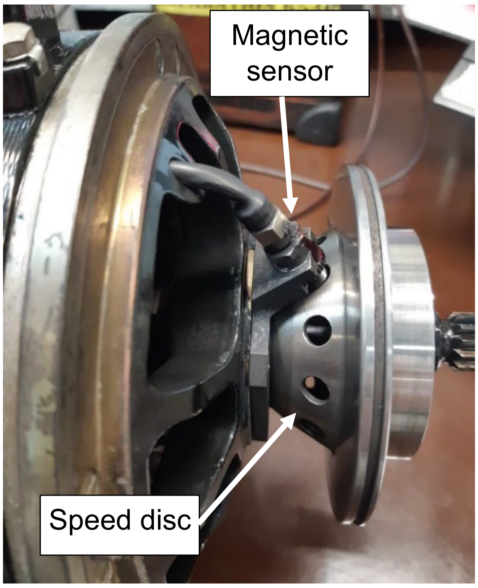


Figure 7

Speed sensor assembly

Electrical system protection

GCUs monitor the supply from the DC generators. If a fault is detected, the GCU will open the generator contactor between the generator and its main DC Bus to isolate it. A DC GEN FAULT pushbutton caption will subsequently illuminate on the overhead panel and an ELEC caution will appear on the CCAS.

Footnote

[1] Either ground power, aircraft main battery, or a combination of main battery and opposite starter-generator (cross-start).

[2] NH High pressure compressor rotational speed, displayed as a percentage of maximum rotational speed.

The GCUs also monitor the generator speed sensor output signal for fault detection at the 45% and 61.5% NH points. If the speed sensor signal is not detected correctly, the GCU will trigger the sequence of events to isolate the respective DC Bus and send a signal to the BPCU to close the BTC. The BTR will then close 10 seconds later.

If the BTC is cycled three or more times within two seconds, an inbuilt system protection locks it open so it will not tie. When the cause of the lock-out is no longer present, the BTC can be reset by cycling the BTC pushbutton switch located on the flight deck overhead DC electrical panel. The conditions that trigger a BTC lock-out are not detailed in the Flight Crew Operating Manual (FCOM). However, the system reset is described in the FCOM and the QRH. The BTR does not have such a system protection lock.

VHF communications

Two VHF systems (VHF 1 and VHF 2) are connected to a Remote Control Audio Unit (RCAU) which is powered by the DC ESS Bus. The RCAU centralises audio signals and enables the flight crew to communicate between themselves, make public address announcements (for passenger operations), or communicate to ATC. VHF transmission and reception mode connections are made via two internal relays.

The RCAU installed on G-NPTF has an emergency mode in the event of power supply failure that, via a relay, directly connects VHF1 to the commander’s side, and VHF2 to the co-pilot’s side.

Transponder

G-NPTF is fitted with two transponders which transmit the aircraft’s identity for the purposes of conspicuity. ATC 1 is powered by DC EMER Bus and ATC 2 is powered by DC Bus 2. ATC 2 was the transponder in use during the incident flight.

Radio altimeter

The radio altimeter provides height information when the aircraft is flying below 2,500 ft. The system consists of two antennas (transmit and receive) and a transceiver. The transceiver is powered by DC Bus 1 and provides height information inputs to aircraft systems including the FDR, EGPWS, and Symbol Generator Units (SGU).

On-aircraft testing conducted by the aircraft manufacturer identified a control signal link between the radio altimeter and SGUs. When the SGU restarts following a power loss, it commands a test signal to the radio altimeter. This test signal results in a low altitude output from the radio altimeter that is transmitted to its linked systems.

EADI and EHSI

The EADI and EHSI on both commander’s and co-pilot’s sides are Electronic Flight Information Screens (EFIS). The commander’s EADI and EHSI are both powered by the DC STBY bus. The co-pilot’s EADI and EHSI are both powered by DC Bus 2. The display signal input to the screens is provided by SGUs: SGU1 (powered by the DC STBY bus) for the commander, and SGU2 (powered by DC Bus 2) for the co-pilot.

Aircraft examination

Two faults had been logged on Built-in Test Equipment (BITE) 'doll's eye' magnetic latching indicators; one on the BPCU 'CNTR' (contactor fault) indicator, and the MFC fault indicator on the co-pilot's maintenance panel. It could not be determined if the faults were logged as a result of the incident, as it was not possible to determine when the indicators had last been checked.

Several single-engine ground runs were conducted to fully power all electrical networks on the aircraft. During the second ground run using the No 2 engine, DC GEN 2 FAULT and ELEC captions were observed, together with cycling aircraft power to the co-pilot's instruments. Multiple rapid relay and contactor switching sounds were heard from the location of electrical panels behind the co-pilot's seat during the power cycling. A fault was latched on GCU 2. Following the ground run, GCU 2 passed confidence checks and was interchanged with GCU 1 to isolate any unit fault.

The third ground run using the No 2 engine resulted in the co-pilot's instruments and the commander's EHSI losing power and the BPCU logged another CNTR fault. In-situ examination of the main generator contactors (11PU for DC Gen 1 and 12PU for DC Gen 2) did not reveal any faults.

The subsequent No 1 engine run began with significant relay operation 'chattering' sounds from the panels behind the co-pilot's seat. The chattering stopped after a couple of seconds, and the relays then operated normally for the remainder of the engine run.

The DC Gen 2 was examined in-situ (Figure 8) for signs of external damage or faults, and none were found.

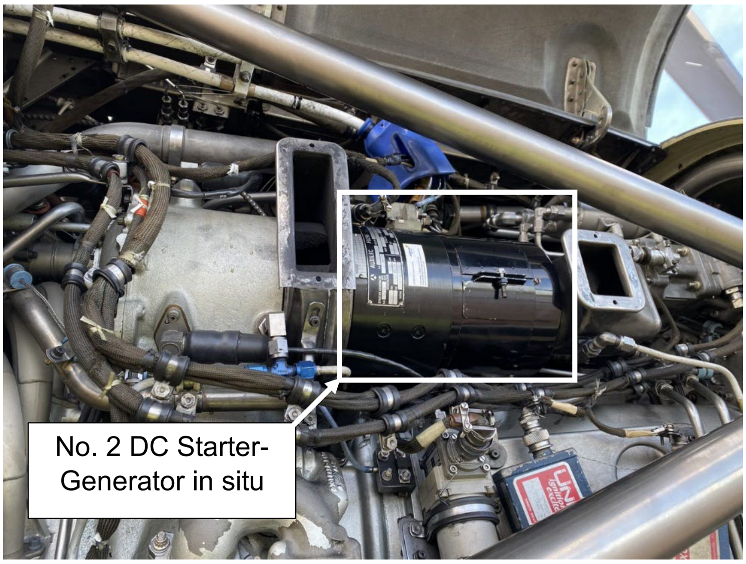


Figure 8

G-NPTF No 2 DC Starter-Generator

Troubleshooting

DC Gen 2 was replaced, and further engine ground runs were conducted. The CNTR BPCU fault reset itself, indicating the fault's causal condition had been removed. No further faults were logged on the GCUs and no other electrical anomalies were observed.

Further troubleshooting using manufacturer maintenance procedures on contactor and relay function, electrical continuity and unit confidence checks were completed, with no faults found.

Tests and research

DC starter-generator

The DC Gen 2 starter-generator removed from G-NPTF was examined by the unit's manufacturer. The examination consisted of a visual inspection, followed by the manufacturer's acceptance test procedure for the unit. Further component-level examination was conducted within the AAIB's laboratories.

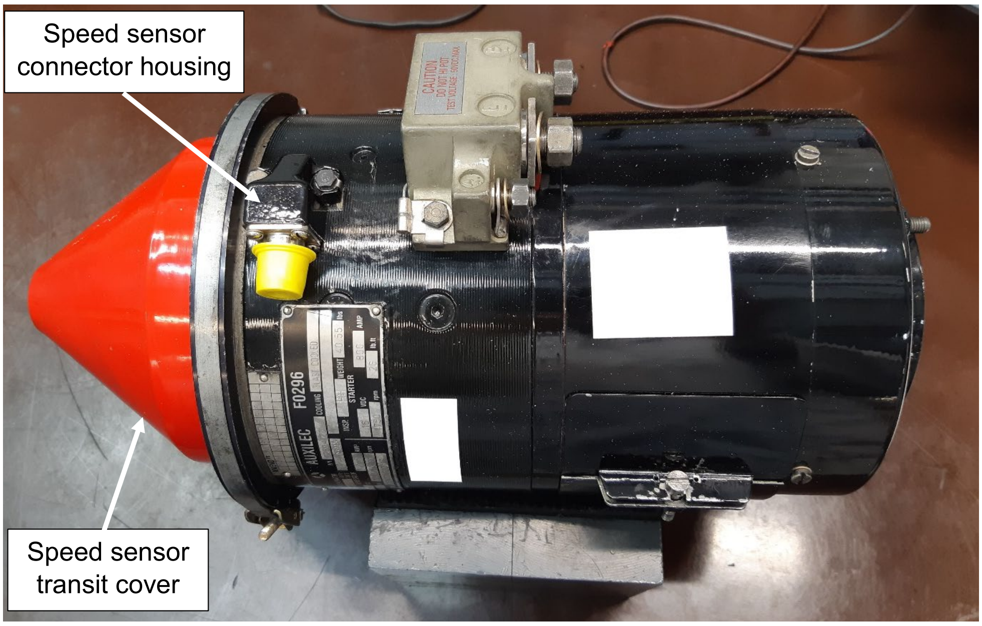


Figure 9

DC Gen 2 starter-generator removed from G-NPTF

Visual inspection

The starter-generator (Figure 9) was visually inspected and considered to be in a satisfactory condition in line with its recent overhaul. There was no sign of external damage of the speed sensor or generator shaft.

The transport cover was removed, and the speed sensor connector and sensor unit were inspected. The speed sensor connector is within a black housing on the outside of the generator casing. It was in good condition, and the pins undamaged. Externally, the cable between the connector and the sensor unit was in good condition and noted to be correctly sealed. Both the speed disc and sensor unit were in good condition.

Acceptance tests

Acceptance tests from the unit's CMM were performed. Shaft spline wear and brush wear were within limits.

Resistance tests of the shunt winding, starter-generator insulation, and speed sensor insulation were all compliant. A resistance test of the speed sensor resulted in an open circuit (infinite measured, criteria 130 Ω ± 10 Ω) and was considered to fail the test.

The starter-generator was mounted to a test rig for dynamic testing where it failed the test due to speed sensor signal measurement. No signal was measured at the beginning of the dynamic test (five minutes); it was then intermittent (one minute), and then recovered and remained stable.

Following the dynamic test, the peak voltage of the speed sensor output was measured separately. The measured value was 1.36 V DC, considered to be able to be adjusted to reach the minimum required specification of 1.4 V DC by reducing the air gap between the speed disc and the speed sensor. This value remained constant during the unit's cool-down over approximately two hours, unaffected by heat.

Speed sensor connector examination

The speed sensor output connector was removed from its housing for examination of wiring condition and further resistance checks (Figure 10). The speed sensor output connector is connected to the sensor unit by two 26 AWG wires, each containing seven strands of 0.15mm diameter.

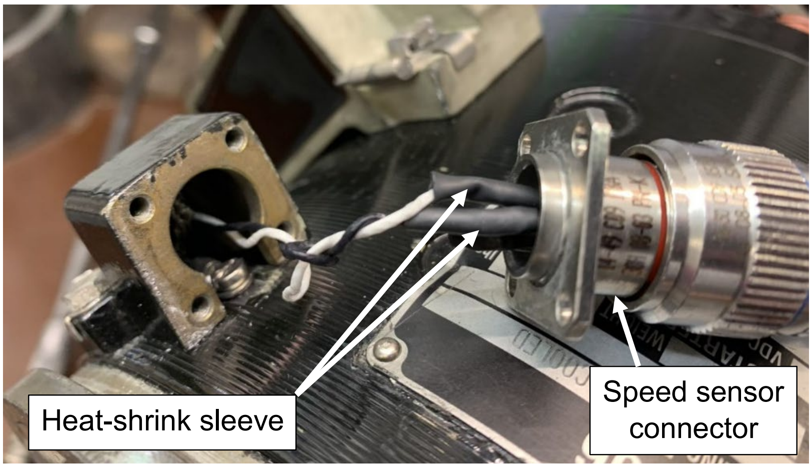


Figure 10

Speed sensor connector and wires

During light manual manipulation of the connector, the resistance measurement fluctuated between the correct value (130 Ω) and open circuit. Activating an open circuit was repeatable through gentle pressure on the speed sensor connector wiring.

The wires are soldered to pins at the rear face of the connector, and the soldered joint covered with heat-shrink sleeve. Removing the heat-shrink sleeve from the white wire showed the wire to be completely broken but, whilst held in place by the heat-shrink sleeve, close enough to make intermittent contact. Removing the heat-shrink sleeve on the black wire showed damage to the wire core (Figure 11).

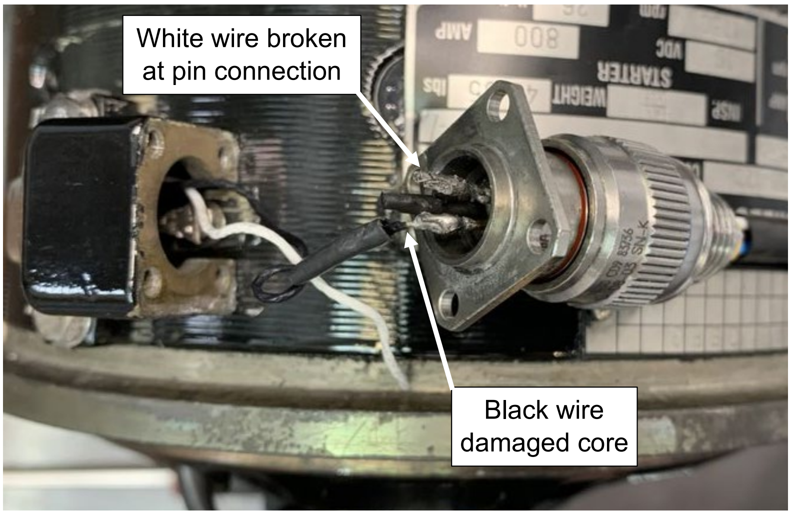


Figure 11

Speed sensor connector with heat-shrink sleeve removed from wires

Speed sensor wire examination

Further microscopy analysis by the AAIB of the white wire showed partial unravelling of the core and breakage damage at the pin connection soldered joint (Figure 12), and evidence of mechanical insulation removal (Figure 13).

Figure 12

Speed sensor connector soldered pin and broken white wire conductors

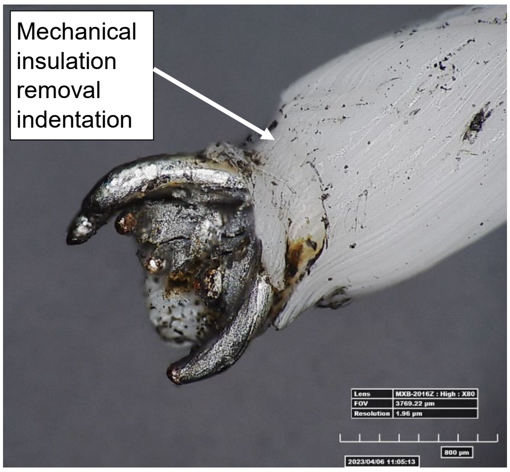


Figure 13

Speed sensor white wire broken conductors

The core of the black wire had two broken strands at the soldered pin joint and evidence of mechanical insulation removal (Figure 14).

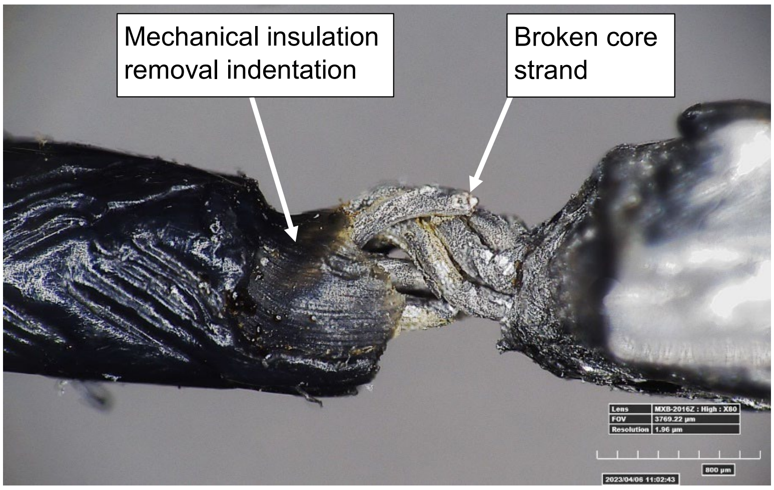


Figure 14

Speed sensor black wire damaged core at connector pin

Speed sensor removal

The manufacturer's overhaul and maintenance procedure requires removal of the speed sensor connector from the wires to facilitate cleaning of the main generator unit. Excess wire length is provided at manufacture, to allow this to be performed multiple times during the unit's service life. To reconnect the wires, a small portion of the wire's insulating outer sleeve is removed to expose the wire core before soldering to the connector pins.

The starter-generator was overhauled, in accordance with the manufacturer's CMM, at a third-party provider. The type of tool required to strip wire insulation is not specified within the CMM and the provider used a standard mechanical stripping tool (Figure 15). To strip the insulation, a wire is inserted through the correct gauge for the wire in accordance with the markings on the tool. The tool handles are squeezed together, and this action clamps the wire whilst the two cutters (shown on the right of Figure 15) close to cut the insulation to the correct depth and then strip it from the wire. Misalignment of the wire with the correct wire gauge on the tool will result in either the insulation not being stripped, or the conducting wires being part-severed by the two cutters as they come together.

Figure 15

Mechanical wire stripping tool used at overhaul

In contrast to the third-party provider, the manufacturer of the starter-generator confirmed that it uses thermal insulation stripping tools (Figure 16) in its facility as it had previously observed the potential for wire damage by using mechanical tools.

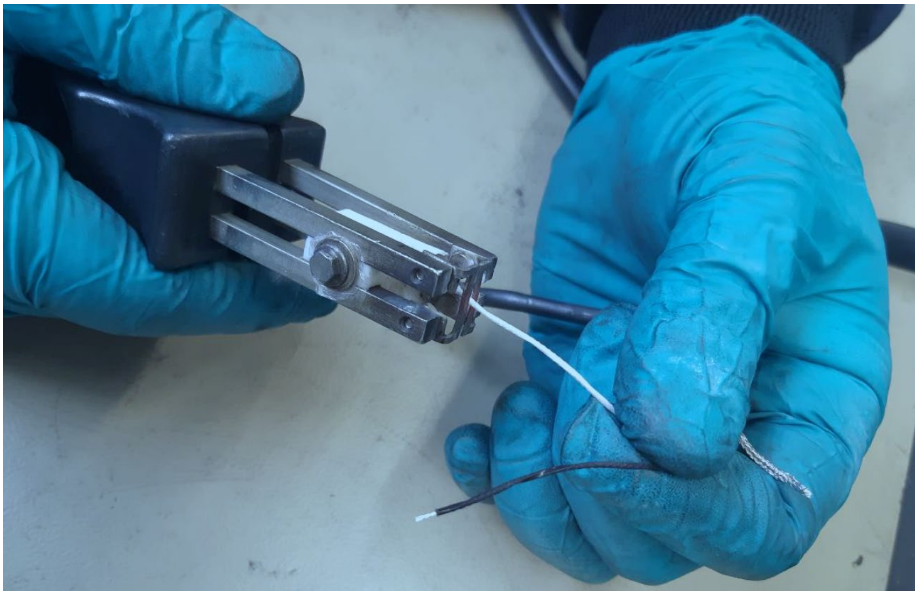


Figure 16

Thermal wire insulation stripping tool

MFC BITE memory

The BITE memory data from both MFCs was downloaded and analysed by the manufacturer.

Some data from the MFC BITE could be attributed to the event as it is logged against a ‘flight’, which is the period of time between two takeoffs. Although the BITE data does not indicate when, or for how long a condition persisted, or whether there were multiple instances detected within a ‘flight’, analysis of this data shows system or sensor failures which are consistent with losses of the following electrical buses: DC ESS Bus, DC STBY Bus, DC Bus 2, DC UTLY Bus 2, and 26V AC STBY Bus and/or 26V AC Bus 1.

Analysis

Conduct of the flight

The crew had reported for duty at 2320 hrs and the incident began approximately four hours later. Both crew members said they felt well-rested and that their roster was not unduly challenging, and so fatigue is not considered to have been a factor.

The event began with the aircraft in cloud at low altitude, carrying out a CAT II approach. In accordance with the company operations manual, when the malfunction occurred below 1,000 ft aal, the crew initiated a go-around. As the aircraft began the go-around, the crew were presented with a significant loss of flight instrumentation and multiple visual and audible alerts including ground proximity warnings. This resulted in a high workload for the crew, but their initial focus was to assure a safe flight path for the aircraft and so prioritised this, and then communications, over any diagnosis of the malfunction. As the commander’s EADI and EHSI went blank for a few seconds, he reverted to the functioning standby instruments for flight path information.

They established the aircraft in the climb and followed the published standard go-around procedure. Due to the likely distraction caused by the many warnings, the crew did not initially retract the flaps. Once level at 3,000 ft, the crew recognised the miss-set flaps and retracted them; flap limiting speed was not exceeded.

At this point, the co-pilot had no reliable flight instruments, and this disrupted the usual crew resource management as his ability to monitor the aircraft’s flight path was significantly degraded. In addition, as the crew were unable to select AP, the commander had to fly the aircraft manually and this added to his higher than normal workload.

Once the aircraft reached the go-around altitude of 3,000 ft amsl, the crew made a PAN call to ATC. The crew did not get a response to this call or to their request for radar vectors toward Birmingham Airport. Concerned that they now also had a communications failure, they continued the published go-around procedure and turned right towards the hold at the EME beacon.

In an attempt to resolve the communications issue, the crew changed frequency to 121.5 MHz, the distress frequency. Again, they received no response and so returned to the EMA Tower frequency. With the prospect of a manually flown diversion, using degraded flight instruments and without radio communications, crew workload was high. They made a MAYDAY call to EMA Tower and, in the static, believed they heard a response directing them to contact EMA Approach. They did so and, on that frequency, re-established clear communications and asked for vectors toward Birmingham.

Once the go-around procedure was complete and the crew had re-established radio communications, they gave more attention to addressing the malfunction. Whilst the many warnings and the loss of flight instruments and communications were not consistent with a failure of just a generator, the first indications the crew had noticed were the ELEC and DC GEN2 captions. They therefore decided to action the QRH procedure for a DC GEN2 fault. With the DC GEN 2 switched off the warnings ceased. As the BTC did not close, due to cycling three or more times within two seconds and entering into a lock-out condition, the co-pilot's side of the cockpit remained unpowered. The BTC could have been reset (as the cause of the lock-out was no longer present) by cycling the BTC pushbutton switch located on the flight deck overhead DC electrical panel. The crew were unaware of this as the conditions that trigger a BTC lock-out are not detailed in the FCOM. However, the system reset is described in the FCOM and QRH. Due to the loss of the ADU, the crew were unable to select any autoflight functions. The resulting aircraft configuration precluded making a CAT II approach, so the crew continued with the diversion to Birmingham, where the weather was suitable for a CAT I approach, with the commander manually flying the aircraft and the co-pilot monitoring.

Prior to landing at Birmingham, the crew reviewed the DC Bus 2 Lost Equipment List and took appropriate action, including cross-feeding hydraulic systems, to manage the issues. The crew workload load was higher than normal due to the lost systems, but the crew managed the diversion effectively and the aircraft subsequently landed without further incident.

Starter-generator wiring damage

The partially-connected, damaged wiring at the speed sensor connector pin joints resulted in a rapid, intermittent speed measurement signal being sent to the GCU. The GCU interpreted this as a fault and indicated a DC GEN2 caution to the crew. It also led to the electrical system GCU rapidly opening and closing contactor 23PA causing power fluctuations and "flashing" of displays.

The appearance of the insulation on both connector wires at the soldered joint end is indicative of a mechanical cutting-type insulation stripping tool being used during the unit's previous overhaul process and this was confirmed by the overhaul provider. It is possible to damage the internal core with this type of tool if the wire is misaligned with the correct wire gauge on the tool, and it is probable that this is how the damage occurred.

The manufacturer of the starter-generator had previously identified the risk of mechanical damage from mechanical insulation stripping tools and uses thermal wire strippers in its own manufacturing and overhaul facility. However, the use of these tools was not specified in its product maintenance documentation.

Consequential loss of aircraft systems

A review of the flight data provided no indication as to why the speed sensor wire failed when it did, but it came at a critical time during the latter phases of a CAT II approach in reduced visibility at night. Due to the rapidly changing and unusual power distribution configuration of the aircraft during this event, it has not been possible to fully explain the behaviour of some of the flight instruments that was observed by the crew and that of other aircraft systems.

Loss of electrical networks

As a consequence of the damage to its speed sensor wire, the speed signal output from DC Gen 2 was intermittent. This meant that the GCU received cyclic input signals indicating that DC Gen 2 was operating below 61.5% NH and therefore not as a generator. In response, the GCU opened and closed the main generator contactor for DC Bus 2 in rapid succession to match the input, leading to DC Bus 2 receiving rapid fluctuations in power.

When power is lost to DC Bus 2, the aircraft's systems reconfigure the power networks to supply DC Bus 2 from DC Bus 1, via the BTC. However, as the power was lost and regained rapidly, the BTC locked open in a self-protection mode, having been cycled three or more times within two seconds. A BTC lock-out can be reset by cycling the pushbutton switch, as long as the cause of the lock-out is no longer present. This requires the crew to have recognised the conditions for a lock-out.

DC Bus 2 continued to receive rapidly cycling power from the DC Gen 2 until it was isolated by the crew. This action stabilised the electrical systems by disconnecting DC Bus 2 and UTLY Bus 2, and the emergency power network reconfigured to supply DC ESS Buses on DC Bus 1 via the 1PA and 3PA contactors.

The flight systems and instrumentation observed to have been lost indicate that the following electrical supply behaviour occurred:

- A rapid cyclic loss of supply to DC Bus 2 before DC Gen 2 was isolated
- A loss of supply to DC Bus 2 after DC Gen 2 was isolated
- Transient loss of supply to DC ESS Bus during emergency power network reconfiguration
- A transient loss of supply to DC STBY Bus
- Automatic load shedding of DC UTLY Bus 2
- A loss of supply to AC Bus 2 via its inverter

The main aircraft battery was seen to be discharging following the isolation of DC Gen 2 for the remainder of the flight, but it was not possible for the AAIB or aircraft manufacturer to ascertain the reason for this.

Loss of flight instruments

The co-pilot's EADI, EHSI and SGU2 are powered by DC Bus 2. Their irregular behaviour and then total power loss can be explained by the intermittent and then full loss of DC Bus 2.

The signal input to the commander's EADI and EHSI is supplied by SGU 1 which is powered by DC STBY bus. The MFC BITE data analysis showed that there was a loss of the DC STBY bus at some point during the recorded 'flight' event. It is possible that the loss of the DC STBY bus could have disrupted the power input to the EADI and SGU1, resulting in blank screens whilst the SGU restarted. However, this cannot be confirmed as the BITE failure logged could have occurred at any time between the previous and the following take-off and this includes on-ground testing conducted after the event. It was not possible to confirm a direct link between the loss of the DC STBY Bus and the speed sensor output signal failure.

The co-pilot's ASI is powered by AC 2. The AC 2 network was not recovered following loss of supply to the AC inverter from DC Bus 2. The co-pilot's ASI did not regain power, indicating that the AC BTR did not close. It was not possible to ascertain why the BTR did not close as it should have automatically done so despite the BTC entering a locked-out state.

Loss of VHF communications

Each time DC Bus 2 was lost, voltage drops occurred whilst DC ESS Bus power supply was reconfigured within the aircraft's emergency electrical network. The RCAU is normally powered by DC ESS Bus and therefore was subject to power fluctuations causing the RCAU to enter a fault mode where the commander's headset was 'locked' to VHF1 and the co-pilot's headset to VHF2. The power cycling led to RCAU internal relay 'chatter', causing temporary losses of VHF communications through audible interference. Once the electrical network was stabilised after DC Gen 2 was switched off, VHF communications were available to both crew.

Radio altitude data

The low radio altitude data outputs seen during the flight were consistent with the co-pilot's SGU restarting after each cyclic loss of DC Bus 2 power and commanding a test signal to the radio altimeter. The data returned to normal once DC Gen 2 was switched off.

EGPWS warnings

EGPWS warnings were consistent with the system working correctly but receiving spurious radio altitude data inputs. The warnings ceased when the DC Gen 2 was switched off and radio altitude data returned to normal.

Conclusion

A wiring defect on the DC Gen 2 speed sensor resulted in rapidly changing erroneous signals being sent to the GCU. This resulted in the rapid opening and closing of contactor 23PA in response to these inputs and, due to the rapidly fluctuating conditions, the BTC entered a self-protection mode and remained open for the remainder of the flight.

As a consequence of the above, the crew lost a significant number of instruments and systems during the final phases of a CAT II approach in reduced visibility at night. The power distribution anomalies also resulted in a number of spurious and potentially distracting EGPWS aural alerts. The crew conducted a go-around and, following a temporary loss of communications and permanent loss of autoflight capability, manually flew the aircraft to Birmingham Airport where it landed without further incident.

The wiring defect was probably caused by incorrect use of wire stripping tools at the third-party organisation that had overhauled the starter-generator.

The starter-generator manufacturer and the overhaul organisation have identified a number of safety actions they intend to take to prevent a reoccurrence.

Safety action

Following this occurrence, the starter-generator manufacturer has stated it will be taking the following safety actions:

- To modify the CMM procedure for this unit to highly recommend the use of thermal wire strippers.
- Extend the use of thermal wire strippers to all other applications.

The overhaul facility has stated it has taken the following safety actions:

- An analysis of standard practice manuals to check the method of wire stripping specified, followed by an update of the relevant Technical Instruction to bring it in line with the standard practices.
- Clarified that tool choice is performed in the following order for each task: CMM, Standard Practice, Technical Instruction.
- The Method Department technicians have been informed of the issue and, where a method is not specified, they will assist the technician in assessing the best way to strip the wire.
- Wire stripping has been declared as an industrial process and training is to be performed.
- Technicians have been informed that the preferred method of wire stripping is to use thermal wire strippers.

Published: 16 May 2024.

Accident

Aircraft Type and Registration:	Spitfire Mk 26B, G-CLHJ	
No & Type of Engines:	1 Isuzu V6 Piston Engine	
Year of Manufacture:	2019 (Serial no: LAA 324-15249)	
Date & Time (UTC):	22 August 2023 at 1403 hrs	
Location:	Near Enstone, Oxfordshire	
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:	68 years	
Commander's Flying Experience:	1,164 hours (of which 26 were on type) Last 90 days - 18 hours Last 28 days - 8 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a test flight towards obtaining a Permit to Fly, control of the aircraft was lost. The flight was testing the effects of leading edge stall strips as part of the Light Aircraft Association (LAA) approved test programme. The pilot was fatally injured when the aircraft struck the ground.

The aircraft was found to have been built with a misaligned fin and rudder. This misalignment made a wing drop at the stall more likely, but it did not prevent or restrict the ability of the pilot to recover from the stall nor any subsequent spin or spiral dive that might develop. Although the pilot's medical history indicated the possibility of an incapacitation this could not be confirmed or dismissed by the pathologist. The possibility of a control restriction preventing recovery could also not be excluded due to the extensive fire damage to the aircraft.

The LAA took action to alert owners regarding the possibility of a fin and rudder misalignment by issuing a Mandatory Technical Directive[1] (MTD) applicable to all Spitfire Mk 26 and Mk 26B aircraft.

History of the flight

The pilot was conducting the 20th test flight on the aircraft as part of the process for obtaining a Permit to Fly. All the test flying was being conducted at Enstone Airfield where the

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Footnote

[1] https://mar2013.lightaircraftassociation.co.uk/engineering/TADs/324/MTD_01-2024_issue_1.pdf [accessed March 2024].

aircraft had been built and where it was based. The aim of the flight was to assess the stall characteristics after the repositioning of stall strips on the inner leading edges of both wings. The pilot completed his usual pre-flight preparation and started the engine at 1344 hrs. At 1350 hrs the pilot began to taxi towards Runway 26 and took off at 1356 hrs. Witnesses reported the aircraft turning right into the circuit whilst continuing to climb to what they estimated to be between 3,000 to 4,000 ft aal. After a few minutes the aircraft was to the south of the airfield and although some distance away, the witnesses could see the aircraft undergoing what appeared to be a series of stall manoeuvres during which the right wing was seen to drop followed by recovery to straight and level flight. After the third manoeuvre the right wing dropped and the aircraft entered a clockwise spin or rotation.

The aircraft struck the ground in an open field near the village of Enstone in Oxfordshire. The aircraft was severely damaged in the impact and caught fire. The pilot was fatally injured.

Accident site

The aircraft came to rest in a field approximately 100 m from a road opposite houses. The initial impact point was directly below 11kV power lines that crossed the field in a north/south direction; there was no evidence the aircraft touched any of the power lines during the accident (Figure 1). The ground marks showed the right wingtip hit the ground first with significant force. The impact mark and trail of debris suggested the aircraft was travelling in a westerly direction. Three propeller blades and a substantial part of the spinner were found together a short distance from the first impact point. Gouging and disruption to the soil from there on showed the aircraft to have carried on forwards until the left radiator fairing on the underside of the left wing ploughed into the soil causing the aircraft to rotate to the left before coming to a stop. The aircraft remained upright throughout the accident sequence. A fire, centred on the cockpit area, caused extensive damage to the centre of the aircraft.

