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.

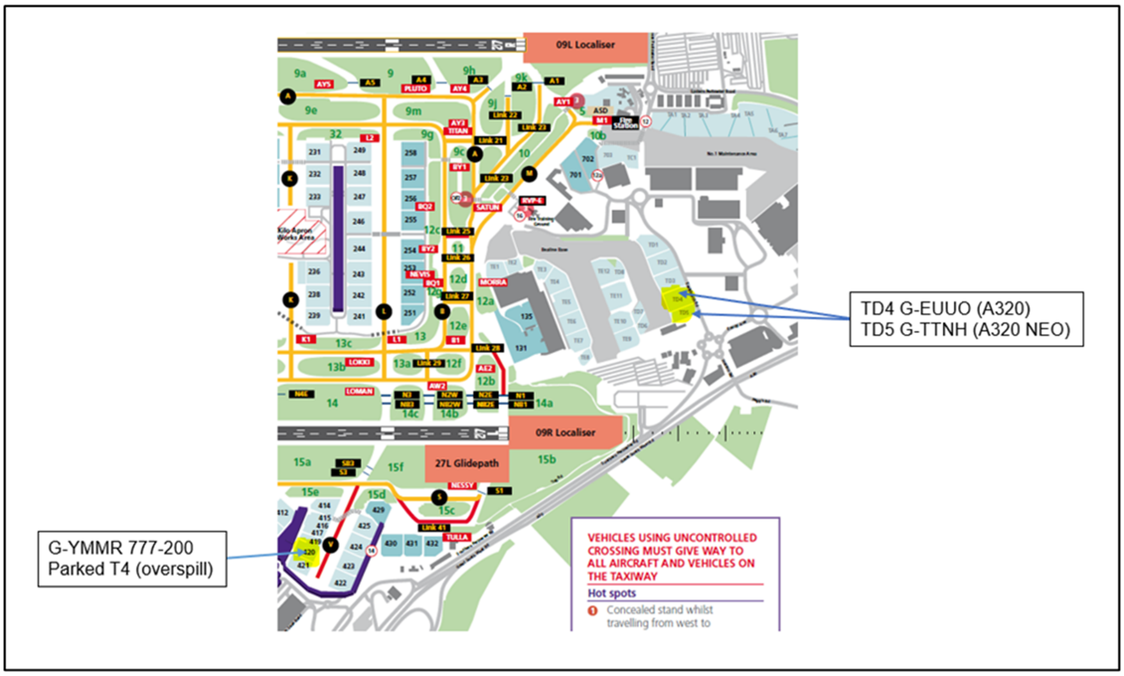

Figure 1

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.

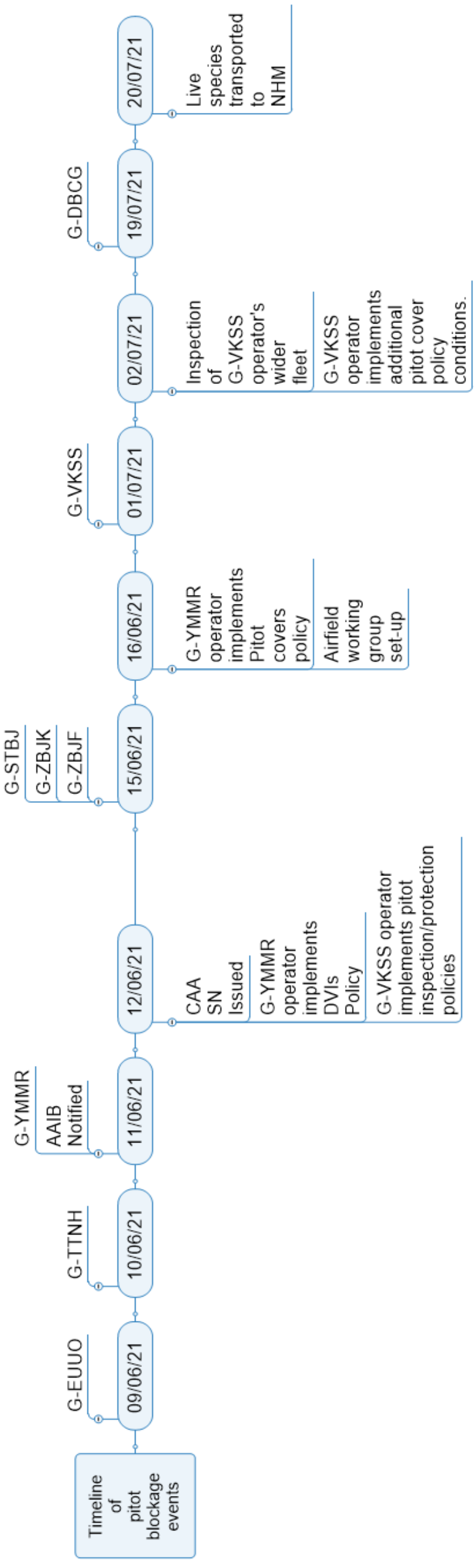

Figure 7

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.

