Air Accidents Investigation Branch

AAIB Bulletin 3/2022

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

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

Published 10 March 2022

Cover picture courtesy of Alan Thorne

ISSN 0309-4278

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

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(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Field Investigation Reports

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

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

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

SERIOUS INCIDENT

Aircraft Types and Registrations: (in date order of occurrence)	Airbus A320-232, G-EUUO Airbus A320-251N, G-TTNH Boeing 777-236, G-YMMR Airbus A330-343, G-VKSS
Other Aircraft Affected:	Boeing 787-9, G-ZBKJ Boeing 777-336ER, G-STBJ Boeing 787-8, G-ZBJF Airbus A319-131, G-DBCG
Date & Time (UTC):	Between 9 June 2021 and 19 July 2021
Location:	London Heathrow Airport, UK
Types of Flight:	Commercial Air Transport (Passenger)
Injuries:	None
Nature of Damage:	Various pitot tubes blocked
Information Source:	AAIB Field Investigation

Synopsis

Between 9 June 2021 and 19 July 2021, several aircraft suffered from abnormal pitot/static system events, two of which resulted in rejected takeoffs. The AAIB investigation identified the cause to be the nesting activity of certain species of wasps and bees within pitot probes. This report addresses the likely reasons as to why there was a concentration of such events over a relatively short period of time.

Although Heathrow Airport and the surrounding area was the focus for these occurrences, detailed information on the environmental factors is provided for the operators of airfields at other locations to take into consideration. Safety action has been taken by the CAA and those airline operators affected to reduce the risk of reoccurrence by introducing additional inspections and changes to the use of pitot covers. In addition, the airport operator is updating its environmental hazard management plan to take into account the findings of this investigation.

Background to the investigation

The investigation was initiated following a series of pitot system blockage events on three different aircraft over a period of consecutive days at London Heathrow Airport (Heathrow). Two of these events resulted in rejected takeoffs whilst one resulted in a return to stand following multiple system alerts during pushback. During the investigation, the AAIB were notified of a fourth abnormal pitot/static system event which occurred on an Airbus A330 flying between Heathrow and Milan Malpensa Airport (Milan), and were provided with ground maintenance inspection reports involving a number of other aircraft.

Chronology of the events

Airbus A320-232, G-EUUO on 9 June 2021

Pre-event

G-EUUO was an Airbus A320 Current Engine Option (CEO) variant that had been parked on maintenance stand TD4 (Figure 1) at Heathrow since 4 June 2021 when it had returned to service after a period of 2 months storage at London Gatwick Airport (Gatwick). Before leaving Gatwick, it underwent a standard return to service works package which included a pitot/static system flush and subsequent leak checks. There were no problems reported during the positioning flight from Gatwick to Heathrow. On arrival at Heathrow the aircraft underwent a maintenance package to prepare it for operations. This included an operational check of the bleed air valves on the engine. There was no further work carried out on the pitot/static system. The aircraft was parked on stand TD4 from 0346 hrs on 8 June 2021 until 0617 hrs on 9 June 2021. In line with regulatory requirements/guidance and the normal company operating procedures at that time, whilst parked at Heathrow the aircraft had not been fitted with pitot/static covers.

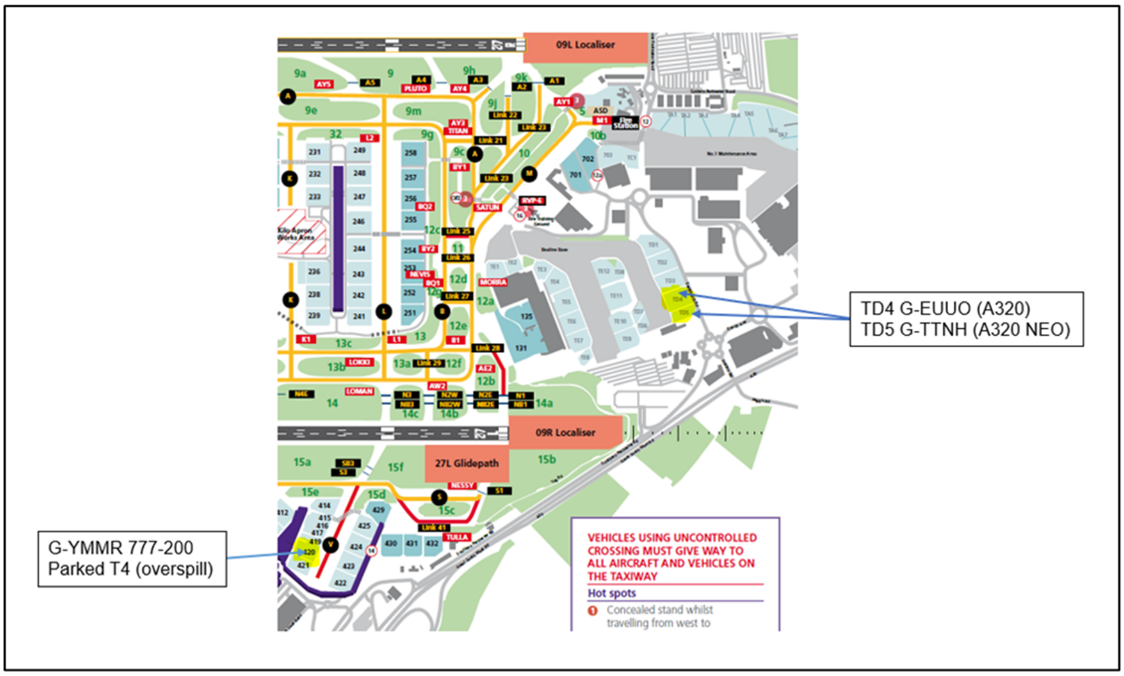

Figure 1

Parking locations of aircraft affected

The event

For the incident flight the commander was pilot flying. The flight crew reported a "brief[1]" smell of "burning hair" from the air conditioning ducts after start but did not observe any unusual cockpit indications until after commencing the takeoff roll. Shortly after the co-pilot, acting

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Footnote

[1] Lasting for approximately 10 seconds.

as pilot monitoring (PM), had called "thrust set," the commander noted that his Primary Flying Display (PFD) speed scale was still showing less than 40 kt airspeed. On glancing across at the PM's PFD, he saw it was already indicating over 70 kt. The commander took the decision to reject the takeoff and called "Stop" almost coincident with the co-pilot announcing "100 kt," a routine airspeed callout for A320 operations. The rejected takeoff procedure was followed, and the aircraft brought to a halt on the runway. Once stationary with the parking brake applied, the flight crew carried out a review of the aircraft status, including brake temperatures which were less than 300°C[2]. Satisfied that, apart from the lack of airspeed indication on the commander's PFD, the aircraft was otherwise serviceable, they taxied clear of the runway and returned to the terminal.

Post-event actions

An inspection of the pitot/static probes found that the left pitot probe, which feeds the commander's PFD, was blocked. The blockage appeared to be formed of a solid soil type material (Figure 2). The pitot probe was replaced, and the system tested and proven serviceable. At this point the operator judged that this was an isolated occurrence in an area of the airfield where insects had historically been problematic for aircraft. Since the previous occurrences, much of the hedgerow had been removed for other reasons.

Figure 2

G-EUUO pitot probe blockage

Airbus A320-251N, G-TTNH on 10 June 2021

Pre-event

G-TTNH was an Airbus A320 New Engine Option (NEO) variant that had been parked without pitot/static covers (in line with the requirements at that time) on stand TD5 at Heathrow for two days since its last flight.

Footnote

[2] The maximum permissible pre-takeoff brake temperature.

The event

The aircraft started displaying multiple, unexpected error messages shortly after being pushed back from stand. The first observed indication was a short duration Electronic Centralized Aircraft Monitor[3] (ECAM) alert relating to the rudder travel limiter system. Towards the end of the pushback manoeuvre, the commander saw his PFD speed scale indicating more than 160 kt and watched as the speed display "washed down to zero." With no hard faults latched on, the flight crew continued the engine start process whilst remaining alert for other potential issues. As per standard operating procedure (SOP) when not single-engine taxiing, engine 2 was the first to be started. Once engine 2 was running, the aircraft began to generate what the commander referred to as "rolling ECAM messages." Failure messages were displayed for both Radar Altimeter systems, engine 1 (although it still had not been started) and the co-pilot's angle of attack (AOA) probe. The flight control software mode had also downgraded from Normal to Alternate Law. On advice from the operator's Technical Control, engine 2 was shut down and the Air Data and Inertial Reference Units (ADIRU) were re-initialised before a second attempt at engine start. Despite system re-initialisation, the ECAM faults remained so the aircraft was taxied back to stand and shut down.

Post-event actions

Inspection of the aircraft pitot/static probes found that two out of the three probes were blocked with debris similar to that found on G-EUUO. The two affected probes were changed, and the following maintenance undertaken: the pitot/static lines were flushed; a leak test of the principal static and total air data system was actioned; a low-range leak test of the standby pneumatic circuits; a functional test of the altitude and airspeed data; and a system test of the system Air Data Reference (ADR) units. All of these tests were passed successfully. Given that this incident occurred on an aircraft parked on a stand next to the one on which G-EUUO had been located, the operator still considered that this was likely to be a problem localised to that particular area of the operator's parking bays.

Boeing 777-236, G-YMMR on 11 June 2021

Pre-event

Before the incident flight, G-YMMR had been positioned at Heathrow for six days, most of the time in the overspill parking area at Terminal 4, but also on a maintenance stand at the north-eastern area of the airport. In preparation for flight, it was towed to Terminal 5 ahead of its scheduled departure.

The event

The flight crew did not detect any system anomalies until early in the takeoff roll. Just after the PM verbally confirmed that takeoff thrust was set, both pilots looked at their flight displays and saw their airspeed indicators were not reading. The commander made the

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Footnote

[3] The ECAM monitors and displays systems information, including faults and corrective actions to be taken by the crew. As well as been accessible to the crew, the information is also text messaged between the aircraft and ground station via the ACARS (Aircraft Communications Addressing and Reporting System) digital datalink system.

executive “Stop” call and the aircraft was brought to a halt on the runway without further incident. After reviewing the aircraft status and noting that the brake temperatures were not excessively high, the flight crew taxied the aircraft back to the terminal.

Post-event actions

Inspection of the aircraft pitot probes showed that both the right and centre probes were blocked. The nature of this debris (Figure 3) was similar to that found on G-EUUO and G-TTNH. However, with the aircraft having been parked at a different location to the other two aircraft, the operator now considered that this was a wider issue, and the event was notified to the AAIB and the aircraft quarantined for inspection.

Figure 3
G-YMMR blocked pitot probe

On arrival at Heathrow the AAIB received a full brief from the aircraft operator on the range of pitot/static issues that had been experienced in the preceding three days. Following an inspection of the nature of the blockages on G-YMMR and given the geographical spread of the incidents, the AAIB engaged with the airport management and the CAA to agree on an appropriate method to raise awareness of the issue to other operators. Following discussion on the potential ways to do this, it was agreed that the most expeditious and effective manner to reach the right stakeholders was to issue a CAA Safety Notice. The CAA published SN-2021/014 – Pitot blockage events[4] the following day, 12 June 2021.

All aircraft undergo General Visual Inspections (GVI) prior to flight. However, this is conducted from ground level and, whilst the pitot/static probes are included in the scope of

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Footnote

[4] https://publicapps.caa.co.uk/docs/33/SafetyNotice2021014..pdf [accessed 16 November 2021].

the inspection, this check is more to look for physical damage rather than blockages which are difficult to see from ground level. After this event the operator introduced a requirement for any aircraft that had stopped at Heathrow overnight to be subject to a Detailed Visual Inspection (DVI) of the pitot probes within the two hours prior to departure. The DVI was required to be carried out within an arm's length of the probes, and visual aids used if required; the results were to be recorded in the aircraft technical log. Between 10 June 2021 and 14 June 2021, 265 pre-departure DVIs were carried out across the operator's fleet; no further pitot probe blockages were identified.

Post-event maintenance

As two of G-YMMR's probes had been found to be blocked (right and centre), all three probes were removed. The Total Air Temperature probes and static ports were inspected and found to be clear. The pitot/static system was flushed, and new probes fitted at the left, centre and right locations. No further debris was found during the system flushes. No previous reports of pitot/static system or ASI system defects had been reported on the aircraft and, following testing, it was released back to service.

Other aircraft affected

On 15 June 2021, the following aircraft failed DVI inspections:

- A Boeing 787-9, G-ZBKJ was found to have its right pitot probe blocked, and insect eggs were present inside the probe. The aircraft had been parked on Stand TA4 for three days prior to operating. The probe was changed, and the aircraft was released to service as the BA165 flight to Tel Aviv (TLV). En-route the aircraft displayed a LH ADM[5] DISAGREE message. This cleared with test on arrival and a DVI of all probes was carried out with no evidence of blockages recorded. On the return sector from TLV to Heathrow the LH ADM DISAGREE message re-appeared. An ADM fault investigation was instigated after the aircraft's arrival at Heathrow.

- A Boeing 777-300, G-STBJ, parked on stand TA6, was found to have its right pitot probe blocked and an insect, suspected to be a bee or wasp, was photographed on the end of the pitot probe (Figure 4). The right probe was removed for further inspection.

- A Boeing 787-8, G-ZBJF, parked on TA3 was found to have its right pitot probe blocked.

Footnote

[5] Air Data Module (ADM) the sensor that measures pressure in the pitot/static system.

Figure 4

Insect entering G-STBJ pitot probe

Following these incidents, the operator introduced the following additional control policies:

- Pitot covers to be installed on any aircraft parked on an engineering base stand at Heathrow until further notice.
- Pitot covers to be fitted to any aircraft staying overnight at any location and a DVI carried out pre-departure.

Additionally, a working group involving the airfield operator, affected airline operators, and the AAIB was set up to enable effective communication of emerging information to those organisations involved.

Airbus A330-343, G-VKSS on 1 July 2021

Pre-event

The operator had already implemented additional actions in response to the CAA Safety Notice including engineering visual inspections, notifications to raise awareness to crews and the installation of pitot covers for aircraft with a planned ground time at Heathrow in excess of 24 hours. G-VKSS had been in long term parking at Manchester Airport (Manchester) until 17 June 2021 when it was reactivated. The return from storage maintenance programme included a flush of the pitot/static system pressure lines before the aircraft undertook a positioning flight to Heathrow. After its arrival at Heathrow, the aircraft underwent maintenance until its first planned flight on 1 July 2021. During the period 17 June to 1 July, G-VKSS had been parked variously on stands VA4, 701 and 702.

Pitot head covers were fitted to the aircraft on 20 June, three days after its arrival from Manchester, and were removed prior to departure on the morning of 1 July 2021.

The event

The incident occurred on the outbound sector of a Heathrow-Milan-Heathrow flight. During the latter stages of the climb out from Heathrow, the aircraft's ECAM system alerted the flight crew to a failure of the co-pilot's pitot probe heater. In accordance with Flight Crew Operating Manual (FCOM) procedures, they switched the co-pilot's air data supply from its normal source, Air Data Computer 2 (ADC2), to ADC3. At no stage did they observe any associated unusual or unreliable indications on their flight instruments. Flight despatch for the return sector was undertaken using the same air data source configuration, this was in accordance with the Operator's Master Minimum Equipment List authorisations. Post-flight investigation by maintenance staff at Heathrow found, during removal, evidence of debris and contamination at the quick-disconnect union on the rear of the co-pilot's pitot probe (Figure 5). During the rectification work, further debris and contamination was found in the commander's pitot probe. No contamination or debris was found in the standby probe.

Figure 5

G-VKSS co-pilot's pitot probe debris

Post-event actions

The operator of G-VKSS notified the AAIB of the incident and the event was subsumed into the ongoing investigation. The operator responded with a risk-based approach and, in the week following the event, conducted a series of checks of the pitot/static systems on a sample of its aircraft fleet (Table 1). None of these checks revealed further instances of blockages or debris.

Aircraft type	Registration	No of pitot/static systems checked
B787	G-VDIA	All 3 systems
A330	G-VGEM	All 3 systems
B787	G-VNYL	All 3 systems
A330	G-VWAG	1 (Captains system)
A330	G-VSXY	1 (Captains system)

Table 1

Summary of initial survey of aircraft pitot/static systems

Following this event, the operator implemented the following policy:

- Pitot covers to be fitted on aircraft parked longer than 12 hours at UK bases (Heathrow and Manchester).
- Pitot covers to be fitted immediately on any aircraft parked for maintenance at UK bases.

Airbus A319-131 (G-DBCG) on 19 July 2021

The event

Whilst conducting a pre-departure DVI, an insect was spotted in the commander's pitot probe. The probe was sealed and removed by the engineers who then captured and secured the live insect (Figure 6). The insect was handed over to the AAIB and then transferred to the Natural History Museum (NHM) to try and identify the species.

Figure 6

Live species collected from pitot of G-DBCG

Summary of events

A summary of the occurrences and the various actions is shown in Figure 7.

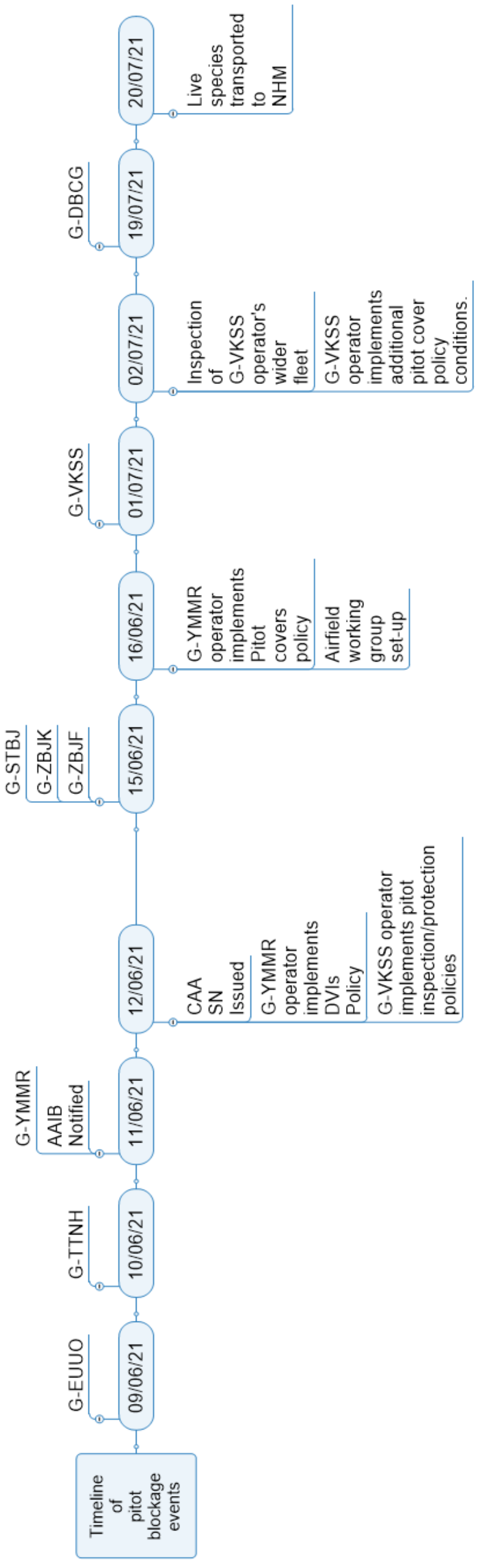

Figure 7

Timeline of events

Flight crew observations

The flight crews involved in the Heathrow incidents all reported being in less regular flying practice than during pre-Covid-19 pandemic times. They referred to this as meeting minimum flying currency[6] requirements but with the lower level of recency[7] giving rise to some degree of high-end skill fade and reduced operational fluency. As a precaution, the crews proactively took things a little slower, extended their briefings and placed extra focus on aircraft external checks and cockpit switch selections. They reported that this approach was in line with their company's "defensive operations" policy which had been implemented as mitigation for reduced pilot recency.

Unreliable airspeed indications had been a module in the pilots' recent recurrent simulator training and all three crews had discussed the topic during their pre-flight briefs, albeit focused on airborne rather than takeoff scenarios.

While both rejected takeoffs followed SOP, one pilot considered that reduced recency had caused them to initially question their fault diagnosis, prompting them to seek additional information before confirming the failure. Despite the obvious and relatively benign nature of the failures when they were detected, the crews reported purposefully following known procedures in a considered and methodical manner while resisting any temptation to expedite vacating the runway before the situation and aircraft status had been fully assessed.

The pilots of G-EUUO observed that, at the unusually low operating weights associated with low passenger numbers, the Airbus A320 SOP 100 kt check can be very close to V_1, leaving little time for a rejected takeoff decision if the speed anomaly is only detected at that point. The equivalent speed check on the Boeing 777 is made at 80 kt. The recorded data traces for the rejected takeoffs showed that both aircraft briefly continued to accelerate after their thrust levers were retarded[8]. The investigation was made aware of a similar incident at Luton Airport where a lightweight Airbus A319's takeoff was rejected at V_1 (109 kt), but before the retardation devices overcame the aircraft's residual acceleration, its airspeed peaked at 120 kt. While its speed exceeded V_1 during the rejected takeoff, the aircraft's relatively light weight meant that there was more than sufficient runway stop margin available.

The pilots of G-VKSS were alerted to the pitot heater failure by a system generated caution. There were no abnormal or unreliable instrument indications and the failure required them to switch the air data source for the co-pilot's instruments to the standby system. This did not present any further operational challenges for the remainder of the flight or the return sector to Heathrow. The co-pilot's pitot contamination was only discovered during the subsequent maintenance to rectify the pitot heater failure.

Footnote

[6] Satisfying the minimum time-based legal requirements to operate as a commander or co-pilot.
[7] An indicator of a pilot's level of recent flying practice compared with statistical norms for airline flight crews.
[8] For approximately two seconds in the case of G-EUUO and 10 seconds for G-YMMR.

Airfield information

General

Heathrow Airport is located on the western edge of London. It is one of the world's busiest international airports and is the UK's only major hub airport. It has two runways and five terminals, and approximately 90 scheduled airlines fly from Heathrow to 176 destinations around the world. The airport is within an area of high emissions with, in addition to the airport itself, significant contributions from London as well as from two nearby motorways, major roads, mainline train routes, local industry (including construction sites) and local housing. Heathrow and its surrounding area are shown in Figure 8 below.