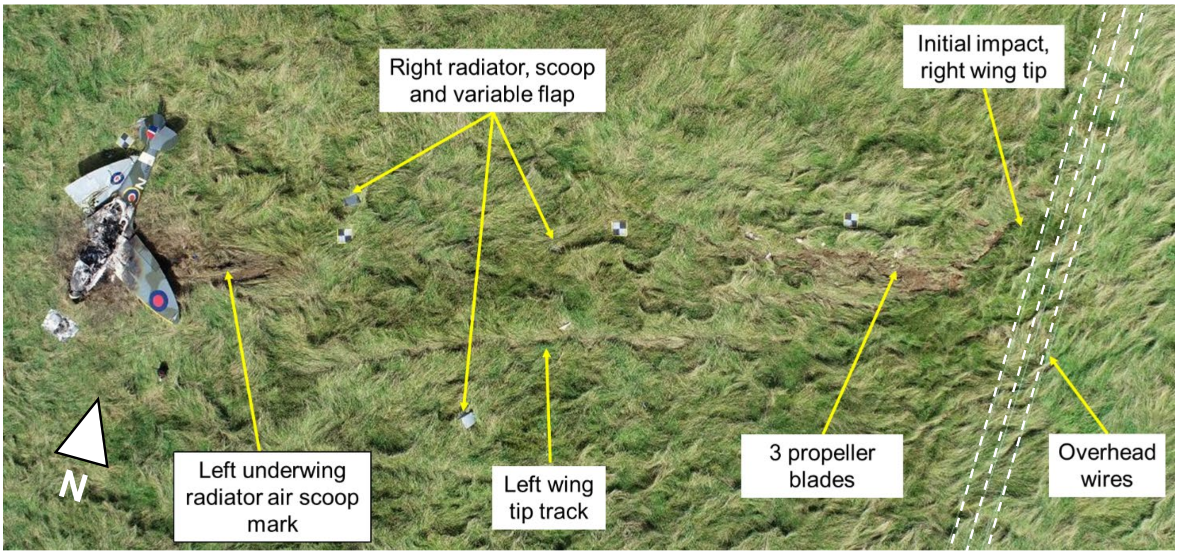

Figure 1

Accident sight overview

Recorded information

Sources of information

The aircraft was fitted with a PilotAware® system[2] and an engine control unit. Any recordings that may have been stored on these items, or any personal devices, were lost in the post-accident fire.

The aircraft was fitted with a transponder but there was no secondary radar detection of the aircraft. There was also no track recorded by the ground network associated with the electronic conspicuity device. The flight was detected and recorded by NATS primary radar. This provided the approximate flight path over ground when the aircraft was high enough to be in view of the radar installations but does not provide altitude information (Figure 2).

CCTV cameras installed at the airfield recorded the taxi and part of the takeoff of the aircraft. Part of the takeoff was also recorded from the ground on a personal electronic device. The takeoff appeared normal to those who were familiar with the aircraft.

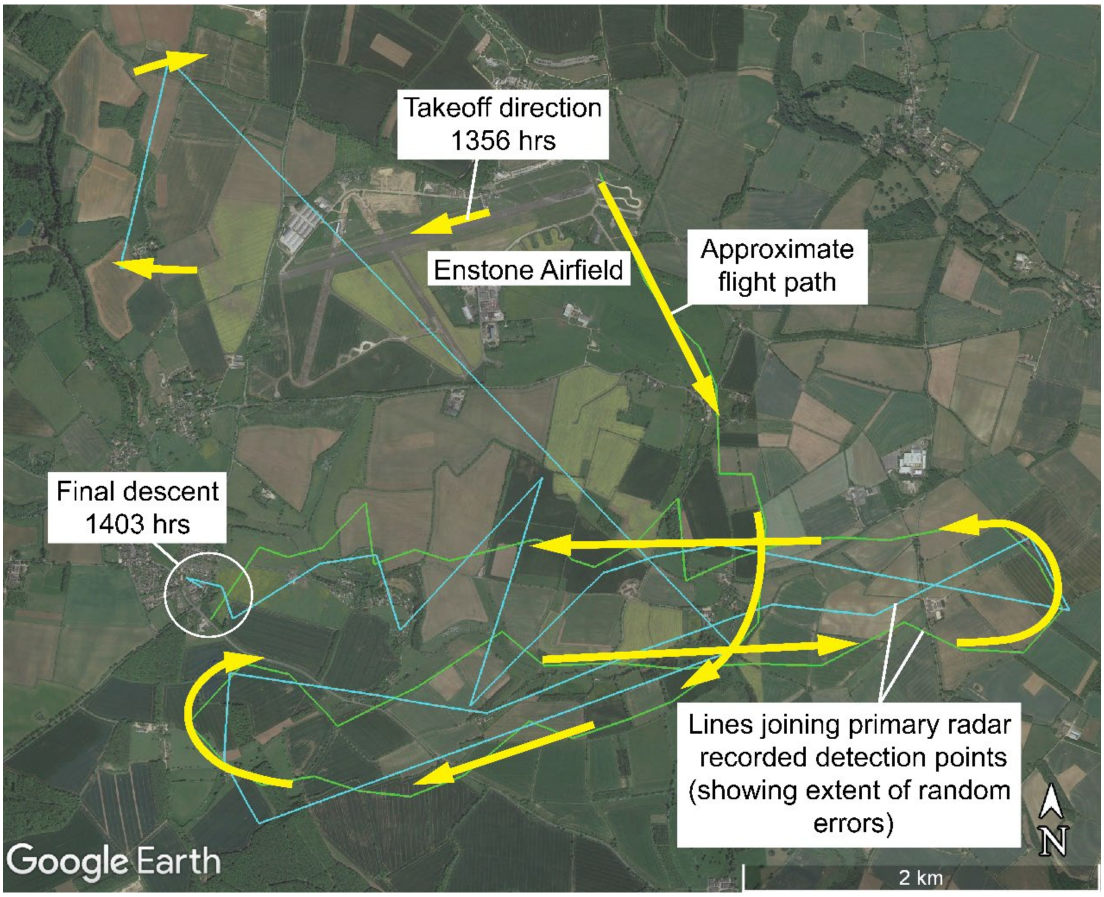

Figure 2

Approximate flight path

Footnote

[2] Pilot Aware® is a commercially available self-contained interoperable conspicuity and warning device fitted to aircraft to enhance airspace safety. It has the capability to receive Mod-S, Mode-C and ADS-B and can up and downlink relevant data to and from ground stations.

CCTV Analysis

A south facing airfield CCTV camera recorded the last part of the final descent from approximately 2 km away. It did not show the aircraft at the entry to the descent which witnesses reported as being between 3,000 to 4,000 ft. Figure 3 shows a compounded image of the aircraft every 0.2 seconds extracted from a version of the recording that has been corrected for lens distortion and perspective. The aircraft size in the image is small compared to the image pixel size; however, rotation during the descent is still visible. The CCTV captured the descent which was generally from west to east ending with a flight path with an increasing component to the west. Combining the CCTV with the location of the accident site itself and the approximate ground track provided by the primary radar recording enabled calculation of the aircraft altitude profile. The derived data is shown in Figure 3. The errors associated with the calculations are shown as error bars. These are larger at high altitude due to distance uncertainty, but the resultant descent rate data is less sensitive to these errors.

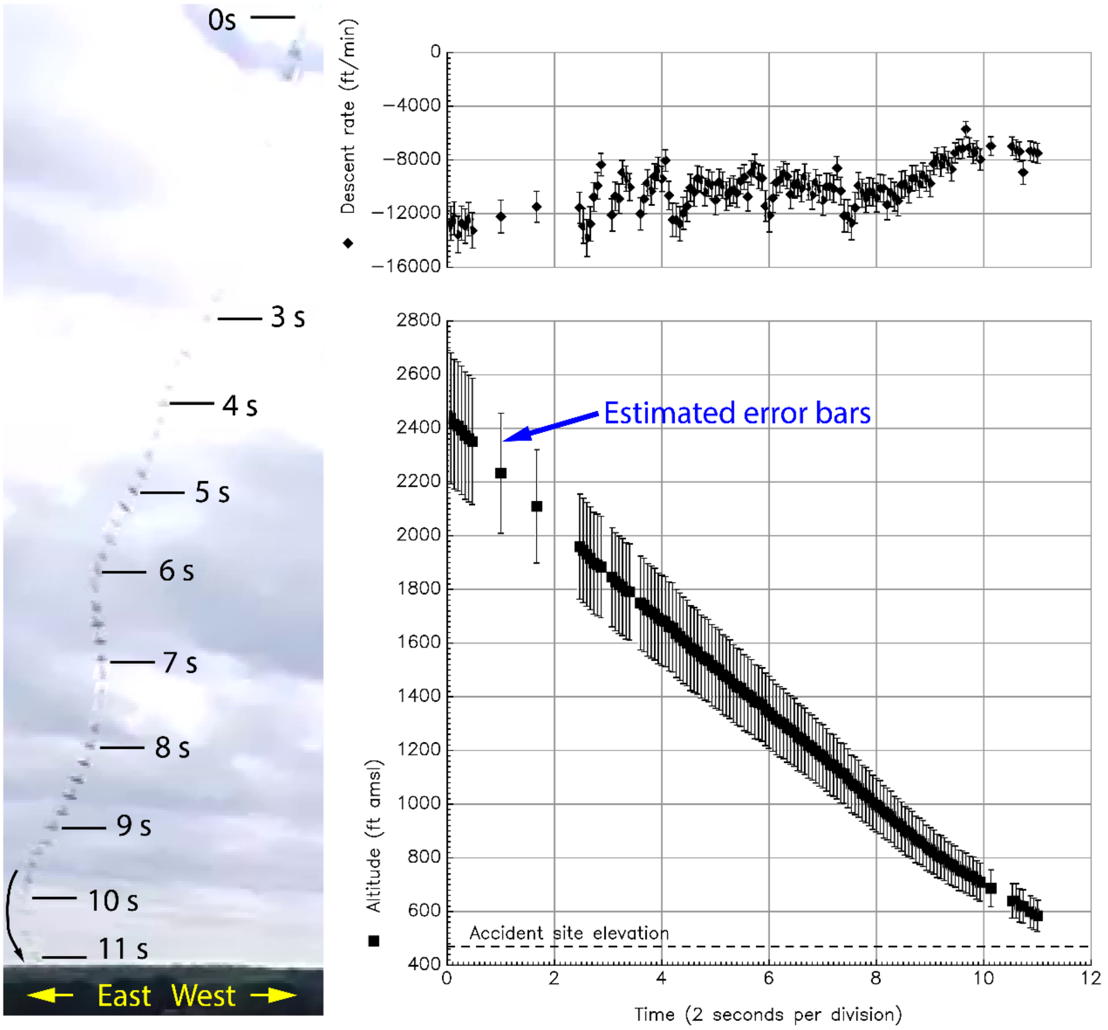

Figure 3

Compound undistorted CCTV image and analysis of the final descent

The aircraft was not visible in the CCTV recording when it was in front of a relatively bright area of the sky during the initial part of the captured portion of the descent. However, the available data points indicate that the flight path appears relatively consistent for approximately the first five seconds of the captured part of the descent. The shape of the descent during the final three seconds indicates a reduced descent rate. The final second of the captured descent indicated an increasingly westerly component to the direction of travel. The aircraft was not in view of the camera for approximately the last 100 ft of the descent.

Aircraft description

The Spitfire Mk 26B[3] is a kit-built scale replica based on the original Spitfire. The aircraft is supplied as a kit from a US based manufacturer. The aircraft structure is assembled by riveting aluminium alloy skins onto pre-formed frames, ribs and longerons. The wing form and empennage, other than overall dimensions, mirror the original Spitfire types. The completed aircraft is shown at Figure 4.

Figure 4

G-CLHJ undergoing engine runs (used with permission)

The flying control system on G-CLHJ was mechanical, using push-pull rods, bell cranks and levers to move the aileron, flap and elevator control surfaces. A trim tab was fitted to the right elevator which is set via a lever and Bowden cable mechanism. The rudder control system consisted of multistrand steel cables running from the rudder along the left and right side of the fuselage to the rudder pedals in the cockpit. A second cable was connected from the rudder pedals through pulleys on the left and right side of the footwell to form a continuous loop of cable to synchronise the rudder pedals (Figure 5). These pulleys were mounted on a steel pulley mounting plate which had holes drilled along its length to engage

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Footnote

[3] The manufacturer introduced a series of scale replica Spitfires identified by their Mark (Mk). The Mk 25 was a 75% scale single seat aircraft. The Mk 26 was a 80% scale replica twin seat and the Mk 26B was a 90% scale replica twin seat. The MK 26 and 26B fuselage dimensions differ from the Mk 25 but retain the 75% scale wing form.

on a pin, pivot and locking pin assembly to allow the rudder pedal position to be adjusted. Simple guide pins were located beside the outer edge of each pulley to prevent the cable derailing in use.

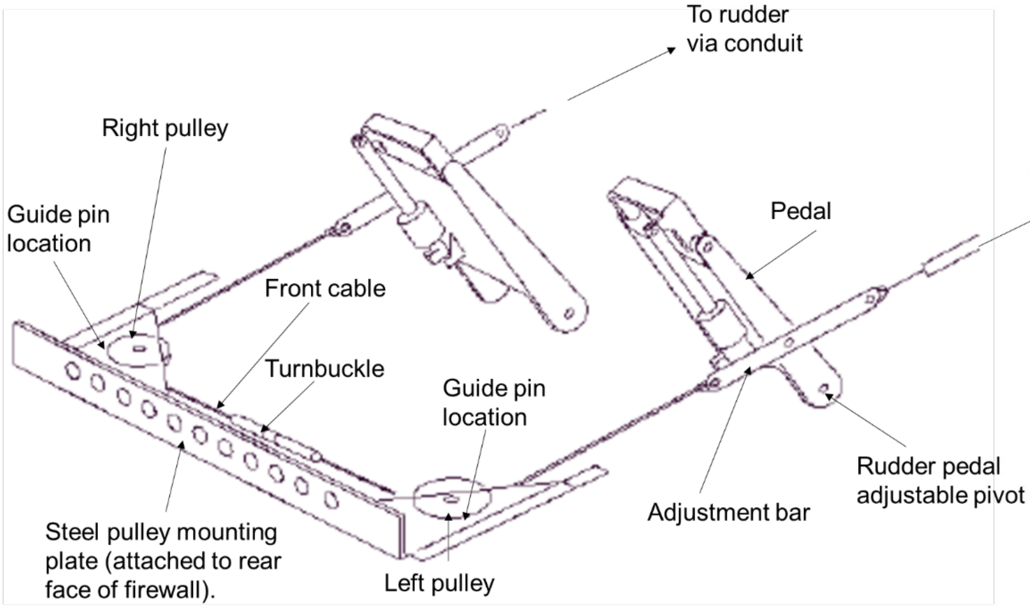

Figure 5

Rudder pedal and cable assembly (schematic)

This aircraft was powered by an Isuzu V6[4] fuel injected, normally aspirated, piston engine driving a three blade variable pitch propeller. The engine was water cooled with a radiator mounted under each wing. An oil cooler was positioned within a scoop on the lower engine cowl.

The aircraft was originally fitted with an electric tab stall warning system on the left wing. This had been removed and the system disabled because it had been incorrectly positioned on the wing leading edge and therefore at the time of the accident flight the aircraft did not have a functioning artificial stall warning system. The cockpit was fitted with modern analogue primary and secondary instruments. In addition, there were several avionic devices which included a digital LCD engine and electrical power monitoring display, and digital radio and transponder.

Footnote

[4] Other engine variants and types can be fitted to the Spitfire Mk 25, Mk 26 and Mk 26B depending on the customer's choice.

Aircraft history

Construction of the aircraft by a small team began in 2013. G-CLHJ was constructed under the LAA regulations. The build had been finished in 2019 but the project was delayed by the Covid19 pandemic. After the satisfactory completion of the necessary LAA airworthiness inspections, the aircraft was given a Certificate of Clearance[5]. This allowed it to be flown by a test pilot nominated by the owners, who was accepted by LAA as being suitably competent and experienced to do so, on a flight test programme to enable the issue of a Permit to Fly.

Flight test programme

During the flight test programme several issues had been encountered which required rectifications, modifications and adjustments. Following each flight the test pilot produced a comprehensive report with clear recommendations and solutions for each issue as they arose. Rectification work and adjustment were comprehensively recorded on sequential work cards which included the signatures of the individuals carrying out the work.

From the second test flight, the pilot reported a marked tendency for the aircraft to roll to the right, to the extent that the aircraft could not be flown hands-off and required a constant left aileron input. To correct this roll, the team made several incremental adjustments to the aileron and flap control rods. These adjustments gradually improved the handling of the aircraft although they were not sufficient to fully resolve the issue. The decision was made to fit a narrow expanded foam wedge on the underside trailing edge of the left aileron.

After the 13th test flight, the pilot reported that the tendency to roll to the right had been resolved to his satisfaction. He carried out clean stall tests and found the aircraft tended to rapidly drop its right wing, and he recommended that stall strips should be fitted. The purpose of the strips are twofold; they provide a means of warning to the pilot by increasing buffet as the wing approaches the stall and by fitting them to the inboard leading edge they can promote the wing root to stall first, reducing the risk of the outboard wing stalling first which can cause a wing drop leading to a spin or spiral dive. For kit-built aircraft the positioning and final fitment of stall strips may form part of flight testing before the approval of a Permit to Fly.

The stall strips consisted of short lengths of angled aluminium alloy fitted to the wing leading edge. During the test flights, the strips were held in place by duct tape, which allowed them to be easily moved following each flight. The team examined the position of the stall strips fitted to the other Spitfire Mk 26B at Enstone and initially attached the strips on G-CLHJ in the same position.

Footnote

[5] Certificates of Clearance are issued by LAA in accordance with BCAR Section A8-9 following inspection and evaluation of an aircraft, to authorise it to be flown under test conditions in preparation for the issue of a Permit to Fly. They are valid for three months at a time and a record is kept of the progress, test results and adjustments.

Although the next few flights were planned to explore the stall characteristics of the aircraft with the strips fitted, the aircraft experienced a number of engine coolant issues which resulted in an engine-off emergency landing back at the airfield on the 15th flight. The engine faults were caused by a warped cylinder head. It was nearly four months before flying resumed with the 16th flight to check the engine operation was normal.

The aircraft was flown on its 17th flight on 25 May 2023 and the pilot again reported a right wing drop in the stall at around 45 kt to 50 kt. Two more flights were carried out on 7 July 2023 and the pilot reported that the aircraft stall characteristics were not so good with the aircraft dropping its right wing with gear and flaps down at 50 kt to 55 kt. The pilot recommended moving both stall strips a few millimetres lower. The stall strip positions were datum marked with a permanent marker pen in line with the top of the aluminium angle and were moved downwards.

The aircraft was being flown on its 20th flight on 22 August 2023, and whilst conducting further stall testing departed from controlled flight.

Aircraft examination

An initial examination of the aircraft was carried out at the accident site with further, more detailed, examinations carried out at the AAIB.

General examination

An intense fire had taken hold in the cockpit and nose section of the aircraft rendering the majority of light alloy, plastic and composite parts unrecognisable. The main spar on the left side had bent rearwards by 30° and the outer section of the wing had twisted upside down and was only attached by a flying control rod. The right wingtip was severely distorted, and the majority of its attachment rivets were missing. Compression damage and buckling was present over the entire surface of the right wing.

The outer sections of both wings, rear fuselage and empennage had not been damaged by fire but had sustained impact damage during the accident. Flying control continuity checks were carried out. Despite the disruption, continuity could be demonstrated in all axes with the damage to various components within the systems directly attributable to the impact sequence and fire. The flaps were fully up, and the landing gear was fully retracted within the left and right wings.

Stall strips

The stall strip fitted to the leading edge of the right wing was still in place (Figure 6) although there was distortion on its surrounding structure. The stall strip that had been fitted to the left wing was found lying beneath the wing at the accident site. The leading edge section to which it had been attached was melted and burnt through and there was no duct tape present. Therefore, the left wing stall strip position on the wing could not be accurately determined. Both stall strips were 24.5 cm in length.

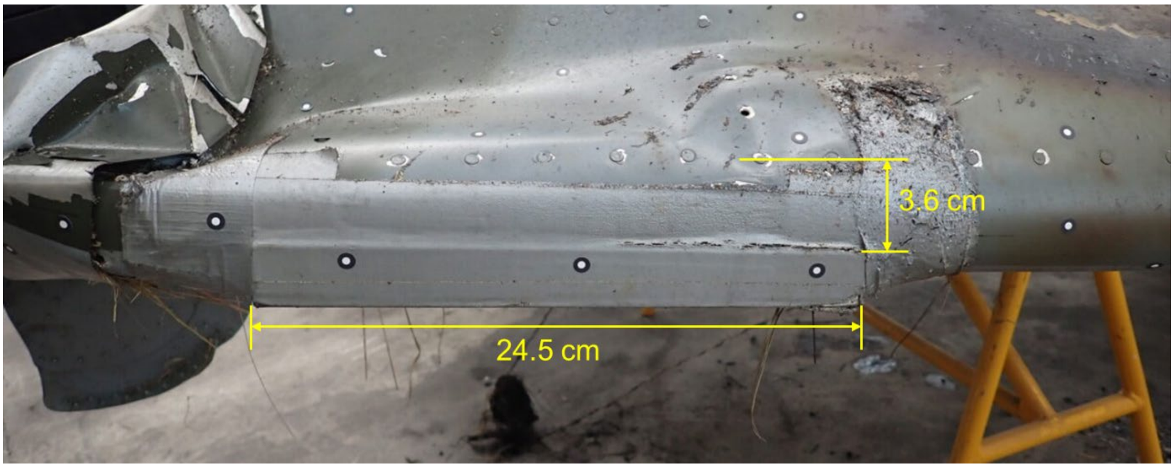

Figure 6

Stall strip fitted to the right wing leading edge

Pictures taken of the aircraft when the stall strips were initially fitted were compared to the current location of the remaining stall strip. Despite the damage to the wing around the stall strip, reference points were established between the before and after pictures which showed that the stall strip had been moved down a few millimetres as requested by the pilot.

Left aileron wedge

Remains of the duct tape attached to the left aileron trailing edge were present with signs of heat degradation of the tape surface. The foam wedge piece or remains of any material identified as such were not found. (Figure 7)

Figure 7

Remains of duct tape on the lower surface of the left aileron

Fin and rudder

A visual examination of the fin and tailplane found the leading edge of the fin appeared to have a significant misalignment to the left. Precision measurements along with laser alignment checks found the fin and rudder were misaligned 4.4° to the left of the aircraft centre line (Figure 8). Removal of the left and right fin root fairings confirmed this and revealed the position of the fin relative to the centre line of its support frame. The left and right tailplane inboard rib measurements show the base of the fin, where it attaches to the fuselage, was misaligned 5 mm to the left of the centre line. Detailed examination of the structure around this area and the fin root fairings found no evidence that the misalignment was because of the impact sequence.

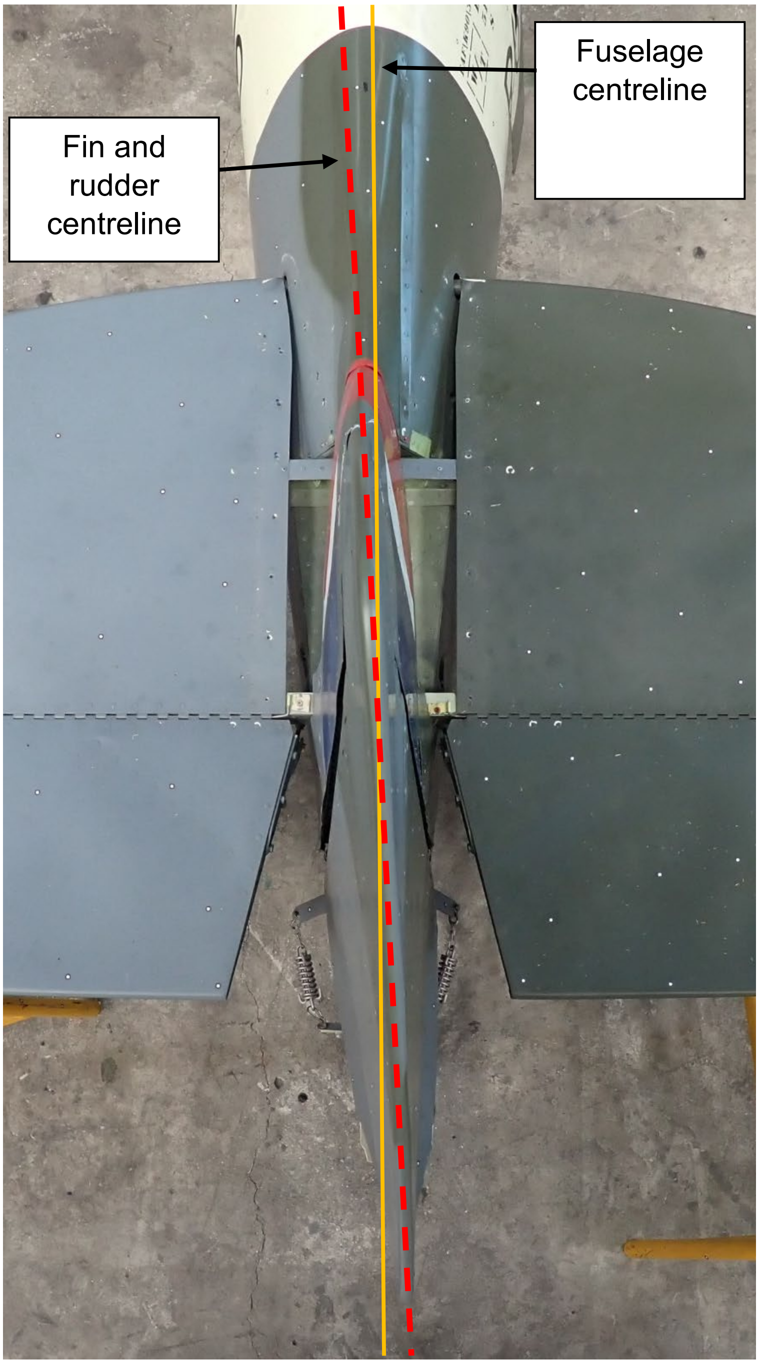

Figure 8

Fin and rudder misalignment from above with the rudder horn aligned with the fin leading edge

Controls

The rudder pedals and adjustment components within the cockpit were partially destroyed in the fire. The steel rudder cables and turnbuckles were generally intact and there was continuity between the ends of each cable. By manually operating the ends of the cables, it was possible to establish that the rudder had a full range of movement and operated in the correct sense.

There have been occurrences on the aircraft type of the rudder cable loop derailing from the pulleys if both rudder pedals are pushed hard at the same time. This can lead to restricted movement. The rudder cable and pulley system were disassembled and examined. Although the pulleys were destroyed in the fire, close examination of the pulley mounting plates and the cables found no evidence of chafing, rubbing, or jamming.

Other examples of the aircraft type were examined and the possibility of a loose item affecting the rudder controls, was considered. Although there is clear space above and around the front of the rudder pedals, the design of the cockpit would make it difficult for a loose object to migrate to this area. The rudder pedal side mechanisms are close to the fuselage inner skin and it is possible that a foreign object could lodge between them.

Due to the damage to the aircraft, the possibility that the rudder controls had been jammed by a foreign object could not be excluded.

Construction of the aircraft

While the aircraft is supplied as ready-to-assemble with parts supplied pre-shaped and pilot drilled, during the construction many of the structural parts required significant rework and alteration. In some cases, this was due to permitted tolerances, and in others, it may have been due to fabrication errors. There is the possibility that as multiple parts are assembled, where these problems exist, a significant non-conformity may go unnoticed. The problems encountered in this aircraft were not dissimilar to those experienced by other builders of this kit. The team took numerous pictures during construction and held regular meetings to discuss and address the problems.

The construction team were aware that there was a slight misalignment in the fin and rudder which was only noticeable when attention was drawn to it. However, the frame and tailplane attachment features presented no difficulties during assembly and fitted together neatly. As the fin assembly was an integral part of the assembly it was assumed that the misalignment was a correct feature of the aircraft. The team inferred that the misalignment was a deliberate feature to offset the propwash yaw effect, but the design of the kit already featured offset engine mounts to deal with this.

The LAA is responsible for inspection and approval of this aircraft type. An LAA examination of the aircraft after the accident lead to the consideration of additional potential difficulties in constructing the Spitfire Mk 26 series aircraft. With several ongoing projects in the UK, the LAA took action by issuing an MTD:

> The LAA issued Mandatory Technical Directive MTD-01-2024 on 13 February 2024 applicable to all Spitfire Mk 26 and Mk26b aircraft. The MTD required geometry and symmetry checks to be carried out to ensure correct alignment of fin assembly and rigging of rudder with comprehensive illustrated instructions how to achieve the checks.

Weight and balance

The aircraft was within both the maximum takeoff weight and the centre of gravity envelope for the flight. For each test flight the weight and balance of the aircraft was the same as previous flights to allow for consistent handling.

Final manoeuvre

Witnesses described the aircraft as entering a ‘spin’ or ‘rotating’ to the right from the third stall. When an aircraft stalls asymmetrically one wing will drop before the other. The dropping wing has an increasing angle of attack and drag. This increase in angle of attack and drag increases any yaw creating a rotation which can continue into a fully developed spin. In a spin an aircraft is rotating about a helical axis and is rolling, pitching and yawing with a very low and stable speed and a high rate of descent. The pitch of the nose will depend on the aircraft characteristics.

To recover from the spin the pilot should close the throttle, apply full opposite rudder to the direction of rotation whilst centralising the ailerons and unstalling the wings by progressively pushing forward on the stick until the rotation stops. The aircraft can then be recovered from the resulting dive.

It is also possible that when a wing drops in a stall, it may then become unstalled and the aircraft may enter a spiral dive. In this condition the aircraft speed will increase rapidly, the rotation will tend to be slower than in a spin but the rate of descent can be very high. In a spiral dive all the controls are effective although they may be heavy due to the high speed of the aircraft. To recover from a spiral dive the pilot must roll the wings level using co-ordinated ailerons and rudder before recovering from the dive.

Aircraft performance

The LAA stated in their Type Acceptance Data Sheet[6] for the Spitfire Mk 26 that:

> *‘The first two UK–built examples exhibited a significant wing drop at the stall and no pre-stall warning as first built. Both the wing drop and the lack of stall*

Footnote

[6] https://www.lightaircraftassociation.co.uk/infolibrary/24a9b2c1-92b4-4b77-ab9d-31c646d8ba91 [accessed October 2023]

> *warning were corrected on G-CCZP by fitting wing leading edge stall strips. Variation between wing leading edge profiles on individual aircraft is likely to cause differences in stall characteristics between individual aircraft'.*

The LAA did not approve the aircraft for aerobatics or spinning (Spitfire Mk 26 or 26B) and as such there was no requirement to test the spinning characteristics of the aircraft type. The Spitfire Mk 26B was only approved for a single pilot due to pitch instability with a rearwards centre of gravity.

All of the Supermarine replica spitfires are kit built and can therefore be significantly different in their performance and flying characteristics. These differences are the result of the 'hand built' nature of the aircraft. Other owners and builders of the Spitfire Mk 26 and 26B aircraft had found there was an inconsistency of some of the prefabricated parts of the aircraft. This has led to subtle, but generally acceptable, differences in finished aircraft. This was evident from the comparison between the two Spitfire Mk 26Bs at the airfield with the other showing much more benign characteristics in its stall testing compared to G-CLHJ.

Spinning the Spitfire Mk 25/26/26B

The investigation was unable to find details of spinning trials conducted on any of the scale replica Spitfires produced by the manufacturer, although owners and pilots outside the UK have spun their aircraft. Pilots who have spun the Spitfire Mk 26B state that entering an intentional spin is very easy either by letting the wing drop in a stall or by using rudder in a nose high attitude with low power. The spin was described as smooth, without hesitation in any axis and the recovery was very quick and controllable.

A report from the New Zealand[7] distributor of the replica Spitfire commented that:

> *'Spins conducted, clean aircraft, one and a half turns each. Entry, full rear stick, throttle closed, full in spin rudder, ailerons central. A/cs nose dropped after 1/2 rotation. Spin slightly faster to right and tending to increase rate when starting recovery. Yaw stopped instantly when opposite rudder applied. Aircraft normal safe recovery, speed builds quickly after roll and yaw stops.'*

Meteorology

The weather around Enstone was good. There was scattered cloud with a base of between 3,500 ft and 4,000 ft agl. Wind was from a west or south-westerly direction with a speed of around 8 kt. The temperature was 22°C.

Pilot

The pilot of G-CLHJ had been accepted by LAA as having suitable competence and experience for the required testing, with significant experience on tail wheel aircraft. He had also flown another Spitfire Mk 26B before undertaking the flying on G-CLHJ. The pilot had a PPL which contained valid class ratings for the flight and a Class 2 medical. He also held an aerobatic rating.

Footnote

[7] http://www.campbellaeroclassics.com/id80.html [accessed November 2023].

The pilot had suffered a myocardial infarction (also known as a heart attack) in 2005, aged 50 and there was significant history of heart disease. Since 2005, for Class 2 certification he was required to undergo regular exercise tolerance tests (stress ECGs) which look for ischaemia of the heart muscle with increasing workload. Since these were all negative, his incapacitation risk in the subsequent years was assessed as statistically less than 1%. This means his risk of a subsequent heart problem was the same as the general population, and he was able to hold a CAA Class 2 medical. His last exercise tolerance test was carried out in April 2023.

There was evidence from the post-mortem examination of the pilot's heart of the previous myocardial infarction, as well as long standing heart disease but the examination did not show any clear signs of a recent event. There was evidence of what was considered to be traumatic damage as a result of the accident. The pathologist did however comment that given the signs of significant coronary disease and the previous infarction: *'This could put the individual at risk of indeed [sic] sudden cardiac death potentially at any time.'*

During his flying career the pilot had regularly flown aerobatics and practised spin recoveries, but he had not done this recently. The pilot did regularly fly another light aircraft which had approval for aerobatics and intentional spins of up to three turns, but witnesses reported that he did not use the aircraft for this. The skills required for upset and spin recovery are perishable, and a lack of recency may mean a pilot does not react as quickly or instinctively to a spin as one who is in regular practise.

According to CAA Safety Sence Leaflet 30 – Loss of Control Spin & Stall Awareness, loss of control through stalling or entering a spin remains one of the leading causes of general aviation accidents.[8]

Survivability

The pilot was wearing flying overalls and a modern 'retro style' flying helmet. The aircraft was fitted with a four-point nylon web safety harness. The pilot was not wearing a parachute.

The aircraft struck the ground with considerable force, sufficient to bend the main spar of the wing. These forces were likely not survivable for the pilot. Evidence from the post-mortem indicated that the pilot had died before the fire began. The front seat harness, except for the steel buckles, and seat furnishings had been destroyed in the fire. The front seat buckles, although fire damaged, were in position within their clasp showing that the harness was correctly fastened. Examination of the seat frame showed the seat back frame and pan had shifted to the right and the seat back had collapsed downwards to a fully reclined position; this would have occurred during the impact sequence.