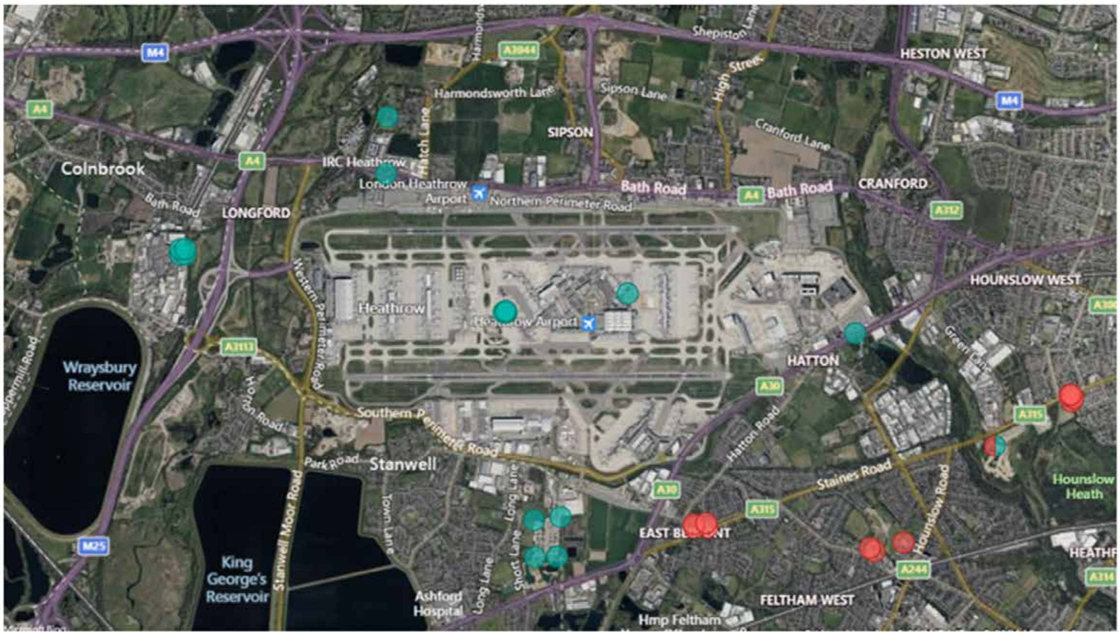

Figure 8

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).

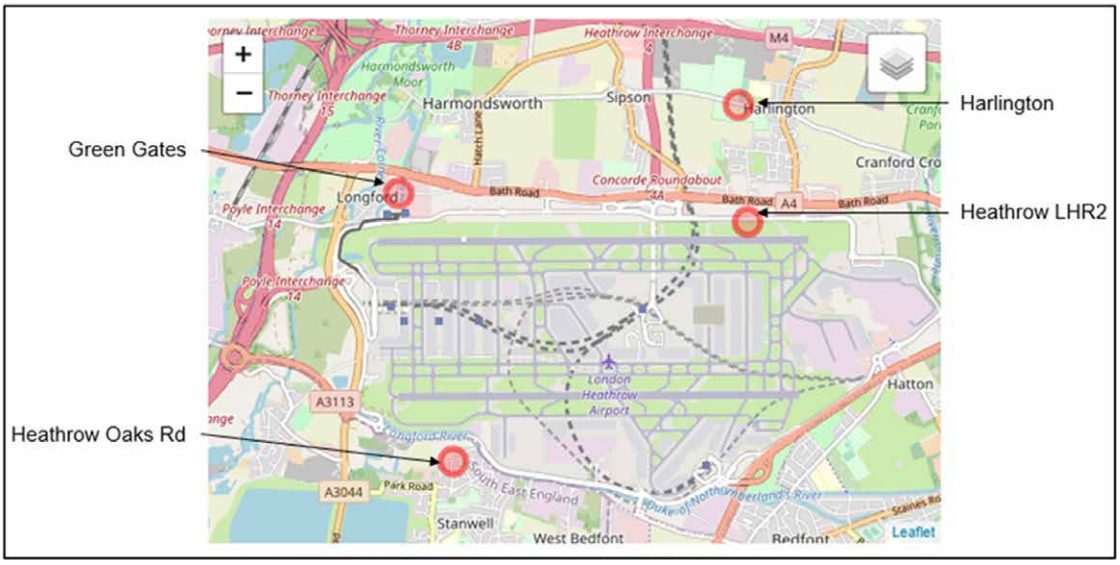

Figure 9

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.