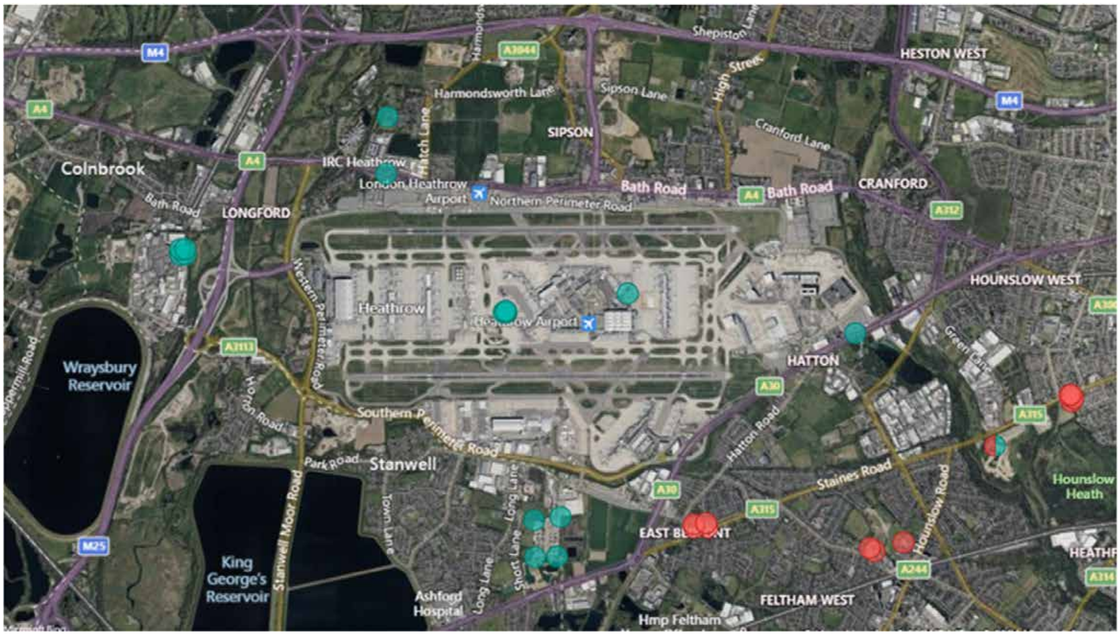

Figure 8

Construction sites at Heathrow and surrounding area
(image, based on Google Earth, used with permission)

Air quality monitoring

Airports are significant sources of many air pollutants. Aircraft jet engines emit pollutants including oxides of nitrogen (NOx), carbon monoxide (CO), oxides of sulphur (SOx), particulate matter, hydrocarbons from partially combusted fuel, and other trace compounds. There are also pollutant emissions from the airside vehicles, and from the large number of road vehicles travelling to and from the airport each day.

The airport operating company therefore carries out monitoring of ambient air quality at four sites (Figure 9) around the airport: on the northern apron near the perimeter and northern runway (LHR2), and outside the airport boundary at Harlington, Green Gates and Oaks Road.

The following pollutants are monitored at these sites:

- Oxides of nitrogen (nitric oxide (NO) and nitrogen dioxide (NO_2));
- Particulate matter (PM_{10} and $PM_{2.5}$ fractions)[9];
- Ozone (O_3) (Harlington);
- Black carbon (BC) (LHR2 and Oaks Road).

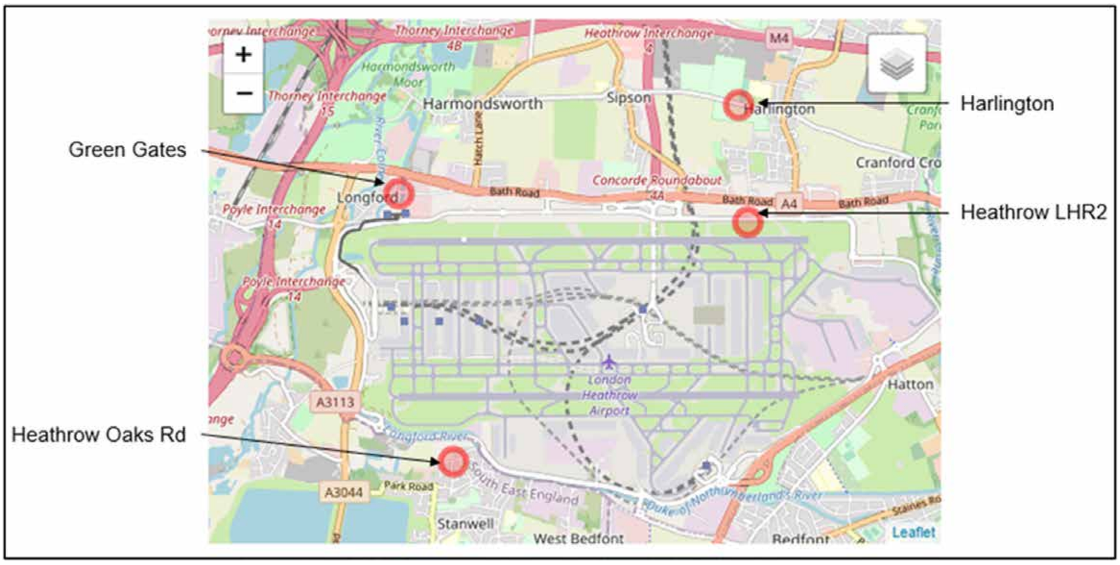

Figure 9

Heathrow Air Quality Monitoring Sites
(image used with permission)

Covid-19 pandemic restrictions saw tight restrictions on international and local travel, with multiple lockdowns imposed and stay-at-home orders issued. These actions saw NO_2 pollution levels across the country drop sharply at the end of March 2020. Overall primary pollutants saw a big decrease in their annual mean values in 2020 and this can be seen in the following graph (Figure 10):

Footnote

[9] The terms PM_{10} and $PM_{2.5}$ are used to describe particles with an effective size with a median aerodynamic diameter of 10 and 2.5 nm respectively.

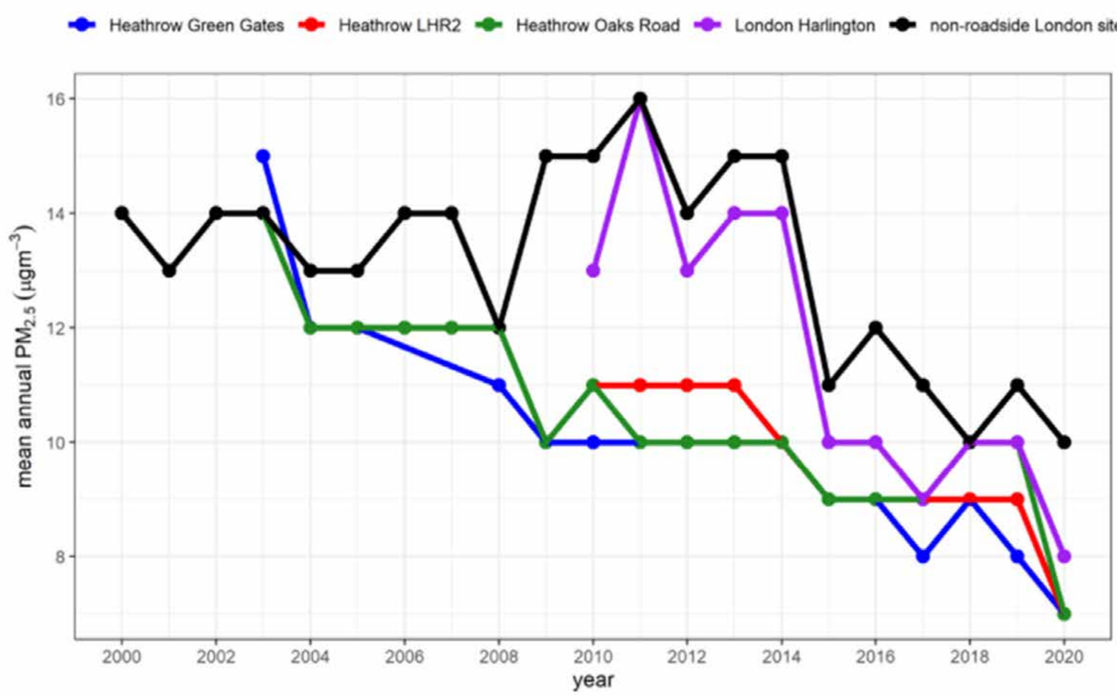

Figure 10

Graphs showing NO_2 and $PM_{2.5}$ levels during 2020

As shown in Figure 11 below, the ozone concentration increased as the traffic levels decreased. Whilst chemically identical, there are two different places that ozone is found; stratospheric ozone which protects the planet from harmful solar emissions, and ground ozone which is seen as a pollutant. Ground ozone is not emitted directly into the atmosphere, but is a secondary pollutant produced by a reaction between ozone precursors (nitrogen oxides and volatile organic compounds[10] (VOC)) and heat and sunlight. One of the main sources of these ozone precursors is road traffic. Counter-intuitively, ground ozone levels are often higher in rural areas than in cities. This is because ozone can also be degraded by the compounds which form it, and in urban areas the high level of VOCs also helps produce ozone-degrading nitrogen dioxide (NO_2).

Unlike NO, which has a lifespan of minutes, NO_2 will stay present for hours if not days. This allows it to be carried by the wind over long distances to rural areas. With lower traffic density and therefore lower VOCs, the increased presence of NO_2 reacts with the sunlight and produces ozone, which is why rural areas tend to have higher ozone levels. So, ironically, when traffic levels fall significantly in cities, the concentration of ozone increases in the short term.

Footnote

[10] Ethane, isopentane, propane, ethylene, toluene, propylene and 2,3-dimethylbutane are some of the most common VOC species in vehicle emissions.

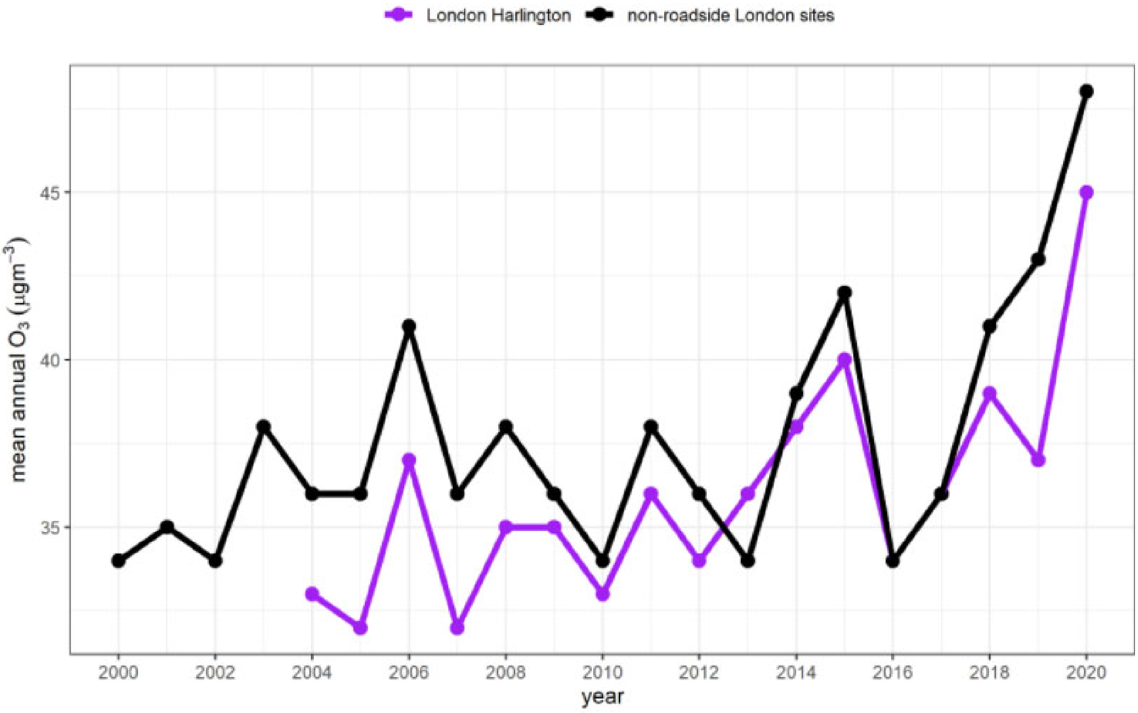

Figure 11

Time series of mean ozone at Harlington site
(image used with permission)

Environmental hazard management

There exist a range of environmental hazards on airfields which are managed by airfield operators in accordance with regulatory requirements[11]. Whilst the regulation is broad in scope, the primary species covered is the hazard to aircraft presented by birds. The control of insects is covered in the regulation under the general approach to habitat management but is focused on minimising the number of insects to reduce attracting birdlife, rather than dealing with a direct risk posed by insects to aircraft systems.

During this investigation, to enable swift communication of emerging information to inform the decision making of the organisations involved, a working group was initiated by the AAIB comprising the airport operator, the airport Biodiversity Management Team, and airline operators who had been affected. This group met regularly as new information and feedback from the control measures, and testing and analysis from the AAIB investigation emerged. Whilst initially chaired by the AAIB, the running of this group was taken on by the airport operator as the appropriate organisation to lead on managing environmental hazards on the airfield. Participation in the group was expanded to include the CAA as it became clear that this issue had the potential to affect other airfields in the UK.

Footnote

[11] CAA CAP 772 Wildlife hazard management at aerodromes, second edition October 2017. Available at https://publicapps.caa.co.uk/docs/33/CAP772_Issue2.pdf [accessed 16 November 2021].

Aircraft information

Pitot/static systems

Aircraft use two types of air pressure to determine their airspeed and altitude; the ambient air pressure around the aircraft (static pressure) is sensed through static ports, and the air pressure exerted as a result of the forward motion of the aircraft (total pressure) is sensed by pitot probes.

A pitot probe is essentially a tube used to sense the total pressure of the airflow. This tube is equipped with a heater cable which is wound around the pressure line to prevent ice accretion/pressure line obstruction. This pitot heater, which is automatically turned on upon engine start, can cause the pitot tip to reach temperatures of approximately 260°C on the ground. A water trap prevents water (coming from water droplets in atmosphere or melted ice) going further into the pressure line and this water is mainly evacuated through the drain holes. Ensuring the pitot drain holes remain free from any contamination is key to ensuring proper anti-icing performances of pitot probes. Pitot probe covers can be installed on the ground to prevent contaminants (such as sand, dust, or mud brought by insects to build their nests, or indeed insects themselves) from entering the probe and causing obstructions which can affect the measurement of airspeed. Also, it is of note that, for a pitot tube that is blocked, the pressure of any air that is trapped will increase when it is heated.

Whilst exact construction varies, a typical pitot is shown in cross section below (Figure 12).

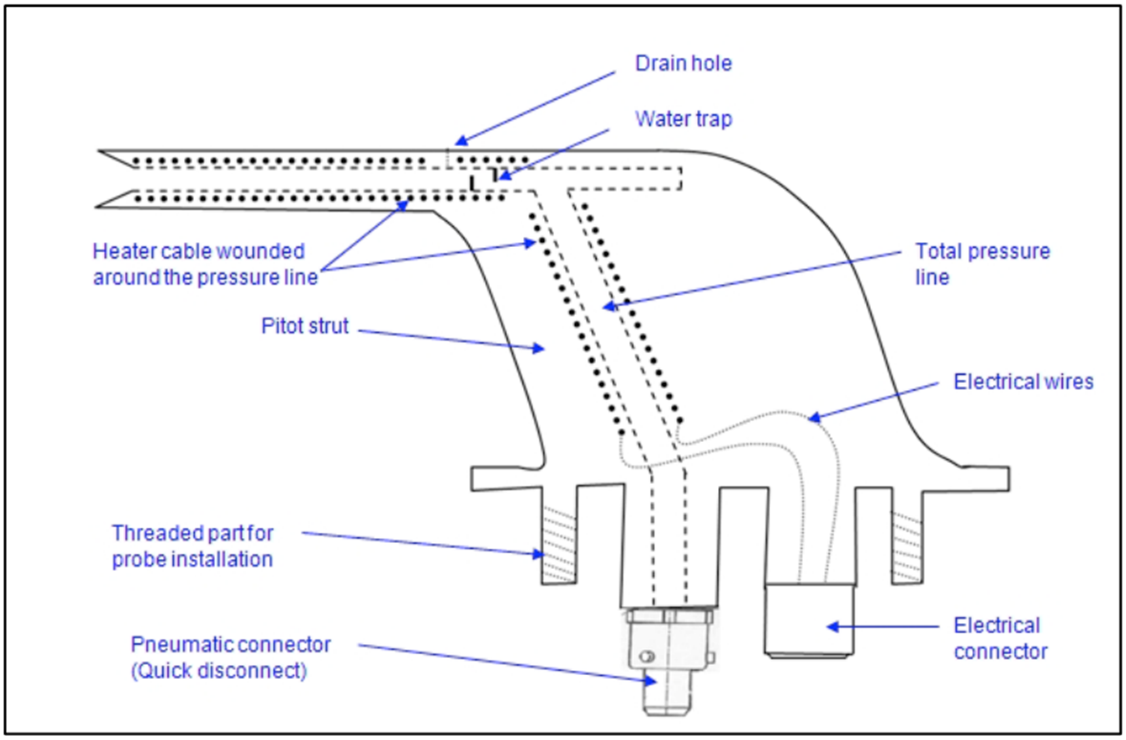

Figure 12

Typical pitot probe cross section
(image used with permission)

Air data system and inertial reference systems

Pitot probes are part of the Air Data and Inertial Reference System (ADIRS). They are installed externally on the nose fuselage and sense the total pressure of the airflow. This total pressure is transmitted to an ADM which measures total pressure, converts it to a digital format, and transmits it to an ADIRU.

Similarly, static probes are used to sense the static pressure, which is then measured by a dedicated ADM and sent to an ADIRU.

From the total and the static pressure, the ADIRU can calculate the airspeed, which is displayed on the flight crews' PFDs.

On many commercial air transport aircraft there are three independent systems and thus three pitot probes as shown below (Figure 13). Typically, these independent systems provide information to the commander's, co-pilot's and standby instruments respectively, although there is provision to reconfigure these assignments.

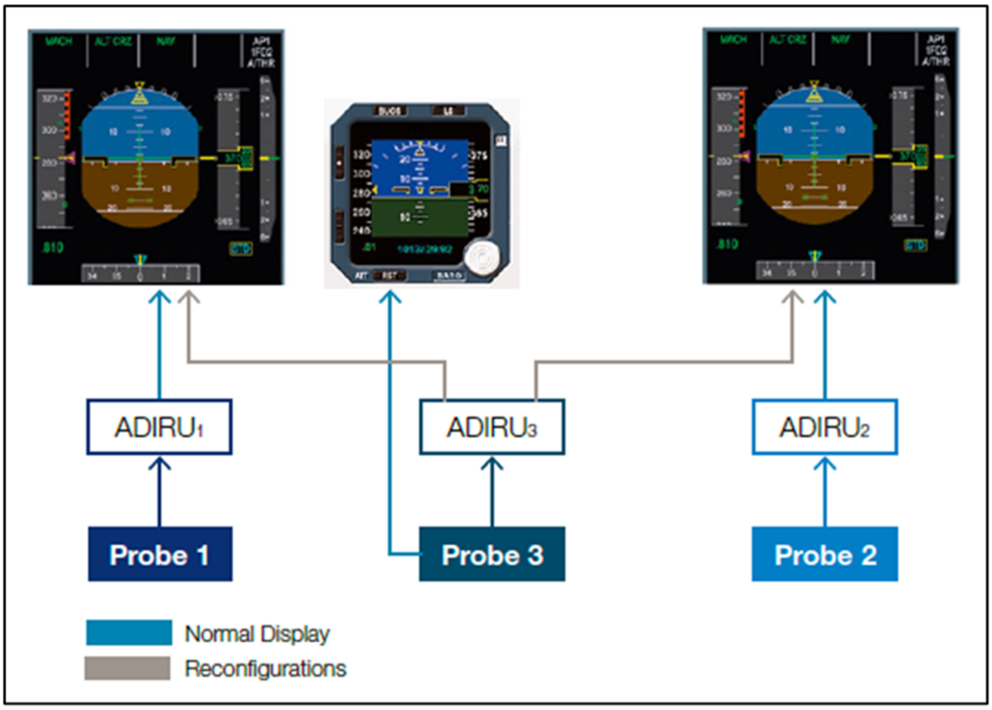

Figure 13

Typical ADIRS layout
(image used with permission)

Airbus A320 ADIRS

General

A schematic of the Airbus A320 air data system configuration is shown in Figure 14.

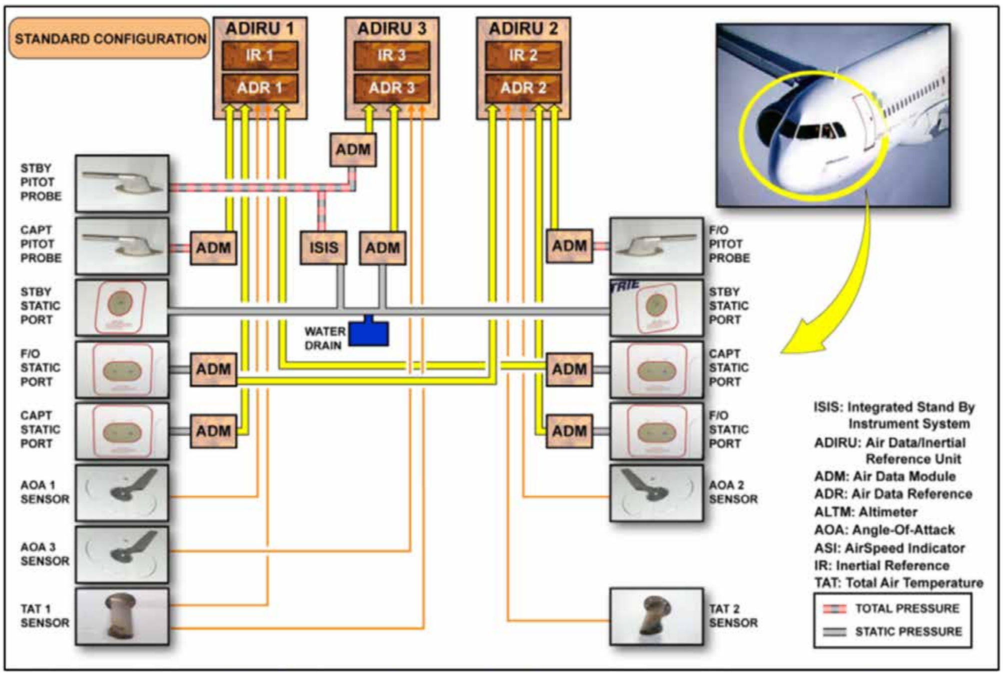

Figure 14

Schematic of A32x ADIRS
(image used with permission)

Airbus A320 family and A330 system indications

Computed airspeed is displayed on the PFDs and on the Integrated Standby Instrument System (ISIS). Various aircraft systems which use the ADR parameters perform some monitoring. If one ADR is different and two are the same, the different one is voted out. If the airspeed that is different is displayed on one of the PFDs and the difference is above a certain threshold, it will be associated with a NAV IAS DISCREPANCY ECAM caution. However, the flight control computers will continue to work using the remaining two ADRs and the flight controls will continue to operate in Normal Law with the autopilot, flight directors and autothrust remaining available.