Footnote

[8] https://www.caa.co.uk/media/ajobzoaq/caa8230_safetysense_30-lossofcontrol_v10.pdf [accessed November 2023].

Human performance

Startle response

When a person encounters something that they are not expecting it can generate a startle response. This is a natural response of the brain to a significant stimulus. Whilst the processing of that stimulus within the brain may not be instantaneous, there is an area of the brain that can respond instantly with an aversive reflex. It is this 'instant response' whilst the processing of the stimulus is occurring that is the startle effect.

The United States Federal Aviation Administration talks about the startle response as being when pilots are *'faced with unexpected emergency situations*' and that such a response may delay a reaction from the pilot but may also lead to an incorrect response being triggered.[9]

All humans have a startle response but training and preparing can reduce the startle response time. This promotes a more timely and effective response to emergencies. Although the pilot had significant experience of both aerobatics and spinning, he was not in recent or regular practise.

Incapacitation

The CAA medical system aims to ensure that the risk of pilot incapacitation remains low. The risk does increase with age as it does with the general population. The pilot of G-CLHJ had a number of risk factors that might have raised his chance of incapacitation, although he was regularly assessed by his AME as part of his medical examination.

Incapacitation can be partial or complete but either case can prevent a pilot from operating an aircraft. Incapacitation as the aircraft was at or close to the stall might have prevented the pilot from recovering the aircraft, and once the aircraft had entered a spin or spiral dive, might have prevented or delayed recovery. Incapacitation can also vary in completeness over short periods of time.

Analysis

During a flight test towards obtaining a Permit to Fly, control of the aircraft was lost. The pilot was fatally injured when the aircraft struck the ground.

Aircraft construction and flying control systems

The aircraft had been constructed from a kit over several years, during which the build team followed the LAA guidance and principles on building and test flying home built aircraft. Numerous short comings with the kit had been addressed and overcome by the build team. Test flying started in 2021 and as it progressed the team made adjustments to correct the tendency for the aircraft to roll to the right. Although the fin misalignment was known about by the build team, it was assumed that the misalignment was a feature of the kit design. It was not considered as a possible cause of the tendency to roll to the right. A comparison of the tail with the other Spitfire Mk 26B aircraft at the airfield was never explored by the build team.

Footnote

[9] https://www.faa.gov/newsroom/safety-briefing/startle-response [accessed November 2023]

Despite the damage sustained during the accident there was no evidence of a malfunction or failure of any of the aircraft flying control systems. Whilst the layout and space around the rudder pedals and the cockpit floor would suggest that a loose article would be unlikely to cause a control restriction, the fire damage in the area around the controls meant any plastic or organic components in the vicinity were completely destroyed. Therefore, a control restriction cannot be completely ruled out.

Fin misalignment effect

The aircraft should not have had a fin misalignment. There is no mention of it in the kit construction manual and the fin is shown symmetrically on the fuselage centre line on the manufacturers drawing. Other Spitfire Mk 26 and Mk 26B aircraft do not have the fin misalignment and during the testing of those aircraft, there was no marked tendency for them to roll.

Despite the adjustments made to correct the roll, when the aircraft is approaching the stall and the effect of the ailerons is reduced, the fin misalignment may have had an effect by inducing a constant yaw causing the right wing to stall first and drop as reported by the pilot. In effect the misalignment fin and rudder created a pro-spin condition.

CCTV and witness evidence show the aircraft descending and rotating to the right. If it is considered that the aircraft was in a spin to the right and the standard corrective action was taken, the fin misalignment and full left rudder would have created a significant aerofoil camber and therefore aerodynamic force to counter the rotation. Therefore, had full left rudder been applied, the misalignment would have been more than sufficient to arrest the rotation. Although the fin misalignment was undesirable, it is not considered to be a causal factor in this accident.

Stall strips

Throughout the flight testing of G-CLHJ the pilot had conducted numerous stalls to ascertain the characteristics and stalling speed of the aircraft. In nearly all of these stalls the pilot reported a wing drop to the right. For the accident flight the stall strips had both been moved down a few millimetres. Both stall strips were located at the accident site, although one was no longer attached to the leading edge of the wing due to the fire.

The pilot conducted two stalls and recovered before the aircraft departed from controlled flight on the third stall. Given the pilot was familiar with the tendency of the aircraft to drop its right wing at the stall, and that he had completed two previous stalls during the flight in which the right wing was seen to drop, it would seem unlikely that he was startled by the aircraft behaviour on the third stall. The position of the stall strips did not seem to significantly change the behaviour of the aircraft compared to previous flights.

Flight manoeuvres

Witnesses observed the aircraft depart the airfield without incident. The pilot climbed to between 3,000 and 4,000 ft which was sufficient for the planned elements of the flight.

Although at some distance away they observed the aircraft undergoing stalls as planned. Immediately after the third stall the aircraft departed from controlled flight and descended. The observers considered the aircraft to have entered a spin.

Analysis of the CCTV would indicate that there was little change in the rate of descent or aircraft speed for most of the descent which would fit with the aircraft being in a spin. However, the steep nose-down attitude of the aircraft could be more indicative of a spiral dive. The distance of both the CCTV camera and the witnesses from the aircraft means that it is not possible to clearly identify whether it was a spin or spiral dive. However, the fact that two stalls appeared to have been carried out satisfactorily suggest the pilot was in full control and flying to the plan for the flight. Something appears to have gone wrong during or immediately after the third stall.

The pilot had suffered a heart attack some years previously and there was significant history of heart disease. Although the assessment of his heart condition for his Class 2 aviation medical indicated he was at a low risk of a cardiac event, the post-mortem found evidence of longstanding heart disease and scarring from the previous myocardial infarction. The pathologist suggested that a cardiac event leading to an incapacitation was possible at any time, but there was no definitive evidence that one occurred during the accident flight.

At some point during the third stall the pilot experienced an event which prevented him from immediately recovering from the stall and the aircraft entered into a spin or spiral dive. The CCTV indicates that for the initial period the flight path of the aircraft remained relatively constant which would indicate either no action or a lack of effective recovery action by the pilot. The pilot had extensive experience in aerobatics and spinning, however he was not in recent practice. Although the wing drop was familiar to the pilot, the subsequent departure from controlled flight possibly startled him leading to a delay in any recovery action. The CCTV analysis did indicate there was a change in flight path characteristics as the aircraft approached the ground which in the absence of other changes to the aircraft, could indicate some level of control input from the pilot. Evidence from the accident site would confirm this change in flight path as the aircraft struck the ground at a shallow pitch angle and did not make contact with the electricity cables running above the point where the aircraft initially struck the ground.

The cause of the loss of control following the third stall and the lack of complete recovery could not be established, but either startle, an incapacitation or a control restriction cannot be ruled out.

Conclusion

Control of the aircraft was lost during a test flight towards the grant of a Permit to Fly. Despite the damage sustained during the accident, there was no evidence of a malfunction or failure of any of the aircraft flying control systems. The aircraft was found to have been built with a misaligned fin and rudder. This misalignment made a wing drop at the stall more likely, but it did not prevent or restrict a recovery from the stall nor any subsequent spin or spiral dive that might develop. The pilot had conducted numerous stalls on the aircraft during its flight testing and was familiar with the wing drop in the aircraft and therefore it is unlikely that he was startled by the behaviour although the subsequent entry into a spin or spiral dive may have. There was sufficient height for a recovery from a spin or spiral dive.

Although the pilot's medical history indicated the possibility of an incapacitation this could not be confirmed by the pathologist. The prospect of a control restriction preventing a full recovery could also not be excluded due to the extensive fire damage to the aircraft.

Safety action

The LAA issued Mandatory Technical Directive MTD-01-2024 on 13 February 2024 applicable to all Spitfire Mk 26 and Mk26b aircraft. The MTD required geometry and symmetry checks to be carried out to ensure correct alignment of fin assembly and rigging of rudder with comprehensive illustrated instructions how to achieve the checks.

Published: 20 June 2024.

Accident

Aircraft Type and Registration:	Amateur-built balloon (DB-6R), G-CMFS	
No & Type of Engines:	1 Ultra Magic Mk 21 LPG twin burner	
Year of Manufacture:	2022	
Date & Time (UTC):	25 June 2023 at 0519 hrs	
Location:	Ombersley Court, Worcestershire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
Nature of Damage:	Balloon destroyed	
Commander's Licence:	Commercial Pilot's Licence (Balloon)	
Commander's Age:	25 years	
Commander's Flying Experience:	569 hours (of which 33 were on type) Last 90 days - 10 hours Last 28 days - 3 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The pilot was taking part in a balloon competition. One part of the competition involved dropping a marker as close as possible to a target location. The accident occurred whilst the balloon was climbing rapidly away from this target. The balloon envelope collapsed, and the basket descended to the ground, fatally injuring the pilot.

The investigation found the balloon was likely to have suffered a parachute stall[1]. The balloon design, the weather conditions, and the rapid climb are all likely to have contributed to the accident.

Three Safety Recommendations are made to the British Ballooning and Airship Club (BBAC) to: develop an effective reporting culture within the ballooning community; issue guidance on the prevention and recovery from unsafe conditions such as parachute stalls; and issue guidance regarding jettisoning of fuel tanks during an emergency. Two Safety Recommendations are made to the CAA to: publish guidance on the design, testing and inspection of amateur balloons insofar as these activities relate to unsafe conditions such as parachute stalls; and publish guidance related to the oversight of competition balloon flying.

Footnote

[1] An explanation of parachute stall is given in the section titled '*Parachute stall*'.

History of the flight

On the morning of Sunday 25 June G-CMFS was participating in a competition event, which was part of the British Grand Prix 2023 series. This was the second flight of the event; the first took place the day before. Four other balloons, G-DANJ, G-CLHS, G-LOKI and G-CLDJ, took part in the event. The launch site was Worcester Racecourse, with all the balloons launching just after 0500 hrs.

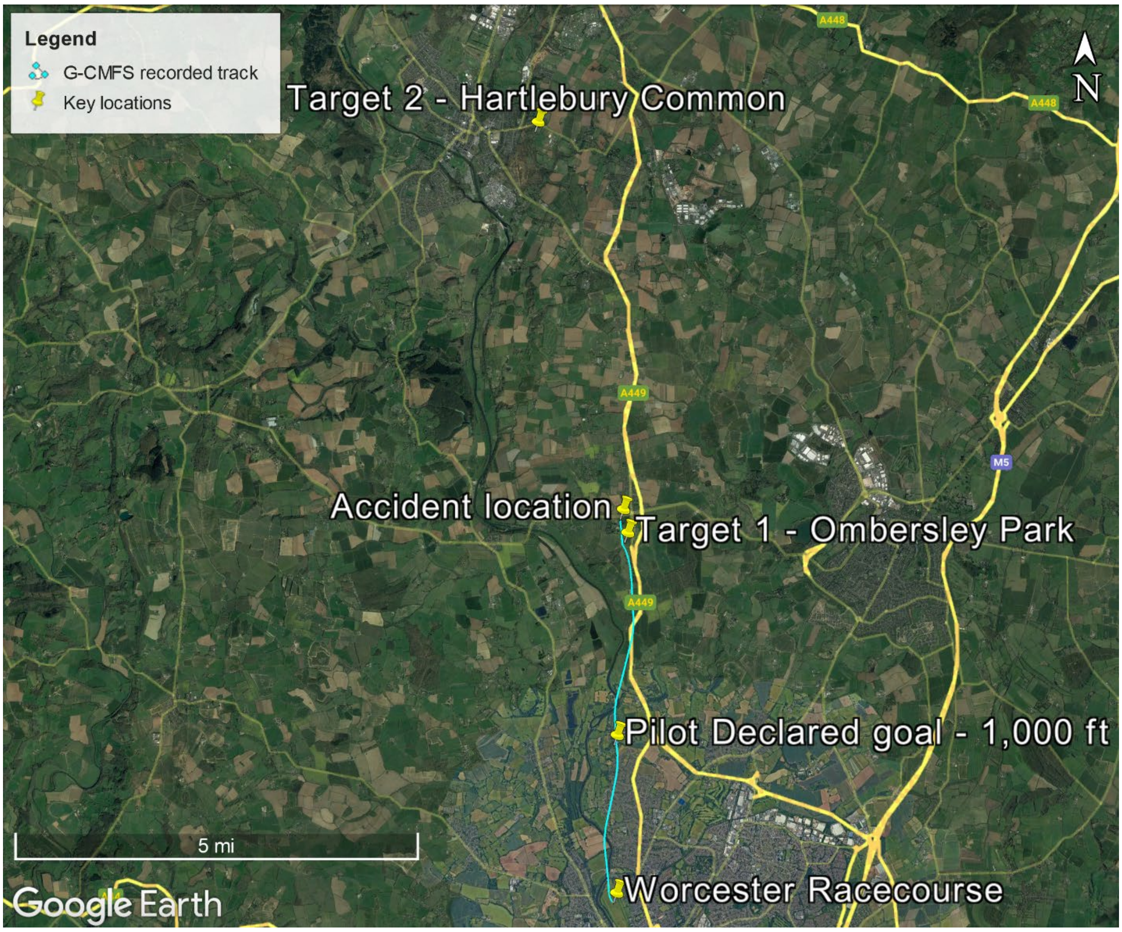

Figure 1

Launch, Accident and Target Locations

Figure 1 shows the three elements of the competition task along with the launch site and route flown:

- Task 1 - A ‘judge declared goal’ where the pilot was required to drop a marker as close as possible to a specified location; Ombersley Park.
- Task 2 - A ‘Gordon Bennett memorial’ which similarly required the pilot to drop a marker within a specified scoring area; Hartlebury Common.
- Task 3 - A ‘pilot declared goal’ where the pilot was required to nominate a position and altitude before takeoff and then try to fly to as close as possible to that point.

Figure 2 shows the balloons prior to launch. G-CLDJ was the first balloon to launch, followed between two and three minutes later by G-LOKI, G-CLHS, G-CMFS, and lastly G-DANJ. Figure 3 shows the balloons after the first three had launched. G-LOKI landed again at the launch site as the pilot had forgotten her markers, so was then behind G-CMFS.

G-CMFS launched at 0506 hrs and Figure 4 shows it just after launch (the balloon parachute can be seen correctly seated at the top of the envelope[2]). The three ground-crew that helped launch G-CMFS reported the launch was normal and that all pre-flight checks were completed successfully. They reported that everything looked fine during the launch.

G-LOKI's pilot stated that she was close enough to G-CMFS during the first part of the flight for them to talk and everything seemed normal. At 0611.05 hrs the accident pilot recorded his 'pilot declared goal' at an altitude of 1,253 ft amsl.

G-CLDJ was the first to reach the Ombersley Park area but missed the target so continued flying to the second location. He did not see any part of the accident.

Figure 2

Five balloons before launch (accident balloon is one in from the left)

Footnote

[2] The 'parachute' is described in detail in later sections.

Figure 3

G-DANJ and G-CMFS just before launch with the other three ahead

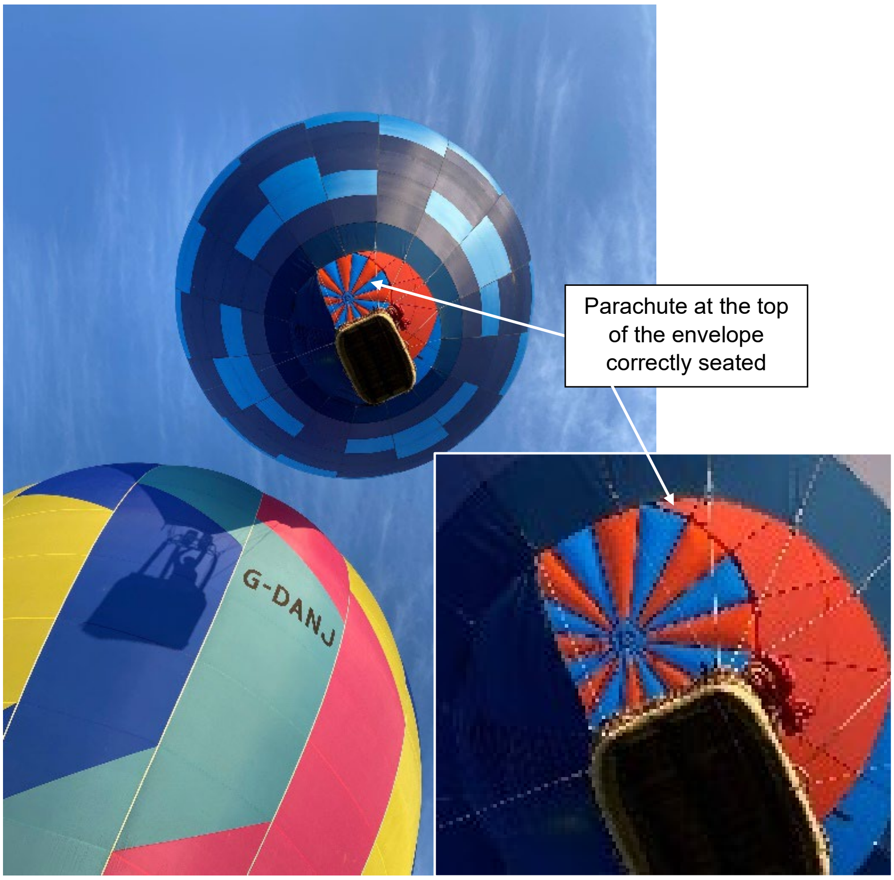

Figure 4

G-CMFS just after launch showing the parachute correctly seated

G-CMFS was the next balloon to approach the target. The pilot's electronic logger recorded that he dropped his marker at 0618:02 hrs at an altitude of 499 ft. The marker landed approximately 40 m from the target. G-CMFS was then seen to climb rapidly. G-LOKI and G-DANJ were close behind, followed by G-CLHS (which had flown at a lower altitude in slow wind so had taken longer to reach the target). Figure 5 was taken from G-CLHS as the balloons approached Ombersley Park.

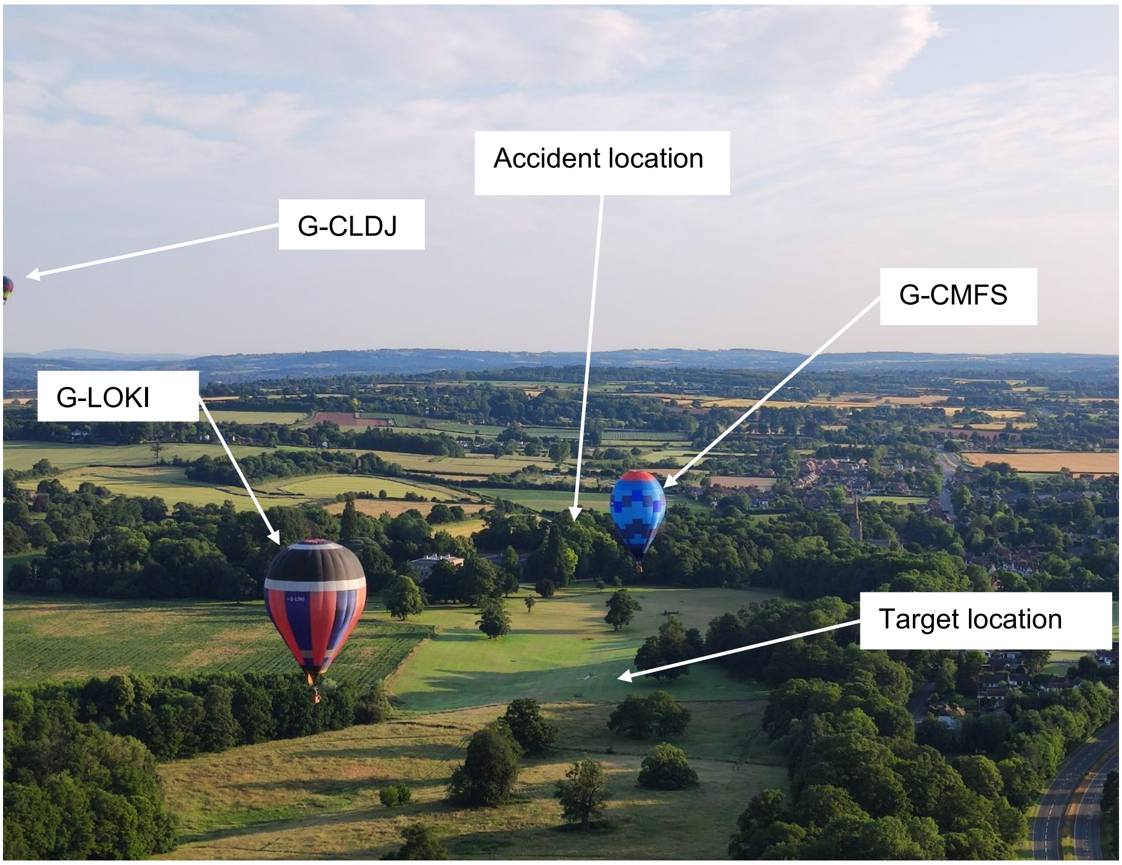

Figure 5

Balloons approaching the target at Ombersley Park (taken from G-CLHS)

G-CLHS's pilot recalled G-CMFS had just flown over the target and was climbing rapidly. He recalled seeing grey smoke coming from G-CMFS, although he stated this was not unusual and it just suggested the pilot was using the burner frequently and for long enough to cause the heat resistant material at the base of the balloon to singe. The next time he looked up he saw the balloon 'streamered' and descending rapidly (Figure 6).

G-LOKI's pilot reported seeing G-CMFS climbing fast, she also recalled seeing the smoke. She recalled that she then heard the sound of fabric "whipping", "the crack of fabric, like you might hear during inflation when the wind caught the balloon". This sound caused her to look up and she saw G-CMFS falling with the balloon streamered. She recalled just seeing burnt fabric streaming above the basket.

G-DANJ's pilot also recalled seeing the balloon envelope streamered and dropping to the ground.

Two scorers were on the ground at the target location and they filmed and photographed the balloons as they approached the target. The footage showed G-CMFS's pilot approaching the target then climbing away and dropping his marker. 46 seconds later, one of the scorers saw G-CMFS falling and, as they both looked around their camera captured the final moments of G-CMFS's descent. Figure 6 was extracted from the video.

Figure 6

G-CMFS descending to the ground with the balloon streamered

All three pilots landed; G-LOKI and G-DANJ in the next field, G-CLHS in the target field. Everyone present ran to the accident site. G-CLHS's pilot was the first pilot to reach the accident scene. He reported that the burner pilot lights were still lit when he arrived, so he switched them off and later turned off the gas cylinders and vented the supply lines. They administered CPR to the pilot until the emergency services arrived.

Witnesses

Several people saw the accident sequence and gave similar accounts of what happened. The witnesses all reported seeing G-CMFS climbing rapidly and then the balloon appearing to deflate and descend rapidly before striking the ground.

One couple at a petrol station on the A449 saw the balloons flying and took some photographs, which were all time-stamped at 0518 hrs (Figure 7). One of them commented that, within seconds of taking the second photo, "the blue one didn't look inflated properly, it looked like it did not have enough air in it". They described that one side of the balloon looked like it was pushed in at its widest part and "it looked like a half-moon shape". As this happened, they instantly saw the burner come on but described that "it caught the right side of the balloon" with "the flame on the outside of the balloon". They then saw the basket fall to the ground. They described seeing "just the basket" and what looked like "a long piece of string". They said it looked like "tissue paper or a shoelace with a thin flame and black smoke", "just a basket on its own dragging a piece of string".

Another witness also took some pictures from the A449 (Figure 8), all time stamped at 0518 hrs. A further witness on the A449 recalled that the burner was still burning during the descent, but there was no fire other than the flame from the burner. A witness, who was 150 – 200 m away from the eventual accident location, was watching G-CMFS as it ascended. He described hearing a "loud puff" and said it was like all the air suddenly disappeared from the balloon, "like the top had opened up" or "someone had lifted the lid on it". He said there was no fire or explosion.

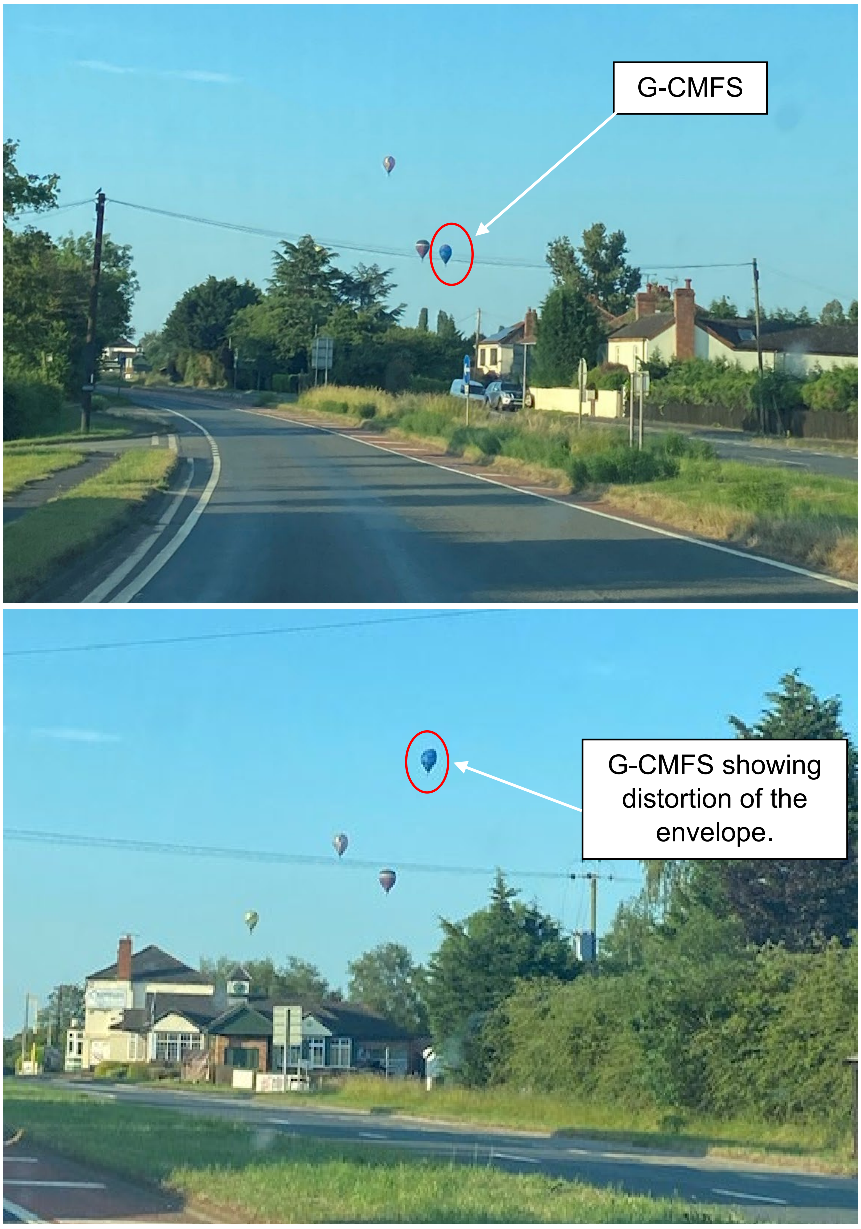

Figure 7

Photos taken by a witness on the A449 both taken at 0518 hrs

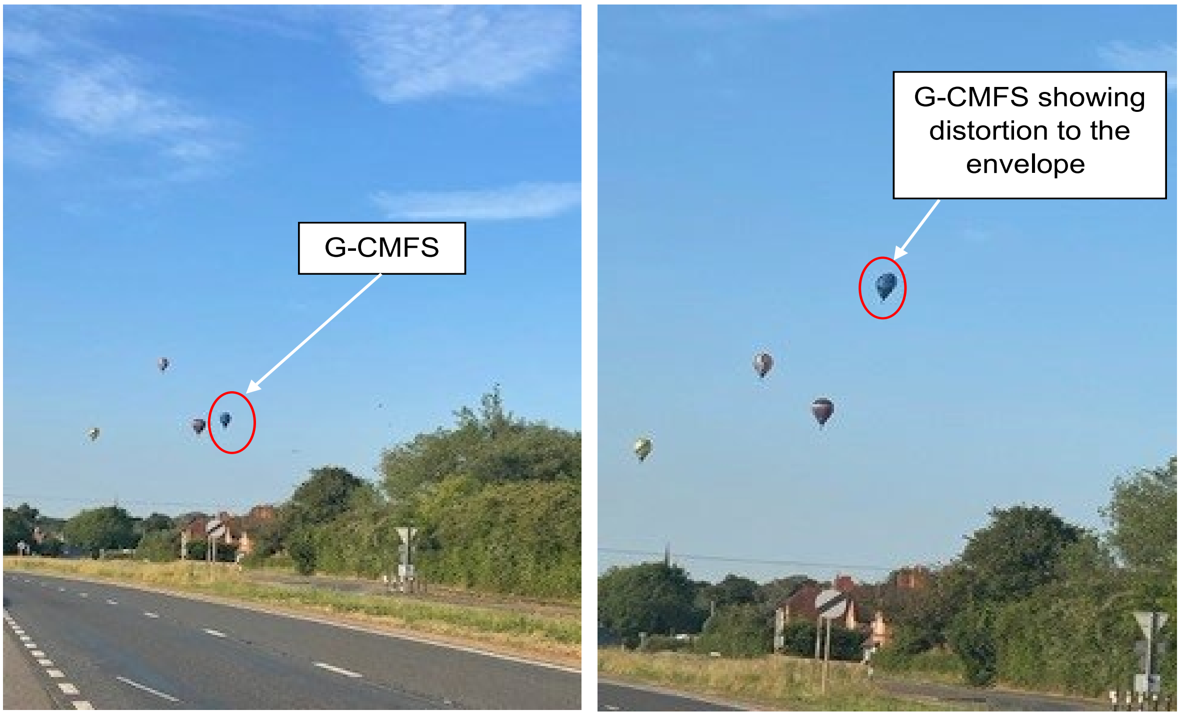

Figure 8

Sequence of photos taken by a witness on the A449 at 0518 hrs

Generic racing balloon design

Figure 9 shows some features of a generic racing balloon design to illustrate subsequent sub paragraph descriptions:

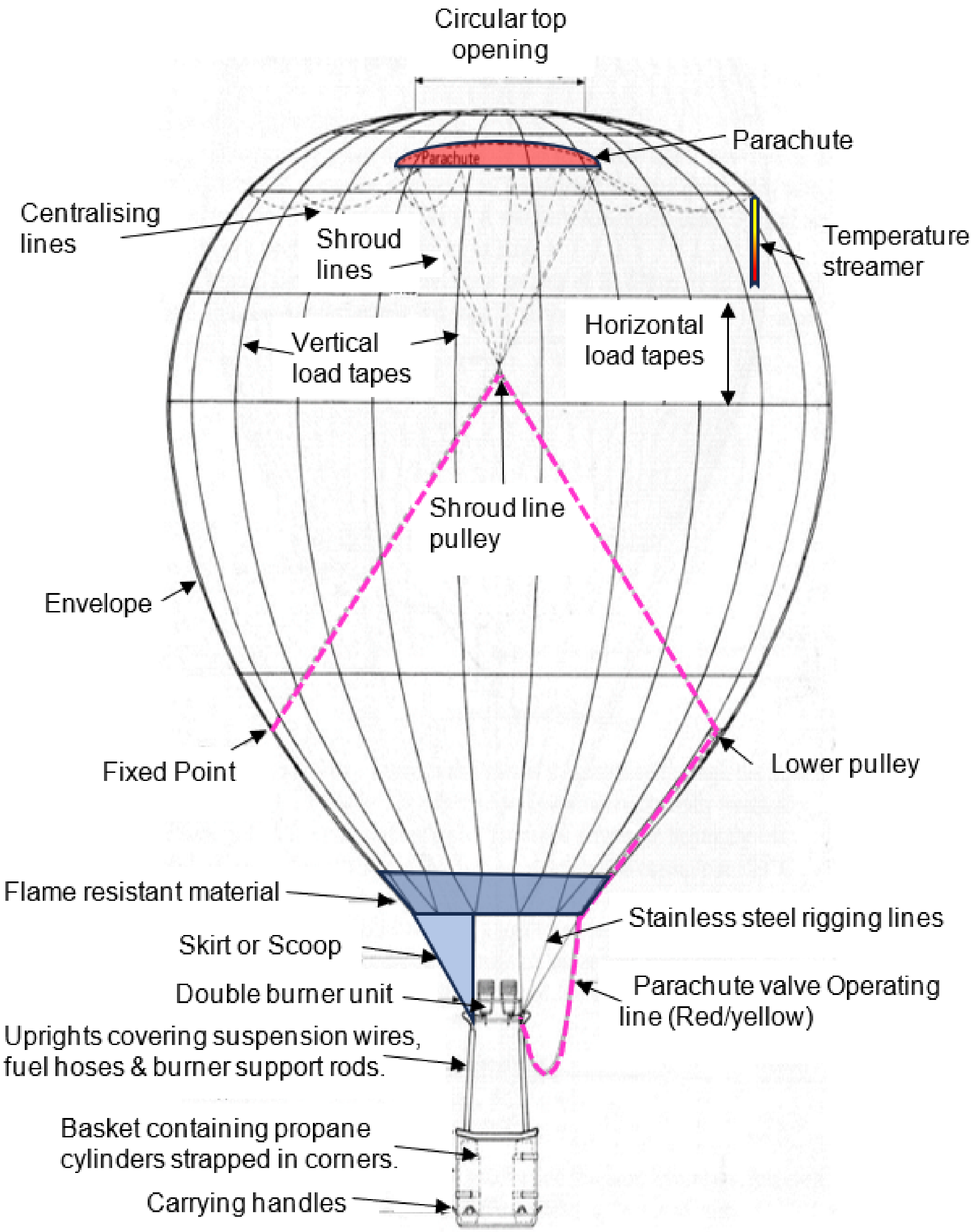

Figure 9

Basic features of a generic racing balloon showing internal rigging arrangements

Envelope

The hot air balloon envelope gives the balloon its well-known shape and provides the lifting force when inflated with warm air. The fabric used to create balloon envelopes must be light but resistant to tears and is generally made from materials such as ripstop nylon or Dacron polyester fabric[3]. The inlet or throat of the balloon and the skirt (or scoop) are

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Footnote

[3] Dacron is a strong, durable, abrasion resistant and moisture-wicking brand of polyester made by DuPont.

made from a fire-resistant material because they are very close to the heat and flames from the burners (See the *Burner* section below).