If there are differences between the two remaining ADRs, the computer logic cannot determine which is erroneous; the flight crew will be alerted by the ECAM caution NAV ADR DISAGREE and the flight control law will downgrade to Alternate Law (which inhibits some of the flight envelope protections that are available in Normal Law). In addition, the autopilot, flight directors and autothrust disconnect; the ECAM cautions AUTO FLT AP OFF and AUTO FLT ATHR OFF are triggered, and the red FD flag is displayed on each PFD.

Boeing 777 Air Data System

General

A schematic of the Boeing 777 air data system configuration is shown in Figure 15 below.

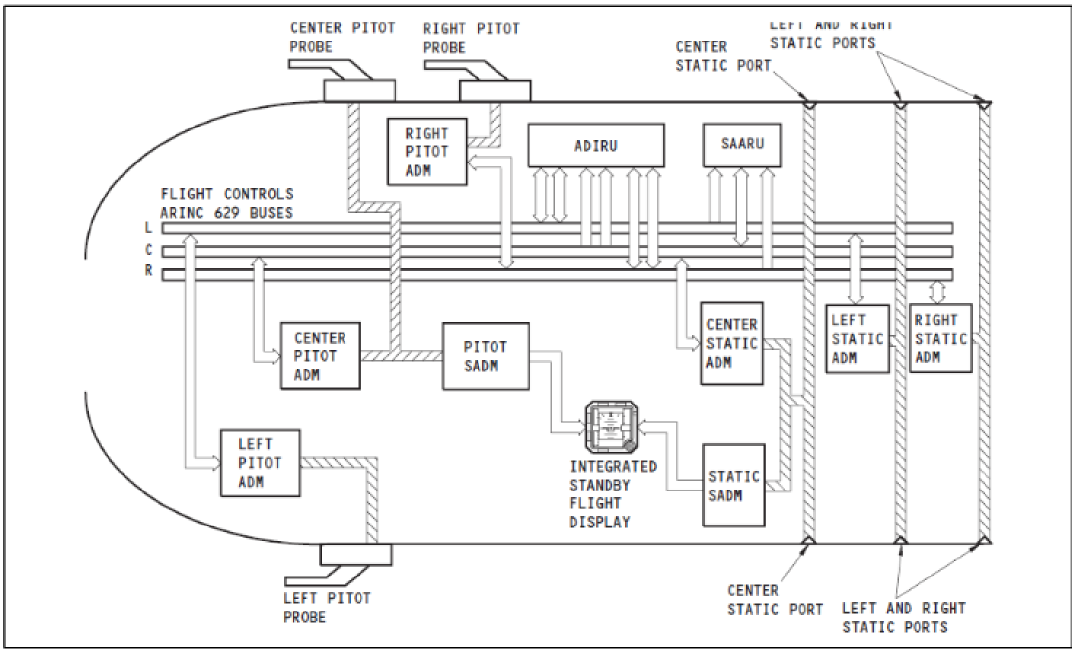

Figure 15

Pitot/static/air data standby instruments interface
(image used with permission)

System Indications

The ADIRU and Secondary Attitude Air data Reference Unit (SAARU) receive air data from the same three sources: the left, centre and right pitot/static systems. The ADIRU and SAARU validate the air data before it may be used for navigation. The data is considered to be valid when two or more sources agree in either the ADIRU, the SAARU, or both.

When ADIRU air data is invalid and the AIR DATA/ATT switch is in the OFF position, valid SAARU air data is used.

Single channel operation occurs when the ADIRU and SAARU air data are invalid. The left PFD displays the ADIRU air data from the left pitot static system (left channel). The right PFD displays the SAARU air data from the right pitot static system (right channel) and the EICAS will display the message AIR DATA SYS.

Recorded information

G-EUUO

Data from the aircraft's Digital Aircraft Condition Monitoring System (ACMS)[12] Recorder (DAR)[13] for the rejected takeoff is shown in Figure 16. The data shows the CAS from the aircraft's three pitot probes: CAS1ADC, CAS2ADC and CAS3ADC. CAS1ADC was displayed on the commander's PFD, and CAS2ADC on the co-pilot's PFD. CAS3ADC is dedicated to the standby systems.

During the event, the recorded CAS1ADC airspeed was zero, indicating that the sensed airspeed by the commander's pitot was below 30 kt (the minimum airspeed that is considered valid by the associated ADC). The takeoff was rejected at 104 kt airspeed (a groundspeed of about 96 kt).

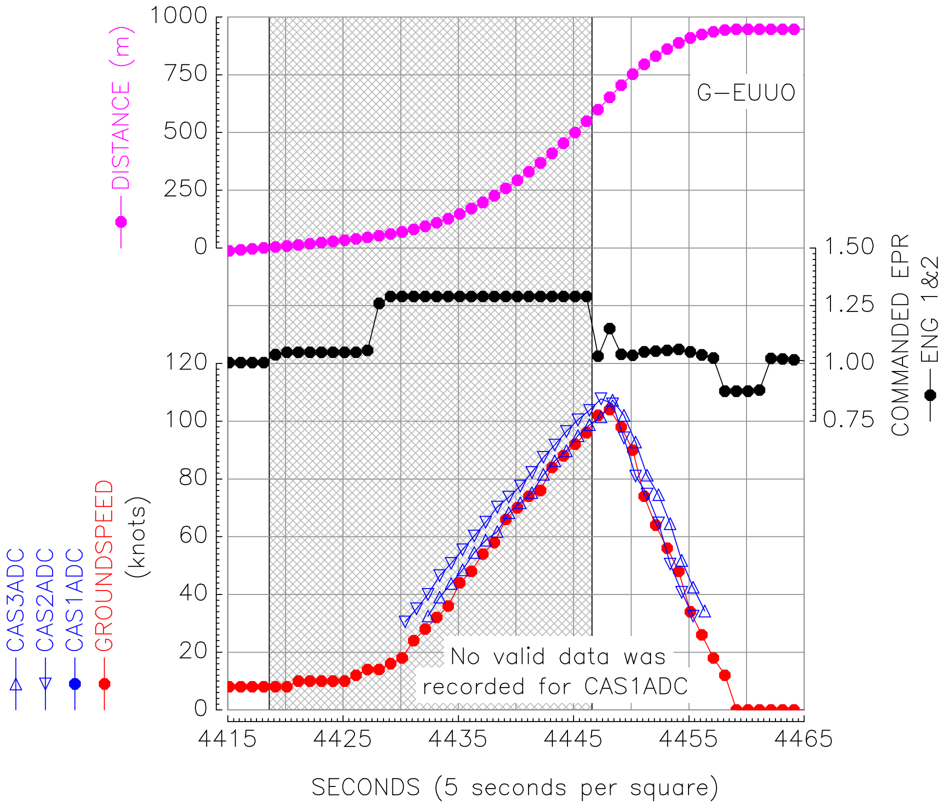

Figure 16

G-EUUO DAR data for the rejected takeoff
(shaded area is from start to abort)

Footnote

[12] The ACMS is a maintenance tool on Airbus aircraft consisting of a data acquisition unit and associated sensors to sample, monitor, and record information and flight parameters.

[13] The DAR forms part of the recording system of the ACMS on some Airbus aircraft. The flight parameters recorded on the DAR are defined by the operator and could include parameters that are not recorded on the Flight Data Recorder (FDR) but are of interest to an operator in support of their maintenance programme for a particular Airbus type. For example, the DARs on the Airbus A320 family fleet of aircraft for the operator of G-EUUO and G-TTNH record the computed airspeed from each of the three pitot probes. In comparison, the computed airspeed on the FDR is the one displayed to the crew, sourced from a single pitot probe.

G-TTNH

Data from the aircraft's DAR after pushback is presented in Figure 17 and shows that all three pitot probes were sensing airspeeds in excess of 100 kt even though the aircraft was not moving.

Between times 0754 hrs and 0757 hrs, whilst the aircraft was stationary, 11 ECAM alerts were generated (detailed in Table 2) that were associated with either a touchdown or landing roll (< 80 kt) phase of flight.

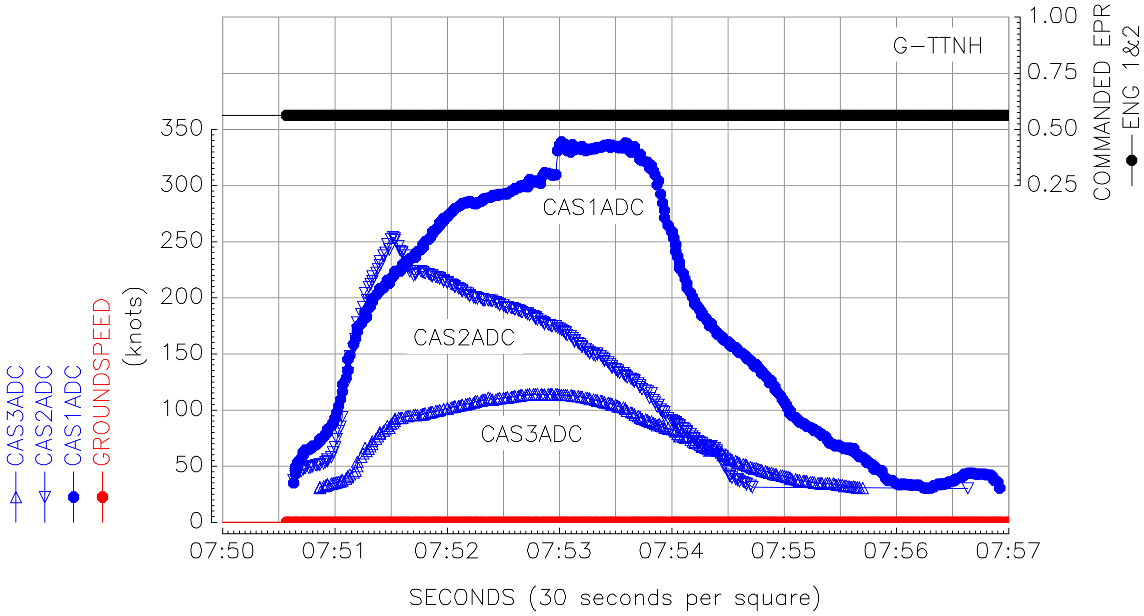

Figure 17

G-TTNH DAR data after pushback whilst aircraft was stationary

Time	Phase	Alert
07:54	Touchdown	ADR
07:54	Touchdown	NAV ADR DISAGREE
07:54	Touchdown	AUTO FLT RUD TRV LIM SYS
07:54	Touchdown	F/CTL
07:54	Touchdown	F/CTL ALTN LAW
07:54	Touchdown	FAC1(1CC1)/DMC2(1WT2)
07:54	< 80 kt	ADM3(19FP3)
07:55	< 80 kt	NAV F/O AOA FAULT
07:55	Touchdown	ADR3
07:56	< 80 kt	NAV RA 1 FAULT
07:56	< 80 kt	NAV RA 2 FAULT

Table 2

G-TTNH ECAM alerts whilst aircraft was stationary

G-YMMR

Data from the aircraft's FDR for the rejected takeoff is shown in Figure 18. For this aircraft, the FDR only records the CAS which is displayed on both crew's PFD and the values recorded are only valid if greater than 30 kt. Throughout the rejected takeoff the CAS remained invalid. The takeoff was rejected 275 m into the takeoff ground roll at a groundspeed of about 64 kt.

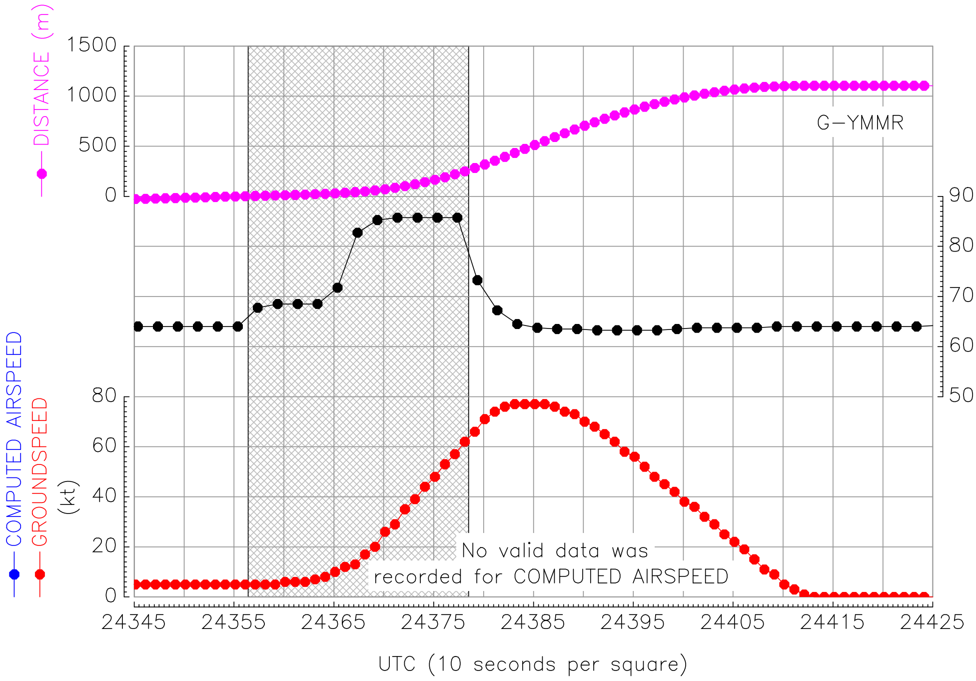

Figure 18

G-YMMR FDR data for the rejected takeoff
(shaded area is from start to abort)

G-VKSS

Data from the aircraft's FDR showed that the airspeed remained valid for the entire flight. For this aircraft type, the FDR only records the CAS which is displayed on one of the crew's PFDs (in this case the commander's ie CAS1ADC) and the CAS available on the ISIS derived from the CAS3ADC. Since CAS1ADC was valid, CAS2ADC was not recorded on the FDR; however, other parameters recorded on the FDR imply that the CAS2ADC exceeded 60 kt at the same time as CAS and CAS (ISIS)[14].

Detailed examinations

Pitot probes that were found to contain debris were removed by the operator. These were inspected by the AAIB to determine if there was any evidence that would help identify the

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Footnote

[14] The recorded AOA on each ADC is coded valid only if the corresponding CAS on the ADC is itself valid and greater than 60 kt. As the AOA on both ADC1 and ADC2 became valid at the same time, this implies that CAS1ADC and CAS2ADC exceeded 60 kt at the same time.

cause of the blockages. After inspection, these probes were returned to the OEMs for reconditioning and tracked with a quality occurrence number to enable feedback from the OEM on the internal condition of the probes. The one exception to this was G-VKSS, as the pitot probes were being replaced as part of an upgrade programme, so these probes were retained by the operator.

G-EUUO and G-TTNH

The probe from G-EUUO had been removed by the operator and the debris removed. Because the pitot tube had been through a heat cycle on engine start, debris inside the tube was charred and had turned to dust. Similarly, the probes from G-TTNH had also been through heat cycles and, whilst the engineers collected the debris by blowing through the pitot tubes with pressured nitrogen, there was little that could be identified from this evidence.

G-YMMR

Following an in-situ visual assessment of the pitot tubes by the AAIB it was determined that insects were most likely the cause of the blockage. In order to determine the likely species causing the problem, the probes were removed to enable closer examination of the blockage material and the inside of the probe. The airport biodiversity team asked a corporate beekeeper to help with the identification, and the blockage was assessed to most likely be caused by a foraging species such as solitary bees. The hard cap that had been formed at the tip of the pitot was prised off and was characteristic of the cap that some species of solitary bees or wasps create on their nests. Because the probe had been though a heat cycle, the debris inside the pitot probe had been reduced to charred material (Figure 19).

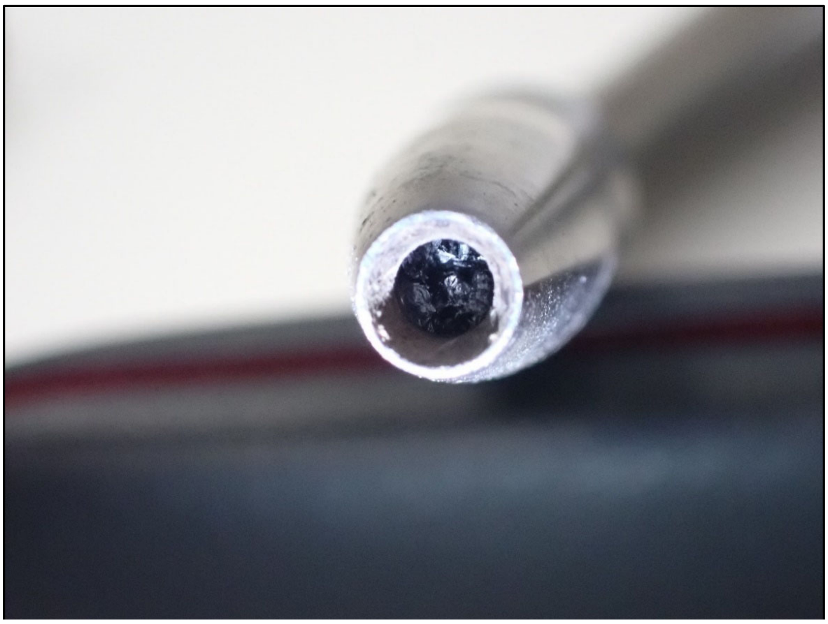

Figure 19

G-YMMR - charred debris inside the pitot probe

G-STBJ

The blockage in the right pitot probe looked externally very similar to the blocked probes from G-YMMR. However, internally, because the blockage had been detected pre-engine start (and the pitot had not been through a heat cycle) the larva in the nest was still alive (Figure 20). The larva was collected and sent for analysis to identify the species.

Figure 20

G-STBJ – blockage and larva in pitot

G-VKSS

As well as being discovered at a different location within the pitot probe, further away from the heater, the debris was different in constitution in that the material was compacted but not cemented as in the previous cases. On removal, inspection showed that the debris contained small shards of leaf material and dead larvae (Figure 21).

The aircraft manufacturer advised that, as the pitot was not completely blocked, there may have been enough residual flow onto the pressure sensor to enable the sensor to function without noticeable effects.

Figure 21

G-VKSS – Nest material and larvae from pitot system

Tests and research

The NHM were contracted to undertake analysis of the insects, larvae and debris collected during the investigation. The NHM Hymenoptera specialist used DNA analysis and visual identification to identify the following two species.

Species 1 identification: Ancistrocerus parietum

The live wasp from G-DBCG was identified as a female *Ancistrocerus parietum* (see Table 3)**,** commonly called the Wall Mason wasp (also known as the Notched Mason wasp). This identification was in keeping with a previous identification by the NHM specialist who, from the photograph of the insect entering G-STBJ's probe shown in Figure 4, tentatively identified the species as being from the subfamily, *Eumeninae* (Potter and Mason wasps). DNA tests on the larvae found in the blocked pitot probe from G-STBJ confirmed that the species was *Ancistrocerus parietum.*

Wall Mason wasp

Order	Hymenoptera
Family	Vespidae
Subfamily	Eumeninae
Genus	Ancistrocerus
Species	parietum

Table 3

Wall Mason wasp species identified

The wasps emerge from their over-wintering sites in the late spring. Once they emerge, they then mate, and the females begin the search for nesting sites. They use the hollow cavities in plant stems as nesting sites, especially of elder and bramble or the straw of thatched roofs. In addition, they have also been known to use the disused burrows of wood-boring insects, such as beetles, as well as disused nests of the social wasp, *Vespula vulgaris*, and of the Mason wasp, *Odynerus*. They also use man-made sites, such as window ledges and the holes in walls and masonry.

Once the nesting site is chosen, the pith from the plant stem (or the debris from the crevice/ hole) is cleared, and the female will plug the inner end of the nest-cell with softened clay. Then an egg is laid, and several paralysed caterpillars are placed in the cell. It is then sealed with another layer of softened clay.

Information on how quickly the nests can be built is difficult to source but as *Ancistrocerus parietum* nests are very simple, with just clay partitions being used in a pre-existing tube, it may only take a few hours or less to build the nest.

The adults are active and in flight throughout the summer from June to August (although this can vary and can start in May and continue until September or early October). This is because the larvae grow very quickly once they hatch, so the species is often able to produce two broods a year.

Ancistrocerus parietum is a habitat generalist, the species is found in a wide range of habitats including sandy and clay soils, open urban areas, parklands, wooded areas riverbanks, and coastal areas. *Ancistrocerus parietum* can be common in sandpits, such as may be found on construction sites, and is probably the UK's most common and widespread *Eumenine* wasp.

The species is found throughout England and Wales including the Isle of Man, Lundy Island, Isles of Scilly, and Scotland. It is also found in many parts of mainland Europe, North Africa, and Asia. It has also been introduced into North America.

Species 2 identification: Megachile pilidens

DNA tests on the larvae from G-VKSS confirmed that the species was *Megachile pilidens,* also known as the Hairy-toothed small leafcutter bee (Table 4). *Megachile pilidens* occurs widely in Europe, North Africa and into Central Asia but is not generally found in Britain or Ireland. As with other *Megachile* species, this is a leafcutter bee, cutting leaf sections to line the insides of cavities and create cells in which to raise young. Sightings[15] in Western Europe have associated the species with rocky or stony habitats.

Leafcutter bee	
Order	Hymenoptera
Family	Megachilidae
Genus	Megachile
Species	pilidens

Table 4

Leafcutter bee species identified

The DNA analysis of the nest material provided from G-VKSS indicated a match with *Ailanthus sp*, a deciduous tree of the family *Simaroubaceae*. Native to northeast China and sometimes called "Tree of Heaven," it is also widely planted elsewhere, including in Europe and North America.

Other information

Investigations and safety notices

The problems posed by insects to aircraft pitot/static systems are not new. In 2006 an ATSB[16] investigation into a rejected takeoff identified wasp activity as contributors to a

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Footnote

[15] Peeters, T.M.J, Raemakers, I.P, van de Nieuwegiessen, J, Kuper, J.T, (2006) The rock bee Megachile pilidens, new to the Dutch fauna (Hymenoptera: Apoidea: Megachilidae). *Dutch Faunistic Communications* 25, 11-18.

[16] Investigation: 200601453 - Rejected takeoff - Brisbane Airport, Qld - 19 March 2006 - VN-QPB, Airbus A330-303 (atsb.gov.au) [accessed 16 November 2021].

number of speed discrepancy events. A study at the same airport discovered 15 reported cases over a two-year period from 2013 to 2015 caused by a number of different wasp species. Airbus promoted in a safety publication[17] in 2016 the importance of installing pitot probe covers for aircraft on the ground to 'protect the air data system performance.' Boeing, in multi-operator message communications for the 737 in 2020 and for all Boeing models in 2021, also issued additional guidance to operators regarding the importance of pitot probe covers and inspections after storage or parking due to the risk of foreign object debris. Most recently, EASA issued a Safety Information Bulletin[18] providing guidance on the return to service of aircraft from storage in relation to the COVID-19 pandemic.

Environmental factors affecting pollinators

Air quality is likely one of a variety of environmental factors that influences the success of pollinators[19]. Flowers and plants emit aromas that provide essential signals to pollinators such as bees or wasps to detect sources of pollen. These floral aromas have been shown to be degraded by certain pollutants[20]. An example of this is the highly reactive pollutant ozone which destroys the hydrocarbons in floral aromas. The result of this attenuation of the scent landscape could be that insects such as bees and wasps forage less efficiently, which leaves less energy for other activities, potentially affecting reproductive output. Ozone also affects plant health, impacting their productivity[21] and reproductivity[22] and thus affecting the habitat of pollinators and insects. This may be another contributing factor to increasing the difficulty of the task of pollinators, making them work harder and travel further to pollinate. A disrupted natural habitat can also make it harder for solitary bees and wasps to find suitable locations to nest and is likely to result in them adapting whatever is available to them to use in urban areas.

Another human-generated impact on nature is vibration and noise pollution. Animals of all kinds are acutely sensitive to vibration and noise pollution, it impacts behaviour, stress levels and even growth. Seismologists measuring ground vibrations during the pandemic lockdown noted a 50% reduction in vibrations across the UK[23]; the biggest reductions were observed at sensors located near human-generated noise. Also, during the lockdown, urban noise in cities reduced by 5 dB (which is 60% quieter). Airports are a source of both noise and vibration, the graph below shows the reduction in aircraft movements at Heathrow Airport (Figure 22). Construction sites also had reduced activity during the pandemic lockdown.

Footnote

[17] Pitot Probe Performance Covered On the Ground | Safety First (airbus.com) [accessed 16 November 2021].

[18] Guidelines: Return to service of aircraft from storage in relation to the COVID-19 pandemic | EASA (europa.eu) [accessed 16 November 2021].

[19] Sirk, E. (2018) Air Quality Implications for Pollinator Species, NASA Goddard Space Flight Center.

[20] McFrederick, Q. S., Kathilankal, J. C., & Fuentes, J. D. (2008). 'Air pollution modifies floral scent trails'. *Atmospheric Environment,* 42(10).

[21] Capps, S. L., Driscoll, C. T., Fakhraei, H., Templer, P. H., Craig, K. J., Milford, J. B., & Lambert, K. F. (2016). 'Estimating potential productivity cobenefits for crops and trees from reduced ozone with US coal power plant carbon standards' *Journal of Geophysical Research: Atmospheres*, 121(24).

[22] Black, V. J., Black, C. R., Roberts, J. A., & Stewart, C. A. (2000). 'Impact of ozone on the reproductive development of plants' The New Phytologist, 147(3).

[23] Nature: liberated by lockdown? | Natural History Museum (nhm.ac.uk) [accessed 16 November 2021].

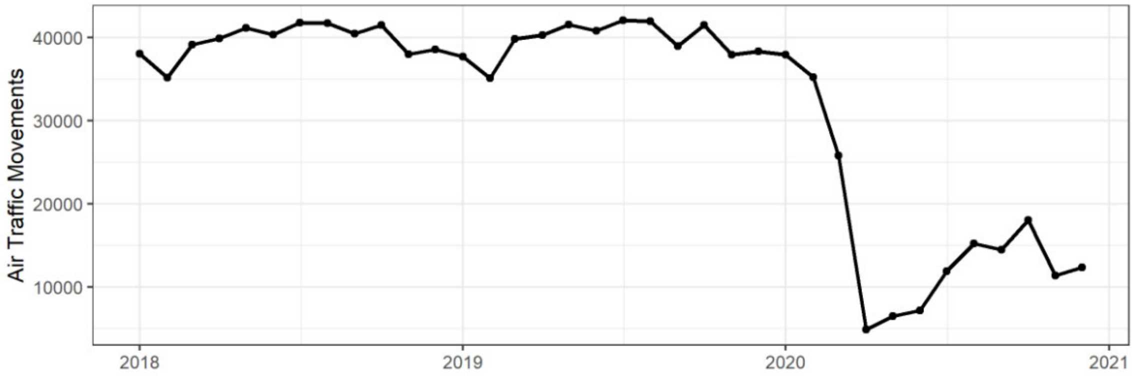


Figure 22

Heathrow Air Traffic Movements
(image used with permission)

Analysis

Introduction

This investigation looked into multiple events affecting a number of different aircraft types and which occurred during a period of just over one month. Although some of these events came to light during maintenance activity, two resulted in aircraft aborting their takeoff and, as such, involved a higher risk. Although it was established within a few days that the cause was insects making nests in pitot tubes, this report considers a number of factors that may have led to a concentration of such occurrences in a short period of time.

Operational aspects

Of the four events investigated, two resulted in rejected takeoffs, one caused a return to stand after engine start and the other required only minimal action from the flight crew and did not significantly affect the aircraft operation. G-TTNH's return to stand was prompted by multiple failure indications arising from the complete blockage of all three pitot probes. It is probable that the heating of the air trapped in the pitot probes resulted in increased pressures which were interpreted by the air data system as airspeeds in excess of 100 kt even though the aircraft was stationary. However, with only a single pitot probe blocked, neither G-EUUO nor G-YMMR detected a malfunction during their start or taxi phases. The two rejected takeoffs were both relatively low speed events handled in accordance with type SOPs and the aircraft were able to return to stand without external assistance. Despite their reduced recency, the pilots involved considered that their training and pre-flight preparation had mitigated the hazards effectively. They were also complimentary about their company's focus on prioritising defensive operations above commercial imperatives.

As well as affecting pilot recency, the operational environment resulting from the Covid-19 pandemic had resulted in significantly different aircraft performance margins for takeoff. With fewer passengers on board, lightly loaded aircraft accelerate more quickly and typically have lower V_1 speeds, factors which could combine to reduce a pilot's decision-making time window during takeoff. The pilots opined that discussing these factors in their pre-flight threat and error management (TEM) could help mitigate the associated risk.

Environmental hazards

At the time of these incidents, the environment of the airport and its surrounding areas had been affected by the following factors; dramatically decreased aircraft movements, very low road traffic levels round the airport, and an overall reduction in human activity. These changes resulted in a decrease in primary pollutants such as NO_2 but, counter-intuitively, an increase in the concentration of ground level ozone. There was also a reduction in noise levels and vibration. For insects such as wasps and bees, the increase in ground level ozone in particular, can cause them to travel further and expend more energy to feed and nest. Although not causal, it seems probable that the change in environment was an influencing factor in these incidents.

The reduced aircraft activity levels during the pandemic resulted in aircraft remaining on the ground for longer periods of time between flights. For the species responsible for most of the incidents in this investigation (*Ancistrocerus parietum*, also known as the Wall Mason wasp), the uncovered pitot tubes of aircraft offer a suitably sized tube for them to build their nests. The water baffle in the pitot provided a surface for them to create the inner end of the nest. A completed nest, sealed with a layer of softened clay, would have prevented air flow through the tube. It also created a sealed pressure chamber so, when the pitot was heated, the pressure behind the nest would have increased. This may explain the anomalous airspeed indications seen by the crews on start-up even though the aircraft was stationary.

The species found on G-VKSS was a *Megachile pilidens,* the Hairy-toothed small leafcutter bee which occurs widely in Europe, North Africa and into Central Asia, but is not generally found in Britain or Ireland. The nest material was identified as coming from a tree that is present in Europe. The nature of this nest was quite different and didn't result in a sealing of the pitot tube as in the other events covered by this investigation. The aircraft manufacturer advised that, as the pitot was not completely blocked, there may have been enough residual flow onto the pressure sensor to enable the sensor to function. This is likely to be the reason why the nest was only found due to an investigation into an unrelated failed pitot probe heater. G-VKSS's pitot/static system pressure lines had been flushed as part of the return from storage maintenance programme before the aircraft returned to operational service. It had been parked at Heathrow for three days without pitot covers fitted and so there was opportunity for the nest to be constructed during this time. It is also possible that the nest was constructed at Milan, at the end of the aircraft's first revenue flight, and at a location where both the bee and tree species can be found. However, as the aircraft was only on the ground for about 90 minutes (and the pitot tubes may still have been at an elevated temperature), there would have been a small window of opportunity for nest construction. On balance, this seems unlikely and so the location of G-VKSS when the nest was constructed remains unresolved.

Environmental hazard management

Whilst the hazard of insects blocking pitot probes is not new, it is unusual for such a spate of events to occur in such a short timeframe. Regulation and wildlife hazard management on airfields has understandably been more focused on the dangers to aircraft presented by birds.

Unreliable airspeed indication (due to blocked pitot systems) is a serious hazard which the aviation industry regularly highlights to raise the awareness of flight crews. However, flight crew monitoring of airspeed indications is the last line of defence, and the work being conducted by the airfield operator in response to this investigation is to generate a more collaborative approach to the management of this hazard.

The airfield operator is developing a layered surveillance and alerting plan to provide information to local airline operators on when the risks posed by insects increase. This will enable the operators to put in place additional control measures in mitigation, eg utilising pitot covers on the ground or requiring pre-flight DVIs. With the CAA engaged in this work, this will also facilitate any best practice identified to be communicated more widely.

It is likely that the temporary surge in these events came about as a result of a confluence of factors of the pandemic, but it is also a reminder that the environmental response to changes in human behaviour can be unpredictable and have unforeseen consequences. The drive to greener aviation and urban environments will result in quieter, cleaner aircraft and less polluting airports, providing the kind of environments that prove attractive to insects such as bees and wasps.

Conclusion

Over a short period of time, several aircraft suffered air data problems related to the blockage of pitot probes by insect nests.

From an operational perspective, pilot training, preparedness and effective TEM should be considered key elements for assuring early detection of pitot/static system blockages in the takeoff roll, thus minimising the hazards associated with high-speed rejections. As the airline industry increases its operational tempo toward pre-pandemic levels, operator support for crews balancing commercial pressures against reduced recency will be an important enabler for safely rebuilding operational fluency.

Insects blocking aircraft pitot/static systems is not a new hazard, but one likely exacerbated at Heathrow in 2021 due to the unusually low operational tempo resulting from the Covid-19 pandemic. Reduced traffic levels and human activity resulted in a surge of insect activity during the pandemic lockdowns. With less aircraft activity, including less noise and jet efflux to deter the insects, the parked aircraft made an attractive opportunity, with the pitot probes providing an ideal construction site for nests.

The high level of insect activity in 2021 could lead to a larger number of insects emerging in the spring of 2022. Therefore, even though traffic levels and aircraft utilisation are expected to increase in 2022, the seasonal risk of insects blocking pitot probes could be significant. Proactive habitat management and aircraft monitoring will be required to mitigate the risk. With the move towards ‘greener’ aviation, this may become even more important in the future.

Safety action

Action taken by the CAA:

> On 12 June 2021, the CAA published Safety Notice SN-2021/014 – Pitot blockage events to raise awareness of a possible 'insect infestation' issue amongst operators, maintenance, and continuing airworthiness management organisations. Flight crews were also to be reminded of the importance of speed checks during the takeoff roll and the actions to be taken in the event of a discrepancy.
>
> In addition, by remaining engaged with action being taken by the airport operator, the CAA will facilitate the communication more widely of any best practice identified.

Action taken by affected airline operators:

> As the investigation evolved, the affected operators introduced enhanced use of pitot covers for aircraft on the ground and one operator introduced a regime of detailed visual inspections as part of the pre-departure checks. These measures were put in place whilst it was determined that insect activity remained at an elevated level.

Action being taken by the airport operator:

> The airport operator is updating its management of airport environmental hazards to include a layered surveillance and alerting plan to provide information to airline operators on when the risks posed by insects increase. This will enable the operators to put in place, when necessary, additional control measures in mitigation, such as enhanced use of pitot covers or additional pre-flight inspections.

Published: 27 January 2022.

SERIOUS INCIDENT

Aircraft Type and Registration:	MBB-BK 117 C-2, G-MPSB	
No & Type of Engines:	2 Arriel 1E2 turboshaft engines	
Year of Manufacture:	2005 (Serial no: 9068)	
Date & Time (UTC):	12 March 2021 at 1150 hrs	
Location:	North Weald Airfield, Essex	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Distorted aft crosstube between skids	
Commander's Licence:	Airline Transport Pilot's Licence (Helicopters)	
Commander's Age:	52 years	
Commander's Flying Experience:	7,170 hours (of which 2,196 were on type) Last 90 days - 28 hours Last 28 days - 14 hours	
Information Source:	AAIB Field Investigation	

Synopsis

This serious incident occurred during the demonstration of an engine failure after takeoff emergency procedure on a revalidation flight for the commander's type rating instructor qualification. The engine failure was simulated by the commander reducing Engine No 1's throttle to IDLE. Shortly afterwards the commander increased the throttle setting, but Engine No 1 did not respond. During attempts to resolve the problem, the throttle setting for Engine No 2 was inadvertently reduced, resulting in insufficient power being available for continued safe flight. The commander rejected the takeoff and executed a firm landing within the airfield boundary.

While the aircraft's skid assembly was deformed as a result of the landing, the touchdown forces did not exceed the manufacturer's threshold for it to be classified as a 'hard landing.' The subsequent engineering investigation did not find any evidence of malfunction in the engine control systems. Engine No 1 probably did not respond because the rotor rpm droop compensation had been inadvertently trimmed in the wrong direction.

History of the flight

The incident flight was a type rating instructor (TRI) revalidation event for the left seat pilot who was also acting as commander. The examiner occupied the right seat and acted as the simulated student. After completing three training autorotations, one demonstration by the commander and two practises by the examiner, the helicopter was positioned to a low hover at the northern end of the mown helicopter takeoff strip adjacent to the runway intersection at North Weald (Figure 1).

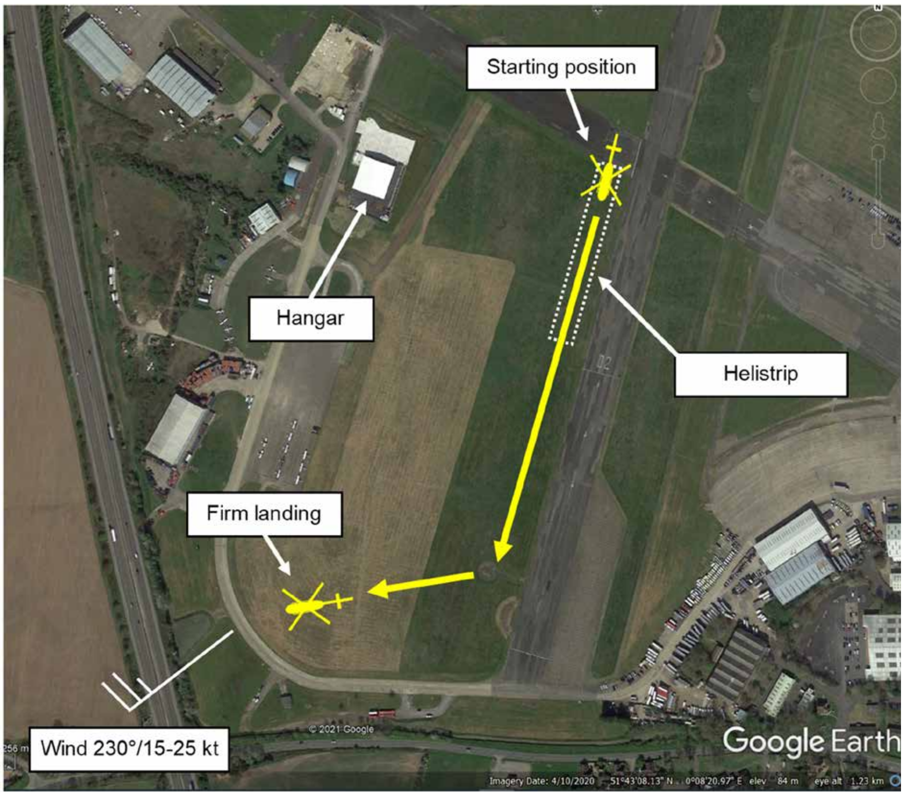


Figure 1

Approximate track of G-MPSB from Cat A takeoff to firm landing (satellite imagery courtsey of Google Earth ©2021 Google)

The intention was for the commander to demonstrate a Category A (Cat A) Clear Heliport takeoff procedure with a simulated engine failure after the takeoff decision point (TDP) and a continued takeoff (Figure 2). This was to lead into a single-engine circuit to Runway 20.

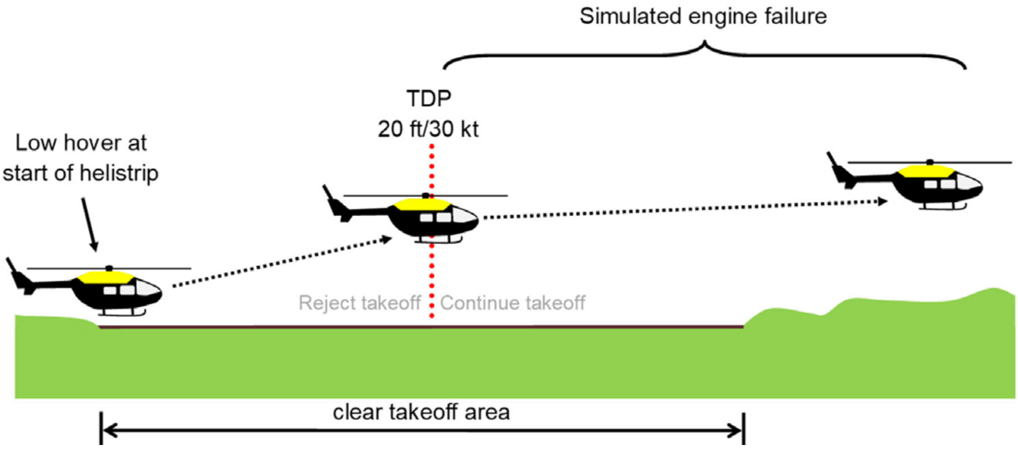


Figure 2

Overview of Cat A Clear Heliport takeoff profile with simulated engine failure after TDP

When established in a low hover at the threshold of the helicopter strip, the commander noted that the first limit indicator (FLI)[1], an analogue representation of the instantaneous power being used and the excess power available to the pilot, was indicating approximately 7.5 (non-dimensional units). He then increased power to FLI 8 to start the takeoff. After assessing that the TDP parameters of a height of 20 ft agl and airspeed of 30 kt had been achieved, the commander closed Engine No 1's throttle to simulate an engine failure. As he continued with the takeoff, the commander saw that the power required from Engine No 2 to execute the flyaway manoeuvre had exceeded the training maximum target figure of FLI 11[2]. Accordingly, he attempted to increase the throttle setting on Engine No 1 by approximately 15% to reduce the power requirement from Engine No 2 to below FLI 11.

Despite increasing Engine No 1's throttle setting the commander did not detect a corresponding engine response. He reported attempting to cycle the Engine No 1 throttle between IDLE and 15% a further "one or two times" with no effect. While manipulating Engine No 1's throttle the commander noticed the Engine No 2 rpm starting to decay. At the same time, he became aware that the main rotor rpm (N_R) was decreasing and there was insufficient power available to establish a positive rate of climb as required by the continued takeoff profile. With obstacles and rising ground ahead, the commander rejected the takeoff and turned right to land on grass close to the south-western perimeter of the airfield. As he did so, he saw that the N_R was close to its lower '*power on*' limit of 85%, giving little performance available to cushion the touchdown. He executed a running landing, which both pilots described as being firm but not dissimilar to what might be experienced with trainee pilots carrying out running landings in simulated one engine inoperative (OEI) scenarios. Shortly after the helicopter came to a halt, both engines accelerated to normal FLIGHT rpm and the N_R increased to approximately 100%. FDR data showed that the engines began accelerating after their engine twist grips were returned to the FLIGHT detent, as indicated by the associated TWIST GRIP caution extinguishing.

While stationary on the grass, the pilots noted that the helicopter was sitting right skid low but attributed that to the ground sloping from left to right. With both engines running normally, the pilots discussed the incident between themselves and, having reviewed the status of the helicopter's systems, elected to reposition the helicopter to a taxiway close to the hangar before shutting it down. When parked on a level surface it became apparent that the aircraft was still sitting abnormally right skid low. After vacating the helicopter, the pilots saw that the skid assembly was deformed.

Incident site

The helicopter landed on an area of grass to the north of the south-western taxiway. Ground marking caused by both skids extended for approximately 17 metres in a westerly direction. The initial landing point was identified by deep furrows which were left in the turf by the helicopter's skids. The markings indicated that the right skid bounced after the initial contact with the ground before it slid and came to rest (Figure 3). The ground marking became less visible as the ground slide progressed.

Footnote

[1] See *FLI description.*

[2] The maximum continuous power (MCP) setting with one engine inoperative (see *Table 1*).

Figure 3

Ground markings from right skid

Helicopter information

The BK 117 C-2 is a multi-purpose twin engine helicopter powered by two Safran Helicopter Engines (formerly Turbomeca) Arriel 1E2 turbo shaft engines. Following the joint venture between MBB & Aerospatiale which led to the creation of Eurocopter, the type was rebranded as the EC145 (type certified as the EC145 / BK 117 C-2).

The two engines drive the main rotor, tail rotor and accessories via the main transmission gearbox, which is in the transmissions compartment on top of the cabin roof. The main rotor system is a rigid head system with four fibre-reinforced plastic blades.

The helicopter's landing gear consists of two crosstubes and two skids. The crosstubes are designed to flex during touchdown to absorb vertical forces.

Engine fuel and control system

The helicopter fuel system provides fuel to the fuel control units (FCUs) on each engine. These FCUs are linked to two twist grip throttles on the collective pitch lever(s) (Figure 4) and the collective output of the hydraulic flight control actuator[3]. The FCUs hydromechanically control the fuel flow to the engine combustion chambers.