The simplest and most recognisable hot air balloon shape, often used by amateur builders, is a hemisphere on top of a truncated cone, referred to as a natural balloon shape. Specialized 'racing' balloon envelope shapes are generally slimmer to reduce aerodynamic drag in the vertical axis, which improves the rates of climb and descent.

During manufacture, the balloon envelope material is cut into panels and sewn together, along with vertical structural load tapes that carry the weight of the gondola or basket. Horizontal load tapes are also sewn into the inside of the envelope which maintain and strengthen its circumferential shape. The individual fabric sections, which extend from the throat to the crown (or top) of the envelope, are known as gores or gore sections. Envelopes usually have between four and twenty-four gores.

At the top of the envelope (the crown) is a circular opening (aperture). The aperture is vented and sealed by a vent device such as a parachute vent valve (see next section – *Parachute vent valve*). Balloons use a crown ring, which is a metal hoop, designed to attach the vertical load tapes to the centre of the envelope's aperture. The load tapes are then extended to the bottom of the envelope where they are sewn into loops and connected to stainless-steel rigging lines (one line per vertical load tape). Karabiners connect these rigging lines to the basket.

Parachute vent valve

The balloon's vent device is designed to enable the pilot to control the release of hot air through the aperture of the balloon to slow an ascent, start a descent, increase the rate of descent, or enable rapid deflation of the envelope on landing. Natural cooling of the hot air inside the envelope allows the balloon to descend at a slower rate than venting, so it is possible to descend without using the vent. The most common top vent valve is a disk-shaped layer of fabric called a 'parachute' vent. The parachute is connected around its edge to a set of shroud lines that converge below the centre of the fabric disk. (The arrangement of the fabric layer and shroud lines roughly resembles the shape of a parachute, hence the name). The edge of the parachute fabric is also connected to centralising lines which extended out to the edge of the envelope and are each fixed in place around the inside circumference. The centralising lines are designed to ensure the parachute remains within the vertical centreline of the envelope during operation. The converged parachute shroud lines are tied to a shroud line pulley through which a brightly coloured parachute operating line runs internally down, from a fixed point on the inside of the envelope, via a series of pulleys and into the basket.

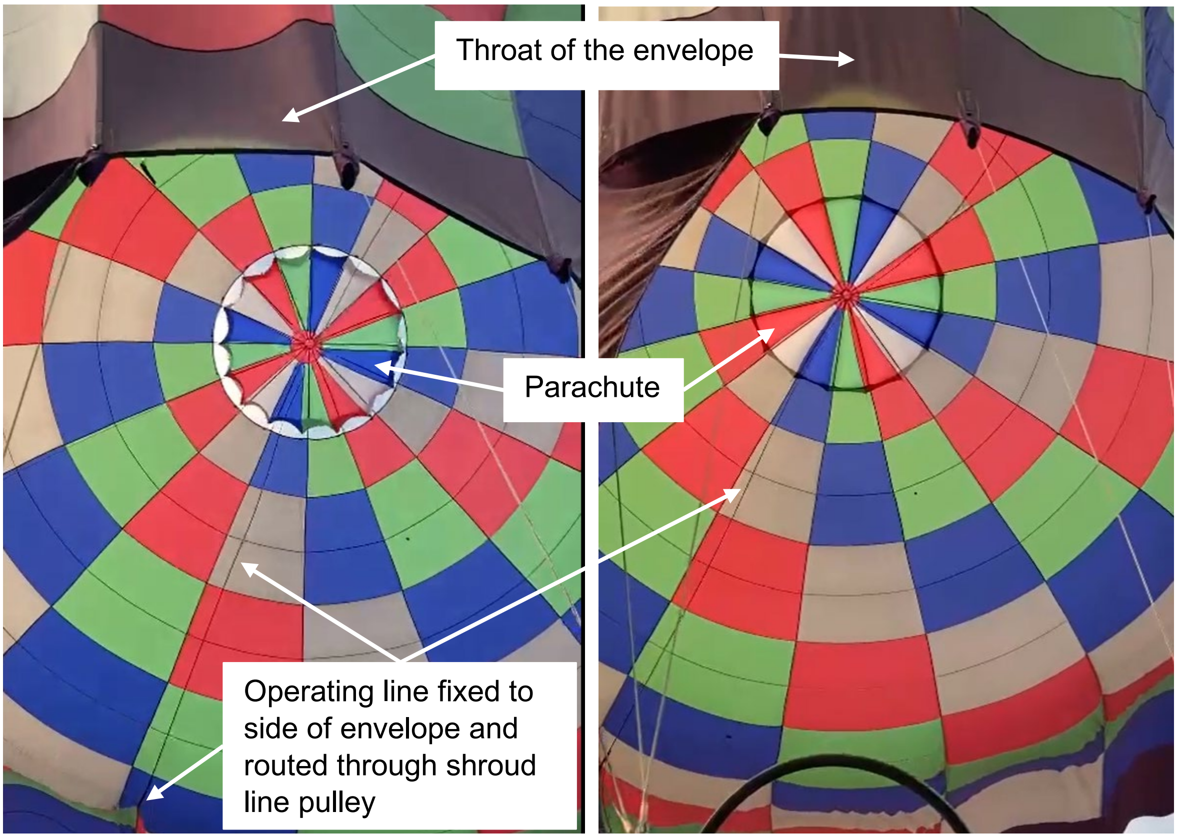


Figure 10

Looking up through the throat of a balloon of the same design as G-CMFS, showing the parachute valve open (left) and closed (right)

When the pilot pulls on the operating line, the parachute is forced down and away from the aperture in the crown of the envelope allowing air to vent. As hot air escapes through the gap between the parachute fabric and the aperture, the buoyancy of the balloon is reduced. Once the operating line is released, a pressure differential above and below the parachute valve sucks it back into place sealing the aperture again (Figure 10). The burners can also be used to send a stream or bubble of heated air upwards to assist the parachute to reseal.

Basket or gondola

Hanging below the envelope is a gondola or basket. In this example it's a wicker (or rattan) basket (Figure 11). The base of the basket is a wooden platform with runners attached to the bottom. The basket frame is attached to basket wires, which in turn are attached to the balloon envelope by the burner frame, karabiners and rigging lines.

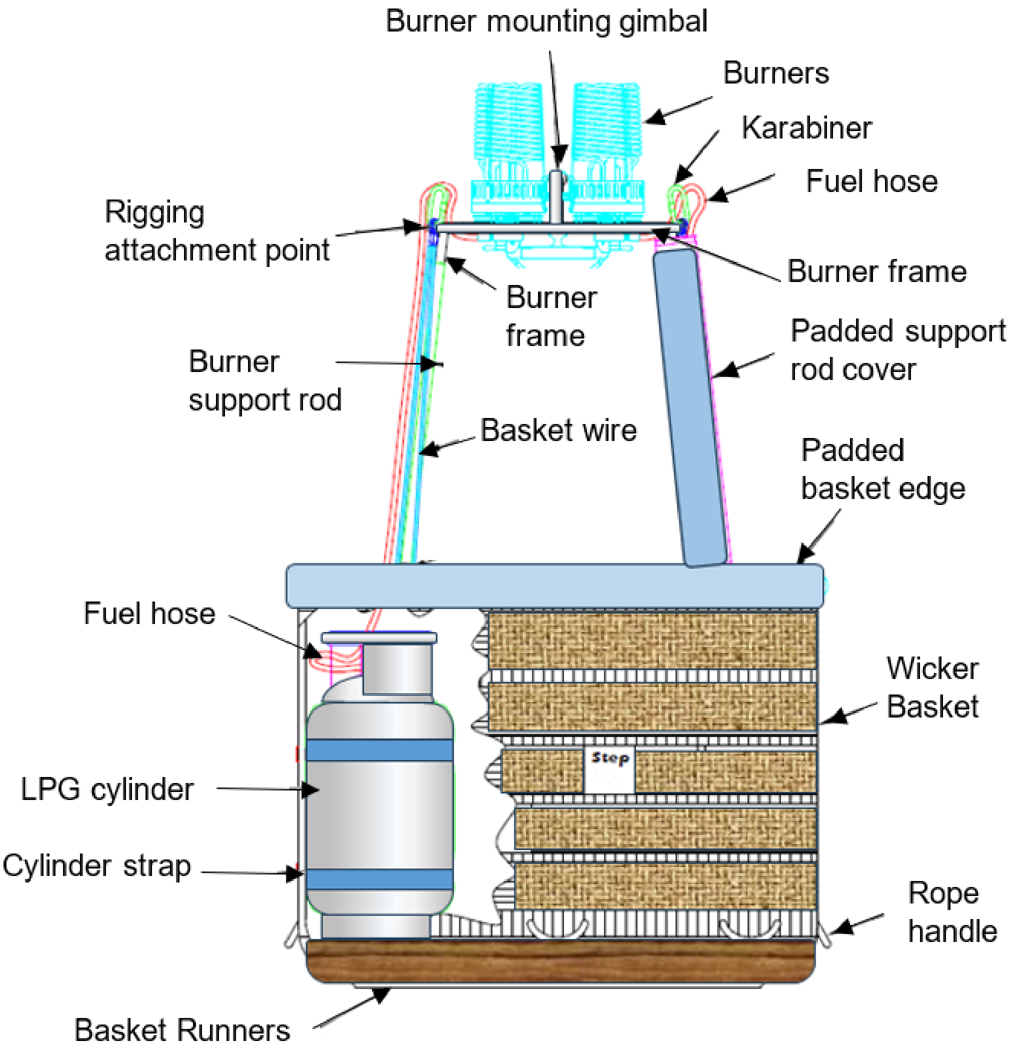


Figure 11

Basket layout showing basic features.

The basket houses cylinders containing liquid propane gas (LPG). These cylinders supply fuel to the burners which in turn produce hot air to inflate the balloon envelope and to adjust its buoyancy in flight.

Burners

In this example, two stainless steel LPG burners are mounted on a simple mechanical gimbal that is hinged on a burner frame above the basket (Figure 12). The burner frame is elevated above the basket by burner support rods. The gimbal frame allows the pilot some limited adjustment to the direction of the burners so the flames can be directed into the centre of the envelope as the throat flexes and moves during flight.

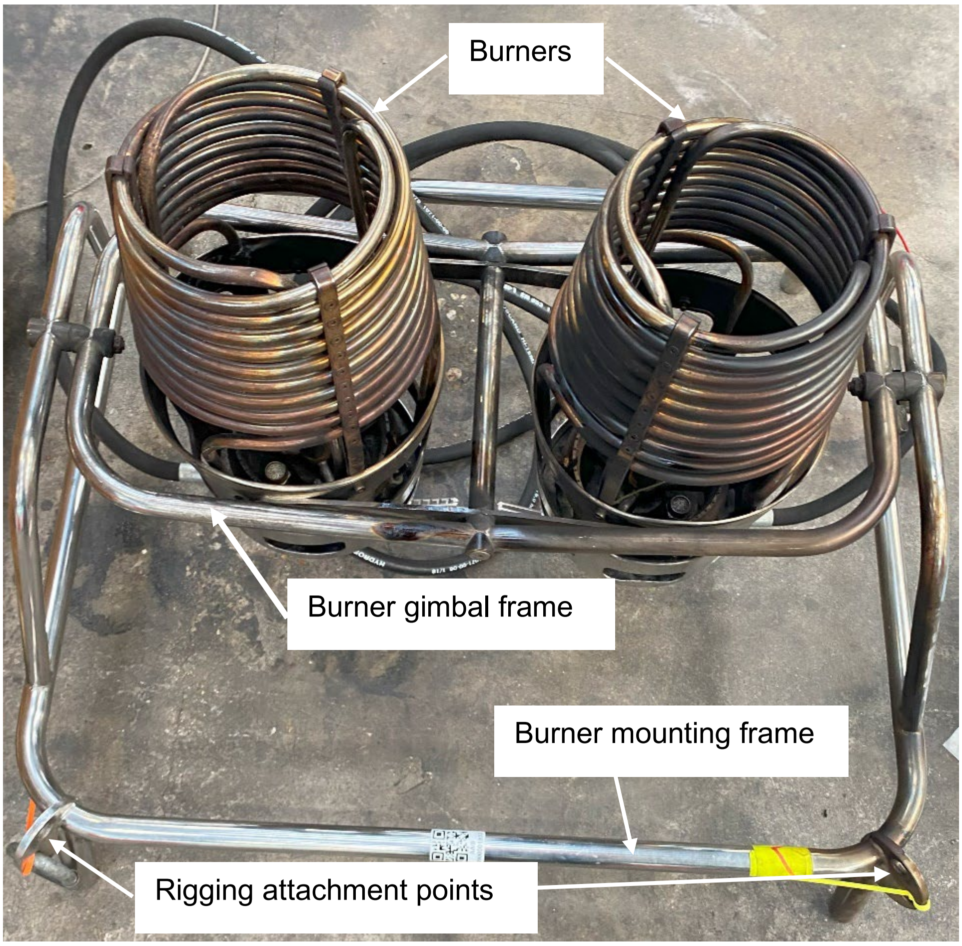


Figure 12

Twin burners mounted on a frame above the basket.

Liquid propane is fed into each burner’s vaporising coils and then into the combustion chamber, where it is mixed with air and ignited by a manually operated ignition switch. To control how long the flame burns, a manually operated ‘blast’ valve allows the pilot to substantially increase the flow of propane to produce a large flame. Burners are often fitted with ‘whisper’ valves that can be used instead of blast valves to avoid disturbing people or frightening livestock when flying over farmland. On average, burners produce approximately 400,000 BTUs (British Thermal Units) of heat.

Aircraft description

G-CMFS was an amateur-built racing balloon and was manufactured by the accident pilot from the DB-6R design plans. The balloon had a 16-gore envelope with a parachute aperture diameter of 4.4 m, throat diameter of 3.6 m and an envelope height of 18.8 m from the crown to the throat. The volume of the envelope was calculated to be 1,698 m^3. It was powered by an Ultra Magic Mk 21 LPG twin burner system mounted onto a wicker basket (Figure 12). The CAA registration G-CMFS was issued on 28 April 2022 and the balloon had its first test inflation at the Midlands Air Festival on 2 June 2022, although it wasn’t flown during this event. The first test flight occurred at the Cheltenham Festival on 19 June 2022.

The logbook for G-CMFS recorded the balloon had flown a total of 21 hours 40 minutes before the accident flight.

Accident site examination of the wreckage

The balloon's envelope was suspended vertically above the ground where it had snagged on the fractured remains of tree branches (Figure 13). Broken branches were scattered around the base of the tree with some landing on top of the balloon's basket.

Figure 13

Balloon envelope suspended by broken tree branches above the basket

The envelope appeared to have been torn by the sharp remains of the branches as it descended through the foliage. Further damage was caused to the envelope as the wind increased throughout the day and conditions became increasingly blustery, resulting in additional tearing as the material billowed in the turbulent air.

At the base of the tree, the balloon's basket was on its side with the burners still mounted to the basket by burner support rods. The rigging points and karabiners were intact and remained attached to their steel rigging lines. The charred remains of blue heat-resistant material were wrapped around the burners, rigging lines, and the bright orange and yellow fluorescent parachute operating line (Figure 14).

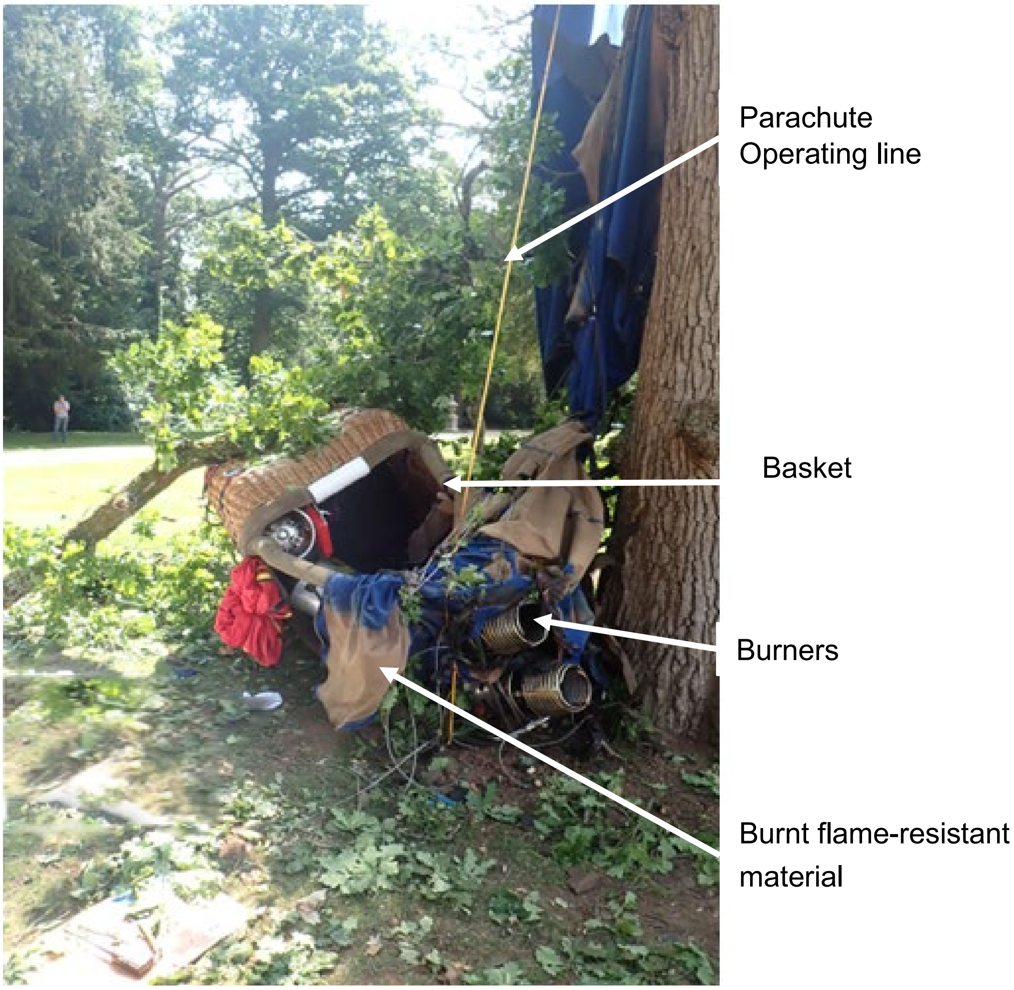


Figure 14

Basket on its side showing burners, operating line and burnt heat-resistant material

Inside the basket were two LPG cylinders used to provide fuel to the burners, a blue jacketed steel cylinder and a yellow jacketed titanium cylinder (Figure 15). The yellow cylinder was still strapped to the corner of the basket and connected to the burners by a flexible fuel supply hose. The blue cylinder was not fully strapped to the basket with the lower buckle undone. A third blue jacketed aluminium LPG cylinder, not connected to the burners or strapped into the basket, was found loose on the ground just outside the open end of the basket. Witnesses stated that this tank had been unbuckled and moved out of the way of the basket to provide room to administer first aid to the pilot.

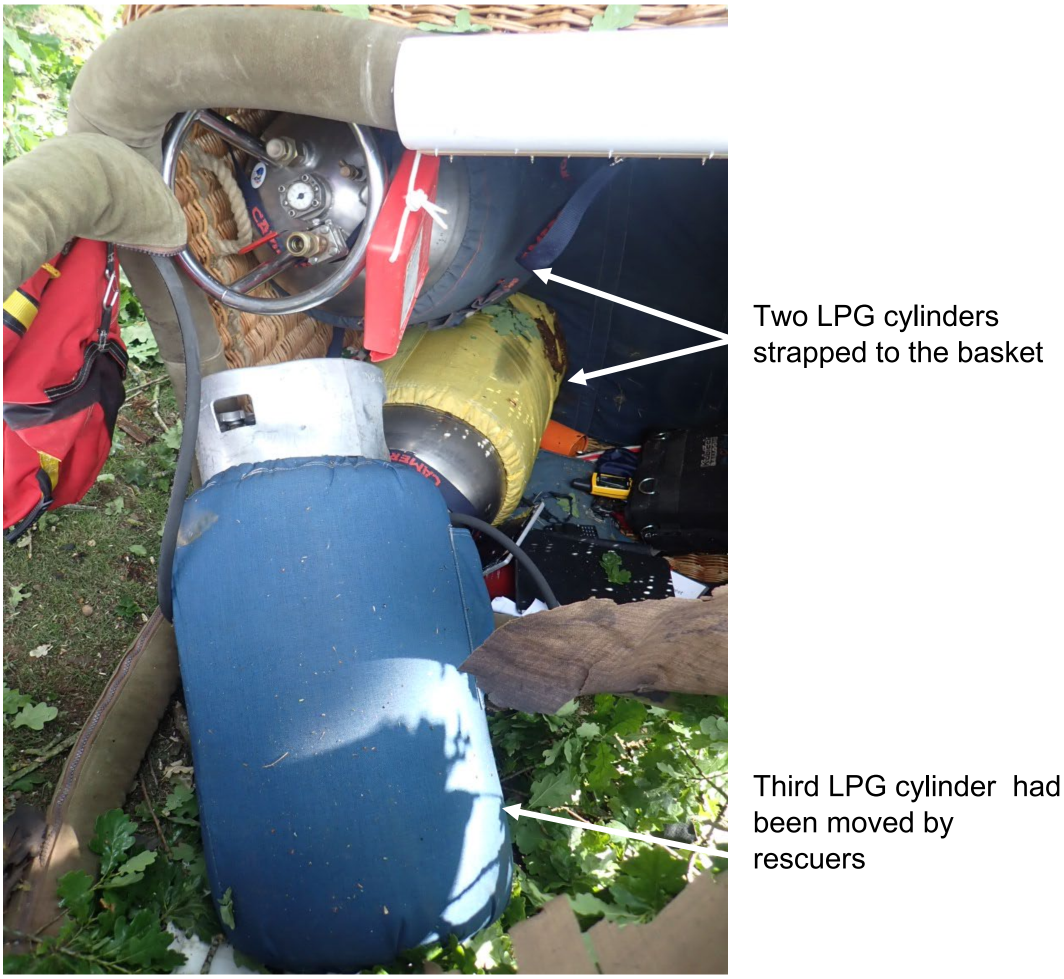


Figure 15

Three LPG cylinders with one loose and resting on the ground

Whilst the loose cylinder was empty of fuel, the yellow jacketed cylinder, shown in Figure 15, was connected to the burners and was found to be approximately half full. The blue jacketed cylinder seen at the top of Figure 15 that was partially strapped to the basket, was not connected to the burner unit and had a damaged contents gauge. It was found to be full during fuel transfer to an undamaged cylinder.

Once the balloon envelope had been recovered from the tree, examination at the site showed the envelope material had been extensively torn by the tree branches. The lower panels, around the throat of the balloon and the skirt, or pressure scoop, showed clear signs of discoloration consistent with being subjected to flames and significant heat. The material had burned through in some areas and the edges of the material had become rigid with the consistency of thin cardboard, also a sign of heat damage. Some small pieces of the heat resistant material were scattered around the site, particularly downwind of the basket location, indicating that the pieces may have floated down as the flames from the burner burned through the material.

There were no signs of fire damage on the ground, around the tree or on the tree trunks. The carbon fibre parachute operating line had suffered some heat damage, with small amounts of orange and yellow nylon rope material that had melted and dripped onto the lower panels of the envelope and the basket. However, the carbon fibre line had not burned through and was still in one piece.

Recorded information

Several data logging devices were recovered from the accident site. No transponder was fitted to the balloon, nor was there a requirement for one to be installed[4].

Competition Logger (Balloon Live Sensor)

A competition logger was recovered which logged barometric altitude and GPS position and altitude data once per second. Climb and sink rate information was calculated from the barometric altitude data which was accurate to ±1 m/s. Figure 16 shows the variation in barometric altitude (blue curve) and calculated vertical speed profile (purple curve).

On several occasions during the accident flight, the data indicated that G-CMFS flew at close to the maximum climb and descent rates allowed by the competition rules[5] (±8 m/s, or about ±1,575 ft/min). This is illustrated by points 1, 3 and 4 in Figure 16.

On the two occasions where G-CMFS climbed at close to or at the allowed limit, it reached this climb rate quickly (points 2 and 5). These climb rates occurred as the pilot climbed away from his pilot declared goal and from the first target drop zone respectively.

During the final climb, after G-CMFS climbed away from the first target drop location, four data samples were recorded which corresponded to a calculated climb rate of 9 m/s (1,771 ft/min) as G-CMFS was climbing through about 500 ft amsl (point 6).

G-CMFS attained 1,200 ft amsl (point 7), before it entered a rapid descent towards the ground. The competition logger recorded a maximum sink rate of about 19 m/s (3,740 ft/min) during this descent.

Footnote

[4] Unless entering Controlled Airspace where the AIP requires the use of a transponder. See UK AIP, section ENR 1.4, at https://nats-uk.ead-it.com/cms-nats/opencms/en/Publications/AIP/ [retrieved 10 October 2023]

[5] See the '*Organisational Information'* section of this report for further information.

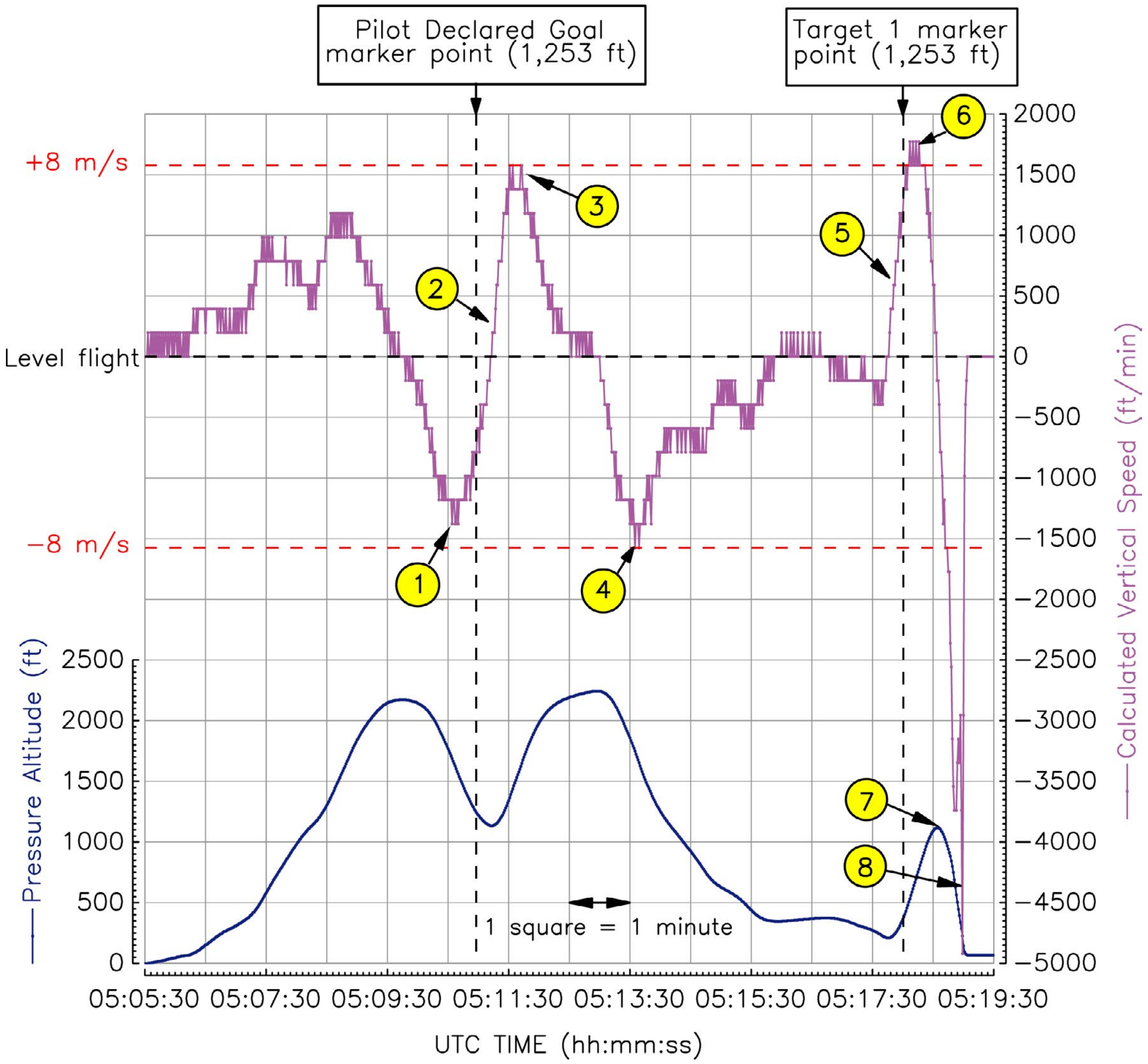


Figure 16

Altitude (blue) and vertical speed (purple) profile of the accident flight

A spike in the vertical speed marked by point 8 differed significantly from other vertical speed samples recorded by the sensor, and from other data sources recovered by the AAIB.

The data logger had recorded many previous flights which corresponded with the pilot's logbook entries indicating when he flew in G-CMFS. The data recorded the pilot attaining an 8 m/s climb rate in G-CMFS on at least three previous flights, including a flight the evening before the accident.

Variometer (FlyTec 6005)

A variometer was recovered, which displayed height, time, and climb/sink rate information in real time to the pilot on an LCD display. The AAIB was assisted by the variometer's manufacturer, which recovered maximum climb and sink rate values for the last 40 flights from a memory chip on the internal circuit board. The data corroborated the peak climb and sink rates obtained from the Balloon Live Sensor, recording the parameters in Table 1 for the accident flight.

Parameter	**Value**
Max. climb rate	8.3 m/s (1,650 ft/min)
Max. sink rate	17.8 m/s (3,525 ft/min)
Max. altitude reached	2,273 ft

Table 1

Maximum climb and sink rates logged by the variometer for the accident flight

The variometer was configurable to sound an aural alarm at a user-defined sink rate, but there was no option to configure a climb-rate alarm. To perform the data readout, it was necessary to remove the batteries from the device, which caused the settings to be lost. The investigation therefore did not determine whether a sink rate alarm was configured.

360-degree action camera

The pilot often flew his balloon with a 360-degree action camera mounted on a boom, but this was not used during the accident flight because its battery was not charged. The AAIB reviewed its footage from a flight on the evening before the accident, which took off from Worcester racecourse and flew locally. The climb/sink rate indicator on the variometer's display was visible from the video under most lighting conditions.

Part of the balloon envelope's interior was visible on the video. The temperature streamer was partially visible, and the operation of the parachute and pulley systems could be seen. The video showed that on twenty-one occasions when the pilot operated the parachute[6], the operating line was pulled firmly but smoothly. The pilot was seen to make short glances upwards on eight of these twenty-one occasions The videos indicated that he generally did not look up, particularly when focussed on other tasks such as identifying landing locations, navigating, or maintaining a look-out for other traffic.

The pilot operated the parachute for between five and ten seconds on about half of its uses during the 24 June flight. On a few occasions, the parachute was operated for more than 10 seconds, though it was not pulled deeply, and the balloon was either descending or landing during these times. On all occasions after he released the operating line, the parachute re-seated centrally. On two occasions during the 24 June flight, there was a short delay between the operating line being released and the parachute re-seating, and it appeared to 'float'[7] momentarily. Recorded data indicated that G-CMFS was in a climb on both occasions. The pilot appeared to be in control of his balloon but was not looking in the direction of the parachute when this occurred. The burners appeared to operate normally during the flight.

Footnote

[6] Three occasions were observed that have been excluded from the count, because they occurred during landing when the pilot's focus was on the landing point.

[7] The 'floating' parachute anomaly was observed during ground testing of a similar balloon design G-CKUN which is described in the *'Amateur-built hot air balloon design, construction and testing'* section in this report.

On one occasion during the 24 June flight, the balloon descended at about 1,200 ft/min through a wind layer at about 3,000 ft amsl. As it did so, the balloon was turning and oscillating slightly. The envelope appeared fully inflated. The wind distorted the envelope on one side, and the throat closed slightly. The video showed the pilot monitoring the envelope as it descended through the wind layer and applying a few short bursts of heat using the burner, which quickly restored the balloon's shape. There was no indication that the pilot was concerned, or that the balloon's behaviour was unusual to him.

Shortly afterwards, the balloon climbed to about 1,200 ft. Recorded data from this flight indicated that it resembled the climb immediately preceding the accident on 25 June. The video showed the burner being operated continuously for about 14 seconds during this climb and the vertical speed increasing quickly. Shortly after reaching 8 m/s, the pilot used the parachute operating line for approximately six seconds, with the sky visible through the opening. When released, the edge of the parachute momentarily fluttered as it re-seated. Intermittent and smaller parachute operations were made by the pilot until the balloon levelled off at around 1,300 ft amsl. When the pilot operated the parachute on this occasion, he looked up at the start and at the end of its use, for slightly longer than on other occasions seen in the video.

Mobile data stream

The pilot also used his mobile phone to log the flight, using a mobile application. Its position and height data were consistent with the track logged by the Balloon Live Sensor.

Handheld GPS

The pilot flew with a handheld GPS navigation device. The unit was significantly damaged, with the display not working and some components having broken off the circuit board. Previous positions logged by the unit or any routes which may have been loaded to the device by the pilot could not be recovered.

Data from other competitors

The AAIB obtained data from the other competitors' balloon sensors, which had been streamed to the cloud. Their height and calculated vertical speed data was compared against that from G-CMFS by aligning the data at their approximate takeoff times[8], illustrated by Figure 17. Some data exhibited errors for undetermined reasons.

Footnote

[8] For G-LOKI, the time was taken from the second takeoff after the pilot collected her markers.