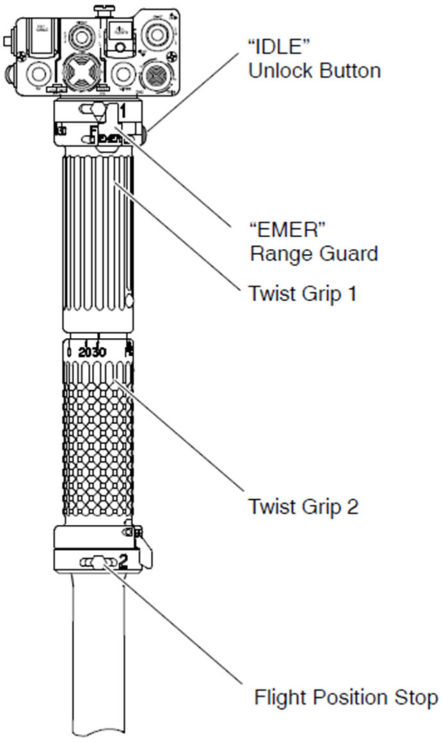


Figure 4

BK 117 C-2 collective pitch lever showing twist grip positions

The twist grips can be turned to set their respective engine in the start position, set it to IDLE, to FLIGHT and, if necessary, operate it in the emergency range. Each twist grip has five markings identifying its angular position as follows:

"0" – The engine is off. The main valve in the FCU is closed. The twist grip has been turned fully to the right.

"20" – Engine start position. The FCU main valve is partially open.

"30" – IDLE. The engine N_1 is approximately 70±2%. An idle stop prevents the twist grip moving from "30" towards "20" if approached from flight. An unlock button on the P1 collective must be depressed to pass the idle stop.

"F" – FLIGHT position. The twist grip has been turned to the left until the stop. This is the position for normal flight operations. The main valve in the FCU is fully open and the fuel flow is controlled automatically to keep the N_2 speed constant. The flight detent on the twist grip has a sprung ball into a notch to give tactile feedback to the pilot when entering and moving from FLIGHT.

Footnote

[3] To maintain rotor speed when collective pitch inputs are applied, a signal from the collective pitch actuator is fed into an anticipator which increases the fuel flow to the engines via the engine trim actuators.

> **"EMER" range** – Used in the case of automatic engine control failure. An emergency guard needs to be flipped open to allow further twist grip operation beyond FLIGHT position. In Emergency range, N_2 speed control is manual.

Each twist grip throttle has a different surface texture and they are also differentiated by position. This provides tactile feedback to pilots for non-visual identification of the throttle being manipulated. The investigation heard evidence from several EC145 type rating examiners who had experienced situations where trainees in stressful or high workload situations had inadvertently taken one throttle out of the FLIGHT detent while manipulating the collective on the BK 117 C-2 variant. It was hypothesised that this was likely due to them unintentionally gripping the collective more tightly than usual, in response to the perceived stress level.

A microswitch on the FCU throttle quadrant is closed when the twist grip is positioned into FLIGHT. When a twist grip is not in FLIGHT or in the emergency range, a TWIST GRIP caution is displayed on the Caution and Advisory Display (CAD) for the relevant engine.

In normal operation, when the engines are selected to FLIGHT, the engines are controlled to a constant output speed (N_2). As the collective pitch is raised the load on all the blades increases, thus fuel flow must also increase. A control rod which is attached to the collective axis hydraulic actuator connects to the left and right engine trim actuators. These actuators are connected, via levers and Teleflex cables, to the N_2 control inputs on the engine FCUs. As the collective lever is raised, the system anticipates the load and requests additional fuel to maintain the engines at the constant N_2. This system is referred to as the droop compensation control system.

In addition to the droop compensation system the engines can be trimmed using a four-way beep trim switch located on the collective pitch lever (Figure 5). This allows the pilot to match engine torque output when in manual control. In an OEI situation trimming forward on both engines will increase the torque output of the operational engine irrespective of which engine has become inoperative. The engines can be trimmed in four ways using this switch:

> **Forward**: the power of both engines is increased simultaneously. Rotor speed is increased.
>
> **Backward**: the power of both engines is decreased simultaneously. Rotor speed is decreased.
>
> **Left**: the power of Engine No 1 is increased, while the power of Engine No 2 is decreased. Rotor speed remains constant.
>
> **Right**: the power of Engine No 2 is increased, while the power of Engine No 1 is decreased. Rotor speed remains constant.

The beep trim switch axis is offset approximately 30° clockwise to align with the natural direction of thumb movement when pushing forward with the pilot's hand on the collective.

The switch will return to centre once thumb pressure is released and is gated so that it cannot be moved from one position to another without first being centred.

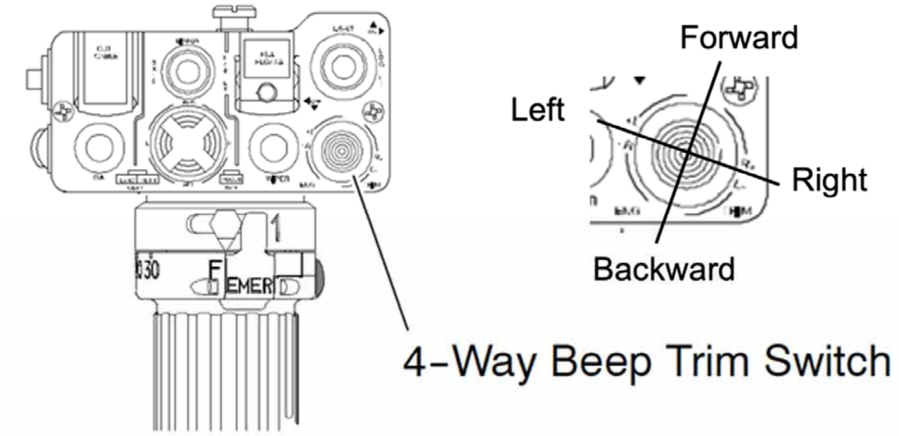


Figure 5

Four-way beep trim switch (with beep trim axis inset)

In addition to the N_2 droop compensation and trim function, the aircraft has a VAriable Rotorspeed control and TOrque Matching System (VARTOMS) which automatically controls the main rotor rpm between 96.5% and 103.5% and matches the torque of the two engines. A VARTOMS control panel (Figure 6) is located on the helicopter instrument panel. This allows the pilot to select VARTOMS to MAN (VARTOMS off) or NORM (VARTOMS on) modes, the button illuminates yellow when the system is in MAN mode.

Another mode button allows the pilot to select Cat A, N_1 or Cat A/N_1 modes. A single push activates Cat A mode, which automatically maintains the rotor rpm at 103.5% when the airspeed is below 55 kt.

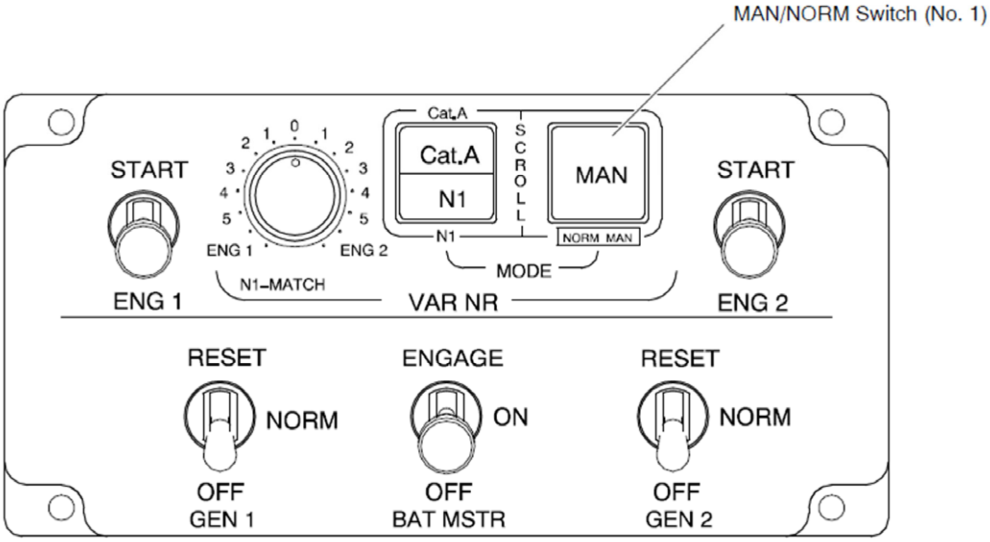


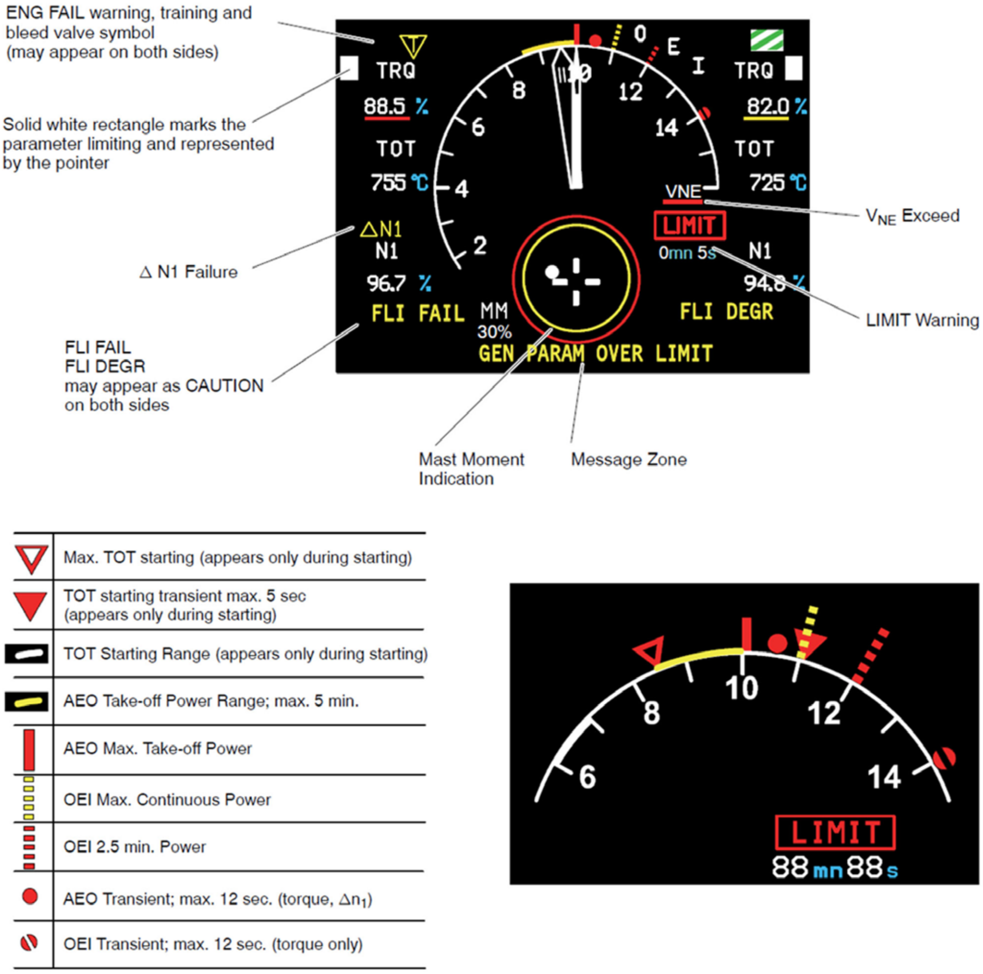
Figure 6

VARTOMS control panel

If the VARTOMS identifies that there is an engine torque split of greater that 15% the system will automatically switch to manual mode and the MAN button will illuminate yellow. If a VARTOMS failure is detected a caution will be illuminated on the CAD.

FLI description

While operating, the engines and transmission system are subjected to loading which, when kept within normal operating limits, incurs no significant damage to the components. If the loading is increased above a threshold the components can start to accrue damage. To allow the pilot to monitor the engine and transmission, an analogue display of the FLI is provided on the vehicle and engine multifunctional display (Figure 7). White rectangles displayed on the FLI adjacent to the most limiting parameter for each engine enable the pilot to determine which engine/transmission limit (N_1, turbine outlet temperature (TOT) or torque) the FLI is representing. FLI indications are non-dimensional, thus pilots can use one set of power limit figures regardless of which parameter is limiting at any given stage of flight (Table 1).



ENG FAIL warning, training and bleed valve symbol (may appear on both sides)

Solid white rectangle marks the parameter limiting and represented by the pointer

Δ N1 Failure

FLI FAIL
FLI DEGR
may appear as CAUTION on both sides

Mast Moment Indication

Message Zone

V_{NE} Exceed

LIMIT Warning

▽	Max. TOT starting (appears only during starting)
▼	TOT starting transient max. 5 sec (appears only during starting)
▭	TOT Starting Range (appears only during starting)
🟨	AEO Take-off Power Range; max. 5 min.
🟥	AEO Max. Take-off Power
┆	OEI Max. Continuous Power
┆	OEI 2.5 min. Power
●	AEO Transient; max. 12 sec. (torque, Δn_1)
◐	OEI Transient; max. 12 sec. (torque only)

Figure 7

FLI indications and legend (CPDS[4] V2006 Software as installed in G-MPSB)
(images courtesy of the manufacturer)

Footnote

[4] Central Panel Display System.

Condition	FLI marking	Transmission (helicopter) limits max torque %	Engine operating limits	
			Max N1 %	Max TOT °C
Starting				
Transient (max 5 sec)	11.0	-	-	865
Starting	8.5	-	-	785
All engines operating				
Takeoff power (5 min when $V \le V_Y$)	10.0	2 x 88	100.2 – 101.9	845
Maximum continuous power (MCP)	9.0 (8.5[1])	2 x 71	98.8 – 100.0	
Transient (12 sec when $V \le V_Y$)[2]	10.5	2 x 97	103.3[1]	-
One engine inoperative[3]				
MCP	11.0	91.5	100.2 – 101.9	845
2½ minute power	12.0	125	101.8 – 103.3	885
Transient (12 sec when $V \le V_Y$)[2]	14.0	140	107.5[1]	-

Notes:

1. When CPDS software V2006 or subsequent installed.
2. '*Unintended use*' only.
3. OEI power ratings are limited to use only after the actual failure of an engine, except for the MCP values, which may also be used for training if the manufacturer's OEI training device is not installed.

Table 1

Engine and transmission power limits specified in the flight manual

If the FLI exceeds 11 for more than 10 seconds there is an associated maintenance activity required.

G-MPSB

When the incident occurred G-MPSB was configured for training operations with removable left seat cyclic and collective controls installed. In this configuration the left collective is identical to the right collective except that the left collective twist grips do not have idle stop buttons so the right collective must be used to shut down the engines.

At the time of the incident G-MPSB had completed 11,038:50 flying hours. At 15 hours 35 minutes before the incident the helicopter had been subject to heavy maintenance which included its annual, 5,600 hour and 400 hour inspections. The helicopter's Certificate of Airworthiness was valid and its Airworthiness Review Certificate was in date.

Recorded information

The helicopter was fitted with a Combined Voice and Flight Data Recorder and two Airborne Image Recorders (AIRs) which recorded footage from two cockpit-mounted cameras. The recorders were downloaded at the AAIB and captured the event flight.

The AIRs were fitted to G-MPSB in April 2019 in response to CAA requirements to fit them to helicopters engaged in State and search and rescue operations[5]. Compliance with these requirements was required by 31 July 2021. One camera faced the overhead panel, allowing a view of the switch positions in this panel. The second camera was mounted behind the flight crew, facing forwards to provide a view of the pilot's displays.

The FDR recorded a number of relevant parameters including engine speeds, torque and FLI, along with the Caution and Advisory Unit (CAU) TWIST GRIP caution. This caution is the same as that displayed to the pilots on the CAD and is triggered when the engine throttle is out of the FLIGHT position. Engine trim, throttle position and fuel flow were not recorded and the CAU TWIST GRIP caution was only recorded every four seconds.

The CVR was reviewed. Throughout the flight, each exercise was briefed and both pilots sounded professionally engaged in the training task.

At 1159:13 hrs, while climbing through 16 ft agl at an IAS of 43 kt, Engine No 1 FLI began to reduce, signifying the point at which the Engine No 1 throttle was reduced. This was confirmed by the CAU TWIST GRIP parameter (Figure 8). The position of the Engine No 1 throttle was not recorded but within 3 seconds, Engine No 1 torque had reduced to less than 3%.

The IAS increased to 47 kt and the aircraft climbed to a maximum of 39 ft with the CVR recording the commander talking through the simulated engine failure. Eighteen seconds into the exercise, the CVR recorded the commander stating "AND WE'VE GOT A TINY RATE OF CLIMB… HARDLY ANYTHING THERE ARE WE". The examiner replied "NO", to which the commander stated "A BIT MORE". At this time, the FDR recorded an increase in the Engine No 1 FLI but also a decrease in the Engine No 2 FLI and the Engine No 2 CAU TWIST GRIP caution was triggered.

Two seconds later, the CVR recorded an audible low rotor rpm warning as the N_R dropped below 95%. The examiner stated "JUST WATCH YOUR N_R", which the commander acknowledged. The examiner stated "PUT THE THROTTLE BACK IF I WERE YOU". However, as this exchange was taking place, the Engine No 2 FLI reduced further and the Engine No 1 FLI increased.

Footnote

[5] CAA Safety Directive SD 2020/001.

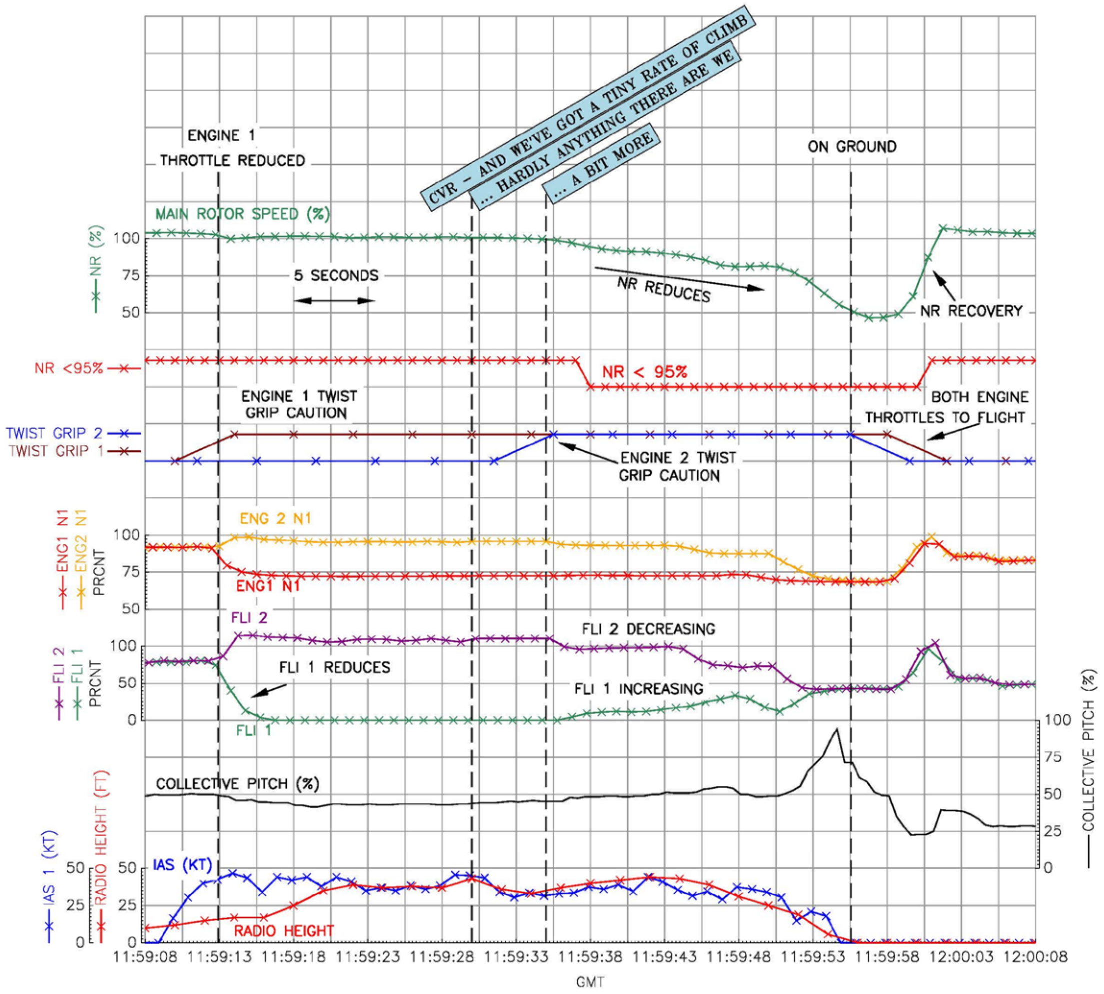


Figure 8

G-MPSB FDR parameters
NOTE FLI is recorded as percentage on the FDR

At 19 ft agl and an IAS of 15 kt, the collective was raised to cushion the landing. At touchdown, both recorded FLI were the same at 43%. After landing, the collective was lowered and a few seconds later, both engine throttles were returned to the FLIGHT position. As a consequence, both engines spooled up and the main rotor rpm recovered.

AIR camera footage

Each cockpit video camera had its own dedicated AIR and the footage from the overhead panel camera was successfully recovered. However, it was discovered that the AIR for the forward-facing camera had failed during the incident flight. The AIR maintenance data was downloaded which indicated that five minutes after power-up, a fault was logged.

The rotorcraft flight manual (RFM) supplement for the AIR installation required a pre-flight check of the system by pressing and holding the REC TEST button on the AIR control panel, with a successful test confirmed with a green light. Anything other than a solid green light indicated a fault within the system, with the colour and/or flashing of the light identifying the magnitude of the fault.

Discussion with the flight crew revealed that during the pre-flight checks, the AIR check was performed and they noticed a flashing green light on the control panel. The flight manual supplement defined a flashing green light represents "*System Operation / No Faults – NOT RECORDING*".

Data for the previous flights was recovered from this AIR which revealed that the forward-facing camera footage was not stable, with the camera vibrating to the extent that the cockpit displays could not be read. The Instructions for Continued Airworthiness for the AIR system required an inspection every 1,000 hours or three years and an AIR replay every two years. The inspection was performed in September 2020 with no issues found, and an AIR replay was conducted in February 2021. This replay failed and a replacement AIR was installed in February 2021 with no reported issues between then and the incident flight.