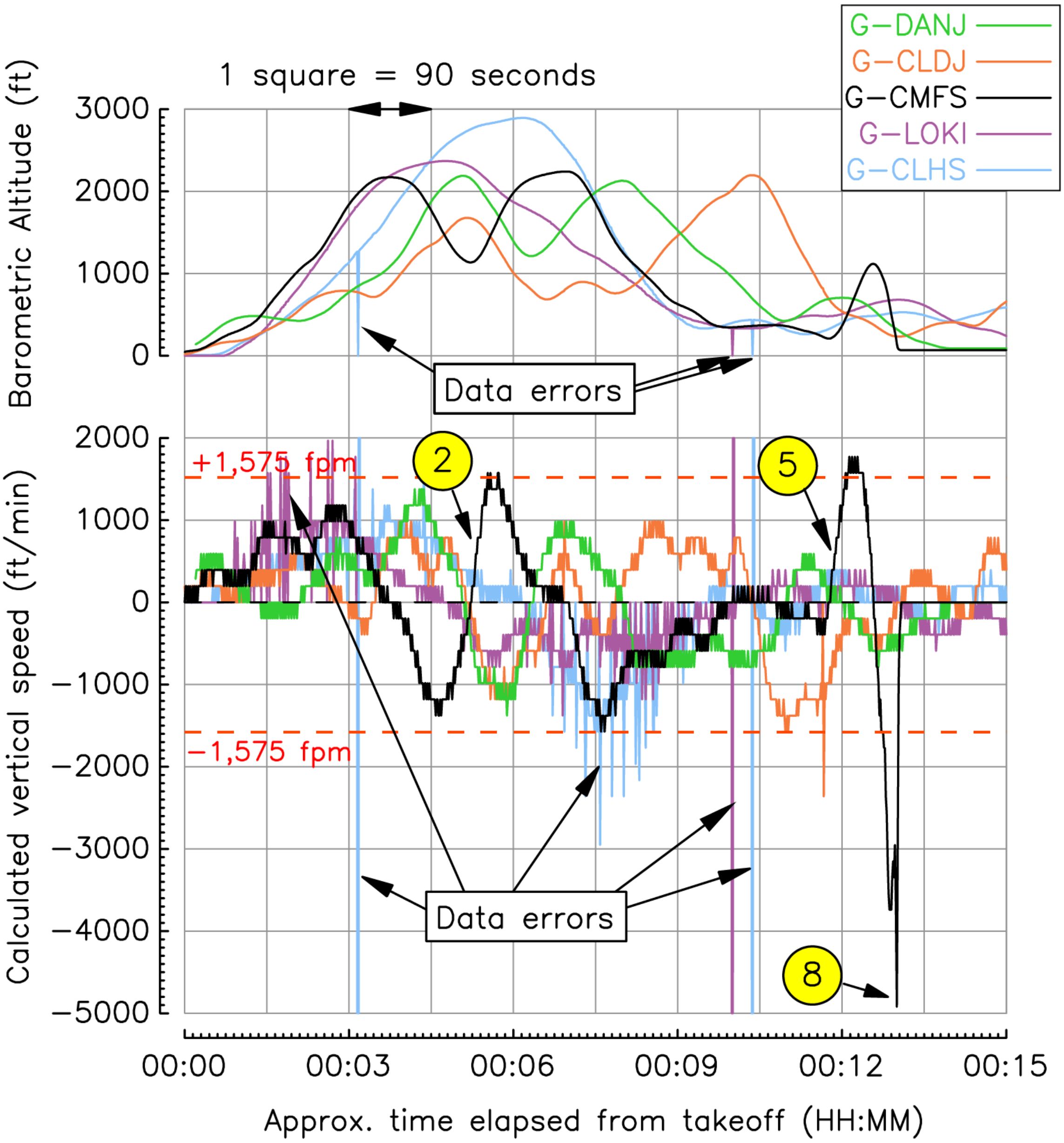


Figure 17

Comparison of altitude and vertical speed for each competitor.

The vertical speed calculations suggest that three balloons, including G-CMFS, descended at the 8 m/s rate allowed by the competition rules. Only G-CMFS attained the maximum 8 m/s climb rate. G-CMFS flew at similar heights to the other balloons in the competition.

Calculated vertical acceleration data indicated that when G-CMFS climbed at points 2 and 5, its acceleration upwards was about 40% greater than the maximum attained by the other balloons. When G-CMFS' climb rate was being slowed and when its rate of descent was being increased, the accelerations were consistent with those achieved by the other balloons, except from the final descent on the accident flight before it struck the ground.

Balloon examination

Envelope

The envelope material was substantially ripped and torn where it had been dragged through the broken tree branches during the accident and later by the sharp edges of the broken tree limbs when the wind increased. Where the material had been ripped and the tear had reached load tapes or seams, the rip had not propagated further. The seam around the circular aperture at the top of the balloon was in good condition with no rips or tears and no sign of distortion or melting from potential overheating. Whilst the temperature streamer had separated from its soldered link, which was clipped to the envelope (Figure 18), there were no signs of heat damage on the upper sections of the envelope. The streamer flag material had also been torn in half widthways. The temperature sensor did not indicate that there had been excessive air temperatures present in the upper areas of the envelope, although the 93°C indicator showed potential signs of discolouration.

Figure 18

Temperature sensor (left) and damaged streamer showing soldered link (right)

The aluminium crown ring was still in place in the centre of the aperture. The 16 vertical load tapes were each still looped around the ring with no signs of damage to the tapes or the ring observed. When the load tapes were measured from the edge of the aperture to the crown ring, there were differences of up to 2.5 cm in length between them.

At the bottom of the envelope, all the vertical load tapes that connected the envelope to the steel rigging lines remained fastened to the lowest edge of the heat resistant throat material. The throat panels showed significant signs of heat damage (Figure 19). The original blue colour of the material was discoloured in multiple, vertical burn patterns. The horizontal load tape seams along the lower edge of the envelope had melted in several places together with some of the vertical load tapes and envelope material.

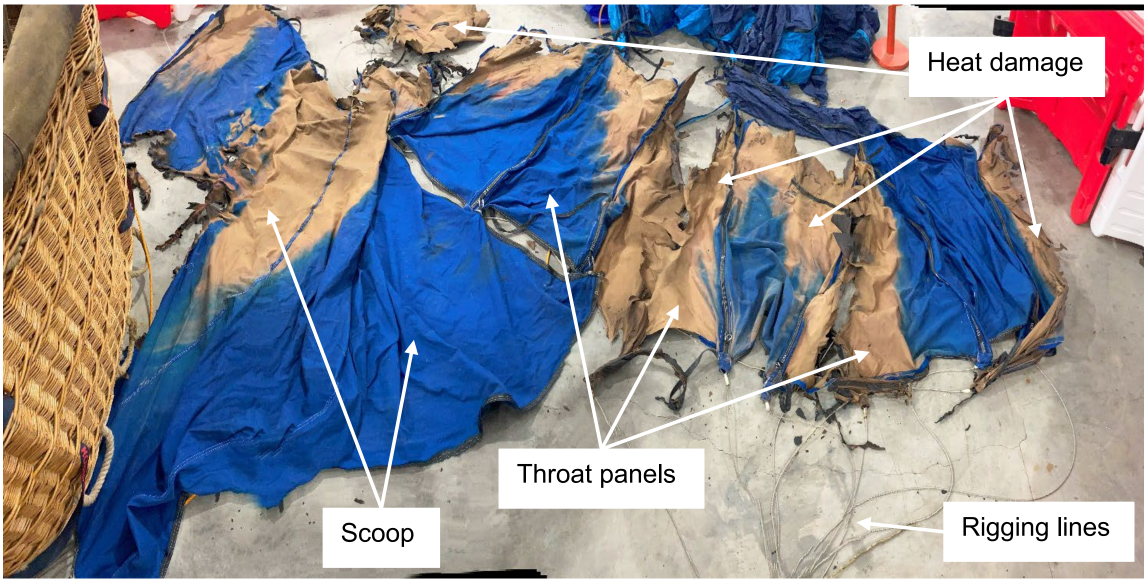


Figure 19

Panoramic picture of the heat resistant throat section with the scoop attached and showing multiple areas of significant heat damage

Figure 20

Scoop showing a hole burned through the material and V-shaped burn patterns

When the throat and the scoop were separated, the full extent of the burn patterns were revealed. The scoop shown in Figure 20 had a large hole burned through the fabric and two V-shaped burn patterns. Much of the upper horizontal seam of the scoop had melted and separated from the edge of the scoop.

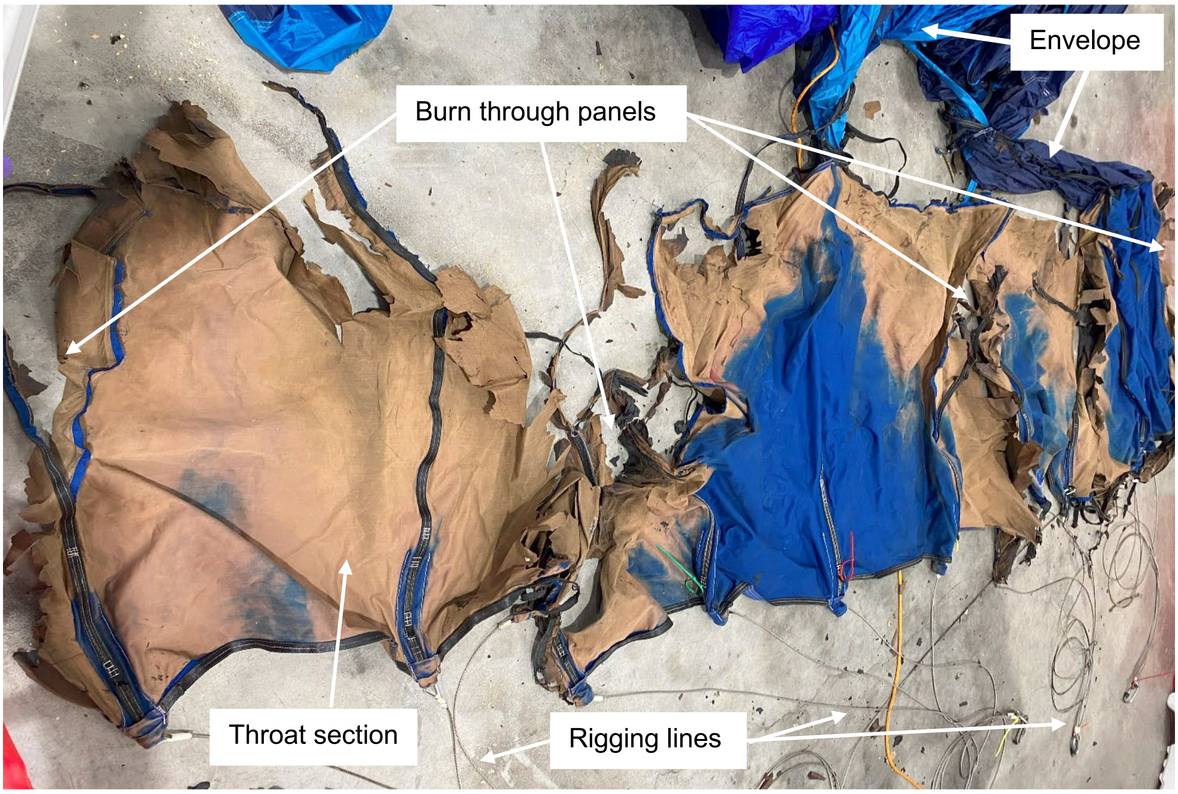


Figure 21

Heat resistant material that formed the throat of the balloon showing multiple, vertical heat damaged areas and burn through

The throat material was in poor condition having been significantly damaged by heat from the burners (Figure 21). There were several burn-throughs and the horizontal load tape attached to the upper edge of the throat panels had melted, separating most of the throat material from the envelope.

Aside from the partially melted lower panels adjacent to the throat material, the remaining envelope material was in good condition with no visible signs of damage or wear prior to that caused when it snagged on trees during the accident.

Parachute

The parachute material was in good condition with no visible signs of damage or wear. The 16 centralising lines were still attached between the edge of the parachute and the junctions between the horizontal and vertical load tapes at the third panel down from the crown. It is more common for the centralising lines to be fixed two panels down from the top. There were differences in length of up to 6.5 cm between the centralising lines. The 16 parachute shroud lines were still attached between the parachute and the shroud line pulley (Figure 9). The orange and yellow operating line remained fastened to the inner surface of the balloon and was routed through the shroud line and lower pullies and into the basket. Where the operating line had passed close to the burner units, some of the line's bright coloured nylon sheath had melted but the line had not broken.

Basket

The wicker basket and frame structure were distorted and the wooden base and runners cracked due to the ground collision. The rigging attachment points, karabiners and burner frame support rods were visually in good condition and still in place.

Burners

The burner frame and gimbal assembly had been distorted by the ground collision and was removed for inspection by a maintenance company. The maintenance inspection report highlighted some damage due to distortion, probably due to the ground collision forces, and one of the piezo electric ignitors was not functioning, but the burners were still functional.

Loading

The mass at takeoff was estimated to be 350 kg (including the basket, equipment, envelope, burners, pilot and full propane tanks). The mass when the accident occurred was estimated to be 335 kg.

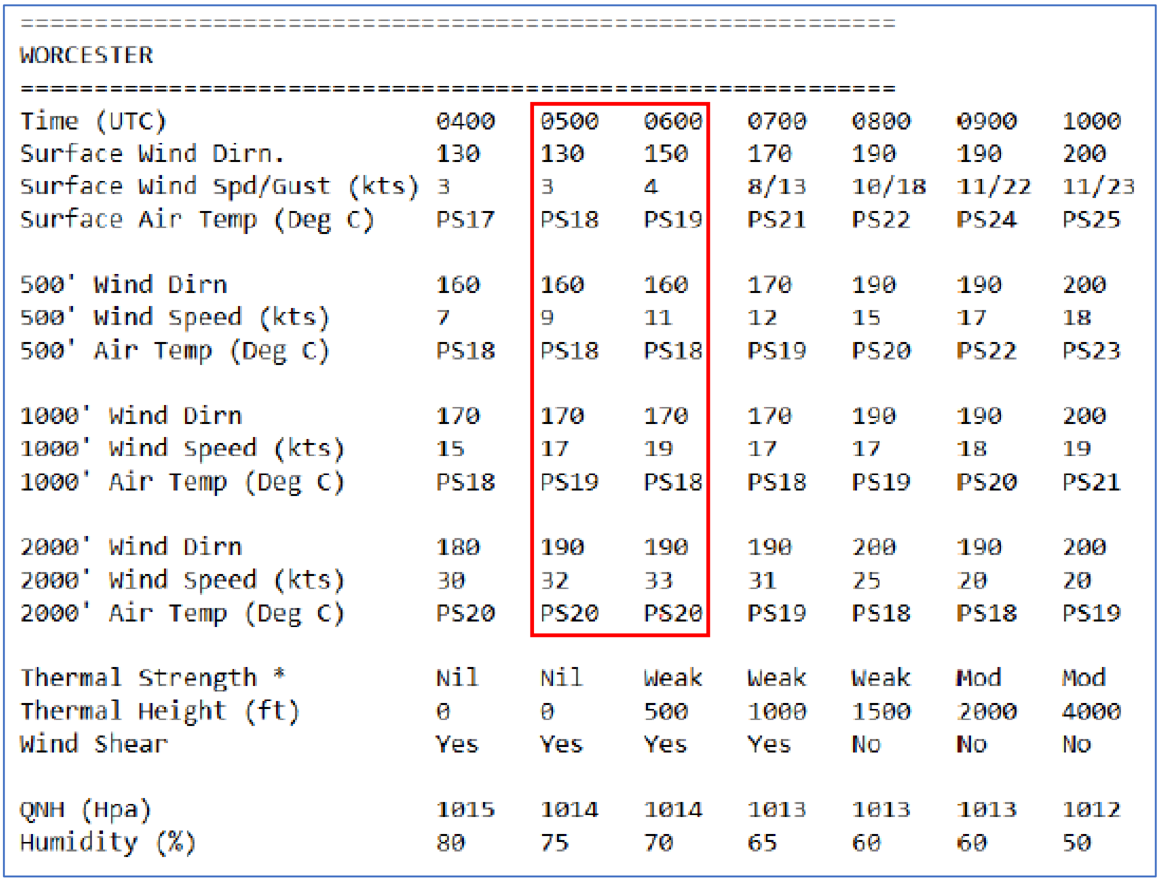
As this was an amateur-built balloon there are no published maximum or minimum weights. However, using calculations from similar production balloons, the maximum permitted lift on the day was estimated to be 455 kg. The minimum landing weight published for a similar production balloon was 276 kg.

Meteorology

The Met Office report on the weather stated that:

> *'The morning of the 25 June 2023 could be described as fine, with clear skies and light surface winds. However, the issued forecast indicated wind strengths increasing with altitude to become 35 kt at 2,000 ft. This was coupled with an elevated inversion with the top of the inversion forecast to be between 2,000 and 3,000 ft. Although the light surface winds would not lead to any turbulence, the vertical shear due to the increasing wind speeds aloft could lead to turbulence which could then also be exacerbated, by any localised directional shear associated with the top of the inversion.'*

An extract from the ballooning forecast for Worcester is shown in Figure 22 forecasting an increasing wind with altitude and a temperature inversion. Some competitors chose not to fly on 25 June, based on the forecast they saw on the evening of 24 June.



```
==========================================================
WORCESTER
==========================================================
Time (UTC)                   0400   0500   0600   0700   0800   0900   1000
Surface Wind Dirn.           130    130    150    170    190    190    200
Surface Wind Spd/Gust (kts)  3      3      4      8/13   10/18  11/22  11/23
Surface Air Temp (Deg C)     PS17   PS18   PS19   PS21   PS22   PS24   PS25

500' Wind Dirn               160    160    160    170    190    190    200
500' Wind Speed (kts)        7      9      11     12     15     17     18
500' Air Temp (Deg C)        PS18   PS18   PS18   PS19   PS20   PS22   PS23

1000' Wind Dirn              170    170    170    170    190    190    200
1000' Wind Speed (kts)       15     17     19     17     17     18     19
1000' Air Temp (Deg C)       PS18   PS19   PS18   PS18   PS19   PS20   PS21

2000' Wind Dirn              180    190    190    190    200    190    200
2000' Wind Speed (kts)       30     32     33     31     25     20     20
2000' Air Temp (Deg C)       PS20   PS20   PS20   PS19   PS18   PS18   PS19

Thermal Strength *           Nil    Nil    Weak   Weak   Weak   Mod    Mod
Thermal Height (ft)          0      0      500    1000   1500   2000   4000
Wind Shear                   Yes    Yes    Yes    Yes    No     No     No

QNH (Hpa)                    1015   1014   1014   1013   1013   1013   1012
Humidity (%)                 80     75     70     65     60     60     50
```

Figure 22

Extract from the ballooning forecast valid from 0400 hrs to 1000 hrs on 25 June 2023 (relevant times highlighted with a red box)

Actual weather

Prior to launch the competition organisers measured the wind at the launch site using a weather balloon and theodolite (the data is shown in Table 2). This data was sent to all the competitors.

Using the position and time data from the competitors' competition loggers, the AAIB calculated the ground speed profiles for each competitor balloon. The data in Table 2 was broadly consistent with the ground speeds attained by the balloons, and with the approximate 6 kt wind gradient between 975 ft and 1,170 ft recorded by the weather balloon and theodolite (Table 2). Most of the balloonists attained around 2,000 ft amsl, where their ground speeds averaged about 30 kt. One balloonist attained about 3,000 ft, where his ground speed averaged about 25 kt.

Height (ft)	Direction (°)	Speed (kt)
195	305	2.8
390	328	5.8
585	342	7.6
780	347	10.0
975	349	13.9
1,170	349	19.5
1,365	354	22.2
1,560	355	26.4
1,755	003	27.0
1,950	000	26.4
2,145	009	25.1
2,340	005	25.5
2,535	001	23.2
2,730	006	20.2
2,925	006	22.9

Table 2

Wind data sent to all competitors prior to launch

Other pilots who flew on the day of the accident reported that the conditions were good, with strong winds at altitude as forecast but no significant turbulence.

Pilot information

The pilot held a current Commercial Pilot's Licence (Balloons) and was rated on Class A, B and C balloons. He was an experienced competition balloon pilot having competed for several years all over the world.

His logbook showed he had 569 hours of balloon flying including 460 hours in command. He had flown 91 hours in competition flights, and 33 hours in the DB-6R type including 17 hours in G-CMFS. He also held a commercial fixed wing licence, had approximately 1,000 hours of fixed wing experience and flew for an airline.

Several people who knew him well said that he was a "very safe pilot" and was often talking about safety. They also said that he was competitive and wanted to win. A friend said that he was one of "the world's best pilots, but [he] would push the limits of what [he] could do". It was stated that "the competition held more significance as he hadn't been able to make many of the competitions that year due to work [and] in order to quality for international events next year, he had to perform well to get a high enough average score".

Post-mortem examination

The post-mortem report stated that death was caused by '*multiple injuries caused by a fall from a height*'. The toxicological analysis found no alcohol or drugs.

Parachute stall

Principles of parachute stall

The parachute vent panel does not generate sufficient lift to support its own weight and that of the rigging, shroud line pulley and operating line. The force holding the vent panel in place is the difference (delta) between the outside air pressure above the vent panel and the pressure inside the envelope below it. Once the vent is operated, dynamic airflow around the edge of the vent panel and through the aperture opening will generate lift and suck the vent panel back into the aperture.

Design and handling considerations

There are known design and operator handling considerations that can lead to a parachute vent panel becoming susceptible to stall:

> Design Choices: If the centralising lines are located too far down from the top of the balloon, it allows the parachute to be pulled down into the envelope to the point where the pressure above and below the vent is equal, and this is the stall point. Below this point, the lift produced from hot air below the parachute is insufficient to overcome the weight of the panel and rigging. Whilst this is a useful feature when landing to rapidly deflate the envelope, it is a dangerous condition in flight. The situation is made worse in a racing balloon because an envelope already elongated by design is elongated more as the balloon deflates, bringing the centralising lines even further down from the top of the balloon. Conversely, if the centralising lines are located too high, the parachute is hard to open and easily snaps back into place, which can be dangerous during landing where rapid deflation is necessary. In this situation, the pilot must haul on the operating line the whole time just to keep the vent open.
>
> Excessive inputs by the pilot: Aggressive use of the vent line in flight can cause the parachute vent to stall. Strong, repeated or extended use of the parachute to vent hot air reduces the internal pressure, elongates the envelope and can cause the parachute to stall. If the pilot does not pay close attention to the parachute in this circumstance, deflation of the envelope can be rapid, causing a dramatic loss of lift.
>
> High rates of climb: With an increase in the rate of climb comes a corresponding increase in the pressure on top of the balloon envelope and above the parachute. The faster the climb rate, the higher the pressure. As this pressure increases, the difference between the pressure above and below the parachute valve decreases, resulting in a decrease in the distance the parachute can be pulled into the envelope before it reaches the stall point. Aggressive venting whilst in a fast climb could more easily result in a parachute stall.
>
> Windshear and turbulence: Windshear and turbulence can also adversely affect the pressure difference above and below the parachute. It can cause deformation of the envelope resulting in dynamic changes to the parachute rigging thereby potentially altering the stall characteristics of the parachute.

> Loading of the balloon: A lightly loaded balloon requires a lower internal pressure for a given ascent rate. When venting under these circumstances, the reduced internal pressure and, therefore, delta pressure across the parachute valve, could cause the parachute to stall at a lower ascent rate, perhaps an even lower rate than the maximum ascent rate specified in a balloon's operating manual. Manufacturers of CAA Part 21 balloons specify a minimum loading of ½ the maximum takeoff mass (MTOM) for this reason.

BBAC guidance on avoiding a parachute stall

If the parachute cannot reseal the vent and stalls, the balloon envelope will collapse. The BBAC pilot training manual contains the following information about parachute stalls:

> *'The manufactures' manuals put the maximum opening time of a parachute vent at 3 seconds, after which it must be allowed to re-seal before being used again. Vigorous venting is still possible by a rapid succession of short pulls with complete closure between each operation. Each pull should be no more than 1.5 metres of line, and in practice the procedure may be quite energetic.*
>
> *If the valve is used repeatedly to produce a steep descent, then the pilot should take care to observe the amount of deflation that this is producing upon the envelope.*
>
> *In very lightly loaded conditions, it may happen that the parachute does not close automatically, because the balloon has cooled too much to support the weight of the parachute. A short blast of heat is usually sufficient to push the parachute back up into place, but this is a matter of judgement at the time. A parachute "stall" as it is called is extremely unlikely when airborne in balloons of normal size range and normally loaded, but a very large balloon with an absurdly light load may stray into this danger area. However, parachute stalls are by no means uncommon when balloons are standing inflated on the ground and are allowed to cool too far to support an action of the parachute.'*

The BBAC manual suggests that parachute stalls are *'extremely unlikely when airborne'* but reports submitted to the AAIB suggested they are more common than previously understood, particularly during competition flying. The reports described 12 previous parachute stall incidents which various pilots had experienced. The events occurred in balloons from several different manufacturers and different designs. There was no evidence that these events had previously been formally reported to the BBAC or CAA or any learning captured in a forum. Where details about the incidents were known, one or more of the following factors were described:

- The balloon was in a rapid climb. In some of the reports, the parachute stalled after it was opened to slow the climb rate.
- The balloon was lightly loaded.

- The balloon entered unstable air or wind gradients. In some cases, the envelope was described as having distorted or 'caved-in' on one side of the envelope.

Most reports described the balloon descending rapidly following the stall. In about a third of these, the pilot burned through the envelope to re-inflate it, which slowed or stopped the descent.

The AAIB obtained flight data from one case involving a lightly loaded balloon that climbed from a low height at 8 m/s, a similar rate to G-CMFS's last climb before the accident. The pilot described a parachute stall which caused the throat to close. The balloon stopped climbing and began descending at about 6 m/s (1,200 ft/min). He managed to burn through the envelope to re-inflate it and landed shortly afterwards.

Several experienced competition pilots who had experienced parachute stalls, also suggested they tend to occur when lightly loaded, in turbulent or unstable air masses, and when using the parachute during a rapid climb. However, the AAIB did not find any published guidance on the factors that increase the likelihood of a parachute stall or the best technique to recover from a stall.

Other pilots who had flown G-CMFS or the identical balloon G-CKUN were asked if they had experienced any problems with the parachute. None had experienced any difficulties, and all reported that the parachute had always resealed. However, none of the other pilots thought they had climbed at greater than 7 m/s (1,400 ft/min) with this design. Recordings of flights by pilots in G-CKUN were not available to the investigation to verify this from recorded data.

Amateur-built hot air balloon design, construction, and testing

Amateur-built balloons and airships[9] are not regulated with respect to airworthiness and there is no airworthiness assurance system in place. Aside from CAA SD-2021/004[10] issued on 21 September 2021, which limits the envelope size and occupancy of amateur-built balloons, design expertise depends very much on the knowledge and experience of the designer. For G-CMFS, construction was completed using high quality materials sourced from balloon manufacturers and in a workshop dedicated to amateur-build balloon construction and assembly. There was plenty of advice and knowledge available regarding balloon construction at the time the balloon was built.

As the balloon was an amateur-build project, there was no requirement to test fly it to determine its handling or flight characteristics or to have it independently examined for build quality or design. The AAIB found no evidence that performance limits for this design, including the rate of climb which could stall the parachute, had been determined.

Footnote

[9] This inclusion "*recognises that balloons can be readily converted to airships by adding propelling and steering means*" CAA Safety Directive SD-2021/004 section 2 paragraph 2.1.

[10] Safety Directive SD-2017/00n, https://www.caa.co.uk/publication/download/19083 [accessed 5 March 2024].

An identical envelope to G-CMFS was made available to the AAIB, and a series of four ground-tethered tests were conducted at a manufacturer's facility to observe the parachute's characteristics during operation. The tests showed that the parachute tended to 'float' when activated for between four and five seconds, before snapping back to seal the aperture at the top of the envelope (Figure 23).

When the parachute operating line was pulled for approximately six seconds, the parachute stalled (Figure 24 left) and the envelope started to collapse before the burners were promptly activated to reseat the parachute and re-inflate the envelope (Figure 24 right).

Figure 23

Parachute 'floating' during ground testing

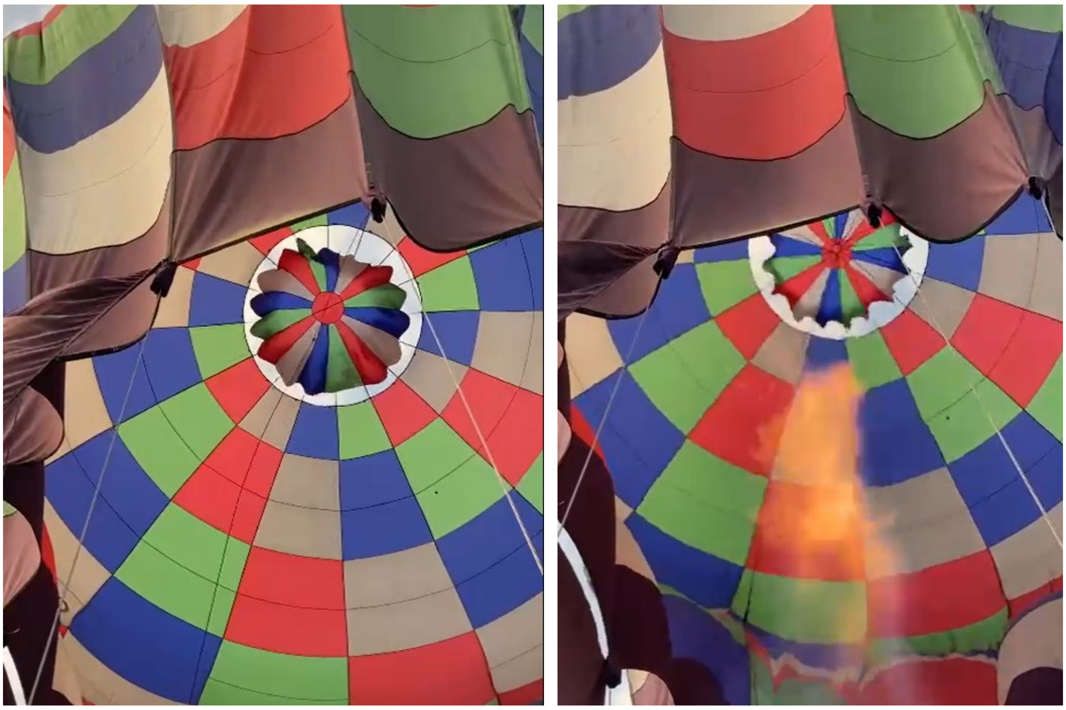


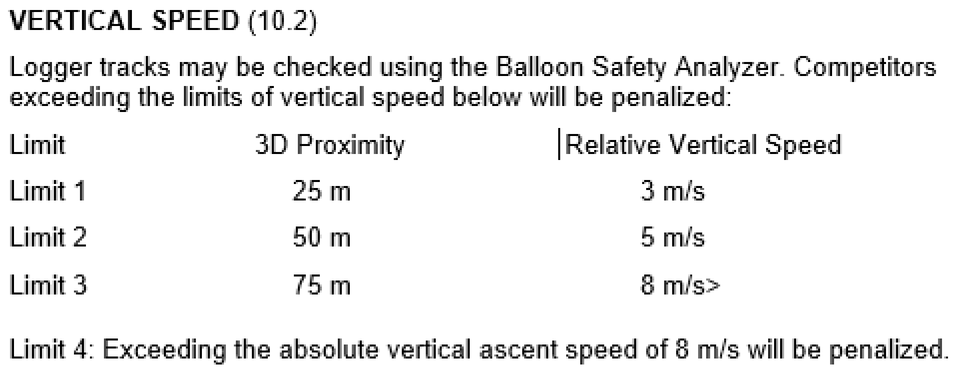
Figure 24

Parachute stalled (left) and burners used to reseat the parachute and reinflate the envelope as it started to collapse (right)

Organisational information

The competition event on 25 June 2023 was organised by the BBAC Competitions Club and was part of their British Grand Prix Series. The event had an Event Director who set the rules, targets and briefed all the pilots prior to launch. Other competitors who took part on the day of the accident reported that the briefing was good and included a discussion of the wind gradient. The rules for the competition were based on a standard set of rules published by the Fédération Aéronautique Internationale (FAI) Ballooning Commission[11].

One of the rules restricted the balloons' vertical speed, but the purpose of this rule was to reduce the chance of collisions. The limiting vertical speed reduced as the separation (proximity) between balloons decreased. The rules are shown in Figure 25.



VERTICAL SPEED (10.2)

Logger tracks may be checked using the Balloon Safety Analyzer. Competitors exceeding the limits of vertical speed below will be penalized:

Limit	3D Proximity	Relative Vertical Speed
Limit 1	25 m	3 m/s
Limit 2	50 m	5 m/s
Limit 3	75 m	8 m/s>

Limit 4: Exceeding the absolute vertical ascent speed of 8 m/s will be penalized.

Figure 25

Vertical speed limits specified in the competition rules

The FAI Ballooning Commission event rules give the following statements regarding weather information and the responsibility of competitors:

> *'Any meteorological report or forecast, or other safety or navigational information, is provided in good faith for the guidance of competitors. Officials may be appointed to regulate the inflation and launching of balloons. However, nothing shall diminish the responsibility of competitors under this chapter.'*
>
> *'Entrants and competitors remain completely responsible for the safe operation of their aerostats[12] at all stages of inflation, launch, flight and landing. They must ensure that their equipment, their crew and their own level of skill and experience are suitable for the conditions in their own judgement.'*

Footnote

[11] The FAI is an international federation for the conduct of air sports internationally. It has a constitution and defined sporting codes for each air sport that it covers and for which it recognises awards. The Ballooning Commission is the arm responsible for conducting International Ballooning Competitions and World Record attempts.

[12] An aerostat is a lighter-than-air aircraft that gains its lift through the use of a buoyant gas.

The BBAC is a volunteer organisation that promotes the enjoyment, advancement and safety of lighter-than-air flight. It aids in the training of pilots and crew members, and encourages the growth of lighter-than-air flying (hot air balloons, gas balloons and airships), from individual flying to large events. It also promotes competitive ballooning at both national and international level.

During the investigation the BBAC raised concerns about the reporting culture in the ballooning community because it was aware that many incidents were going unreported. These concerns were supported by the fact that the AAIB was made aware of previous similar parachute stall events that had not been formally reported. The BBAC considered that the lack of reporting limited its ability to extract learning from previous incidents and share that knowledge with the ballooning community.

To address this the BBAC proposed to promote the importance of safety reporting via its monthly newsletter, bi-monthly magazine and website, and to hold a Safety Day to raise awareness of the issues raised by this accident. To promote best practice in the organisation of all balloon events in the UK, the CAA intended to produce a guidance document about organising ballooning events.

Parachute anti-stall systems

After extensive testing and trials, some manufacturers concluded that whilst a parachute vent remains suitable for balloons where the rate of climb is limited in the Pilot's Operating Manual to between 1,000 and 1,200 ft/min, it may not be suitable for racing balloons with rates of climb as high as 1,800 ft/min. Their conclusions were based on the parachute vent's propensity to stall and their sensitivity to unstable weather conditions at those higher climb rates.