The operator had three additional aircraft of the same type and was requested to review other downloaded camera footage. The same problem was evident and was attributed to a camera mounting issue, which the company intended to rectify ahead of the CAA's installation deadline of 31 July 2021.

Aircraft examination

The helicopter was moved to a hangar after it had landed. External examination identified significant deformation of the aircraft landing gear (Figure 9). The aft crosstube had bowed, resulting in both skids moving outboard. The right skid had deflected further than the left. Other than the aft crosstube damage, no other physical damage was identified with the aircraft.

Figure 9

G-MPSB landing gear (viewed from front looking rear)

Assessment of the flight data by the operator and helicopter manufacturer determined that the loads associated with the landing were below the threshold to require heavy landing checks to be completed. The loads were likely to have been attenuated by the deformation of the crosstubes and furrowing of the soft ground.

Both engines were in good condition. Their control systems were correctly installed and connected with continuity from the twist grips on both collectives to their associated FCUs. The microswitches on each FCU throttle quadrant (which, when opened, indicated that the twist grip was not in FLIGHT) functioned correctly. Manipulation of the engine trim function for both engines also confirmed correct functionality.

A ground run of both engines showed full and normal operation of both engines and that the engine trim VARTOMS were setup correctly.

Laboratory assessment of fuel samples taken by the operator immediately after the incident revealed them to be satisfactory.

Weight and balance

The pilots completed pre-flight weight and balance calculations using the '*Easyweigh*' software application. With 495 kg of fuel on board at start up, the calculated initial takeoff gross mass of the helicopter was 3,299 kg. Based on the fuel recorded at shutdown, 394 kg, the gross mass of the helicopter at the time of the incident was approximately 3,200 kg. The helicopter remained within the operational CG envelope throughout the flight.

Helicopter performance

The Cat A Clear Heliport profile is designed such that the helicopter can either land safely or climb away should one engine fail during the takeoff. Between starting the takeoff acceleration and reaching TDP[6] the helicopter can decelerate and land within the clear takeoff area remaining ahead. After TDP a rejected takeoff within the available clear heliport area is no longer assured and the pilot is required to fly a continued takeoff (CTO). For a CTO, the pilot accelerates the helicopter to 45 KIAS (V_{TOSS}[7]) while climbing to 35 ft before then climbing away with due regard to obstacles on the planned departure track (Figure 10).

Calculating the maximum mass for simulating OEI conditions during Cat A Clear Heliport training with one engine at IDLE[8] requires interpolation of the corresponding RFM performance chart[9] (Figure 11). Using the environmental conditions at the time of the incident, the maximum training gross mass (MTGM) for G-MPSB was approximately 3,320 kg.

Footnote

[6] TDP is the first point from which a continued takeoff capability is assured and is the last point in the takeoff path from which a rejected takeoff is assured within the available rejected takeoff distance.

[7] Takeoff safety speed.

[8] RFM Section C.2.1. Mass Limitations.

[9] Fig. C1 Training takeoff and landing gross mass category a [sic] (clear heliport)

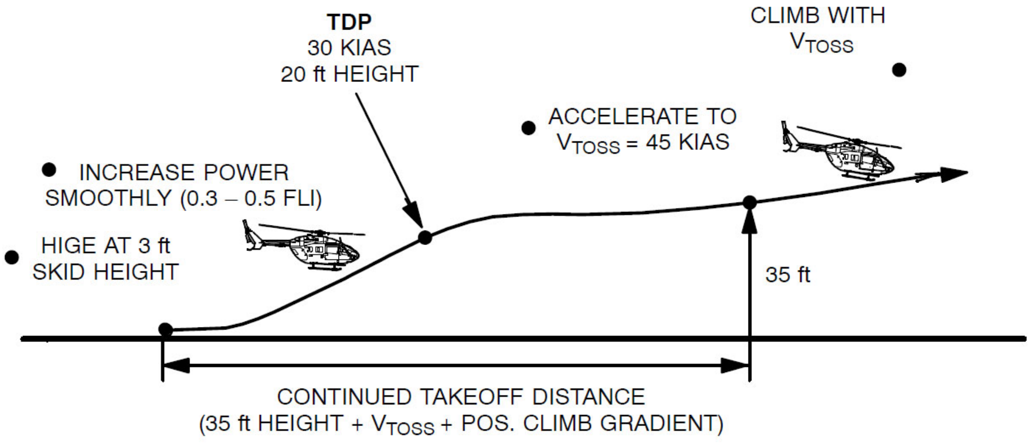


Fig. B5 OEI Continued Takeoff Profile – Clear Heliport

Figure 10

RFM Cat A Clear Heliport initial climb profile for single engine failure after TDP
(RFM Fig.5B courtesy of the manufacturer)

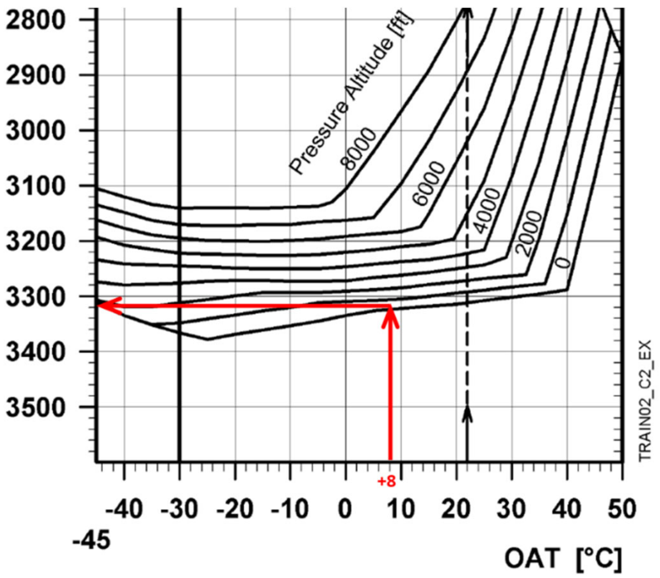


Fig. C1 Training takeoff and landing gross mass category a (clear heliport)

Figure 11

Interpolation of RFM Figure C1 using 8°C and 364 ft pressure altitude
(RFM Fig.C1 courtesy of the manufacturer)

OEI training

The operator had previously sought to establish a flight simulator training contract in support of its BK 117 C-2 training, including instructor revalidation events, but the procurement process had failed when no acceptable tenders were received. In the absence of a suitable flight simulator, TRI revalidation fights were conducted in the helicopter. Dual controls were fitted to helicopters being used for this training.

Rather than attempting to immediately diagnose which engine has failed and selectively trim the other engine's power to maximum, BK 117 C-2 pilots are trained to respond to any OEI situation by pushing forward on the engine trim button. Trimming the live engine (for real or simulated OEI conditions) to maximum power[10] is necessary to guard against N_R droop at power levels lower than OEI MCP.

With no suitable flight simulation training device (FSTD) available or accessible to the operator, there were three options open to their pilots for generating a simulated OEI condition for training on the BK1 17 C-2. The choices were.

> **Manufacturer's OEI training device**. The manufacturer's training device system[11] employs collars to restrict throttle movement, which can be affixed to either twist grip throttle, and training switches on the overhead console (Figure 12) which modify the FLI display to simulate the OEI condition. The system can be used at gross weights at or below MTGM, but the BK 117 C-2 RFM only explicitly requires it to be used for Cat A OEI training when at MTGM[12]. Opinions varied, across the BK 117 C-2 user groups consulted by the investigation, as to the merits of using the training device system. The investigation heard that the manufacturer, and at least one other large helicopter training organisation, exclusively used the training device for OEI training. G-MPSB's operator had previously experienced engine overtorque incidents when using this system and their training manual[13] explicitly prohibited its use. Several pilot witnesses who spoke to the investigation stated that fitting the collars and the associated throttle '*tuning*' procedure was "fiddly" and wasted valuable rotors-running training time[14]. A manufacturer's OEI training report[15] provided to the investigation stated that '*experience has shown that the estimated time to set up the collar is about 2 minutes on the ground.*' Some pilots reported that, once configured, there was no guarantee that the engine setup would not drift in a very short time.
>
> **Both engines at FLIGHT setting**. When employing this method both engines are left at the FLIGHT detent and an artificially low FLI target is used. The benefit of leaving both engines at FLIGHT is that, should it be required, full power is immediately available by raising the collective lever. A reported drawback of this technique was that trainees would not experience simulated OEI flight in true power-limited scenarios close to the ground, meaning they were not necessarily exposed in a training environment to the handling demands of a real engine failure.

Footnote

[10] *See Engine fuel and control system.*
[11] Manufacturer's part number B032M0820101.
[12] Approved Rotorcraft Flight Manual BK117 C2 Section 9.1-3.C.2.
[13] Operations Manual Part D (OMD).
[14] Reportedly between 5 and 15 minutes each time the OEI throttle setting needed to be tuned.
[15] AHI/19R-E-184: Helicopter Limitations and OEI Training on BK117-C2.

Figure 12

Manufacturer's training device (collars and overhead switches)

One engine at IDLE. Using this technique, engine failure is simulated by moving one engine throttle to the IDLE position while leaving the other in the FLIGHT detent. A pilot-reported benefit of using this technique for OEI simulation was that it reinforced the need to use the engine trim button and gave pilots exposure to the handling demands of staying within the engine and transmission limits while still achieving the required OEI flight profile. Pilots stated that a drawback was that "often" with one engine at IDLE the power requirement from the remaining engine exceeded the OEI MCP limit of FLI 11. The incident pilots reported that common practise was to roll one throttle to IDLE and then, if necessary, increase engine rpm by approximately 15% to offset the power demand on the engine set to FLIGHT to avoid exceeding the OEI MCP limit. One experienced BK 117-C2 instructor explained that, when using the engine to IDLE technique, he found it safer and more reliable to incrementally reduce the throttle towards IDLE to achieve the desired engine power disparity rather than reducing immediately to IDLE. His reasoning was that he then always had power in hand and was not reliant on the engine responding to a subsequent increased throttle demand. The manufacturer publishes guidance for flying Cat A takeoffs with engine failure for real but does not include throttle handling guidance in the RFM for instructors or examiners simulating OEI for training purposes. The investigation noted that the RFM describes simulating OEI operation with one engine at IDLE[16] but does not mention the use of a fixed intermediate throttle setting between IDLE and the FLIGHT detent for the simulated failed engine.

Procedures for training and testing conducted by an AOC holder as required by Part Ops, for example Operator Proficiency Checks, are contained within the operator's Operations Manual Part D[17] (OMD) and are to be followed by examiners conducting such activities. TRI revalidations are a licensing requirement which sits outside of Part Ops and are, therefore, subject to RFM rather than OMD limitations. For the OEI serial being flown on the incident flight, the only material difference between OMD and RFM limitations was that the latter were less-restrictive in allowing, but not requiring, use of the OEI training device system. The regulator does not specify how OEI conditions are to be simulated, other than requiring the procedure to be RFM-compliant. Based on their prior experience of using the manufacturer's training device, both pilots reported that, although allowed to when flying under RFM limitations, they would not choose to use it for OEI simulations.

OEI training risk

Training for emergencies is a balance of risk. The regulatory expectation was that simulated higher risk emergencies, such as engine failures, should be conducted in an appropriate FSTD, unless one was unavailable or inaccessible. Exemplar risks for the three 'live aircraft' OEI training options are outlined below.

Training Mode. Operator identified risks were the loss of rotors-running training time when setting up the training device and maintenance penalties from inadvertent engine overtorque events. The operator had prohibited the use of the manufacturer's device for their routine training to mitigate against engine overtorque situations previously encountered. They also found the setup procedure could take ten or more minutes of rotors-running training time and the collar would need to be reset regularly because the setting would 'drift'. The abstract to the manufacturer's OEI training report[18], however, concluded that '*the use of* [the] *OEI training device provides more realistic training…and does not cost overtime* [sic] *to the training session.*'

Training with both engines in the FLIGHT detent. The key operator-perceived risk was pilots not gaining and/or being able to demonstrate confidence and competence in safely controlling the helicopter with limited power margins as might be experienced following a real engine failure during Cat A operations.

Footnote

[16] RFM Section 9.1-3 C.1. General.
[17] Operator's training manual.
[18] AHI/19R-E-184.

> **Training with one engine at IDLE.** The operator identified as a significant risk a maintenance penalty if OEI training engine limits were exceeded. As highlighted by this incident, continued safe flight was also at risk if the engine left at FLIGHT subsequently suffered a power loss.

Immediately following this event, the operator suspended training with one engine at IDLE until the circumstances of the incident were more fully understood. It also raised a technical request with the manufacturer to clarify procedural elements of OEI training with one engine retarded to IDLE. Pending the outcome of the investigation, the operator elected to only conduct OEI training with both engines at FLIGHT. The operator also pursued a new contract to provide simulator-based OEI training for their BK 117 C-2 pilots and this became fully established by the end of Autumn 2021.

Meteorology

The reported weather at the time of the incident was a south-westerly wind of 10-15 kt with gusts to 25 kt, good visibility under a 2,500 ft cloud base, temperature of 8°C and a QNH of 1,000 HPa.

Airfield information

In addition to the helicopter operating strip used on the incident flight, North Weald Airfield has a grass runway adjacent to the northern end of Runway 02/20. For noise abatement reasons, the operator does not conduct routine training on the grass runway.

Personnel

The pilot occupying the left seat was revalidating his TRI qualification and was being assessed by the examiner who was flying from the right seat.

Both pilots were qualified as BK 117 C-2 type rating examiners, each with approximately 7,170 total flying hours. The commander had 2,200 hours on type and was also qualified on the EC135 helicopter. The examiner had flown 2,600 hours on BK 117 C-2 helicopters. They were both familiar with the training profile being conducted and reported having conducted Cat A Clear Heliport OEI training using the one engine at IDLE technique "over a hundred times." The crew explained that the pilot revalidating his TRI qualification was nominated as aircraft commander because he would be manipulating the throttles during the engine failure training scenarios.

Earlier in the year, the examiner had taken on additional managerial and strategic responsibilities including the Head of Flight Operations role. As a result, he had a higher workload and had been flying less than in previous years.

Neither pilot reported any personal or work-related factors that they felt affected their performance.

Organisational information

The operator was in the process of a significant national programme of organisational change that included changes of location, job roles and working pattern for some pilots. The programme of change was being managed through the operator's Safety Management System (SMS). In October 2020, the operator identified the start of an increasing trend of fatigue and distraction due to the uncertainty associated with the changes. The operator was attempting to manage these hazards while recognising that they are an inevitable consequence of some types of organisational change and that there are limited options for reducing them while uncertainty continues. Some of the role changes had resulted in additional workload. The operator recognised the potential for this to affect pilot performance and took safety action in this area.

Tests and research

Following the occurrence and subsequent aircraft examination, a rotors-running ground check confirmed the correct operation of the VARTOMS and trim system. Tests to assess the authority of the engine trim system were made by a test pilot from the helicopter manufacturer and were overseen by AAIB.

Trim authority was assessed by setting VARTOMS to MANUAL, manipulating the trim function and assessing the engine speeds when the twist grips were set to IDLE and FLIGHT. The results are shown in Table 2. Collective pitch remained at zero throughout the testing.

Test number	Trim position	No 1 Twist Grip position	No 2 Twist Grip position	No 1 N1 (%)	No 2 N1 (%)
1	Neutral	FLIGHT	FLIGHT	80.1	79.1
2		IDLE	IDLE	69.6	70.9
3	Fully forward	FLIGHT	FLIGHT	79.1	82.0
4		IDLE	IDLE	70.0	71.1
5	Fully backward	FLIGHT	FLIGHT	79.1	77.1
6		IDLE	IDLE	70.5	71.2
7	Fully left	FLIGHT	FLIGHT	83.9	73.1
8		IDLE	IDLE	70.5	70.9
9	Fully Right	FLIGHT	FLIGHT	69.8	85.9
10		IDLE	IDLE	69.8	71.6

Table 2

Engine speeds at Idle and Flight when trimmed using engine trim function

These tests revealed that when the engines were set to FLIGHT and then trimmed fully right, Engine No 2's N1 increased and Engine No 1's N1 reduced. Engine No 1's N1 settled at approximately 70% and when the throttle was moved to IDLE and back to FLIGHT the engine speed remained at approximately 70% N1. A similar but opposite result was observed when the engines were trimmed to the left; as shown in the results of tests 7, 8, 9 and 10.

Analysis

Examination and ground running revealed no technical malfunction with the helicopter that would have prevented Engine No 1 from responding to the twist grip as it was moved from IDLE toward FLIGHT during the initial phase of the OEI manoeuvre, or to cause the twist grip for Engine No 2 to come out of the FLIGHT detent during the latter part of the manoeuvre. Ground running did, however, identify that if the engines were fully trimmed right, ie the No 1 engine trimmed down, Engine No 1's response was similar to that in the event flight.

Operation of the trim switch

Without a trim parameter or twist grip position recorded on the FDR, it was not possible to confirm whether the trim was inadvertently moved to the right, instead of trimming both engines forward. From the pilot's recollection of advancing the Engine No 1 twist grip without response it is likely that when he applied forward trim, as trained to do in OEI situations, the four-way trim switch was inadvertently moved to the right trim position.

By trimming Engine No 2 up and Engine No 1 down while Engine No 1 was set to idle, the engine response would initially have been the same as if the trim had been pushed forward. Engine No 2 would have increased torque with Engine No 1 remaining at a low torque output. Only when the Engine No 1 twist grip was advanced would the engine trim split manifest itself.

The trim switch is offset to align with the pilot's thumb when holding the collective so that movement forwards (power of both engines is increased simultaneously) is the easiest action. The offset alignment makes inadvertent movement to the right less likely compared to a straight alignment because movement to the right position requires a slight rearward movement, but it is still possible. If the switch is inadvertently moved into the right gate, any forward pressure moves it against the side of the gate, feeling similar to when the switch is positioned against the forward stop. There is no feedback to the pilot to indicate the location or direction of trim, so if this occurs there is little opportunity to recognise and correct it.

OEI training risk

Having previously been unable to establish an appropriate simulator training contract, the operator was required to choose between the three options available for live emergency training in the helicopter. Balancing the risk factors for the various options, the operator chose to use the 'one engine at IDLE' method to train pilots for OEI conditions.

Incident event

The CVR evidence suggested a relaxed professional atmosphere in the cockpit with both pilots focused on the exercises that were being flown. Accordingly, it is unlikely distraction or interpersonal factors contributed to the occurrence.

For the incident event, the commander was using a technique specified in the RFM to simulate an engine failure on a Cat A Clear Heliport takeoff. The helicopter was below the maximum gross mass for simulating OEI conditions with one engine at IDLE so there was no RFM requirement for it to be fitted with the manufacturer's OEI training device. The investigation observed that the RFM limitation requiring the device to be fitted for training at MTGM was of limited value; training could not be conducted above MTGM and at 1 kg below that mass use of the device was not required. The manufacturer undertook to review the appropriateness of this limitation.

During the takeoff acceleration the commander was judging his height and airspeed by looking across the cockpit to the examiner's flight instruments. He recalled announcing "flyaway" when he saw they were above 20 ft and 30 kt based on the examiner's displays, he then retarded Engine No 1's throttle to initiate the simulated engine failure. The FDR trace showed the helicopter at 16 ft radio height and 42 KIAS when the throttle came out of the FLIGHT detent. The helicopter maintained a shallow climb and passed through 20 ft radio height approximately 3-4 seconds after the throttle had been closed, the recorded IAS at that point was close to 43 kt. The reason for the apparent discrepancy between the commander's interpretation of the examiner's altimeter display and the recorded radar altimeter height was not identified. While the helicopter might possibly have been below the target TDP height parameter when the engine failure simulation was initiated, the excess speed meant that less power would have been required to maintain level flight or fly away than at the nominated TDP parameters of 20 ft and 30 KIAS. Given the energy state of the helicopter, the investigation assessed that continuing the takeoff was a reasonable course of action.

During the OEI demonstration, the power required from Engine No 2 to execute the flyaway manoeuvre exceeded the training limit, therefore the commander increased the throttle setting of Engine No 1. Then, while the commander was manipulating Engine No 1's throttle in reaction to its lack of response, Engine No 2's throttle moved out of the FLIGHT detent, thereby putting the engine into manual control. The evidence supported the commander's theory that, if his hand had overlapped both twist grips (Figure 13) while adjusting Engine No 1's throttle, it could account for FLIGHT being deselected inadvertently on Engine No 2. The commander also reported that the breakout force from the FLIGHT detent was relatively low compared with other helicopter types he had flown. The TWIST GRIP caution for Engine No 2's throttle would have been displayed on the CAD, but it did not have any attention getting properties. The commander's attention would have been focused on other indications and there was limited time for diagnosis.

In a rapidly deteriorating situation, the commander made an appropriate decision to reject the takeoff and managed the collective effectively to maintain minimum N_R and achieve a firm touchdown that resulted in some damage to the helicopter but no injuries. Although using the more-northerly grass runway could have given the pilots more obstacle free distance to diagnose and resolve the throttle handling issues, noise abatement considerations precluded its use.

Throttle handling technique

While the commander had no reason to suspect that Engine No 1 would not respond to his increased throttle demand, had he used the alternative technique of initially reducing to an intermediate throttle setting, rather than IDLE, the encountered problems might not have occurred. The subsequent inadvertent deselection of FLIGHT on Engine No 2 probably resulted from the commander's hand accidentally overlapping its throttle as he tightened and/or moved his grip on Engine No 1's throttle while manipulating it in response to the unfolding emergency. The investigation heard that inadvertent manipulation of the throttles during high stress/workload situations was an uncommon, but not unknown occurrence on this type of helicopter. The helicopter manufacturer undertook to review their handling guidance for pilots employing the one engine to IDLE technique for simulating engine failures during Cat A Clear Heliport takeoffs.

Figure 13

Pilot's hand overlapping both throttle twist grips

Throttle and trim switch design

The throttle control incorporates several tactile features to aid non-visual operation and reduce the chance of inadvertent movement of the throttles. The investigation did not identify any design features that could have increased the likelihood of inadvertent right trimming or inadvertent movement of the throttle out of FLIGHT mode.

Organisational change

There was no indication the pilots' performance was affected by the scale of organisational change. They did not report any adverse effects on them that were relevant to the incident. The operator was managing the process in the SMS. The SMS was effective in that it had identified an increasing trend of distraction and fatigue and the operator attempted to minimise this as far as possible.

Conclusion

This serious incident occurred in a serviceable helicopter while the pilots were following an RFM-approved training procedure. While FDR data indicates that the helicopter was slightly below 20 ft when the simulated engine failure was introduced, the excess speed at that point meant it did not materially affect the outcome.

Ground running trials conducted on behalf of the AAIB indicated that, with no faults detected in the helicopter's engine control systems, the most likely cause of Engine No 1 failing to respond to the commander's increased throttle demand was an inadvertent initial RIGHT, rather than FORWARD, trim selection on the 4-way beep trim switch. There was no evidence the incorrect selection was caused by the design of the switch.

The actions taken when Engine No 1 did not respond to the commander's inputs led to Engine No 2's throttle being inadvertently moved out of the FLIGHT detent, which exacerbated the situation. The subsequent landing was firm and caused damage to the helicopter's skid assembly.

The event could possibly have been avoided by using a different throttle handling technique when simulating the engine failure. This incident reinforces the benefit of using flight simulators wherever possible to de-risk training, thus avoiding the requirement for live emergency training in the helicopter.

Safety action

The helicopter's operator has:

- issued a temporary Flying Staff Instruction prohibiting engines being retarded to idle in flight during BK 117 C-2 training and checking.
- raised a technical request with the manufacturer to clarify procedural elements of OEI training with one engine retarded to idle.
- initiated a review of workload at all management levels where change was occurring, including the Head of Flight Operations role.
- introduced simulator training, including OEI serials, for BK 117 C-2 pilots.

The helicopter manufacturer reported that it intended to:

- develop formal guidance to pilots delivering simulated OEI training in the helicopter using the one engine at IDLE technique, and
- review the appropriateness and scope of the RFM limitation requiring the use of the manufacturer's training device when conducting OEI training at MTGM.

Published: 3 February 2022.

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:	Spitfire Mk.T IX (Modified), G-CTIX
No & Type of Engines:	1 Packard Motor Car Co Merlin 224 piston engine
Year of Manufacture:	1944 (Serial no: PT462)
Date & Time (UTC):	20 July 2021 at 1305 hrs
Location:	Duxford Aerodrome, Cambridgeshire
Type of Flight:	Safety Standards Acknowledgement and Consent (SSAC)
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Paint marks on underside of right wing
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	19,000 hours (of which 500 were on type) Last 90 days - 42 hours Last 28 days - 17 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

While returning to park following a short local flight, the pilot of a Spitfire was unaware of an aircraft ahead that was conducting pre-flight checks at a holding point on the taxiway. Despite immediately turning away from the traffic when he saw it, the Spitfire pilot was unable to avoid a collision, resulting in minor cosmetic damage to the aircraft.

History of the flight

Following an experience flight in the local area, the Spitfire landed on the paved Runway 24L at Duxford Aerodrome. The pilot was given taxi instructions to its parking position to the north-east of the Eastern Apron (Figure 1). The aircraft taxied across the grass runway onto the paved taxiway, where it was given a further instruction by ATC to hold position due to conflicting traffic under tow. Once this traffic had passed, G-CTIX was given onwards taxi instructions. There was a Bearcat aircraft preparing for departure to the right of the taxiway which the pilot commented was not a common sight.

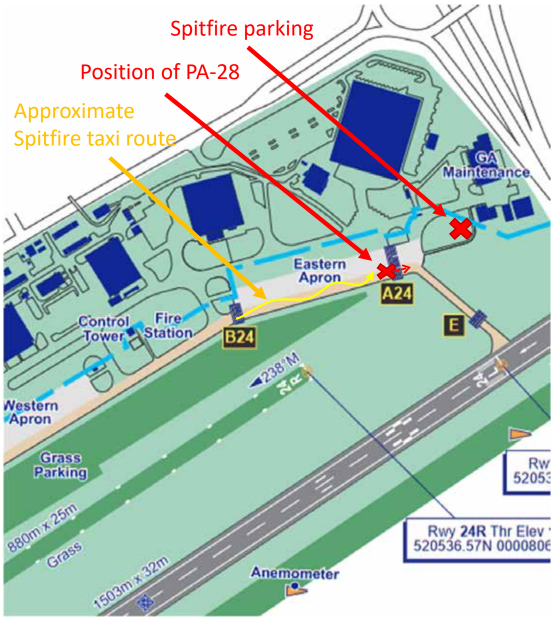


Figure 1

A portion of G-CTIX taxi route relative to PA-28

There was work in progress on an extension of the public area on the Eastern Apron. Therefore, the space available for apron parking was reduced, while the full area of the taxiway remained usable. A FISO familiar with operations at Duxford noted that when the full Eastern Apron area was available, it would routinely be used by taxiing aircraft to pass traffic holding on the taxiway at Holding Point A as in this event. A NOTAM had been published regarding reduced apron size, but this expired two days before the event and an extension was not sought by those carrying out the work.

The pilot stated that recently he had become mindful of potential exposure to carbon monoxide from engine exhaust as a result of taxiing with the canopy of the aircraft open. Consequently, he elected on this occasion to taxi with the canopy closed. This was the first time he had done so.

It is normal in a taildragger such as a Spitfire to weave from side to side when taxiing, enabling the pilot to see along the intended route. In preparation to leave the main taxiway and enter its parking area to the left, the pilot turned the aircraft right, away from the barrier; as he commenced the reverse turn, he saw a PA-28 forward of the right wing at the A24 holding point. The PA-28 was facing in a north-easterly direction and could not have seen the Spitfire approaching.

On seeing the PA-28 the Spitfire pilot applied full left rudder and brake. The Spitfire then swung to the left and its right wing contacted the left wing of the PA-28. The Spitfire pilot stopped the aircraft and shut down the engine. He also indicated to the PA-28 pilot to shut down, and went to check on the occupants. The airfield emergency services attended the scene, as did staff associated with the experience flight who arranged for the passenger to disembark. Both aircraft sustained minor cosmetic damage and there were no reported injuries.

Aircraft information

Originally built as a single seat aircraft in 1944, G-CTIX is a monoplane with a conventional landing gear which was restored to flying condition in 1987. During its restoration it was modified to a two-seat configuration. Although this places the pilot seat somewhat further forward than in its original configuration, the view ahead is still substantially obscured by the aircraft's nose.

Discussion

Duxford Aerodrome provides an AFIS[1], in which AFISOs issue instructions to aircraft on the ground and provide traffic information to aircraft while airborne[2]. The pilot had not been advised of the PA-28 traffic holding at A24. The AFISO on duty believed there was sufficient room for the aircraft to follow its cleared taxi route while the PA-28 conducted its checks. The AFISO commented that there is no other appropriate location for aircraft to carry out pre-flight checks prior to departing Runway 24.

An investigation by the aerodrome operator found that the appropriate traffic information was not passed to the pilot of G-CTIX. The report recommended issuing an operational reminder to AFISOs to pass traffic information to taxiing aircraft, in particular taildraggers.

CAP 797 – *Flight Information Service Officer Manual*[3], which details the responsibilities of an AFISO, states:

> *'The importance of issuing clear and concise instructions to taxiing aircraft cannot be over-emphasised. The visibility from an aircraft flight deck is limited and, when taxiing, the pilot is dependent to a large degree upon the AFISO to assist him in determining the correct taxi route to be followed. Essential aerodrome information is to be passed to the pilot to assist him in preventing collisions with parked aircraft and obstructions on or near the manoeuvring area.'*

The pilot, who is familiar with operating at Duxford, stated that ordinarily he would receive traffic information from the AFISO. As there were works to the extended public area along the cleared taxi route, he considered that there was not sufficient room to follow his cleared route on this occasion. Whilst the responsibility of the safe operation of an aircraft ultimately lies with the pilot, the service provided by an AFISO can assist in maintaining the pilot's awareness of traffic and other obstacles.

The pilot noted that taxiing with the canopy closed had reduced the view from the cockpit, indicating that more pronounced turns might be necessary to check the way ahead was clear. He also commented that activity beside the active taxiway to extend the public area was a significant distraction.

Footnote

[1] UK AIP, Duxford Aerodrome https://www.aurora.nats.co.uk/htmlAIP/Publications/2021-11-04-AIRAC/html/index-en-GB.html [accessed 12 November 2021].

[2] Civil Aviation Publication CAP 413 *'Radiotelephony Manual'*.

[3] Civil Aviation Publication CAP 797 *'Flight Information Service Officer Manual'* Chapter 8.68.

The NOTAM which had been published to advise AFISO's and pilots of the reduction of the Eastern Apron size was not valid at the time of the accident. Had the NOTAM been extended when the works continued after the planned period, it is more likely the FISO and pilot would have been aware of the reduced apron area and ongoing works.

Works on an apron area do not necessarily require a NOTAM to be published[4]. However, CAP 2173[5] states:

> *'The aerodrome operator shall:*
>
> *(1) establish and implement procedures in accordance with which it originates a NOTAM issued by the relevant aeronautical information services provider:*
>
> *(i) that contains information on the establishment, condition, or change of any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel involved with flight operations;'*

Given the proximity of the Eastern Apron to Holding Point A and the main taxiway, it would be reasonable to consider information about works on the apron as essential for those involved with flight operations.

The aerodrome operator stated that, in response to this event, it has issued an Operational Notice to all ATC staff advising them of a new form, *'Eastern Apron Usage Requests'*, which must be completed prior to the approval of any future works on the area. It also requires a temporary fence line be assembled to leave a clear space around Holding Point A.

Conclusion

Temporary reduction of the movement area without a valid NOTAM, the pilot's decision to taxi with the canopy closed in order to reduce exhaust exposure, and the lack of traffic information provided to the pilot by the AFISO, contributed to the loss of separation between the aircraft on the ground. The aerodrome operator has issued an Operational Notice to AFISOs reminding them of the restricted visibility experienced by pilots of taildragger aircraft and of the benefit of passing traffic information to taxiing aircraft.

Footnote

[4] Civil Aviation Publication (CAP) 2173 Assessment, Measurement and Reporting of Runway Surface Conditions for Certificated Aerodromes ADR.OPS.A.057 (b).

[5] CAP 2173 ADR.OPS.A.057 (a) available at https://publicapps.caa.co.uk/docs/33/GRF%20Certificated%20(CAP2173).pdf accessed 31 January 2022.

ACCIDENT

Aircraft Type and Registration:	Pioneer 300 Hawk, G-OPYO	
No & Type of Engines:	1 Rotax 912 ULS piston engine	
Year of Manufacture:	2009 (Serial no: PFA 330A-14597)	
Date & Time (UTC):	25 November 2021 at 1530 hrs	
Location:	Near Sleap Aerodrome, Shropshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to fuselage underside and minor damage to wings	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	68 years	
Commander's Flying Experience:	676 hours (of which 55 were on type) Last 90 days - 15 hours Last 28 days - 7 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB.	

History of the flight

During the pre-flight inspection, the pilot estimated from the fuel gauges that he had enough fuel for just under an hour of flying in his left tank and fuel for about 30 minutes of flying in the right tank. As he intended to practice circuits and go-arounds he believed he had sufficient fuel in either tank, but would select the left tank to ensure there was sufficient margin to undertake his planned flight.

After takeoff he completed his first circuit and a touch-and-go landing. Whilst on his second circuit, he descended on the base leg and had started to turn onto final when the engine vibrated, slowed and stopped within a few seconds. He called a Mayday, raised the undercarriage and flaps, and lined up for Runway 36. He attempted two engine restarts but although the engine turned, it would not re-start. He did not notice the fuel pressure or fuel tank contents readings.

Realising he was not going to reach his intended landing point, he attempted to land in a nearby field. On touch down, the aircraft traversed a ditch, and hit the far bank hard before coming to a stop. The pilot experienced some back pain but was able to exit the aircraft without assistance.

Comment

After the flight the fuel tank contents were checked and the pilot found the right tank was empty but the left tank still had approximately the same fuel as before the flight. He commented that the right fuel tank had been selected rather than the left, causing the engine to run out of fuel and stop during the flight.

Chapter 23 of the Safety Sense Leaflet 1e - ‘*Good Airmanship*’, published by the CAA includes guidance on in-flight checks for monitoring fuel tank usage as well as for fuel planning.

ACCIDENT

Aircraft Type and Registration:	Piper PA-22-150, G-ARDS	
No & Type of Engines:	1 Lycoming O-320-A2B piston engine	
Year of Manufacture:	1959 (Serial no: 22-7154)	
Date & Time (UTC):	11 August 2021 at 1012 hrs	
Location:	Beverley Airfield, Yorkshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Damaged beyond economical repair	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	66 years	
Commander's Flying Experience:	119 hours (of which 27 were on type) Last 90 days - 16 hours Last 28 days - 11 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

During the flare in a crosswind landing the aircraft's right wing lifted, causing it to slew off the runway and came to rest in a nearby field. The pilot suggested that the turbulence effects from a windfarm to the south of the airfield may have been a contributory factor in the loss of control.

History of the flight

The pilot had flown from his home airfield of Sherburn in Elmet to Beverley Airfield. The weather conditions were good. Runway 12 was active, with a left-hand circuit and a crosswind from 180° at 10 kt.

The pilot conducted an overhead join and flew a normal circuit. He reported that final approach was stable and aligned with the runway's extended centreline. As the aircraft passed through 150 ft agl the pilot felt "strong" turbulence and had to correct quickly to keep the wings level. He continued the approach, using the "wing-low" method[1] for the crosswind landing. The pilot reported that after the turbulence at 150 ft the approach was stable, until he flared for touchdown. He recalled that at this point he experienced a sudden "violent" gust which lifted the right wing. He attempted to correct with right aileron, and applied power to go around. This was unsuccessful and the aircraft continued to move to the left.

Footnote

[1] Using the rudder to align with the runway and aileron to roll into the crosswind to correct for the drift.

It missed a ditch to the north of the runway but struck the ground in a field beyond, causing substantial damage to the aircraft (Figure 1).

Figure 1
G-ARDS after the accident

In reviewing the accident, the pilot reported that he believed that both the turbulence during final approach and the loss of control during the flare may have been associated with wake turbulence downstream of a wind turbine installation to the south of the airfield. The pilot also commented that as the aircraft still had its rudder/aileron interlink installed[2], the coordination of the rudder with aileron inputs whilst responding to a gust, may have affected the aircraft's response.

Airfield information

Beverley is an unlicenced airfield located 4 nautical miles north-northeast of Beverley with a 710 m grass runway with 12/30 orientation. The aeronautical plate for the airfield identifies that there is a wind turbine installation 1 nm south of the airfield.

The installation comprises twelve 82 m diameter wind turbines, the most northerly is approximately 1.4 km south of Runway 12 threshold and 1.2 km south southwest of Runway 30 threshold (Figure 2).

Footnote

[2] The PA-22 was originally configured with a rudder/aileron interlink that coordinates the movement of the rudder and ailerons to simplify flying the aircraft. This is a sprung interlink that can be overridden. Many PA-22 aircraft have subsequently removed the interlink, however the interlink was still fitted to G-ARDS.

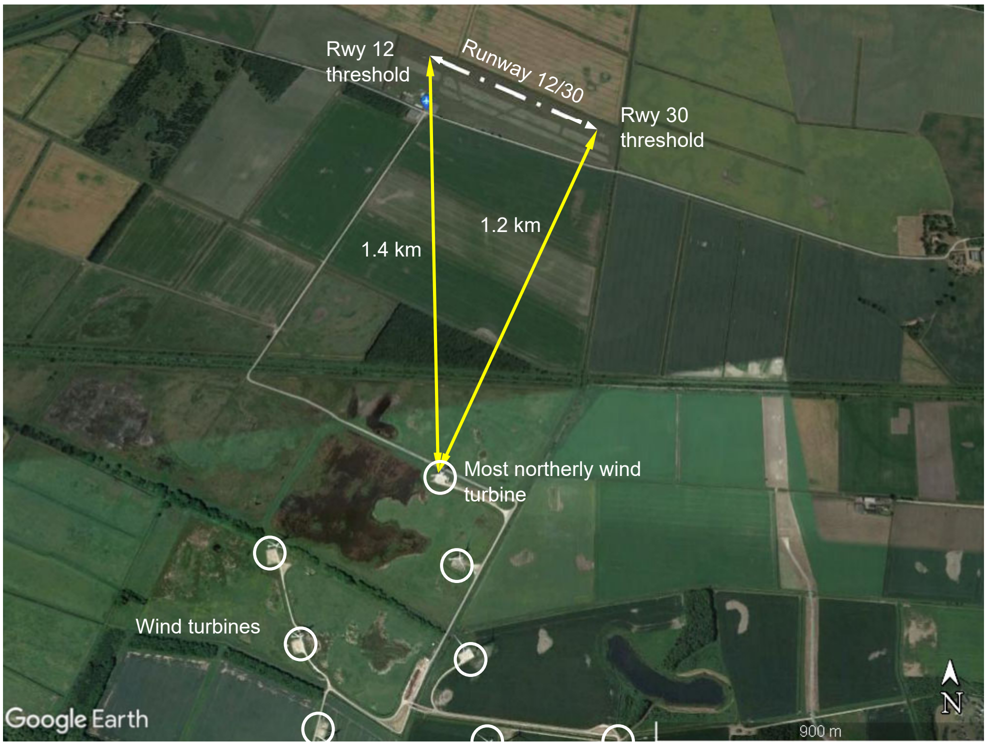


Figure 2

Location of most northerly wind turbine at Hall Farm in relation to the runway at Beverley Airfield

The AAIB contacted the airfield management enquiring whether there had been any reports of aircraft experiencing turbulence on approach and landing when with a southerly wind direction. They were not aware of any occurrences but did suggest that there can be some shadowing from the trees to the west of the clubhouse.

CAP 764 - CAA Policy and Guidelines on Wind Turbines

CAP 764, the CAA Policy and Guidelines on Wind Turbines, issue 6, February 2016[3] identifies the risk wind turbines pose to aviation. Paragraphs 2.51 to 2.61 discuss turbulence caused by the wake of the turbine. They describe that the wake turbulence, which is similar, but not identical to, that produced by aircraft, extends downwind behind the wind turbine blades and tower. The turbulence experienced in the 'near field' (within one rotor diameter) is well understood and can be related to the efficiency and power extraction from the airflow through the turbine. The 'far field' effect is less well understood, with the dissipation of the turbulence, and therefore its reduction of intensity, being dependent on the convection, turbulence diffusion, the topography (such as obstacles and terrain downwind the turbine) and the atmospheric conditions.

Published research referred to in the CAP identifies that turbulence effects could still be noticeable up to 16 rotor diameters downstream of a wind turbine. However, research

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Footnote

[3] http://publicapps.caa.co.uk/docs/33/Cap764.pdf [accessed 18 Janaury 2022.]

published by Liverpool University[4], in conjunction with the CAA, suggests that the turbulence should become dissipated below noticeable levels within five rotor diameters of the turbine. This was based on computational fluid dynamics and 'light detection and ranging' (LIDAR) measurements of the 'velocity deficit'[5] in the wake of a 30 m diameter wind turbine.

A more recent publication by the Netherlands Aerospace Centre[6], identified that for helicopter operations wind turbine wake turbulence had diminished sufficiently for safe operation by six rotor diameters downwind of the rotor. This analysis was based on a *'relatively simple analytical wake model'* of a single 8 MW wind turbine with a 164 m rotor diameter. The report also suggests a safe distance from a windfarm (of multiple wind turbines) would be eight rotor diameters. A maximum 'wind velocity deficit' of 6 kt was used in this analysis, based on helicopter susceptibility to such turbulence.

The windfarm installation to the south of Beverley Airfield is 1.4 km from the Runway 12 threshold, which is just over 17 times the wind turbine diameter. The threshold of Runway 30 is within 15 times the wind turbine diameter.

The CAP states that there *'are currently no Mandatory Occurrence Reports (MOR) or aircraft accident reports related to wind turbines in the UK'*. It goes on to state *'Pilots of any air vehicle who firmly believe that they have encountered significant turbulence, which they believe to have been caused by a wind turbine, should consider the need to report this through the existing MOR scheme.'*

AAIB Comment

The available literature would suggest that the possibility of encountering wake turbulence from the windfarm at this airfield is remote. However, it cannot be entirely ruled out. The accident aircraft flew an approach that crossed downwind of the wind turbines but the distance from the closest turbine to the location that the aircraft encountered the upset was further than 16 rotor diameters identified in CAP 764 as the furthest distance that turbulence would be encountered. It was also well outside that of the most recent estimates of eight rotor diameters downwind of windfarms.

The analysis that has been conducted has been based on limits for commercial fixed-wing and rotary-wing aircraft and may not take into account the effects on general aviation operations. It is therefore incumbent on the General Aviation community to provide feedback to the CAA, via an MOR, if they suspect they have been affected by wind turbine wake turbulence. This will allow a more representative understanding of the issue and ensure the guidance for operating close to a wind farm is based on theoretical and practical knowledge.

Footnote

[4] Aircraft Encounter with Wakes - Flight Science and Technology - University of Liverpool

[5] Velocity deficit is variation in average wind speed in the flow downwind of a turbine.

[6] https://reports.nlr.nl/bitstream/handle/10921/1496/TP-2019-083.pdf?sequence=1&isAllowed=y [accessed January 2022.]

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-180, G-AVBT
No & Type of Engines:	1 Lycoming O-360-A4A piston engine
Year of Manufacture:	1967 (Serial no: 28-3945)
Date & Time (UTC):	9 July 2021 at 1033 hrs
Location:	Mid Wales Airport, Welshpool, Powys
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Substantial damage to the landing gear and propeller
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	314 hours (of which 21 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Approximately 10 minutes into a training flight the main door started to open and the instructor made a few unsuccessful attempts to close it. During the approach and at approximately 150 m from the runway the aircraft lost altitude and struck a hedge.

History of the flight

The instructor was undertaking her first instructional flight, a trial lesson with a planned landaway at Mid-Wales Airport, Welshpool. Approximately 10 minutes into the flight, with the student flying, the main door started to open. The instructor made a few unsuccessful attempts to close it and then decided to continue to Welshpool as they understood the departure airfield was busy.

A straight-in approach was requested, and the instructor explained the approach procedure to the student. The aircraft was lined up with the runway centreline with the flaps extended and was stable at 67 kt. The student flew the approach with the instructor following through on the controls whilst holding the door closed. The instructor reported, at approximately 150 m from the runway the aircraft "lost lift and dropped, losing altitude, full power was immediately applied and the aircraft was pitched-up, but it kept descending, making a go-around impossible". The main landing gear stuck a hedge in the undershoot and detached. The aircraft came to rest about 200 m from the hedge and beside the runway.