Manufacturers have developed anti-stall vent systems for balloons, some examples of which are in Appendix A. One of the anti-stall vent systems is free from Intellectual Property Rights and is illustrated and described on the respective manufacturer's open-source website. Adding one of these systems to an amateur-designed racing balloon is unlikely to be cost-prohibitive and is likely to improve handling and safety.

Survivability

During a similar incident reported to AAIB inspectors during the investigation, an envelope had collapsed but the pilot had managed to reinflate it in time to prevent a ground collision by using the burners to burn through the scoop and lower heat resistant panels. Sufficient hot air was eventually streamed into the envelope to reseat the parachute and re-inflate the envelope. The pilot also jettisoned the LPG cylinders over the side of the basket to reduce the weight of the basket.

The AAIB was unable to find any guidance which established the benefit and risks of jettisoning heavy cylinders during an uncontrolled descent. Discussion with experienced balloon pilots generated varying opinions about whether jettisoning tanks in an emergency affected the outcome.

Analysis

During a rapid climb from the first target location the balloon envelope was seen to collapse. The pilot was unable to re-inflate the envelope before the basket struck the ground.

There was no evidence that the balloon envelope had suffered any structural failure prior to hitting the trees. The damage found to the lower fabric panels and load tapes was consistent with heat damage, caused by the pilot attempting to reinflate the envelope, and tearing from the collision with trees. Witnesses stated that the burners were still working during the descent, and testing during the investigation showed that the burners were still functional. A burner failure would not account for the sudden envelope collapse, rapid descent and burn patterns found on the scoop and lower sections of the envelope.

The likely explanation for the envelope collapse is that the balloon experienced a parachute stall during a rapid climb, which peaked at 8.3 m/s prior to the collapse. G-CMFS was an amateur-build balloon which was not required to complete any formal testing, so the maximum safe rate of climb was not known. However, data from the flight the previous day showed that the balloon had climbed at a similar rate on that flight with no report of a stall. It is likely, therefore, that other aggravating factors combined during the accident flight to cause a stall.

There was a strong wind gradient on the day of the accident. As the balloon climbed through 1,000 ft amsl it is likely the wind increased by at least 10 kt. This wind gradient was forecast and discussed at the pre-flight briefing the day before, but the competitors who flew reported the conditions were fine with no significant turbulence. Climbing into a changing wind can cause the balloon to distort, increasing the chance of a stall. This can be managed by climbing slowly and ensuring the balloon is heavily loaded so that the envelope pressure is relatively high and the envelope more rigid. On the accident flight, the load calculations showed that the balloon was loaded approximately midway between the advised minimum and maximum loading limits. Whilst climbing rapidly into the wind gradient (more rapidly than other competitors), photographs taken by witnesses (Figures 7 and 8) showed the envelope distorting during the climb. This factor was likely to have increased the chance of a stall.

One possible scenario is that the pilot used a high rate of climb to gain a competitive edge because of his desire to do well in the competition and, if he noticed he was exceeding the competition's climb rate limit, he is likely to have wanted to rapidly reduce his climb rate to avoid receiving a penalty. This may have caused him to use the parachute excessively or for an extended period, which could have triggered the rapid onset of a parachute stall. It is not known where the pilot was looking during the rapid climb. Video evidence from the previous flight showed he did not always look up at the parachute when operating it, and when he did, it was usually a quick glance. This may not have given him sufficient time to recognise what he was seeing and respond accordingly. If he was not looking up when he operated the line, he may not have immediately noticed that the parachute might not have re-seated correctly. An envelope collapse can occur quickly when the parachute stalls, so the opportunity to respond in time to correct it is limited.

Design factors affecting stall characteristics.

The parachute centralising lines on G-CMFS were attached to the envelope three panels down from the crown, rather than two panels down as more commonly found on other balloon types. Whilst this allowed the parachute to descend further into the envelope to improve the responsiveness and effectiveness of the parachute in flight, this also made it more prone to stalling.

As a racing balloon design, the diameter of the upper envelope of G-CMFS was smaller than that of a conventionally shaped balloon. Therefore, if the envelope distorted, the contraction in the envelope's diameter was likely to be faster than that of a conventionally shaped balloon, slackening the parachute's centralising lines more quickly. As a result, the parachute would be free to fall further into the envelope, increasing the stall risk further and reducing the time available for the pilot to react to prevent a collapsing envelope from developing into a streamed envelope.

The testing of an identical balloon showed that the parachute was susceptible to floating and easy to stall. However, since the balloon was tethered to the ground, the testing was not fully representative of in-flight conditions on the day of the accident and may not have reflected how the pilot of G-CMFS used the parachute during the accident flight.

The investigation considered the possibility that the balloon's limit of performance was reached on the accident flight when the recorded data indicated that G-CMFS climbed at slightly above 8 m/s before it was seen descending to the ground. Because there was no requirement for performance testing on amateur-built balloons, it was likely the pilot was not fully aware of the operating limits of G-CMFS and the rate of climb at which there would be an increased risk of experiencing a stall. The increased climb speed would have reduced the differential pressure securing the parachute vent, and hence the margin before stalling, although there was insufficient evidence to conclude that this alone caused the accident. Knowing the performance limits of an aircraft is essential because those limits are likely to be approached when pilots attempt to maximise their aircraft's performance in a competition.

Two overseas balloon manufacturers stated that they would not use a basic parachute vent system on racing balloons which are expected to ascend at high rates of climb. Instead, they had developed alternative anti-stall vent systems for designs expected to achieve rates of climb above 1,200 ft/min (about 6 m/s). Anti-stall vent systems have been designed to avoid or quickly rectify a parachute stall, and had one been fitted to G-CMFS the accident may have been avoided.

There is no written guidance or best practice to assist amateur designers in ensuring their balloons avoid features that might impinge on safety, such as the potential for parachute stall. There are no requirements for amateur designers and amateur manufacturers to determine essential performance limits. The finished product is not required to be inspected, and there are no inspection criteria to apply to amateur-built competition balloon designs other than the general criteria that would be applied regardless of type. Therefore the following Safety Recommendation is made:

Safety Recommendation 2024-008:

It is recommended that the Civil Aviation Authority publish guidance on the design, testing and inspection of amateur-built balloons to reduce the risk of accidents due to unsafe conditions such as parachute stall.

Whilst there were some differences in the lengths of the centralising lines between the sides of the envelope and the edge of the parachute, and some differences in vertical load tape lengths from the aperture to the crown ring, these were not considered contributary to the accident. The video footage from 24 June showed the parachute remaining centred both when closed against the crown and when pulled to vent hot air.

Prevalence of parachute stalls

Twelve previous parachute stall events were reported to the AAIB during the course of the investigation. These occurred in various balloon types and under similar conditions to G-CMFS, suggesting that the risk was not unique to the DB-6R design. The reports also suggested that a parachute stall is more likely in a climb than in a descent. However, none of these events had been formally reported, meaning that any opportunity to learn from them has not been captured. An effective reporting culture is an important way to improve safety and therefore the following Safety Recommendation is made::

Safety Recommendation 2024-009:

It is recommended that the British Balloon and Airship Club routinely communicate the importance of safety reporting to its members to promote an effective reporting culture, capture safety learning and help prevent a recurrence of ballooning accidents and serious incidents.

Operational prevention of and recovery from parachute stalls

Several experienced balloon pilots reported to the investigation their experience of a parachute stall, and options on how best to prevent and recover from one. However, this guidance and experience is not captured in any document.

The evidence suggested that the pilot of G-CMFS tried to reinflate the balloon by burning through the fabric after the envelope and throat collapsed, which was an action taken by some of those who shared with the AAIB their experiences of a parachute stall. Whilst the AAIB has learned of these parachute stall events in which pilots recovered successfully, the knowledge and best practice has not been collated and published. Therefore the following Safety Recommendation is made:

Safety Recommendation 2024-010:

It is recommended that the British Balloon and Airship Club publish guidance on best practice for the prevention of and recovery from unsafe conditions such as parachute stalls.

Jettisoning one of the cylinders to reduce weight, which has been suggested as one possible action a pilot could take in these circumstances, in order to slow the descent, is only likely to be effective in cases when a balloon is still partially inflated and exerting a buoyancy force, which is not the case when in a streamered state. Experienced balloon pilots shared varying opinions with the AAIB on the effectiveness of jettisoning heavy cylinders during an emergency. A lack of guidance on this subject means it is unclear whether this is the best course of action in either an uncontrolled descent due to a parachute stall, or in some other emergency. Therefore the following Safety Recommendation is made:

Safety Recommendation 2024-011:

It is recommended that the British Balloon and Airship Club publish guidance material on best practice regarding jettisoning of fuel tanks during an emergency.

Safety oversight of competition flying

Competitors who took part on the day of the accident reported that the event was well organised and they received a good pre-flight briefing. They were aware of the significant wind gradient and, although the day before some competitors had chosen not to fly based on the forecast, those who did fly reported the conditions were fine. The rules make it clear that the decision to fly rests with the pilot of each balloon.

It is important that competition pilots balance the desire to do well and compete with the need to operate safely. The advice in strong wind gradients, to climb slowly and fly at a relatively heavy weight (which results in an increased pressure in the envelope), can conflict with the desire to push the balloon to its limits to win the competition. It is vital that all competition organisers ensure that this risk is well managed. Therefore the following Safety Recommendation is made::

Safety Recommendation 2024-12:

It is recommended that the Civil Aviation Authority publish guidance for the safe oversight of competition balloon flying in the UK, to ensure the risks associated with the activity are appropriately understood by competitors and managed by competition organisers.

Conclusion

Whilst the AAIB could not establish the exact cause of the accident, G-CMFS was likely to have suffered a parachute stall whilst climbing rapidly from the first target location. It is likely that the rapid climb, wind gradient, and the balloon design all contributed to the stall occurring.

Recommendations are made to the BBAC to publish guidance about unsafe conditions such as parachute stalls and to establish the efficacy of jettisoning fuel tanks in an emergency. A recommendation is made to the CAA to review the rules and provide guidance for amateur-built balloons.

The investigation found a lack of safety reporting in the ballooning community and a recommendation is made to the BBAC to proactively address this. It was also recommended that the CAA publish guidance about the safety oversight of competition balloon flying in the UK.

Appendix A

DESCRIPTIONS OF THREE ANTI-STALL VENTING SYSTEMS

Paralite system

The Kubicek Balloons Paralite system, (Figure A-1), is similar to a parachute system except that the centralising lines are free to travel through pulleys near the edge of the vent aperture at the top of the envelope. The opposite end of the centralising lines is connected to a weight that ensures the vent panel is easier to reset. Two vent operating lines are fitted, a red and white line which is pulled to vent the hot air in the same way that it is for a parachute valve. When released, the Paralite resets itself by internal overpressure and the action of the weight. The weight provides some compensation for pressure increases above the vent panel during a rapid climb or during turbulent conditions, effectively adjusting the stall point to a higher-pressure delta. The white operating line is designed to close the vent aperture manually if necessary.

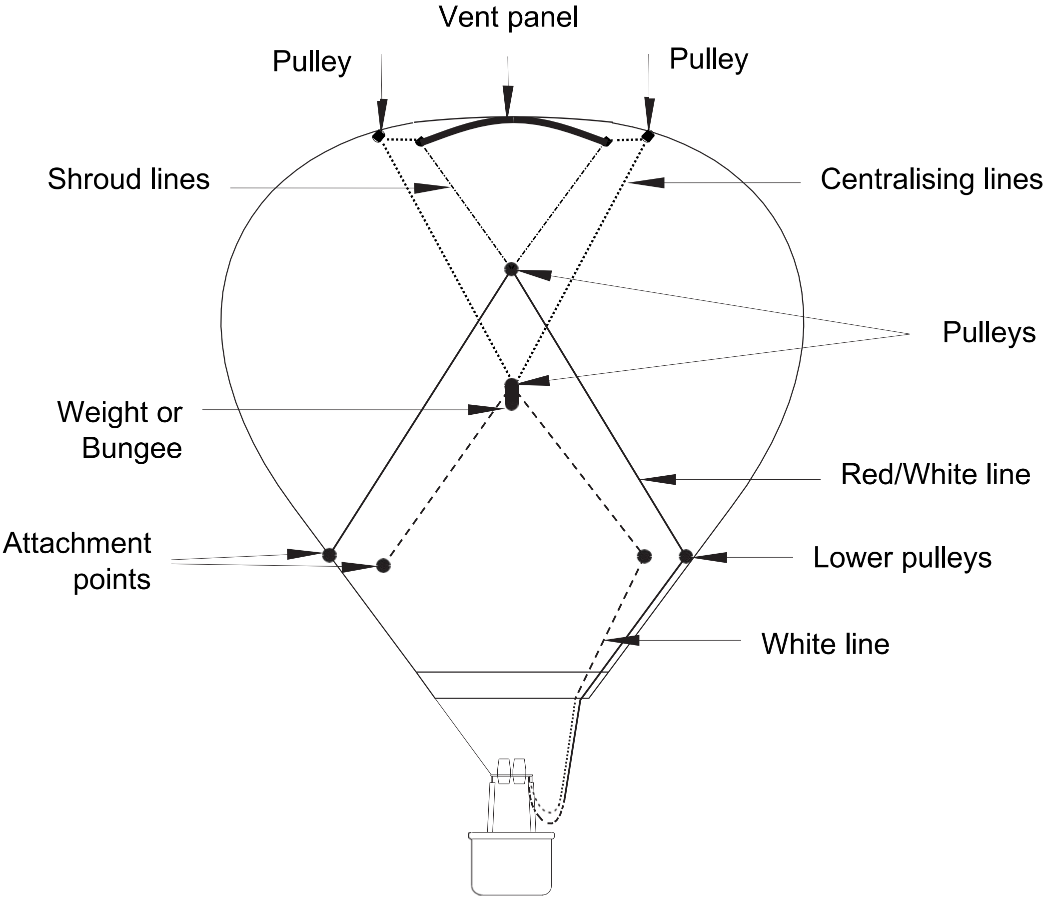


Figure A-1

Diagram of Paralite venting system.

Table A-1 below shows the action and controls of the operating lines to open and close the vent aperture:

Paralite controls	Desired action	Control motion required
In-flight venting and deflation	Open Paralite	Pull and hold RED-WHITE line
	Close Paralite	Release RED-WHITE line – Paralite closes itself Pull WHITE line if necessary

Table A-1

Paralite control actions using the two operating lines.

Lite Vent deflation system

The Kavanagh Balloons Lite Vent deflation system (Lite Vent) was developed in 1998 and was fitted to racer type balloons to prevent dangerous situations developing from a stalled vent. The Lite Vent uses a floating centralising/reset line system that allows free movement of the panel when operating the parachute vent. Shown in Figure A-2[13], the reset lines travel a short distance to a pulley (A) on the side of the balloon adjacent to the vent aperture. From that point they travel down to a reset weight (B) where the lines join. A control line at the base of the reset weight allows the pilot to haul the vent closed manually if necessary. The weight works to balance the mass of the rigging lines in the system and keep the vent panel stretched open to cover the aperture.

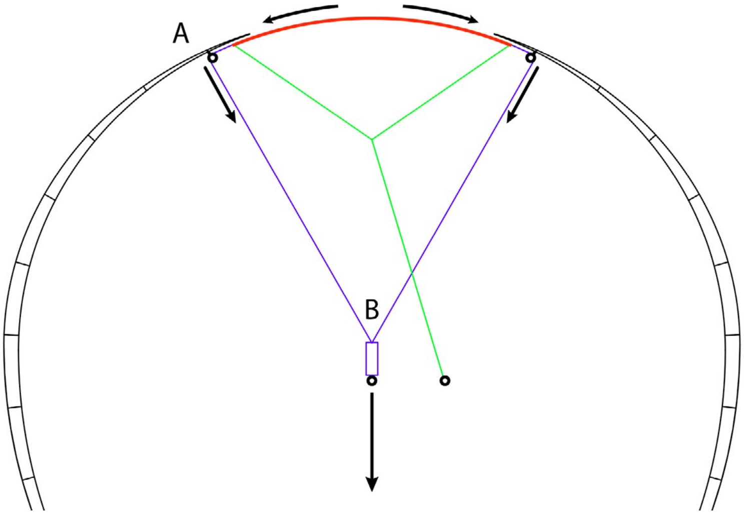


Figure A-2

Lite Vent diagram showing rigging and reset weight.

When activating the vent, Figure A-3, the reset weight is drawn up towards the vent allowing the centralising lines to extend as needed during activation. The vent panel edges are rolled inwards to allow air to flow out of the aperture (Figures A-4 and A-5).

Footnote

[13] All images in Figures A-2 to A-5 are used with permission.

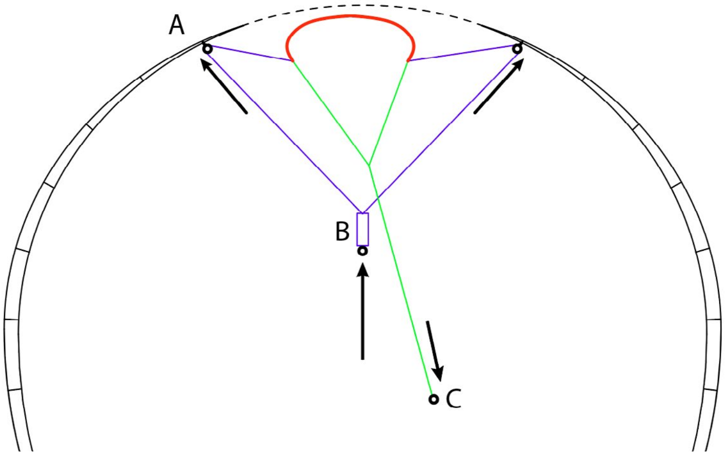


Figure A-3

Lite Vent diagram showing activation of the vent when (C) is pulled.

Figure A-4

Picture of Lite Vent showing vent edges rolled inwards.

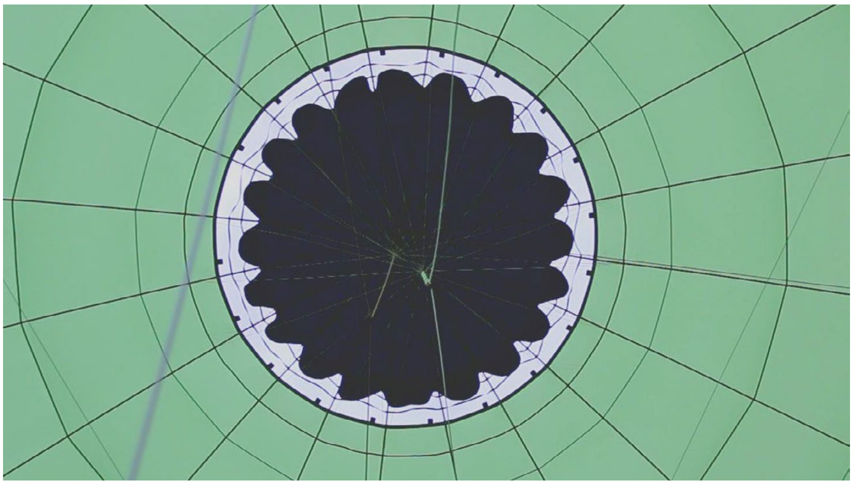


Figure A-5

Lite Vent open as seen from throat of envelope.

Whilst the vent panel can still be pulled away from the crown ring with some effort or during extreme rates of climb, a pull on the reset line closes the vent again with no requirement for the use of the burner. The manufacturer stated that this vent design is free from Intellectual Property Rights, therefore, it can be copied for use in any balloon design to enhance safety.

Para Plus system

The Cameron Balloons Para Plus system is a blend of the venting and deflation action of a standard parachute vent but with the centralising lines of a rapid deflation system. This results in light operating line loads for venting and deflation, with extra security during fast climbs but without the need for Velcro tabs to hold the vent in place to enable the envelope to be inflated on the ground (Figure A-6).

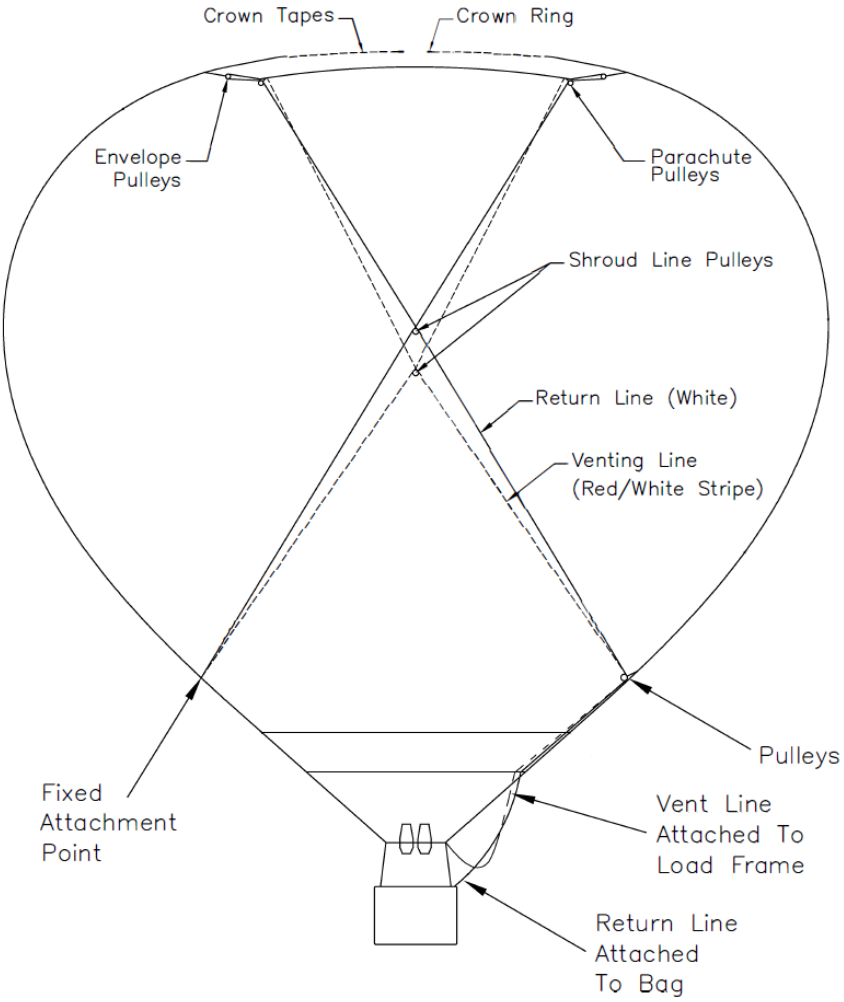


Figure A-6

Schematic of the Para Plus venting and deflation system

The Centralising lines of the panel are run through pulleys on the envelope and parachute edge, allowing them to extend when the red-and white line is pulled. The centralising lines are attached to a white "return" line which can be used to force a closure of the panel (Figure A-7).

In normal operation the panel will automatically close after each vent operation, but the white closing line may be operated to re-seat the panel if it doesn't close automatically.

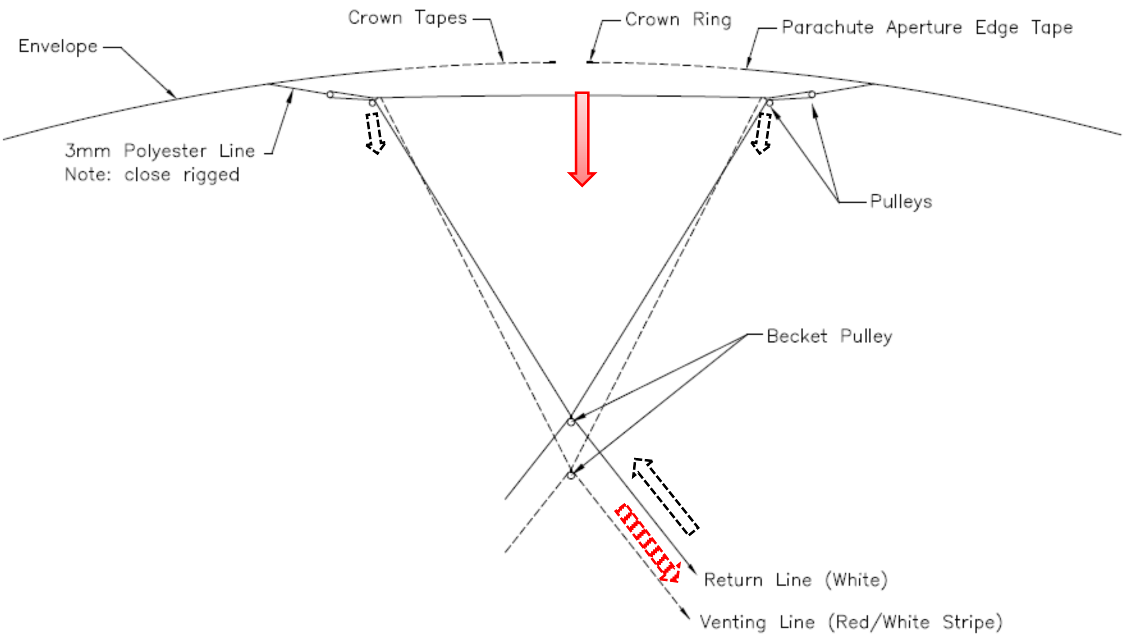


Figure A-7

Schematic showing a detailed view of the vent and return line system (Arrows depict movement of lines and parachute valve when vent operating line pulled)

Published: 23 May 2024.

Accident

Aircraft Type and Registration:	Schleicher ASW 24, G-CHBB	
No & Type of Engines:	None	
Year of Manufacture:	1991 (Serial no: 24132)	
Date & Time (UTC):	16 August 2023 at 1125 hrs	
Location:	Dunstable Airfield, Bedfordshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
Nature of Damage:	Unknown	
Commander's Licence:	Sailplane Pilot's Licence and BGA Certificate	
Commander's Age:	47 years	
Commander's Flying Experience:	131 hours (26 of which were on type) Last 90 days - 11 hours Last 28 days - 0 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The accident occurred during an aerotow launch from Dunstable Airfield. Eyewitnesses reported that, at an early stage in the launch, the glider's vertical positioning behind the tug was unstable. While the pilot appeared to regain some control over the instability, shortly after the towing aircraft lifted off, witnesses noticed the tow rope had become detached from the glider, which was below 50 ft agl at the time. Despite the lack of traction from the towing aircraft, the glider continued to climb to between 50 and 100 ft agl before it entered a steep left turn with low and reducing airspeed. Shortly after entering the turn the glider yawed left and autorotated into an incipient spin before striking the ground nose first. Witnesses on the airfield arrived at the glider within 80 seconds of the accident but nothing could be done to save the pilot who had suffered fatal injuries during the accident sequence.

The investigation did not identify any mechanical issues with the tow release or other defects which could have led to an uncommanded release of the tow cable or adversely affected the controllability of the glider.

The investigation could not conclusively determine why or how the tow rope came to be released from the glider at an early stage in the takeoff. With the glider no longer connected to the towing aircraft, the accident pilot found himself in a challenging position, possibly suffering from the negative performance shaping effects of startle and/or surprise. With little height or speed available to him he needed to quickly decide on an appropriate course of action. That he decided to turnback toward the airfield indicates he did not consider landing ahead was a viable option. Tragically, at the height and speed he found himself, turning back proved unachievable.

This accident serves to highlight how challenging it is to make effective decisions when something goes wrong unexpectedly at a critical stage of flight. While pilots may verbalise their intentions as part of an eventualities brief, being able to enact the plan when startled, surprised and under extreme pressure, is not necessarily assured.

History of the flight

The accident pilot arrived at Dunstable Airfield on the morning of 16 August 2023 and proceeded to rig G-CHBB after removing it from its trailer. Other than asking for the assistance of another club member to help him attach the wings, the pilot completed the rigging process by himself. The glider was then towed to the launch queue at the start of the westerly aerotow run (Figure 1).

With the help of a wing runner, the pilot conducted a check of the glider's tow cable release mechanism before beginning the launch sequence. Once the tow rope had been finally secured and the slack taken up, the accident pilot used his onboard radio to call "all out" to the tug aircraft's pilot, signalling that he was fully ready for the launch. The tug pilot then applied full power and began the takeoff roll.

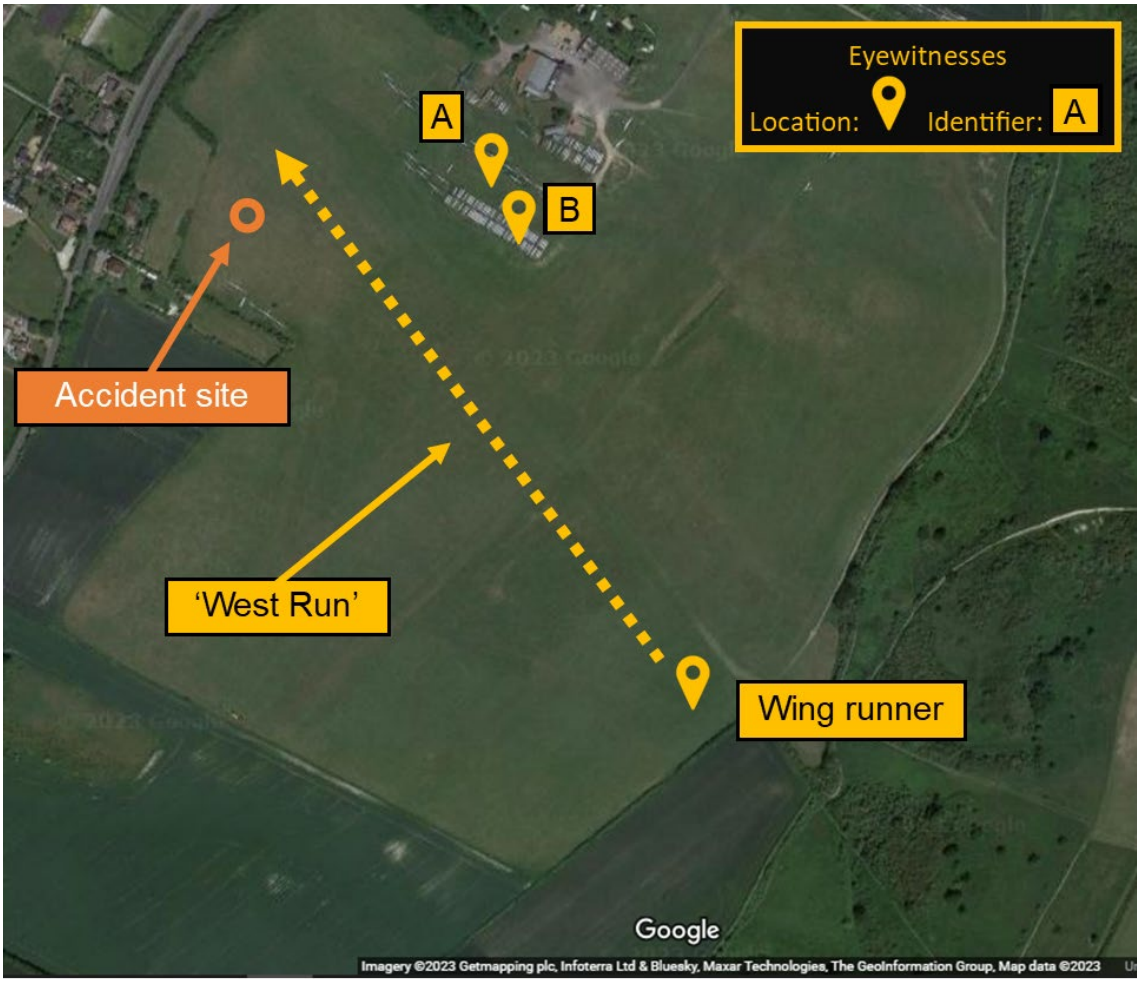


Figure 1

Overview of Dunstable Airfield, including accident site and eyewitness locations

The wing runner ran with the glider until its speed was too fast for him to keep up, so he released the wingtip. At that stage everything seemed normal with the glider, its airbrakes were retracted, and the pilot appeared to have no difficulty holding its wings level. The wing runner headed back to the starting position but on hearing shouts from nearby onlookers turned around to see what was happening. At that point he saw G-CHBB initially below the level of the tug aircraft before it then climbed higher. From the way the glider was flying, he assessed that it became very slow as the climb progressed and that the takeoff was going "badly wrong." G-CHBB then entered a steep left turn, during which the left wing dropped and the glider appeared to enter a spin to the left before striking the ground nose first shortly thereafter.

The tug pilot reported that the initial stages of the aerotow were as expected. Shortly after commencing the ground roll he looked in his mirrors and saw that all looked normal with the glider, its wings were level and its airbrakes were retracted. After checking on the glider, he focused his attention on flying his own aircraft, G-LGCC, safely off the ground. Shortly after lifting off, and while still over the airfield, he detected an unexpected increase in performance from the tug as it started to climb and accelerate faster than expected. While he had not felt any sensation of the tow rope releasing, he could not see the glider in his mirrors and became concerned that it was no longer attached to the tug. He radioed the glider pilot asking him to confirm that he had released the tow but did not receive a reply. Shortly afterwards, an observer on the ground radioed the tug pilot informing him that the glider had crashed. The tug pilot then flew an abbreviated left hand circuit to land on the Northeast Run and parked his aircraft at the aerotow launch grid. On vacating the aircraft, he inspected the tow rope which he saw remained hooked onto to the rear of the tug. The tow rope was intact, with its weak link and connecting rings still attached at the glider's end.

The nature of the glider's flightpath after it lifted off caused Eyewitness A, who was stood on the airfield near the row of glider trailers (Figure 1), to become concerned about the general vertical stability of the tow. He reported that, at an early stage in the aerotow, while the tug was still on the ground the glider was flying "unusually high." The glider pilot initially corrected by descending to an estimated 0.5-1.0 m above the ground but this correction was followed by a second vertical oscillation. After the tug got airborne the glider appeared to settle into a more stable position, climbing with the tug. When it was passing through a height of approximately 6 m the glider appeared to pitch forward slightly. This pitch forward was preceded by a noise that the witness thought could have been the sound of the glider's towing hook back releasing[1] due to the oscillations. This witness reported then being "surprised to see the glider pitch up to re-establish the original climb angle, at [which] point the tug was clearly accelerating away" from the glider. He watched the glider climb to approximately 25 m where it levelled to a "normal gliding attitude" before entering a steep left turn. He estimated that the glider completed approximately 90-120° of turn before its nose dropped into an "almost vertical" attitude from which it did not recover. The witness ran to the accident site to find the pilot "still strapped in but unconscious."

Footnote

[1] As a safety precaution for winch launching the hook was designed to release the tow cable if the attachment ring was pulled rearwards, for example, if the glider were to be still connected as it flew past the winch position.

Eyewitness B, who was standing to the southeast of Eyewitness A, also noticed the glider when it was at low level approximately over the middle of the airfield. His attention was drawn because the distance between tug and glider was increasing, indicating they were no longer connected by the tow rope. His expectation at that point was the glider pilot would lower the nose and land ahead, but he described the aircraft as initially turning right before starting to climb and then entering a steep left turn. To Eyewitness B, the left turn appeared to be a deliberate action.

On seeing the events unfold two club members who were at the aerotow launch point immediately drove to the accident site. They arrived within 80 seconds of G-CHBB striking the ground, with Eyewitness A having reached the glider just before them. The pilot had observably suffered significant injuries and was unconscious. One of the responders was medically trained and initially managed to detect a weak pulse at the pilot's neck, although this faded shortly thereafter. An emergency services ambulance arrived at the glider within eight minutes of the accident, but nothing could be done to save the pilot.

Recorded information

An International Gliding Commission (IGC) logger and two navigation devices were recovered from the accident site, each of which could record positional flight data. The IGC logger and both navigation units were damaged because of the ground collision such that the stored data was unrecoverable from their internal memory. The navigation devices each had a supplementary microSD card for the logging of data; however, no record of the accident flight was found on either of those.

The glider and tug both had FLARM units fitted that logged and broadcast positional data (ie GNSS). The broadcast data was picked up by Open Glider Network (OGN) ground station receivers in the local area and recorded by the central OGN system.

Data for the takeoff rolls of both G-CHBB and G-LGCC on the accident flight are presented at Figure 2. This figure presents the information relative to the runway so that from above and side, the distance between the two aircraft can be visualised. It also compares the groundspeed of both aircraft.

Figure 3 plots the calculated distance between the aircraft, based on interpolations of their position each second. This figure highlights that the distance begins to diverge from about time 11:24:49, which corresponds to 1 s before G-CHBB reached 400 m distance on Figure 2. G-CHBB then veers slightly left, then right, before beginning the final steep turn to the left. The maximum recorded height was 60 ft agl.

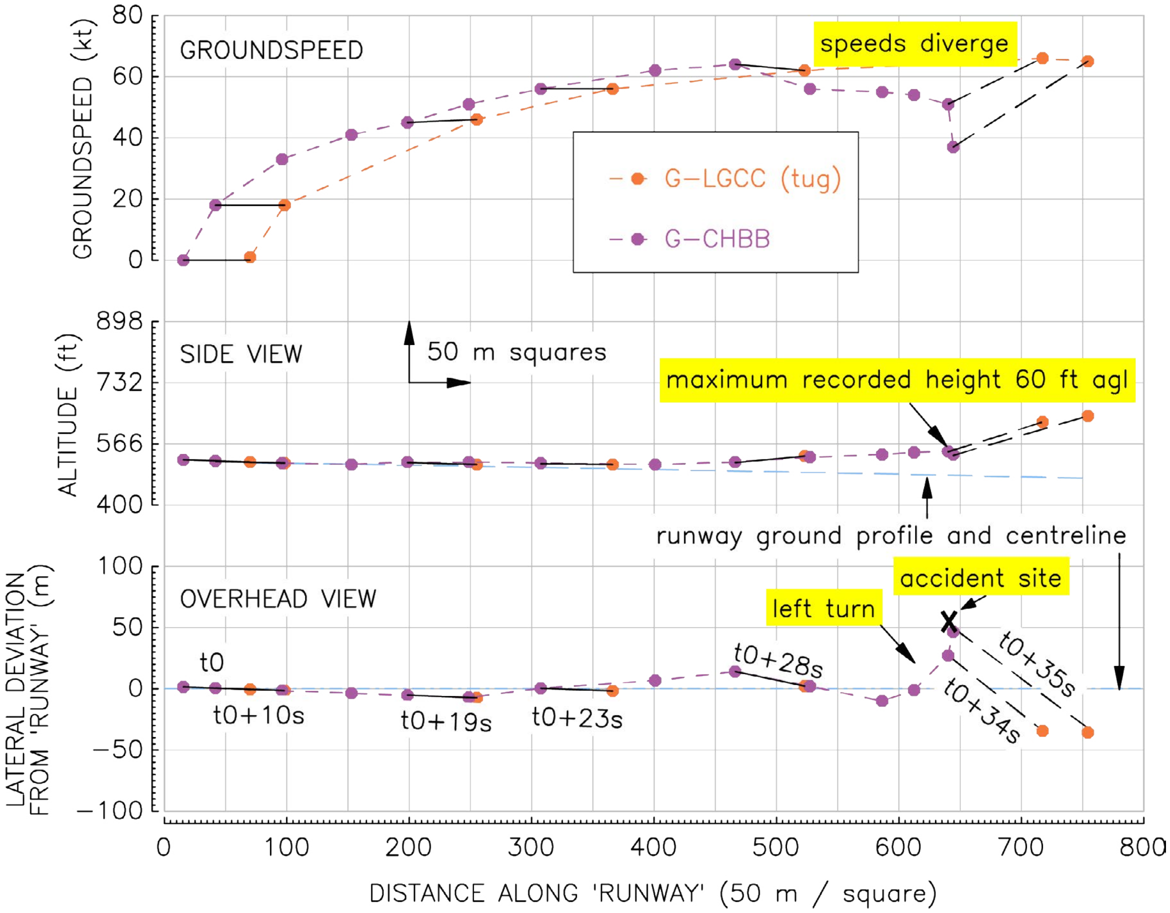


Figure 2

GPS-derived data comparing speed and relative positions of G-CHBB and G-LGCC (note that points for both aircraft that share the same time and linked with a line that is solid if the distance between them is approximately the length of the tow cable)

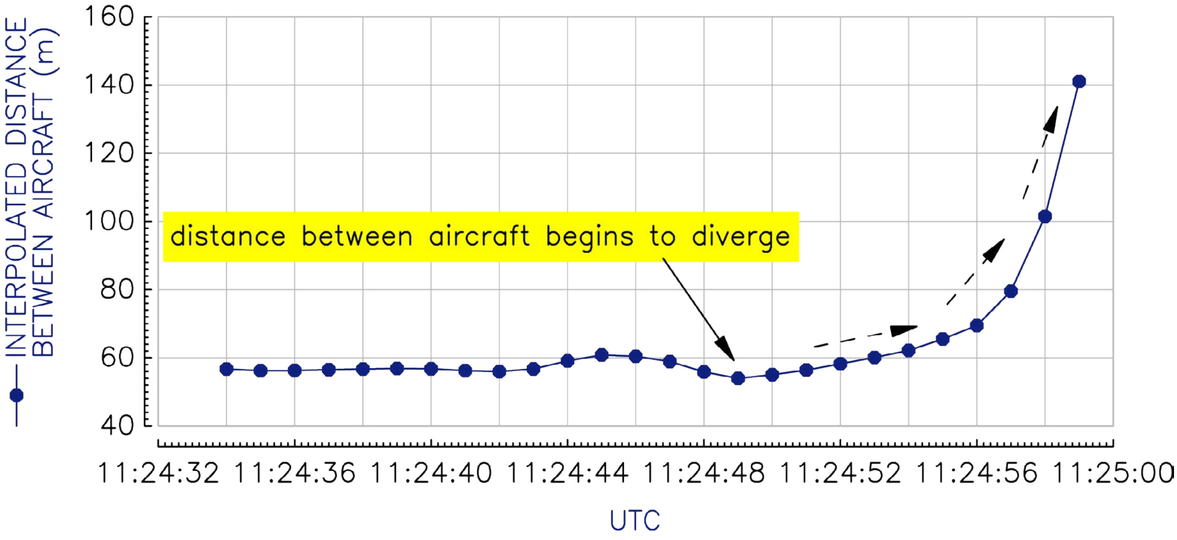


Figure 3

Interpolated distance between aircraft

Accident site

The accident site was located on the airfield, close to the western boundary which is bordered by the B489 road. The glider had come to rest upright, pointing in a northerly direction and the wreckage distribution was confined to a small area.

Onsite examination

Ground marks corresponding to the profile of the glider's nose and the leading edge of the right wing, indicated that the glider had struck the ground in a steep nose-down attitude. It then bounced, coming to rest several metres aft of the initial impact point.

The nose of the glider and cockpit area had suffered substantial disruption and the canopy had shattered. The right wing had completely fractured at the approximate mid-point, remaining attached to the inner part of the wing only by the aileron control rod. The outboard leading edge showed evidence of contact with the ground, as did the right wingtip which was partially dislodged.

The left wing appeared largely undamaged, except for some cracking close to the wing-root.

The tailboom had separated from the glider during the impact and remained attached to the fuselage only by the horizontal elevator control rod, which was bent. The tailboom and tail assembly came to rest parallel to the right wing trailing edge, with the tip of the horizontal tailplane resting on the upper wing surface.

The airbrakes on both wings were found extended. The left airbrake appeared undamaged. The forward web of the right airbrake was buckled, and the top surface exhibited a concave profile. A light linear scuff mark on the right side of the vertical fin, was consistent with it having struck the top of the extended right airbrake, during the impact sequence.

Control continuity was confirmed within the elevator, rudder, aileron and airbrake control circuits.

Aircraft information

The ASW 24 is a single-seat high-performance 'standard class' sailplane. It was designed and manufactured by Alexander Schleicher GmbH and first flew in 1987. It is of predominantly composite construction and is equipped with a retractable mainwheel and single cable-operated centre-of-gravity (CG) tow release (also known as a "belly hook" or "CG hook"). The flight control systems for the aileron, airbrake, wheel brake and elevator are of the pushrod type, while the rudder is operated by cables.

The ASW 24 has a provision for the carriage of water ballast but there was no evidence that water was being carried on G-CHBB.

G-CHBB was constructed in 1991 and was initially privately operated in the UK. Since 2002 it had been owned and operated by the resident gliding club at Dunstable Airfield. Between January and May of 2016, at 2,473 flying hours (FH) and 1,138 launches, G-CHBB underwent a 3,000 hour life extension inspection at a maintenance facility in Poland. The glider gelcoat was also refinished at this time and it was repainted.

Since 2019, G-CHBB was maintained under the gliding club's Self-Declared Maintenance Programme, which was based largely on the BGA's Minimum Inspection Programme. It underwent an annual inspection and Airworthiness Review Certificate renewal on 5 December 2022, at 2,759 FH and 1,340 launches. The most recent maintenance inspection took place on 1 August 2023, following a field landing. Prior to the accident flight G-CHBB had accumulated 2,776 FH and 1,351 launches.

Detailed aircraft examination

Canopy release

The canopy release levers were found in a partially open position, however damage to the canopy rim and the shoot bolts of the release mechanism, indicated that the canopy was closed at impact. Disruption to the cockpit due to impact forces would have caused the release levers to move.

Flight controls

The control rod attached to the airbrake handle was bent 90° upwards, having suffered substantial disruption during the impact. While the right airbrake was damaged by contact with the vertical fin, close examination of the left airbrake, did not reveal any indication that the airbrakes had been deployed prior to the impact.

Due to the disruption of the cockpit, it was not possible to confirm the trim setting.

Tow release system

It was not possible to test the function or measure the release force of the tow release system in its installation condition, due to the extent of the disruption to the cockpit and forward fuselage. The tow release handle was undamaged and the cable was intact, free from bends or kinks, and appeared to move freely through the cable guides/sheaths. Upon removal from the glider, the housing and hook of the tow release coupling were free from dirt or corrosion and the hook appeared to operate normally. The tow release was taken to the manufacturer's facility for detailed examination and testing.

A short section of winch cable, likely from a previous winch cable break, was retrieved from the airfield in the approximate area of G-CHBB's takeoff roll. It was damaged and badly deformed with individual cable strands splayed. Its condition was consistent with having been run over by the airfield tractor mower. There were no witness marks on G-CHBB's lower fuselage or on the tow release itself, to indicate that this debris could have interacted with the tow cable release in any way. Its presence on the airfield was therefore considered incidental.

Tow release

Maintenance requirements

The tow release on G-CHBB was a Tost Type G88 release, serial number (SN) 056068 which was manufactured in 1991 and fitted to G-CHBB at the time of production. Tow releases are certified, safety-critical parts and are treated as lifed items. Other than routine cleaning and lubrication, no modification, adjustment, or overhaul is permitted and overhaul can only be conducted at Tost facilities.

The overhaul requirements for the Tost tow releases have evolved somewhat over time. Earlier models of tow release were required to be overhauled every three years. When the G88 model was introduced, the initial issue of the operating manual published in 1989, specified a maximum operation period of four years or 2,000 launches, whichever occurred soonest.

In 2001, Tost issued a Technical Note (TN) No.1-2001 amending the maximum overhaul interval for all models of tow release to 10,000 actuations, which it considered equivalent to 2,000 launches, and the four-year interval became a recommendation. The G88 operating manual was updated accordingly. Airworthiness Directive 1989-018/3 effective date 2 April 2002[2], was issued to mandate the requirements of TN No.1-2001.

Prior to the EASA taking over responsibility for the airworthiness of aircraft in 2008, UK gliders were unregistered and unregulated, and their airworthiness was supported at a national level by the BGA. Historically, under the BGA system, Tost tow releases were maintained 'on condition,' subject to a daily function check, annual inspection and replacement when found to be worn. This 'on condition' self-regulated approach was withdrawn effective 30 April 2005, since when Tost tow releases fitted to UK gliders became subject to the life limitations described in AD 1989-018/3. The BGA's interpretation of the Tost life limitations indicated that club gliders could assume 4 to 5 actuations per flight, which equates to 2,000 – 2,500 launches and private gliders could assume 3 to 4 actuations per flight, which equates to 2,500 – 3,000 launches.

G-CHBB relevant maintenance records

G-CHBB's maintenance documentation did not include any records to indicate that the tow release had been overhauled since its manufacture.

Life-limited items on G-CHBB were tracked on a 'lifed items status report' included in the maintenance documentation for each annual inspection. For each item, the recorded information included the current hours and launches of the component, the overhaul interval, when an overhaul had last been conducted and when it was next due (in launches). Following the introduction of a new format logbook in 2019[3], this information was also

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Footnote

[2] Airworthiness Directive 1989-018 issue 3 effective date 2 April 2002 (issued by German Luftfahrt-Bundesamt), superseded AD 1989-018 dated 23 February 1989 and AD 1989-018/2 dated 18 October 2001. The original version of the AD was not applicable to the G88 model of tow release.

[3] G-CHBB's first logbook covered the period September 1991 to November 2019. A second logbook covered the period November 2019 to 2023.

recorded on the 'lifed items' page of the logbook. The gliding club used 2,500 launches as the overhaul interval for the tow release on G-CHBB; but as the glider had not reached this threshold, these reports typically showed that the overhaul was next due at 2,500 launches.

Photographs taken during the life extension inspection in 2016 (at 2,473 FH and 1,138 launches) showed that the tow release had been removed from the glider, cleaned and repainted after which it looked as if new (Figure 4). While the associated worksheets and life extension inspection checklist indicated that the hook had been inspected, no other maintenance on the tow release was documented.

Figure 4

G-CHBB tow release before (left) and after (right) cleaning and repainting in 2016

The subsequent 'lifed items status report' in January 2017 continued to show that the next overhaul was due at 2,500 launches. However, the equivalent report for the next annual inspection in November 2017 (at 2,528 FH and 1,183 launches) indicated that the tow release overhaul had last been completed at 1,138 launches (which corresponded with the 2016 life extension inspection) and was next due when the glider reached 3,638 launches. This information was then carried through on subsequent 'lifed item status reports' and was transferred into the new logbook in 2019.

Both the January 2017 and November 2017 reports were compiled by the same inspector. He indicated that he could not imagine having changed the information without some corroborating evidence but given the time elapsed, could not recall what that may have been. He offered a possible explanation that upon seeing the photographs taken during the life extension and/or the apparent 'as new' condition of the hook during a subsequent annual inspection, he may have made the assumption that it had been overhauled.

Examination and testing of the tow release

The tow release from G-CHBB was taken to the manufacturer's facility for examination, testing and disassembly. Its records showed that S/N 056068 had not been returned for overhaul since its original manufacture. External visual examination confirmed the tow release to be in its original design condition, with the exception that the housing and ring cage had been repainted, using paint different to that used by the manufacturer. All mechanical parts moved freely, although there was no evidence of recent cleaning or lubrication.

The force required to release a tow cable with 750 daN load was measured twice, at 128 N and 126 N. For new or overhauled tow release couplings, the manufacturer adjusts this value to be within the range of 110 ±15 N. Although marginally out of range, the manufacturer stated that lubrication would bring the release force within range, and therefore considered the measured value to be acceptable. The automatic release angle was measured as 81°, which was in the allowable range of 83 ± 7°.

Disassembly revealed that all internal parts were present and unaltered from the original design. Residue of old grease was evident on internal components. Neither the inside of the housing, nor the bolt shanks had been repainted, indicating that repainting had taken place without disassembly.

In summary, there was no indication that the tow release coupling had been modified, disassembled or damaged in the past. Its condition was consistent with a tow release of its age that had not been subject to overhaul. The manufacturer considered that the painting and apparent lack of recent lubrication appeared to have no negative effects on the function of the tow release. Based on the test results, the manufacturer considered that the release was in an acceptable technical condition.

The manufacturer considered that G-CHBB's tow release would have lost its airworthiness in 1995, four years after its manufacture, because prior to 2001, it required G88 tow releases to be overhauled every four years or 2,000 launches, whichever occurred first. Being a German company, its position was based on the German regulations applicable at the time. However, at that time, tow releases on UK gliders operated under the BGA system were maintained 'on condition' and were not required to comply with the manufacturer's four-year overhaul interval.

Airfield information

The airfield occupies an undulating site on lower ground to the west of Dunstable Downs. The resident gliding club oversees flying from the airfield including winch, aerotow and self-launch operations. There are several launching tracks (runs) available depending on the wind conditions on the day (Figure 5). On 16 August 2023, the wind was relatively light and blowing from a northerly direction, so the Northeast Run was operational for winch launching. There were a significant number of pilots participating in a club cross-country event and requiring aerotow launches, therefore a grid-style launch queue was established on the West Run to deconflict from the winch launching activities. As a further measure, the winch cables were retracted and no winch launching took place during the period when the aerotow run was active.

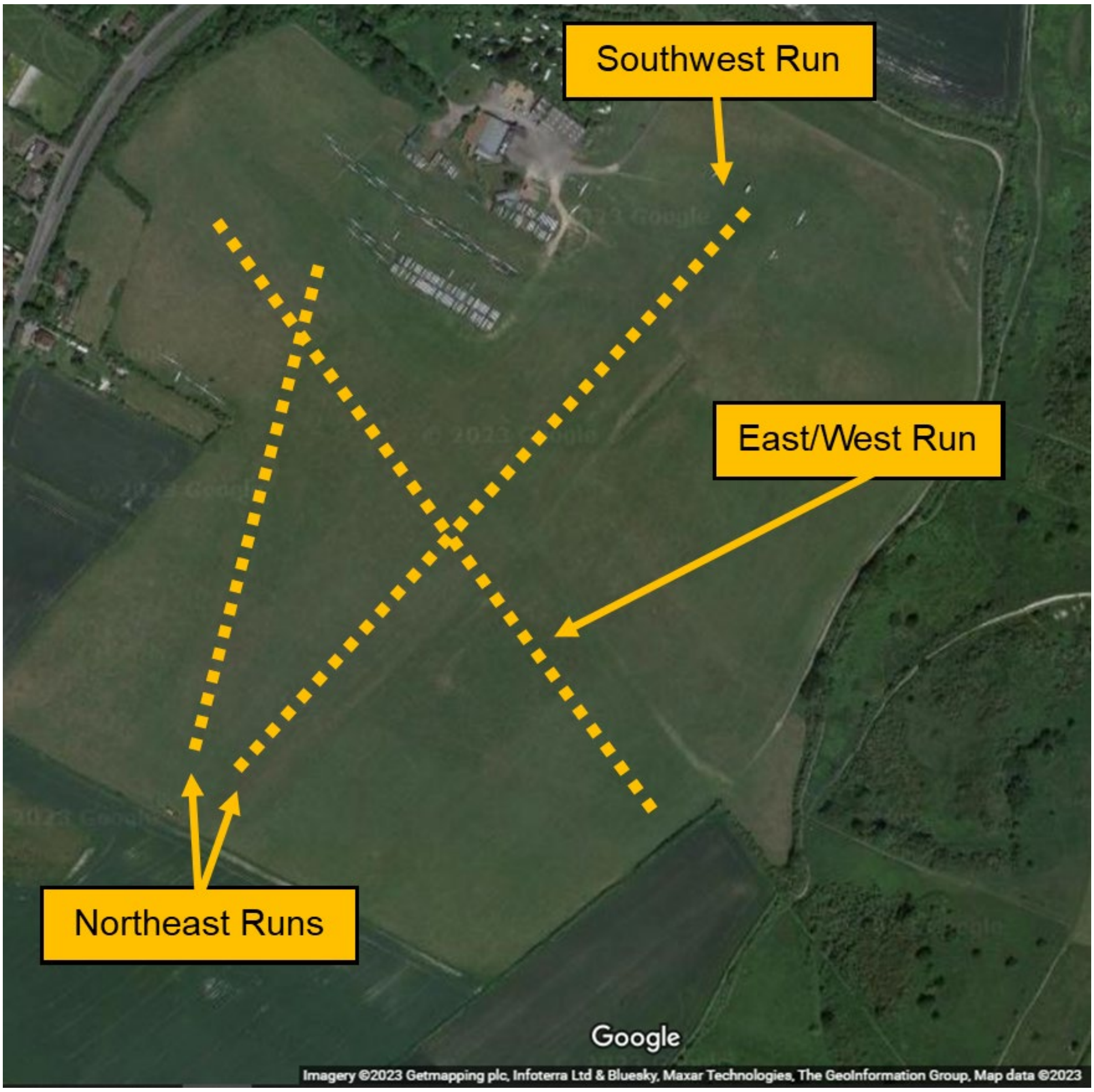


Figure 5

Launch runs at Dunstable Airfield

The West Run's average gradient is 2.4% downhill from the launch point to the airfield's north-western boundary. Beyond the boundary the ground falls away more steeply toward the B489 road, residential buildings, and trees before rising gently over open farmland beyond (Figure 6). In part to avoid overflying the hazards west of the road, but also for noise abatement considerations, tug pilots aerotowing on the West Run would aim to turn right onto a more north/northeasterly track once safely airborne.

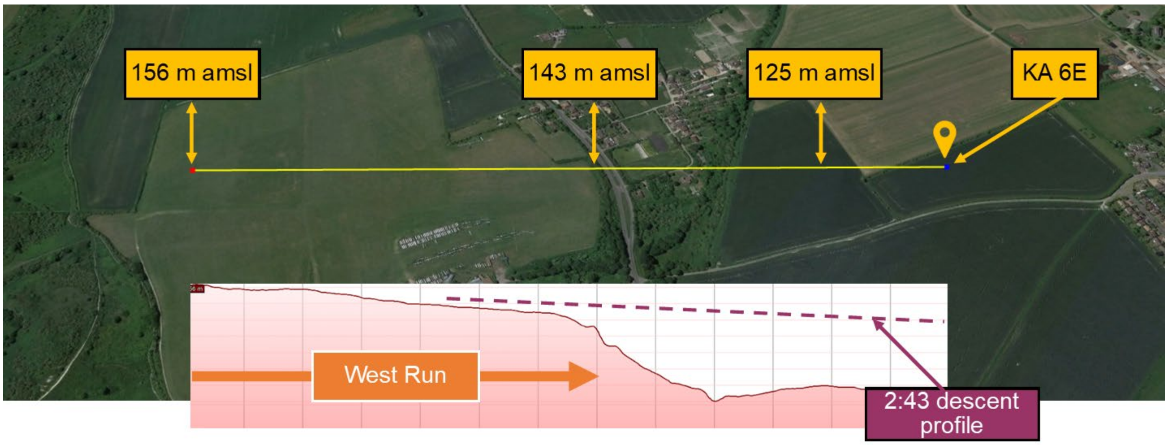


Figure 6

Cross sectional elevation of the West Run[4,5]
(imagery ©Google Earth 2023)

On the West Run there are only two realistic options for landing in the event of an aerotow launch failure below a height at which a turnback toward the airfield would be achievable. The first is to land within the remaining airfield ahead, the second is to glide over the B489 to land in one of the fields beyond the intervening hazards. Pilots at the club are trained that, before the tow commences, they should have in mind a cut off/decision point during the launch where the first option of landing and stopping within the airfield boundary is no longer possible, thereafter landing out would become the target. These decision points would vary for each launch depending on factors such as the known gliding performance of the aircraft being flown and the prevailing weather conditions. Given the area of inhospitable ground between the B489 and the open fields, there could be occasions where a launch failure occurred with insufficient clear airfield ahead for a normal braked landing yet the distant fields were unreachable due to the glider's performance. In such a situation, landing on the airfield and deliberately executing a ground loop[6] would likely be the preferred option. The images at Figures 7 and 8 below are from two separate points approximately 40 ft above the West Run and give an indication of the likely view ahead for the accident pilot from those locations. Figure 7 was thought to be the earliest point at which the tow rope could have released and Figure 8 was the approximate position of the glider when it commenced the final left turn.

Footnote

[4] Position KA 6E is explained in section '*Organisational information/Aerotow launch failure events at Dunstable Airfield.'*

[5] The significance of the 2:43 descent profile is detailed in section '*Aircraft handling/Gliding performance.'*

[6] See section '*Aircraft handling/ASW 24 handling notes*.'

Figure 7

View from the estimated earliest position when the tow rope became disconnected

Figure 8

View from the approximate position of G-CHBB immediately before the left turn

Weight and balance

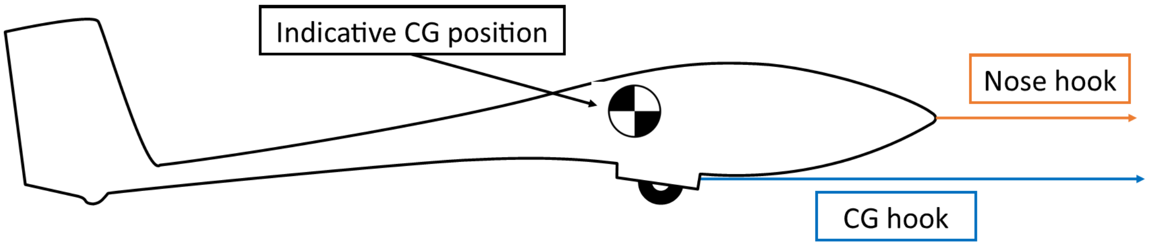
Based on the glider's last weighing record, dated October 2022, the basic weight of the aircraft was 255 kg and the range of allowable pilot weights to remain within CG limits was 67-110 kg. While wearing his parachute, the pilot's boarding weight would have been approximately 90-95 kg.

Aircraft handling

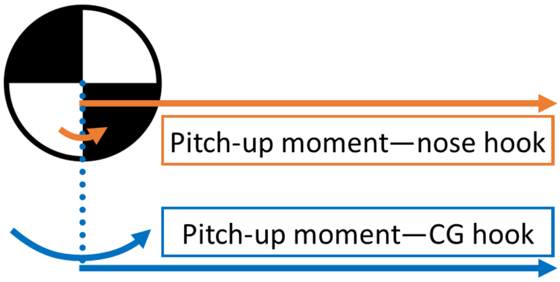
Aerotowing using CG vs nose hook

For either winch or aerotow launching, gliders need to be fitted with an appropriate hook to which the launching cable or tow rope can be attached. Gliders are primarily equipped with a CG hook which has a back release capability and is compatible with either winch or aerotow launch methods. While the CG hook can be used for aerotowing, having the tow cable attached lower than the glider's vertical CG position generates an undesirable, but unavoidable, nose-up pitching moment. Where fitted, a nose hook is preferred for aerotowing because, while the pull force from the nose hook might not always be vertically aligned with the CG, the magnitude of any resultant pitching moment would be significantly less than when using the CG hook (Figure 9). G-CHBB did not have a nose hook, therefore the CG hook was necessarily used for both winch and aerotow launching.

The club explained that the mitigations to compensate for the CG hook pitch-up moment, "setting the correct trim position and applying modest forward inputs on the control stick," are drawn to the attention of pilots when they are first converting to the ASW 24 type.



(a) Nose vs CG hook configuration



(b) Exemplar comparison of nose vs CG hook, pitch-up moment about CG

Figure 9

Indicative comparison of nose-up pitching moments for CG and nose hooks
(Illustration not to scale nor representative of the actual CG position for the ASW 24 type)

ASW 24 handling notes

The ASW 24 Flight Manual (FM) describes the type as a '*high-performance*' aircraft, '*suitable for record breaking and competition flying*' which possesses '*pleasant flying characteristics*.' It further states that, in the event of a stall '*in straight or circling flight, relaxing of back pressure on the stick will always lead to recovery.*' An independent flight test evaluation report, published in 1994[7], described the stalling characteristics of the ASW 24 as being '*relatively gentle for a high-performance sailplane*,' but that '*it would drop a wing if provoked and will start to spin if the stick is held aft.*'

The FM guidance for aerotowing is that a tow rope between 40 m and 60 m in length should be used and the pitch trim should be set '*nose heavy.*' Pilots are also advised that fully deploying the airbrakes at the start of the takeoff run can be '*useful*' to prevent the glider from overrunning the tow rope until the slack is taken up. If used in this manner, the airbrakes should be '*promptly closed and locked*' once the ailerons have become effective during the ground run. The tow rope was 50 m long and the air brakes were seen to be retracted before takeoff. Disruption of the cockpit area meant that the takeoff trim setting could not be determined.

The recommended aerotow takeoff technique is that, once airborne the glider pilot should initially climb to and maintain between 1 m and 2 m above the ground '*in order to avoid pitch oscillations caused by ground effect and slipstream turbulence from the tug*.' The FM states a '*maximum acceptable crosswind component*' of 13½ kt for aerotowing.

The '*Emergency Procedures*' section of the FM directs that, '*if the aircraft threatens to roll out beyond the intended landing area*,' the pilot should initiate a controlled ground loop '*not less than 40 m'* from the boundary hazard. The aim of ground looping would be to scrub off speed and bring the glider to rest before it overruns the landing area.

Stalling speed

Interpolation of the FM performance information using an assumed all up weight of 350 kg gives a basic stalling speed for an ASW 24 in level flight of approximately 36-37 kt. In a balanced turn at 60° angle of bank[8] the stalling speed would increase to approximately 57 kt and would further increase with steepening bank angle.

Gliding performance

The performance chart at Section 5.3 of the glider's FM (Figure 10) indicated that, in a clean configuration and wings level flight, airspeeds in the range 47-59 kt would generate a maximum achievable glide ratio of 1:43, equating to an approximate descent gradient of 2.32%. Either side of that speed range gliding performance would be reduced.

Footnote

[7] Flight test evaluation of the Schleicher ASW 24W by Richard H Johnson. Published in Soaring Magazine, May 1994.

[8] The maximum bank angle provided for on the relevant FM '*Stalling Speed Diagrams*.'

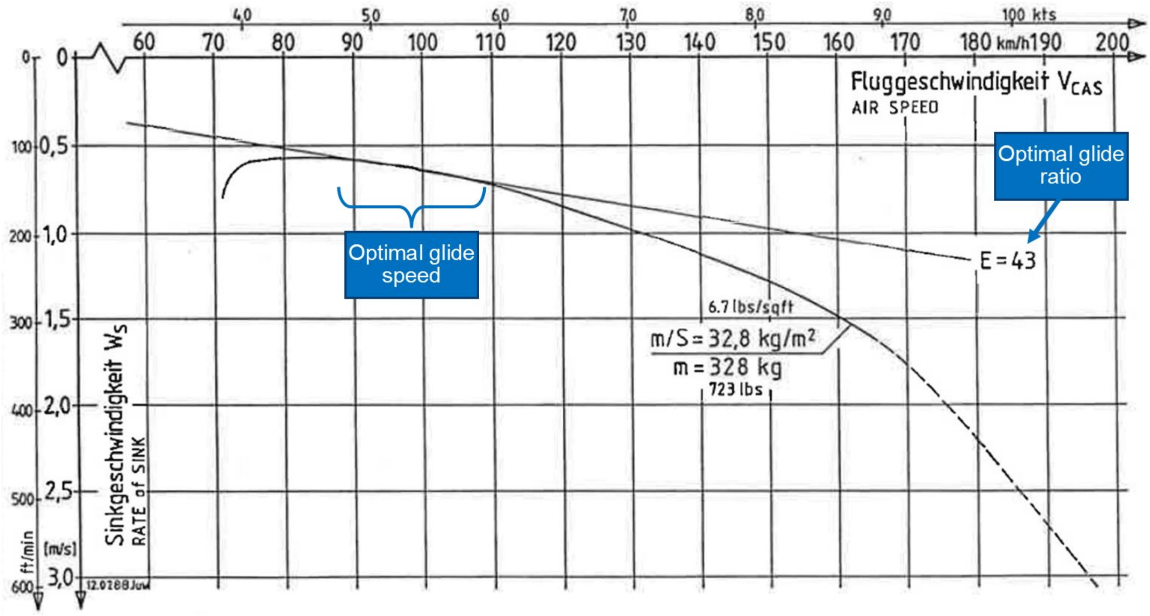


Figure 10

ASW 24 FM performance chart (courtesy of manufacturer)

The FM did not contain performance data for other than the clean configuration. An experienced ASW 24 pilot reported that, in their opinion, gliding performance would be reduced to approximately 1:30 with the landing gear extended. As an additional margin for uncertainty, the investigation used a notional 2:43 (1:21.5) glide angle when estimating the gliding range options available to the pilot after the tow rope became disconnected[9].

Meteorology

At the time of the accident, good weather prevailed at the airfield. It was a sunny day with broken cloud above 1,000 ft and excellent visibility. There was a gentle northerly breeze which would have resulted in a crosswind from the right of approximately 5-10 kt for aerotows using the West Run.

Personnel

The accident pilot had been a member of the club at Dunstable since taking up the sport in 2018 and most of his flying had been undertaken there. He held a Sailplane Pilot's Licence issued by the CAA in August 2021 as well as a UK Gliding Certificate issued by the BGA[10]. He first flew solo in July 2018 and completed the requirements for the Silver Badge[11] endorsement in September 2021. In 2022 he qualified as a BGA Basic Instructor[12] and successfully completed a bi-annual competency check flight with one of the club's instructors in February 2023.