Relevant safety information

The CAA Skyway Code, in the section entitled, General Aviation Risks, highlights distraction, such as an open door, as a risk that can lead to a loss of control. It states:

> *'The most important message is to fly the aircraft'*

The Pilot's Operating Handbook for this aircraft does not include a procedure for an open door in flight, but later versions for similar aircraft do contain a procedure and operating advice in Section 3, Emergency Procedures as follows:

> *'3.31 OPEN DOOR*
>
> *The cabin door is double latched, so the chances of its springing open in flight at both the top and side are remote. However, should you forget the upper latch, or not fully engage the side latch, the door may spring partially open. This will usually happen at takeoff or soon afterward. A partially open door will not affect normal flight characteristics, and a normal landing can be made with the door open.*
>
> *If both upper and side latches are open, the door will trail slightly open, and airspeed will be reduced slightly.*
>
> *To close the door in flight, slow the airplane to 87 KIAS, close the cabin vents and open the storm window. If the top latch is open, latch it. If the side latch is open, pull on the armrest while moving the latch handle to the latched position. If both latches are open, close the side latch then the top latch.'*

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ACCIDENT

Aircraft Type and Registration:	Star-Lite SL-1, G-SOLA	
No & Type of Engines:	1 Rotax 447 piston engine	
Year of Manufacture:	1988 (Serial no: PFA 175-11311)	
Date & Time (UTC):	17 July 2021 at 1030 hrs	
Location:	Near Pembrey Airport, Carmarthenshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Bent nosewheel leg	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	67 years	
Commander's Flying Experience:	150 hours (of which 66 were on type) Last 90 days - 1 hour Last 28 days - 1 hour	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft suffered fuel exhaustion after a second go-around at the end of a local flight. The pilot had been distracted during pre-flight preparations and departed with less fuel onboard than he had intended.

History of the flight

The pilot was planning to carry out a flight test from Pembrey Airport to renew the aircraft's Permit to Fly. He had not flown for eight months, during which the aircraft had been stored with its fuel tank empty.

The pilot carried out pre-flight checks and had planned to refuel the aircraft from three fuel containers which he had brought with him in his car. He emptied one 5 litre container and one 10 litre container into the fuel tank before being distracted, leaving another full 10 litre container in the car. As a result, when the aircraft departed it contained approximately 15 litres of fuel, rather than the 25 litres intended.

The pilot reported he successfully completed the flight test in about 45 minutes. He then continued to practise some general handling in the local area for a similar length of time before returning to Pembrey. Weather conditions were good at the time with only a very light wind, which the pilot stated made speed control of the 'slippery' aircraft more difficult. He reported that he was unable to slow to the correct approach speed during the approach and made the decision to go around. He then repositioned the aircraft for a second approach, during which the aircraft floated along the runway in ground effect. Judging the aircraft was too far along the runway to land safely, the pilot once again chose to go around.

On climbing away, at a height of about 500 ft, the engine stopped and the pilot carried out a forced landing in a nearby field. Having touched down successfully, the nosewheel hit a rut causing the nosewheel leg to bend backwards under the fuselage. The aircraft came to rest and the pilot, who was uninjured, was able to vacate the aircraft unaided.

Aircraft examination

On examination after the accident there was no fuel remaining in the fuel tank. Other than the nosewheel leg the aircraft was undamaged.

Other information

The pilot estimated the aircraft normally consumed about 10 litres of fuel per hour. He found the aircraft fuel gauge was not accurate, and relied instead on dipping the fuel tank to determine the fuel onboard before departure.

Analysis

The engine failure was caused by fuel starvation resulting from inadvertent departure with less than the intended amount of fuel onboard. The pilot had calculated the fuel required for his flight but had been distracted, breaking the routine of his before-flight preparation. This had been partly due to pre-occupation with conducting the flight test.

Because he considered that the fuel gauge was inaccurate, the pilot preferred to rely on dipping the tank to determine how much fuel was onboard. He had not done so on this occasion as he believed he had already loaded the required amount of fuel for the flight. Had he loaded the intended 25 litres the aircraft would have had approximately an additional hour of endurance, which would have been more than sufficient for the flight undertaken.

The pilot commented that his lack of recency and the light wind had contributed to the unsuccessful approaches. Other than in respect of the lack of fuel, of which he was unaware, his decision to go around on both occasions was sound. He was able to carry out a safe forced landing from a low height, damage resulting from the rough nature of the terrain.

Conclusion

The aircraft was damaged during an otherwise safe off-aerodrome forced landing after running out of fuel during a go-around. The aircraft ran out of fuel because the pilot was distracted while refuelling before the flight, with the result that its tank contained 40% less fuel than he intended. The event highlights the danger posed by distraction during routine tasks, especially when under additional pressure.

ACCIDENT

Aircraft Type and Registration:	Quik GTR, G-GTRX	
No & Type of Engines:	1 Rotax 912ULS piston engine	
Year of Manufacture:	2013 (Serial no: 8646)	
Date & Time (UTC):	3 July 2021 at 1500 hrs	
Location:	Credenhill, Hereford	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Serious)	Passengers - 1 (Serious)
Nature of Damage:	Damaged beyond repair	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	54 years	
Commander's Flying Experience:	406 hours (of which 370 were on type) Last 90 days - 12 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot was conducting a series of local flights between Broadmeadow Airfield and Credenhill, in good weather. Three previous landings on Runway 26, which is a grass strip, had been conducted without issue. The pilot stated that the aircraft was high and slow on the approach to the final landing, which resulted in the aircraft bouncing as it touched down. The pilot considered that engine power was applied too late in response, and this resulted in the aircraft accelerating into the ground in a nose down attitude, rather than flying away. The pilot and passenger suffered serious injuries[1], but received immediate medical attention from staff located onsite.

Footnote

[1] As defined by ICAO Annex 13.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 300	
No & Type of Engines:	4 electric motors	
Year of Manufacture:	2020 (Serial no: 1ZNDHAL00CPC93)	
Date & Time (UTC):	17 August 2021 at 0036 hrs	
Location:	Cam, Dursley, Gloucestershire	
Type of Flight:	Private	
Persons on Board:	Crew - None	Passengers - None
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	Motor carrier arms broken from the casing	
Commander's Licence:	Other	
Commander's Age:	34 years	
Commander's Flying Experience:	26 hours (of which 2 were on type) Last 90 days - 3 hours Last 28 days - 2 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The unmanned aircraft (UA) was completing an aerial search flight and whilst on approach to its landing site, it became unresponsive and dropped to the ground. Its motor carrier arms were damaged when the UA hit the ground. The nature of the damage suggests, although is not conclusive, that one of the arms was not correctly locked in place. In this condition it is possible the thrust from that rotor became variable rendering the UA unresponsive to control inputs.

History of the flight

The UA was being operated at night to carry out an aerial search. It had completed the flight lasting approximately 18 minutes and was on approach to its primary landing site. At about 30 m agl, the UA became unresponsive and immediately dropped to the ground. All its motor carrier arms were damaged during the impact and had detached from the casing. There was no indication of any malfunctions during the flight prior to the accident.

Examination of the UA

In this design, the motor arms are hinged to enable them to be folded to allow the UA to fit in its transportation case. When the arms are extended during preparation for flight, they are each locked in place by a 'twist to lock' collar. An examination of the UA by the operator found that three of the four arms had broken away from the structural casing of the machine, with their foldable joint locking collars still in place. The hinges of these three arms were surrounded by their collars and were undamaged. However, the fourth motor arm appeared to have broken at its hinge with its locking collar loose and the collar had then moved outwards, along the arm.

The damage to this arm suggests that the collar may not have been fully locked and had become loose during the flight. With a single arm not locked in place, it is probable this would result in variable thrust and cause the UA to become uncontrollable. However, this evidence is not conclusive, and the cause of this accident cannot be confirmed.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice M300	
No & Type of Engines:	4 DJI electric motors	
Year of Manufacture:	2020 (Serial no: 1W93J6H000M007)	
Date & Time (UTC):	21 November 2021 at 2251 hrs	
Location:	Blacon, Chester	
Type of Flight:	Commercial Operations (UAS)	
Persons on Board:	Crew - None	Passengers - None
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	UA damaged beyond economic repair	
Commander's Licence:	Other	
Commander's Age:	27 years	
Commander's Flying Experience:	35 hours (of which 26 were on type) Last 90 days - 22 hours Last 28 days - 5 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB	

Synopsis

The UAS was prepared for flight to carry out an aerial search. Just after launch and prior to airborne safety checks, a "cutting noise" was heard coming from the UAS. It then lost control and dropped to the ground and was severely damaged. This was caused by one of the motor arms folding during flight which appeared not to have been correctly locked in place.

History of the flight

The UAS was prepared for flight to carry out an aerial search. Just after launch and prior to airborne safety checks, a "cutting noise" was heard coming from the UAS. The UAS moved to the left, yawed to the right and gained altitude in a spiralling motion and then dropped to the ground. The UAS structure, battery, propellers and camera were severely damaged when it hit the ground.

Cause

Examination by the operator found evidence that the front and rear right side propellor blades had intermeshed and collided with each other. This was caused by the right rear motor arm not being fully secured and folding forwards during the early stage of the flight. This led to an asymmetry of thrust and loss of control.

AAIB observation

There are previous reports of this type of UAS losing control because one of the motor carrier arms was not fully secure and it folded during flight. In this and the previous case in this Bulletin, the DJI Matrice 300 (AAIB-27593), it resulted in catastrophic damage to the UAS.

When the arms are extended during preparation for flight, they are each locked in place by a ‘twist to lock’ collar. To prepare for flight the collar is slid along each arm towards the main body of the UAS to a position where it encloses the hinge mechanism. The collar is then rotated clockwise which engages and tightens on a threaded section and the collar ‘clicks’ into a locked position. This action ensures the arm is held rigidly. There is a small alignment placard on each arm to show that the collar is locked.

However, the arm, hinge and collar assemblies on these commercial grade UAS are of high quality and are manufactured to close tolerances. As a result, when the collar is slid into its initial position to surround the hinge, it immediately holds the arm rigidly in the extended position even though the collar has not been rotated and locked. It is therefore possible to assume the arm is held correctly but the collar is not locked. If the UAS is launched in this condition the vibration in the arm caused by the motor and propeller, although slight, causes the collar to move outwards, releasing the hinge. A combination of procession and thrust from the rotating propeller then causes the arm to fold.

AAIB Record-Only Investigations

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

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

The accuracy of the information provided cannot be assured.

Record-only UAS investigations reviewed: December 2021 - January 2022

11 Jun 2021 **Skylift V18001** Tur Langton, Leicestershire

During a manually-flown, routine test flight in a mild breeze which was within the UA's limits, the UA began to behave erratically. Despite the pilot's attempts to regain control, the UA pitched inverted and fell to the ground from a height of about 40 m, suffering substantial damage in the impact. A review of the recorded data by the operator did not identify any mechanical or electrical failures, and their internal investigation considered it possible that localised turbulence from surrounding trees may have been sufficient to cause the loss of control.

26 Jul 2021 **DJI Mavic Pro 2** Belper, Derbyshire

After takeoff, with the UA at approximately 12 m agl one rotor arm, which had not been fully extended, partially folded which resulted in one propeller striking the fuselage and breaking. The UA fell to the ground from a height of 10 m.

28 Jul 2021 **G2** Sennybridge, Powys

The operator lost control during landing. Attempts were made to recover control, but the UA pitched down and struck the ground.

5 Sep 2021 **DJI Inspire** Barnsley, South Yorkshire

During a routine commercial flight, the pilot misjudged the flight path and the UA became caught in the branches of a tree. The UA suffered damage to two of its propellers, but was recovered without further incident.

9 Sep 2021 **DJI Mavic 2 Enterprise Advanced** English Channel

The 1.1 kg UA was launched from a ship in the English Channel to search for a small craft. The wind at takeoff was 14 kt from 090°. While the UA was airborne the ship had to manoeuvre for traffic and headed eastwards at 10 kt, overtaking the UA. The pilot tried to fly it back but when it reached 500 m from its takeoff point it stopped. The pilot had to repeatedly update the takeoff point to his current position to keep it moving towards the ship. After 28 minutes of flight the battery was low and the UA initiated an auto-land into the sea.

10 Sep 2021 **DJI Matrice 300 RTK** Ilminster, Somerset

The UA was being flown for a survey at approximately 150 m from the pilot and observer. There was an unexpected crunching sound and the UA fell to the ground. The flight log recorded a 22 m/s rate of decent and a loss or malfunction to a propeller or motor, however the precise cause of the malfunction could not be determined.

Record-only UAS investigations reviewed: December 2021 - January 2022 cont

11 Oct 2021 **Malloy TRV-80** Portland Harbour, Dorset

The UA was operating at 50 m amsl when it entered an uncommanded roll manoeuvre which exceeded the UA's maximum bank angle and it struck the sea. The UA was not recovered.

23 Nov 2021 **Aeryon Skyranger R60** Newbold Revel, Warwickshire

The operator was flying the UA at a lower than normal height due to the presence of low flying aircraft. The UA did not respond to the control inputs as expected and it struck a tree.

24 Nov 2021 **Parrot Anafi** East Molesey, Surrey

During an inspection flight, the UA veered sideways into a concrete structure and fell into the river below; it was not recovered. The pilot advised that the propeller guards fitted to the UA may have contributed to the loss of control.

13 Dec 2021 **DJI Inspire 1** Traquair Forest, Peebleshire

Shortly after taking off, the UA lost the GPS signal and went into altitude hold mode. It drifted into a tree and then struck the ground.

14 Dec 2021 **Acecore Zoe 8X** Burnley, Lancashire

The remote pilot and an observer were making a familiarisation flight from a car park. The UA, which is operated by a surveying organisation, made a rapid uncommanded descent from 40 m agl and sustained substantial damage.

14 Dec 2021 **DJI Mavic Mini 2** Taggs Island, Hampton, Middlesex

While flying over a lake, the UA clipped a branch on a tree and fell into the water. The UA was not recovered.

15 Dec 2021 **DJI Inspire 1** Ipswich, Suffolk

During takeoff the UA struck a wall.

16 Dec 2021 **DJI Mavic 3 Pro Cine** Bradford, West Yorkshire

The pilot was testing the UA following a software update when it flew into some branches and fell into a pond.

3 Jan 2022 **MA Arising Star** Harefield, Hertfordshire

The UA was in flight when it suddenly became unresponsive. Although the remote pilot attempted recovery of the UA by resetting the controls and transmitter, the UA flew away to the east towards open ground. The UA was later recovered in an open field and had suffered significant damage.

Record-only UAS investigations reviewed: December 2021 - January 2022 cont

9 Jan 2022 **DJI Mavic Mini 1** St John's Wood, London

The pilot lost control of the UA and it struck a roof once the batteries depleted.

17 Jan 2022 **DJI Mavic Mini** Saint Nicholas, near Cardiff

The UA was at approximately 65 m agl when a motor error was generated. It lost control and subsequently struck the ground.

22 Jan 2022 **MA Junior 60** Beeley, Derbyshire

Approximately four minutes into the flight from a model flying field in a rural area the model aircraft lost radio signal. It disappeared from view and was not recovered.

26 Jan 2022 **Skymantis** Stoke-on-Trent, Staffordshire

After takeoff the UA drifted in the prevailing wind. The remote pilot commanded the UA to climb in an attempt to stabilise it, and at a height of 60 m the UA began to rotate uncontrollably so the pilot attempted to land the UA. During the descent the UA remained unstable and struck the ground.

Miscellaneous

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

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

BULLETIN ADDENDUM

Original AAIB File Reference:	EW/G2018/08/08
Aircraft Type and Registration:	Europa XS, G-IMAB
Date & Time (UTC):	4 August 2018 at 1555 hrs
Location:	East Kirkby Airfield, Lincolnshire
Information Source:	Engineering examination by an approved inspector and additional enquiries by the AAIB

AAIB Bulletin No 1/2019, pages 84 to 86 refer

The original AAIB report stated that the aircraft had been repaired after a previous landing gear collapse but a previous owner, who had been associated with the aircraft for several years, advised that this was not correct therefore the following correction has been made.

Original text:

> **Pilot's assessment of the cause**
>
> The pilot had acquired G-IMAB a few months prior to the accident and his operating experience of the Europa XS was limited to this airframe. The aircraft had been repaired after a previous landing gear collapse before he bought it and when describing the gear lever operation, he noted that "there appeared to be an undue amount of pressure required to engage the down position". Given his limited experience of the aircraft type, he considered this to be normal; a belief that was perhaps reinforced by flying the aircraft with another pilot who had previous experience of the type. He also said that the gear lever on G-IMAB was not biased to the right.

Amended text:

> ***Pilot's assessment of the cause***
>
> *The pilot had acquired G-IMAB a few months prior to the accident and his operating experience of the Europa XS was limited to this airframe. When describing the gear lever operation, he noted that "there appeared to be an undue amount of pressure required to engage the down position". Given his limited experience of the aircraft type, he considered this to be normal; a belief that was perhaps reinforced by flying the aircraft with another pilot who had previous experience of the type. He also said that the gear lever on G-IMAB was not biased to the right.*

The original AAIB report also stated that '*An initial check by an LAA inspector found wear in the landing gear mechanism, but no obvious cause for the uncommanded landing gear retraction. At the time of writing, the aircraft was awaiting a more detailed inspection prior to repair.*' This inspection has been completed and the LAA inspector reports that no anomalies were found with the landing gear system. The aircraft has been repaired and an optional spring to assist the operation of the landing gear safety latch has been installed.

The online version of the report was amended on 10 February 2022.

AIRCRAFT ACCIDENT REPORT CORRECTION

Original AAIB File reference:	EW/C2019/01/03
Aircraft Type and Registration:	Piper PA-46-310P Malibu, N264DB
Date & Time (UTC):	21 January 2019 at 2016 hrs
Location:	22 nm north-north-west of Guernsey
Information Source:	AAIB Field investigation

AAIB Aircraft Accident Report 1/2020 refers

On 13 March 2020, the AAIB published Air Accident Report 1/2020 into the loss of Piper Malibu, N264DB, on 21 January 2019. The aircraft took off from Nantes Airport, France, at 1915 hrs and was lost from radar 22 nm north-north-west of Guernsey at approximately 2016 hrs. The aircraft was found on the seabed on 3 February 2019, and the body of the passenger was recovered from the wreckage and passed into the care of Her Majesty's Senior Coroner for Dorset. The body of the pilot was not found.

During the Senior Coroner's pre-inquest review process ahead of the full inquest hearing touching upon the death of the passenger, information was provided to the Senior Coroner related to the maintenance carried out on the aircraft during the annual inspection completed on 30 November 2018. This information was contrary to Finding 28 of AAR 1/2020, which stated:

> *A pressure test of the heater muff was not carried out during the previous two Annual maintenance inspections.*

The AAIB carried out further enquiries and established that there is doubt about the maintenance actions carried out during the last annual inspection. Consequently, the following sections of the report have been amended:

Page 23: Section 1.6.14.3 (first paragraph)

Original text:

> The maintenance organisation informed the investigation that the heater muff shroud was removed, and a visual inspection was carried out using mirrors and a light source in accordance with the guidance in the engine manufacturer's Service Bulletin, SB10-1A. The SB also contains guidance on how to pressure-test the exhaust system, but this was not done because the mechanic and inspector were satisfied that they could establish the condition of the exhaust and heater muff by the visual inspection alone.

Corrected text:

> *The maintenance organisation informed the investigation that the heater muff shroud was removed, and an inspection would have been carried out in*

> *accordance with the guidance in the engine manufacturer's Service Bulletin, SB10-1A, which included a pressure test of the exhaust. However, there was no record of the SB having been called up or actioned, and it was not possible to determine if a pressure test of the muffler had been carried out.*

Page 24: Section 1.6.14.3 (Engine Group, point 38, and footnote 29)

Original text:

> 81-2-00

Corrected text:

> *81-20-00*

Page 85: Section 2.8 (second paragraph)

Original text:

> During the Annual maintenance of N264DB, two separate maintenance organisations carried out a detailed visual inspection of the exhaust system which they believed was sufficient to establish its condition. A pressure test would only have been carried out if they were unable to visually examine all parts of the heater muff or there was evidence of damage or deterioration. Moreover, because the aircraft manufacturer's maintenance schedule (which they used) did not call for the exhaust system to be pressure tested, they believed they were only required to carry out a visual inspection. There was no AD for the exhaust system on the PA46-310P to be pressure tested when operating in accordance with 14 CFR Part 91.

Corrected text:

> *During the last two Annual maintenance inspections of N264DB, two separate maintenance organisations carried out an inspection of the exhaust system. Both stated that their normal practice was to pressure test the exhaust, but neither had records to show that such a test had been carried out. The aircraft manufacturer's maintenance schedule (which they used) did not call for the exhaust system to be pressure tested, and there was no AD for the exhaust system on the PA46-310P to be pressure tested when operating in accordance with 14 CFR Part 91.*

Page 89: Finding 27 (first sentence)

Original text:

> The exhaust system, including the heater muff was visually inspected during the Annual maintenance 11 flying hours before the accident.

Corrected text:

> *The exhaust system, including the heater muff, was inspected during the Annual maintenance 11 flying hours before the accident.*

Page 89: Finding 28 (first sentence)

Original text:

> A pressure test of the heater muff was not carried out during the previous two Annual maintenance inspections.

Corrected text:

> *There was no record that a pressure test of the heater muff was carried out during either of the two previous Annual maintenance inspections.*

The online version of the report was corrected on 4 February 2022.

The full amended version of the report can be read on the AAIB website at: https://www.gov.uk/aaib-reports/aircraft-accident-report-aar-1-2020-piper-pa-46-310p-malibu-n264db-21-january-2019 [accessed February 2022].

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

1/2015	Airbus A319-131, G-EUOE London Heathrow Airport on 24 May 2013. Published July 2015.
2/2015	Boeing B787-8, ET-AOP London Heathrow Airport on 12 July 2013. Published August 2015.
3/2015	Eurocopter (Deutschland) EC135 T2+, G-SPAO Glasgow City Centre, Scotland on 29 November 2013. Published October 2015.
1/2016	AS332 L2 Super Puma, G-WNSB on approach to Sumburgh Airport on 23 August 2013. Published March 2016.
2/2016	Saab 2000, G-LGNO approximately 7 nm east of Sumburgh Airport, Shetland on 15 December 2014. Published September 2016.
1/2017	Hawker Hunter T7, G-BXFI near Shoreham Airport on 22 August 2015. Published March 2017.
1/2018	Sikorsky S-92A, G-WNSR West Franklin wellhead platform, North Sea on 28 December 2016. Published March 2018.
2/2018	Boeing 737-86J, C-FWGH Belfast International Airport on 21 July 2017. Published November 2018.
1/2020	Piper PA-46-310P Malibu, N264DB 22 nm north-north-west of Guernsey on 21 January 2019. Published March 2020.
1/2021	Airbus A321-211, G-POWN London Gatwick Airport on 26 February 2020. Published May 2021.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

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

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