Footnote

[9] See *Analysis/Decision making* section.

[10] Under delegation from Royal Aero Club who are recognised by the Fédération Aéronautique Internationale as the air sports authority in the United Kingdom.

[11] Qualification requirements detailed at Sporting badges and diplomas requirements - Pilot & Club Info (gliding.co.uk) [accessed 28 November 2023].

[12] Details of BGA instructor rating scheme can be found at About BGA Instructor and Coach ratings - Pilot & Club Info (gliding.co.uk) [accessed 28 November 2023].

The club advised that, because G-CHBB was a club-owned glider, prior to flying it, the pilot had been required to "demonstrate his abilities to a senior instructor." The type conversion process comprised "an evaluation of the pilot's suitability to fly the type, the associated training on rigging/derigging, and check flights in another high-performance glider, with his first flights on type being supervised."

Having first flown G-CHBB in March 2019, the accident flight was the pilot's twenty-fifth launch in the glider, and he last flew it on 16 June 2023. All his flights in G-CHBB were launched by aerotow. From the data available to the investigation, since March 2019, over 72% of all the flights undertaken by the pilot in any glider were aerotow-launched.

Autopsy findings

A post-mortem examination did not discover evidence of the pilot suffering from any acute or chronic medical condition that might have contributed to or caused the accident. The pathologist's finding was that the pilot died from '*multiple traumatic injuries.*'

Organisational information

Oversight of UK gliding

The BGA, as the sport governing body of gliding in the UK, publish their own operational regulations through their '*Laws and Rules*' webpage[13]. This webpage also contains links to BGA protocol documents detailing requirements and guidance for its member pilots. One of these documents, Managing the Flying Risk[14] (MFR), has the described aims of providing '*pilots and clubs with guidance on how to better understand, minimise and manage the hazards associated with gliding operations, including with powered gliders and tug aircraft.'* The guidance contained within the document comprises 24 sections designed to cover the complete spectrum of gliding operations, for example, Section 5 contains a 'currency barometer' and Section 10 provides guidance on safe aerotowing.

The Section 5 barometer acts as a quick reference guide for pilots to assess their level of currency. It uses inputs of launches completed and hours flown in the previous 12 months to generate a pilot currency status of Red, Yellow or Green. The accident pilot had flown a total of 53 launches and 18¾ hours flight time since 17 August 2022, correlating to a Green ('*your status is good but take care*') currency status, as described by the barometer. In addition to generating a currency status, the barometer also recommended that pilots who had completed less than three takeoffs and landings in the previous 90 days should undergo a dual check flight before flying as pilot in command. The accident pilot had flown three takeoffs and landings within the preceding 90 days. The club's operations manual also explicitly recommended the BGA currency barometer to it members and explained where a copy could be found displayed on a noticeboard in the club buildings.

Footnote

[13] Available at Laws and Rules - Pilot & Club Info (gliding.co.uk) [accessed 10 April 2024].

[14] Available at https://members.gliding.co.uk/bga-safety-management/managing-flying-risk-index [accessed 11 October 2023].

The guidance in Section 10 of the MFR document focused on aerotowing and listed '*gliders fitted with* [CG] *hook only*' as an additional risk factor which might contribute to a tug upset[15] situation due to the undesirable pitch up moment generated by geometry of the tow hook being below the glider's CG.

Guidance for launch failures

In common with powered aviation, losing launch traction during takeoff is an acknowledged risk factor for gliding. Exemplar failure modes might be a launching winch losing power or the tow rope breaking at a critical point on an aerotow. Techniques for safely handling such emergencies, generically referred to as cable breaks, are introduced at an early stage in a pilot's training. Cable breaks are routinely practised during subsequent check flight details for qualified pilots. When conducting dual training and check flights, launch failures are typically simulated by the instructor initiating an unannounced early cable release during a launch. Due to the elevated risk of landing away from the airfield, invariably such simulated emergencies will be initiated when the glider is able to safely land within the runway remaining ahead or is high enough to fly an abbreviated circuit to land back on the airfield.

Simulated cable breaks are not routinely initiated below turnback heights on aerotows, instead low level failures are practised in motor gliders. For these simulations, the motor glider's throttle is closed to simulate the cable break and reopened once the trainee has completed their immediate actions of establishing a safe gliding speed and identifying a suitable landing area.

In the June/July 2023 edition of their Sailplane & Gliding magazine, the BGA published an article titled 'Aerotow Options'[16] which discussed the topic of preparation for aerotow launch failures. The article included discussion on launch failure eventualities and reference to the use of simulators and motor gliders to safely simulate low-level aerotow launch failure events.

The club reported that their instructors teach students about launch failures, and how to handle them, in a manner consistent with the BGA Instructors' Manual and reinforce to pilots the potential hazards of turning back without sufficient height. The club was commissioning a flight simulator to further supplement the teaching of low-level aerotow failures in addition to "continuing emphasis being applied as part of a pilot's eventualities assessment."

Attempting to turnback toward the airfield following a loss of traction in the early stages of a takeoff attracts significant risk. In such a situation, the aircraft is critically low on both height and airspeed meaning there are limited viable options open. In a turn an aircraft's stalling speed and the amount of induced drag generated both increase. Unless height is available for the pilot to maintain speed by descending, the glider will decelerate. In situations such as this, the tighter and more prolonged a turn the more rapid the speed decay and the more likely it is the aircraft will enter a stall and/or spin with insufficient height available for recovery.

Footnote

[15] When an out of position glider causes the tow rope to exert a sufficiently destabilising force on the tug aircraft that its pilot loses control of their aircraft.

[16] Available at Aerotow options - Pilot & Club Info (gliding.co.uk) [accessed 11 April 2024].

Loss of roll control leading to a glider's wingtip touching the ground during the takeoff roll has led to fatal cartwheel accidents in the past. Glider pilots are instructed to immediately release the tow by pulling on the cable release if an uncontrollable wing drop occurs on the ground. To facilitate a timely reaction, pilots are encouraged to keep one hand on the cable release toggle, at least until they are safely airborne[17].

BGA instructor guidance

Among various resources for instructors across the many clubs comprising its membership, the BGA publishes an instructor manual on its website. Section 4-17 of the manual[18] covers aerotow launching. Specifically, some of the hazards associated with aerotow launch failures are outlined as follows:

> *'During the early stages of an aerotow, safe landing options are limited. Unlike wire launches, there can be a period when it isn't possible to land safely within the airfield boundaries. In the event, there is little time to think about the options or to search for places to go, so it's important to identify suitable off-field emergency landing areas during the tow… Until the glider is at a safe height to turn back, the only options are to land straight ahead or a few degrees to either side. At some sites there may be a short period in which the only available option is a more or less controlled crash. The primary aim then is to avoid personal injury. Fly the glider onto the ground in a clear space and ground loop at the slowest achievable speed… If the controlled crash option seems unpalatable, compare it with the risks of doing a low turn, catching a wingtip and cartwheeling, or spinning.'*

A key risk factor for aerotowing is the glider getting significantly out of position, vertically and/or in azimuth, which poses a serious threat to the towing aircraft. Glider pilots are taught that in such situations, the only safe option is to release the tow and abort the launch. Regarding tug upsets, section 4-17 of the manual states:

> *'These are serious and have caused the deaths of a number of tug pilots. If the glider is allowed to climb rapidly behind the tug, it can very quickly become impossible to prevent it accelerating upwards in a slingshot action (rather like a winch launch) and tipping the tug over into a vertical dive... Once that has happened only height can save the tug pilot from disaster. Downward displacement of the glider to a position below the slipstream is quite acceptable, but upward displacements are much more critical. The glider pilot must release immediately if the glider is going high and the tendency cannot be controlled, or the pilot loses sight of the tug. Factors which can combine to create a tug upset accident [include] … glider with a belly or CG hook…'*

Footnote

[17] BGA Instructor Manual, sections 17-3 (*Ground Operations*) and 17-7 (*Take-off*).

[18] Available at https://members.gliding.co.uk/library/instructors/bga-instructor-manual-section-4-17 [accessed 11 October 2023].

In addition to guidance contained in its instructor manual, the BGA publishes comprehensive aerotow safety information via its website. Their '*Safe Aerotowing*' webpage[19] includes detailed information and links to resources relating to the '*inherent hazards*' of aerotowing. One of the linked resources is the BGA's '*Safer Aerotowing leaflet*'[20] which focuses on the risk from, and prevention of, tug upsets.

Gliding club operations manual

The resident gliding glub at the airfield published its own operations manual designed to ensure that '*all club operations* [were] *carried out safely and efficiently, and that all members* [were] *fully aware of both the club's operational requirements and their own responsibilities*.' The local rules and procedures contained within it were complementary and subordinate to regulations contained in publications issued by relevant higher authorities (eg the CAA and the BGA). Pilots flying from the airfield were required to read and abide by document's contents.

One specific requirement of the manual was that '*before requesting a launch, each pilot must carry out a pre-flight safety check*.' This check was to include a pre-flight walk round inspection of the aircraft by the pilot in command and the completion of an internal pre-flight checklist following '*the standard BGA procedure, represented by the mnemonic CBSIFTBEC*.' The letter 'E' of the mnemonic was explained to represent '*Eventualities: consider the range of available options in the event of a launch failure…*'

The consensus amongst glider pilots asked by the investigation was that, when considering eventualities, they would brief (self-brief if solo) the height and geographical cut off points they planned to use in the event of a launch failure and that from a low height landing ahead would likely be the safest and preferred option. Subject to local conditions on the day, approximately 300 ft would be the minimum height at which they considered turning back toward the airfield, would present as a viable option when operating from the West Run.

Tests and research

Aerotow failure statistics

Including the accident flight, the BGA's safety archive contained records of 40 reported aerotow failures below 300 ft in the 10 years to August 2023. The accident flight was the only one of those launch failure events to prove fatal. Three people suffered serious injuries in two of the other occurrences, both of which involved two-seat gliders, each with two people on board. On 22 of the reported events the pilot elected to land straight ahead, and from a total of 26 occupants from the aircraft involved, only three suffered minor injuries, the rest were unhurt.

Footnote

[19] Available at https://members.gliding.co.uk/bga-safety-management/safe-aerotowing [accessed 11 October 2023].

[20] Available at https://members.gliding.co.uk/library/safety-briefings/safe-aerotowing-booklet [accessed 2 May 2024].

On all occasions where occupants suffered serious injury, the pilot had initiated a turn rather than choosing to land straight ahead. The BGA statistics did not contain details of the degree of turn attempted in each case. The information was caveated that it '[did] *not imply the pilot definitely attempted to turn back to the airfield*' and that such turns '[could] *have been to avoid an obstruction, or by reason of loss of control, or some other reason.*'

Aerotow launch failure events at Dunstable Airfield

To supplement the BGA's statistics, the gliding club provided more detailed information about low level aerotow launch failure events[21] which had occurred at Dunstable Airfield since early July 2022.

On 8 July 2022, the pilot of a Schleicher KA 6E glider inadvertently operated the tow release shortly after the tug got airborne on the West Run. The glider pilot judged that he would be unable to land and stop within the remaining clear area in front of him and that, being at a very low level, turning back was not an option. He continued ahead and landed in a crop field approximately 300 m past the inhospitable area that lay between the B489 road and the start of the open fields to the northwest. The glider touched down close to the point marked as '*KA 6E*' on Figure 6. The only damage sustained in the landing was to the tailplane which caught on the wheat crop growing in the field. In reviewing the incident, the club observed that '*aerotowing from Dunstable, like most gliding clubs, carries a strong risk of damaging a glider in the event of a low level launch failure… When we consider a low termination of aerotow under 'Eventualities' before launching we can only aim to avoid an accident which would injure the pilots*.'

On 17 December 2022, a Schleicher ASK 21 got out of position high behind the tug at an early stage in the takeoff and the instructor released the tow rope at an estimated height of 75-100 ft. Judging there was enough height available to him, the instructor turned right to land back on the airfield. Witnesses observed that the start of the turn '*looked okay*' but that the glider quickly ran out of speed before descending out of sight behind intervening higher ground in the middle of the airfield in a steep turn with a low nose attitude. Moments later the sound of an impact could be heard. The glider's right wingtip had struck the ground in the turn causing the aircraft to cartwheel, during which the fuselage broke in half and the tailplane was ripped from the fin. While the glider was severely damaged, the two occupants escaped serious injury.

On 7 October 2023, approximately eight weeks after the G-CHBB accident, a Schleicher ASK 21 glider was being aerotowed on the Southwest Run when it became apparent, from the tug aircraft's slow initial acceleration and protracted ground run, that it was not performing as expected. While the tug managed to get airborne, it then sank back onto the runway so the instructor in the glider took control and released the tow to abort the launch. The instructor then flew a shallow 'S-turn' to position for landing in a field just beyond the airfield boundary. The glider did not suffer any damage and neither occupant was injured.

Footnote

[21] In addition to the accident flight.

Other information

Startle and surprise

Startle is a '*brief, fast and highly physiological reaction to a sudden, intense or threatening stimulus*'[22]. A startle response occurs immediately in response to a startling stimulus and can impair pilot responses for a short period of time, usually between 0.3 and 1.5 s[23].

Surprise is '*an emotional and cognitive response to unexpected events that are (momentarily) difficult to explain, forcing a person to change his or her understanding of the problem*'. Surprise often follows a startle response if the cause of the stimulus that triggered the startle is not understood. Experimental studies looking at the effects of surprise on pilots have shown for example, delayed initiation of responses[24] and incorrect or incomplete application of procedures[25].

Analysis

Technical aspects

The investigation did not identify any defects which could have adversely affected the controllability of the glider. While it was not possible to rule out a technical issue during takeoff which may have caused the pilot to be distracted or his attention to be diverted, no such issues were identified by the wreckage examination. Although the airbrakes were found extended, the evidence suggests that this occurred when the glider struck the ground. This is consistent with the wing runner and tug pilot's observations that the airbrakes were not deployed during the takeoff run.

Examination and testing of the tow release coupling did not identify any mechanical issues which could have led to an uncommanded release of the tow cable. The measured release force was only marginally outside the normal range, despite an apparent absence of recent lubrication and the manufacturer considered the release to be in an acceptable technical condition.

The investigation noted that G-CHBB's more recent technical records did not accurately reflect the overhaul status of the tow release. The tow release had never been overhauled and had not reached the 2,500 launch overhaul criteria. However, an erroneous entry in the maintenance documentation implied that it had been overhauled at 1,138 launches. The reason for this was not determined, but it is possible that repainting of the release during maintenance in 2016, which gave it the appearance of a new or overhauled release,

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Footnote

[22] Landman, A., Groen, E.L., van Passen, M.M. Bronkhorst, A. & Mulder, M. (2017) 'Dealing with unexpected events on the flight deck: A conceptual model of startle and surprise' in Human Factors, Vol 59 pp 1161-1172.

[23] Martin, W., Murray, P. & Bates, P. (2012) 'The effects of startle of pilots during critical events: a case study analysis' Proceedings of 30th EAAP Conference: Aviation Psychology & Applied Human Factors – working towards zero accidents.

[24] Martin, W.L., ' Murray, P.S., Bates, P.R., & Lee, P.S. (2016) 'A flight simulator study of the impairment effects of startle on pilots during unexpected critical events.' Aviation Psychology and Applied Human Factors, Vol 6, pp24-32.

[25] Casner, S.M., Geven, R.W. & Williams, K.T. (2013) 'the effectiveness of airline pilot training for abnormal events.' Human Factors, Vol 55, pp-477-485.

could have created a false assumption that an overhaul had taken place. While this is not ideal from the perspective of airworthiness management of a lifed component, this documentation discrepancy had no bearing on the subsequent maintenance or condition of the tow release. Although it could have done so in the future if the glider had continued to operate beyond 2,500 launches.

Despite having been in service for 32 years, due to G-CHBB's low utilisation it had accumulated only 1,351 launches and, in other circumstances may have continued to operate for many more years before eventually meeting the 2,500 launch overhaul criteria for the tow release. While the tow release manufacturer recommended overhaul every four years, since 2001 there has been no mandatory calendar backstop to the overhaul interval. While not relevant to this accident, the absence of a mandatory calendar backstop may have relevance to other low utilisation gliders currently in operation.

Tow instability

G-CHBB was not fitted with a nose hook and towing using the CG hook was a known potentially destabilising factor for glider pilots aiming to maintain a consistent relative vertical position on aerotow. Nonetheless, the pilot had successfully flown 24 previous aerotows in G-CHBB using the CG hook. While the investigation considered other potential operational factors, such as distraction, it did not find evidence to support a finding that any of them directly contributed to the observed initial vertical instability on the accident flight. Considering the aerotow safety guidance published by the BGA, the pilot's status as a Basic Instructor, and that aerotowing was his preferred launch method, it was thought likely the pilot was aware of the risk posed by tug upsets and the BGA instructor manual's direction to release a tow if '*the glider is going high and the tendency cannot be controlled*.'

Cable release scenarios

While no evidence was found as to the mechanism by which the tow rope released from the glider, it was considered most likely to have resulted from the observed vertical instability of the tow. Credible scenarios for the disconnection were thought to be the hook mechanism back releasing or the pilot operating the tow release, either deliberately or by accident.

- For the mechanism to have back released, a force opposite to the direction of the tow would need to have acted on the CG hook. With a taut tow rope this would be impossible unless the glider was at an extreme angle. If the glider had started to catch the tug, possibly due to speed gained when recovering from the initial balloon after liftoff, the tow rope would have become slack and bowed. A slack rope would make back release more likely, especially if the tug was still on the ground and/or the glider was low enough for the rope to drag on the grass and impart a rearward force on the CG hook. That the tug pilot did not feel his aircraft react to the glider releasing suggests the tow rope was not taut when it became unhooked.

- Unintentional operation of the tow release mechanism could have occurred if the pilot was holding onto the release handle during the launch and inadvertently pulled it, as happened on 8 July 2022 in the incident involving a KA 6E glider. Inadvertent operation could have been made more likely if the primary focus of the pilot's attention was controlling the pitch oscillations experienced after liftoff. A factor strengthening the possibility of inadvertent release (which could include a back release) is that, from the earliest estimated point of disconnection, there appeared to be enough airfield ahead in which to land and stop before the boundary hedge. The pilot being unaware the rope had already released might also explain why the glider appeared to follow the tug's climb after the disconnection. The temporary pitch forward seen by Eyewitness A as the glider passed through a height of approximately 6 m might possibly have been an artefact of the release removing the nose-up pitch moment from the CG hook, which was then compensated for instinctively by the pilot. For an unintentional release it is more likely the pilot would have suffered from startle and/or surprise on realising that he was no longer connected to the tow rope. A response delayed by startle or surprise would have put the glider even closer to the point at which landing on the airfield ahead became untenable.

- It is possible the pilot released the tow intentionally due to concern about the risk of causing a tug upset if he was significantly out of position. The investigation did not find evidence to support or disprove any other factor, medical, operational or technical, that might have prompted the pilot to abort the launch. Factors considered to mitigate against an intentional release were:

    - It appeared to Eyewitness A that the accident pilot had managed to control the initial vertical instability and was in a normal position when the tug lifted off, thus the risk of an imminent tug upset seemed to have been avoided.

    - As soon as the pilot knew they were no longer connected to the tow, lowering the nose to maintain an efficient gliding speed would have been the most appropriate course of action. Climbing and losing speed would be counterintuitive.

    - If he made a conscious decision to release the tow cable it would be less likely for the pilot to experience subsequent startle and surprise and more likely that he would respond to the emergency without additional delay.

While the investigation considered these three scenarios, it was not possible to determine, which, if any of them, explained how the tow rope came to be released.

Decision making

Regardless of how it happened, once the tow rope had detached, the pilot was committed to an immediate emergency landing and needed to quickly decide the most appropriate course of action.

Based on interviews with other glider pilots, from the height and position at which the disconnection occurred, landing ahead would appear to have been the most appropriate course of action. The investigation learned of three recent aerotow launch failures from similar heights at the airfield, one of these happened approximately eight weeks after the G-CHBB accident. Of those three events, the two where the pilot continued ahead and landed out were successful, the one where the pilot attempted a turnback resulted in a cartwheeling accident, although both occupants escaped serious injury.

Analysis of recorded data and imagery taken by the investigation indicated that, from the earliest estimated point at which the tow rope released, there was probably enough of the airfield ahead for some form of emergency landing short of the airfield boundary. Any delay to recognition of, or response to, the disconnection would increase the risk of landing too close to the trees and bushes bordering the airfield to avoid a collision, thus making that option increasingly untenable.

Comparing a notional 2:43 glide angle with the terrain elevation profile of the West Run (Figure 3), from the earliest point of disconnection it could theoretically have been possible for the pilot to glide past the B489 and land in the open fields beyond. While theoretically possible, this may not have been apparent to the accident pilot at the time and it was not known if he was aware of the successful field landing carried out by the KA 6E pilot in July 2022. From below 100 ft agl the pilot would have been largely unsighted on the low ground and intervening hazards between the airfield boundary and the fields to the northwest (Figure 5), making it more challenging to judge the distance to a safe landing area.

Previous accidents, in powered and non-powered aviation, have shown that turning back to the airfield following a loss of launch traction at low level is a high-risk manoeuvre. The BGA statistics, supported by details from those incidents which occurred at Dunstable, reinforce the message that landing ahead from a low level launch failure is likely to offer the greatest probability of a successful outcome. Based on the pilot's flying background and interviews with instructors who had flown with him, the investigation concluded that, ordinarily, when conducting his pre-flight checklist, the accident pilot would have self-briefed to land ahead following an abort below 300 ft and to only contemplate returning to the airfield when above that height.

While the pilot may have self-briefed to land ahead, startle and surprise could have contributed to him not executing his pre-determined plan, especially if at the point of decision neither of the landing areas ahead looked assured. It was not possible to determine why the accident pilot made the decision to initiate the steep left turn that precipitated the final loss of control.

The flight evaluation published in the May 1994 edition of Soaring Magazine reported that the ASW 24 type had relatively gentle stalling characteristics but would '*drop a wing if provoked and* [would] *start to spin if the stick is held back*.' The glider's angle of bank, seen on CCTV as it turned left, appeared to exceed 60° and to generate the observed rate of turn the stick would need to have been pulled rearwards. At 60° angle of bank the glider's stalling speed would have increased to approximately 57 kt. The glider's airspeed was not recorded but its groundspeed on entering the turn was 57 kt and this reduced during the turn even though the tailwind component was increasing. The tightness of the turn and reducing airspeed meant the glider entered an unsustainable flight regime and departed from controlled flight at a height and attitude from which recovery was impossible.

In response to the accident, the resident gliding club has begun a process of trying to identity where they could make recommendations and improvements regarding low level aerotow failures. They noted that, while such failures are practised, because of the risks associated with field landings, they would never be initiated at a height which precluded a successful turnback and landing on the airfield. They considered that this practice might seduce pilots into thinking that a turnback would always be possible. To counter this risk, the club aerotowing training syllabus includes training in a motor glider so that low level failures can be simulated in a safe and realistic manner. Following the accident, the club's flight simulator became operational and their intention was to use it to supplement the teaching of low level launch failure handling. The club were also intending to review the way they taught eventualities, '*to better reflect what we would actually do in the event we found ourselves somewhere we weren't expecting*.' They observed that while pilots would include landing out in their eventualities brief, taking the decision to land off-site '*is something a lot of people might well struggle with*.'

Conclusion

Whatever the cause of the tow rope becoming released from the glider, the accident pilot found himself in a challenging position, possibly suffering from the negative performance shaping effects of startle and/or surprise. With little height or speed available to him he needed to quickly decide on an appropriate course of action. That he decided to turnback toward the airfield indicates he did not consider landing ahead was a viable option. Regardless of that perception, at the height and speed he found himself, turning back proved unachievable.

The hazards associated with launch failures are acknowledged at all levels within the gliding community and mitigation in the form of procedures, awareness programmes, and pilot training and assessment are well-established. Nonetheless, pilots experiencing a low level aerotow failure are potentially faced with an unenviable dilemma. In the words of the BGA instructor manual, they could find themselves needing to deliberately initiate a '*controlled crash*' with the primary aim of minimising personal injury. Turning away from a certain accident might seem lower risk, but in a situation such as the accident pilot found himself, by potentially avoiding a controlled crash pilots can quickly find themselves facing an uncontrolled one where the outcome relies entirely on providence. Tragically, the accident pilot was not as fortunate as the occupants of the ASK 21 that cartwheeled at the airfield in December 2022. From the BGA statistics, it is compelling that, while some of the gliders suffered substantial damage, where pilots elected to land ahead following a low level aerotow failure, none of the occupants suffered more than minor injuries. Although only a small sample size, being able to analyse in more detail the four events which occurred at Dunstable reinforces the argument; landing ahead proved successful, while turning back resulted in the loss of both aircraft and the death of the accident pilot.

This accident serves to highlight how challenging it is to make effective decisions in the heat of the moment when something goes wrong unexpectedly at a critical stage of flight. While pilots may verbalise their intentions as part of an eventualities brief, being able to enact the plan when startled, surprised and under extreme pressure, is not necessarily assured. Practising such failures at low level on live aerotows would carry significant risk and likely result in an unacceptable percentage of training events ending in accidents. Using motor gliders to safely train for low level aerotow failures is an established practice within the gliding community, flight simulators, provided they are sufficiently representative, would appear to offer an additional opportunity to help de-risk the process. Another technique to make decision making more consistent and to reduce the likelihood of startle and surprise is for pilots to regularly rehearse the actions they would take in response to failures at various stages of flight. For maximum benefit, rehearsals should include mental visualisation as well as physical movement simulating the actual control inputs and selections that would be required. In this way, an emergency scenario becomes more familiar to the pilot, therefore making it potentially less startling or surprising if it occurs for real. With most of the decision making and preparation being done beforehand, when faced with rehearsed emergencies pilot response can be more consistent and reliable.

Published: 30 May 2024.

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:	Europa XS Monowheel, G-BYIK	
No & Type of Engines:	1 Rotax 912-UL piston engine	
Year of Manufacture:	1999 (Serial no: PFA 247-12771)	
Date & Time (UTC):	16 March 2024 at 1300 hrs	
Location:	Full Sutton Airfield, Yorkshire	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Tail fin, left wing, aileron and propeller damaged	
Commander's Licence:	Other	
Commander's Age:	76 years	
Commander's Flying Experience:	475 hours (of which 209 were on type) Last 90 days - 5 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB	

History of the flight

The aircraft bounced while landing at Full Sutton Airfield and the pilot initiated a go-around. He opened the throttle, the aircraft lifted off and started to climb. However, he felt that he had pitched up too much and so levelled off at about 80 ft agl, at which point the left wing dropped and the aircraft descended. The left wing hit the ground and the aircraft partially cartwheeled damaging the propeller, wing tip and tail fin before coming to a stop. The pilot was able to exit the aircraft with minor injuries.

Pilot's comments

The pilot considered there were several factors which led to the accident. He touched down "a little faster" than he would have liked which resulted in the bounce. He then applied power too late during the go-around and, whilst reducing the pitch angle and levelling off, the aircraft airspeed decreased. He believes the aircraft may also have been affected by turbulence and airflow around the nearby hangars.

Accident

Aircraft Types and Registrations:	1) Slingsby T.21B, WB 924 2) DJI Mini 2	
No & Type of Engines:	1) 0 engines 2) 4 electric motors	
Year of Manufacture:	1) 1947 2) Unknown	
Date & Time (UTC):	7 October 2023 at 1657 hrs	
Location:	Dunstable Airfield, Bedfordshire	
Type of Flight:	1) Private 2) Private	
Persons on Board:	1) Crew - 1 2) Crew - 0	Passengers - 1 Passengers - 0
Injuries:	1) Crew - None 2) Crew - N/A	Passengers - None Passengers - N/A
Nature of Damage:	1) Superficial damage to the fabric surface of the leading edge of the glider's left wing. 2) The damage to the unmanned aircraft is unknown.	
Commander's Licence:	1) BGA Gliding Certificate 2) Not known	
Commander's Age:	1) 59 years 2) Not known	
Commander's Flying Experience:	1) 864 hours (of which 3 were on type) Last 90 days - 14 hours Last 28 days - 8 hours 2) Unknown	
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB enquiries	

Synopsis

During the approach, the glider was struck by a small, unmanned aircraft (UA) that from the memory card recovered from the UA showed that it was intentionally flown close to the glider. The glider sustained superficial damage to the surface of the wing.

History of the flight

On the approach to land at Dunstable Airfield, at approximately 100 ft agl, the pilot and passenger in WB 924 saw a small UA which several seconds later passed close to the head of the passenger and struck the leading edge of the left wing. The glider landed safely, and the damage was later assessed as “cosmetic”. The glider pilot reported that the UA was flown from a ridge, east of the airfield.

The UA fell to the ground and was retrieved by two young individuals who shared the UA log and video footage with a witness. The log and video show that the UA was flown on the direct approach path of the glider, and the glider was in view of the camera on the UA. Figure 1 is an image taken from the UA video just prior to impact. The video also shows that the UA was being flown from a public car park located on Dunstable Downs and that the young operator was accompanied by two adults.

Figure 1

View from the UA camera just before impact (used with permission)

Operation of unmanned aircraft

UA involved in the accident

From a photograph of the UA, taken by a witness after the accident (Figure 2), it was identified as a DJI Mini 2, which is equipped with a camera and weighs 249 g. The images supplied to the AAIB did not display an Operator ID, nor was an ID reported to the AAIB.

Figure 2

UA after the collision (used with permission)

Regulations and guidance

A UA is classified as an aircraft and the Air Navigation Order Article 241 states:

> *'A person must not recklessly or negligently cause or permit an aircraft to endanger any person property.'*

The Regulations for the operation of UAs are in UK Regulation (EU) 2019/947. The CAA have published guidance material in The Drone Code[1]. The Code states that for a UA below a weight of 250 g, and equipped with a camera, an Operator ID is required, which must be labelled on the UA. Operators must be 18 years or over to obtain an Operator ID. Younger pilots can still fly the UA under the supervision of their guardian or parent providing they register for an Operator ID.

Conclusion

The midair collision occurred because the UA was intentionally flown on the approach path of the glider. Operation of the UA required an Operator ID, but the pilots were both too young to obtain one.

Footnote

[1] The Drone and Model Aircraft Code The Drone and Model Aircraft Code | UK Civil Aviation Authority (caa.co.uk). [accessed March 2024].

AAIB Record-Only Investigations

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

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

The accuracy of the information provided cannot be assured.

Record-only investigations reviewed: April - May 2024

2 Mar 2024 **UAS BFD Systems GD-40** Belfast

The 25 kg UAS was conducting a pre-planned commercial filming flight on a closed film set. A 'drone safety briefing' had been given to relevant cast and crew members and a defined 'lock off' area for the operation was cleared of personnel before the aircraft launched. Shortly after takeoff, the UA stopped responding to command inputs, and at approximately 5 m agl, flew out of the lock off area before colliding with part of the film set. After the collision the UA dropped to the ground, striking a film crew member as it fell, causing minor bruising to their leg. The pilot opined that in future he would consider restricting operations on busy film sets to sub 4 kg aircraft.

20 Mar 2024 **UAS DJI M210** Redcar and Cleveland, North Yorkshire

Approximately 13 minutes into a site survey flight the UA moved sharply to the right and began to lose height; the controller display showed an Electronic Speed Control error. The UA fell rapidly before striking the ground.

17 Apr 2024 **UAS DJI M300** Near Bolventor, Cornwall

The UAS was conducting a survey flight approximately 100 m from the remote pilot. It became unresponsive to control inputs and a propulsion failure message was generated. It flipped over and the payload detached, before the UA fell to the ground.

23 Apr 2024 **UAS Evolve Dynamics Sky Mantis** The White Cliffs of Dover, Kent

The link to the UA was lost and the UA flew off, possibly into the sea, and was not recovered.

24 Apr 2024 **UAS DJI Matrice 300** Near Mixbury, Oxfordshire

During a survey flight the remote pilot was notified of a connection issue with the payload. The pilot selected return to home and when the UA was about 30 m away the UA climbed vertically upwards with the engines at high speed. The pilot initiated emergency procedures, but the UA continued to climb for a "few minutes". It then descended at an increased speed and struck the ground roughly 50 m from pilot. The UAS manufacturer determined that the accident was caused by a hardware malfunction that resulted in ‘abnormal vertical fusion’.

26 Apr 2024 **UAS Titan** Draycot Aerodrome, Swindon

The UA took off and climbed to 90 m. It suddenly lost power to all drive units and fell to the ground.

Record-only investigations reviewed: April - May 2024 cont

4 May 2024 **UAS MA Chris Foss Multiphase Glider** Mitchinhampton Common, Gloucestershire

The model glider, weighing 3.3 kg and with a 144 inch wingspan, was being flown from Minchinhampton Common when the wings failed. It was reported that as it fell to the ground, the glider narrowly missed some members of the public before it struck, and damaged, the rear window of a camper van.

10 May 2024 **UAS XAG P40** Arundel, West Sussex

The UA was being used to spray plants in an industrial greenhouse. A rotor head and blades detached during a turn, and the UA struck the greenhouse.

13 May 2024 **UAS DJI M30T** Armthorpe, South Yorkshire

The UA took off at night and struck some overhead cables. The cables were not spotted by the remote pilot.

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).

Aircraft Accident Report Correction

Aircraft Type and Registration:	1) Ventus-2CT, G-KADS 2) E1 Antares, G-CLXG
Date & Time (UTC):	17 August 2023 at 1356 hrs
Location:	Melton Mowbray, Leicestershire
Information Source:	AAIB Field Investigation

AAIB Bulletin No 06/2024, page 72 refers

The report stated incorrectly that the rear fuselage and tail fell to the ground to the east of the main accident site rather than to the west.

Original text:

The rear fuselage and tail fell to the ground 450 m to the east of the main accident site, in an open area of vegetation.

Corrected text:

The rear fuselage and tail fell to the ground 450 m to the west of the main accident site, in an open area of vegetation.

The online version of this report was corrected when published on 24 May 2024.

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

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

Published October 2015.

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

Published March 2016.

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

Published September 2016.

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

Published March 2017.

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

Published March 2018.

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

Published November 2018.

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

Published March 2020.

1/2021 Airbus A321-211, G-POWN
London Gatwick Airport
on 26 February 2020.

Published May 2021.

1/2023 Leonardo AW169, G-VSKP
King Power Stadium, Leicester
on 27 October 2018.

Published September 2023.

2/2023 Sikorsky S-92A, G-MCGY
Derriford Hospital, Plymouth,
Devon
on 4 March 2022.

Published November 2023.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

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

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