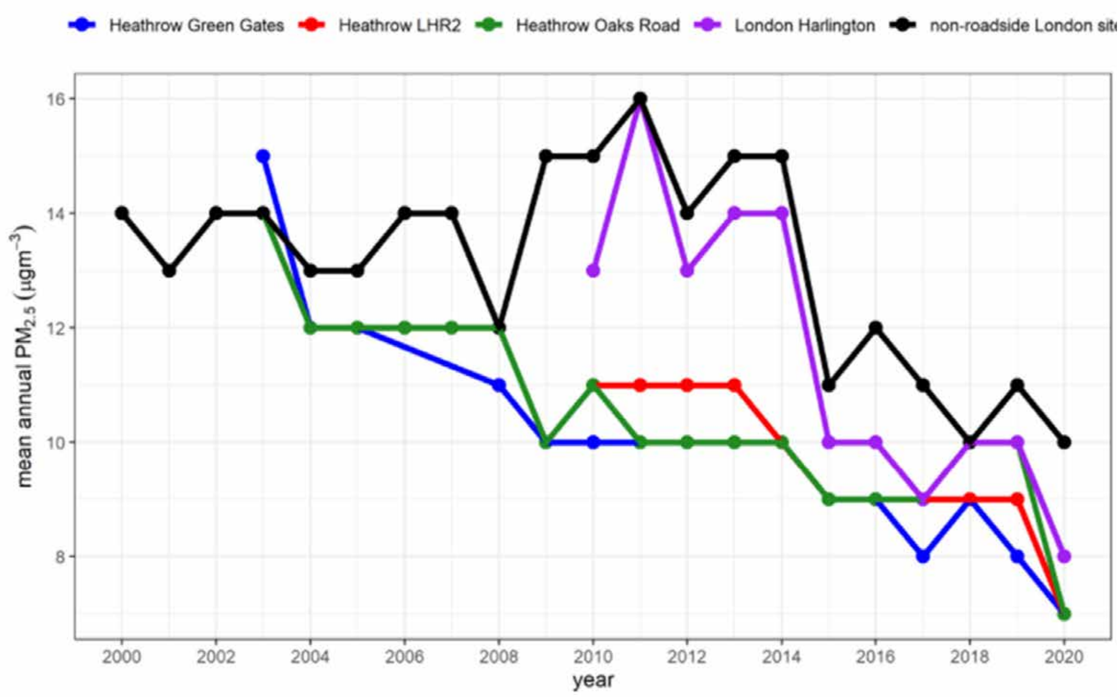

Figure 10

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.

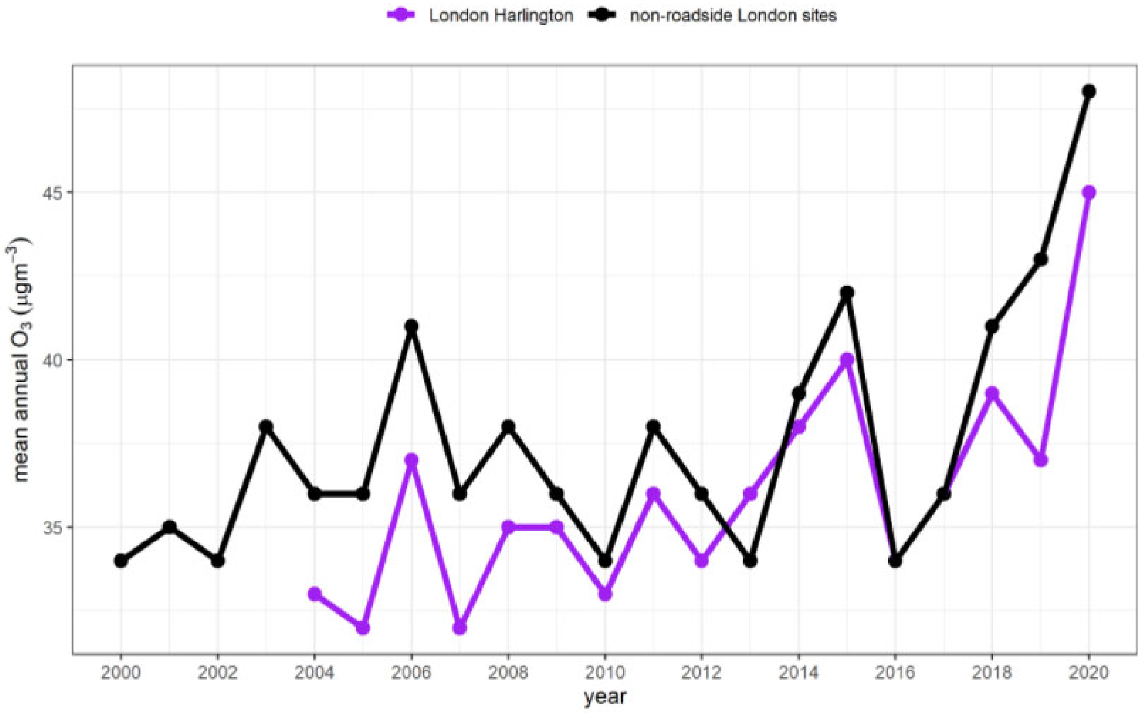

Figure 11

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).

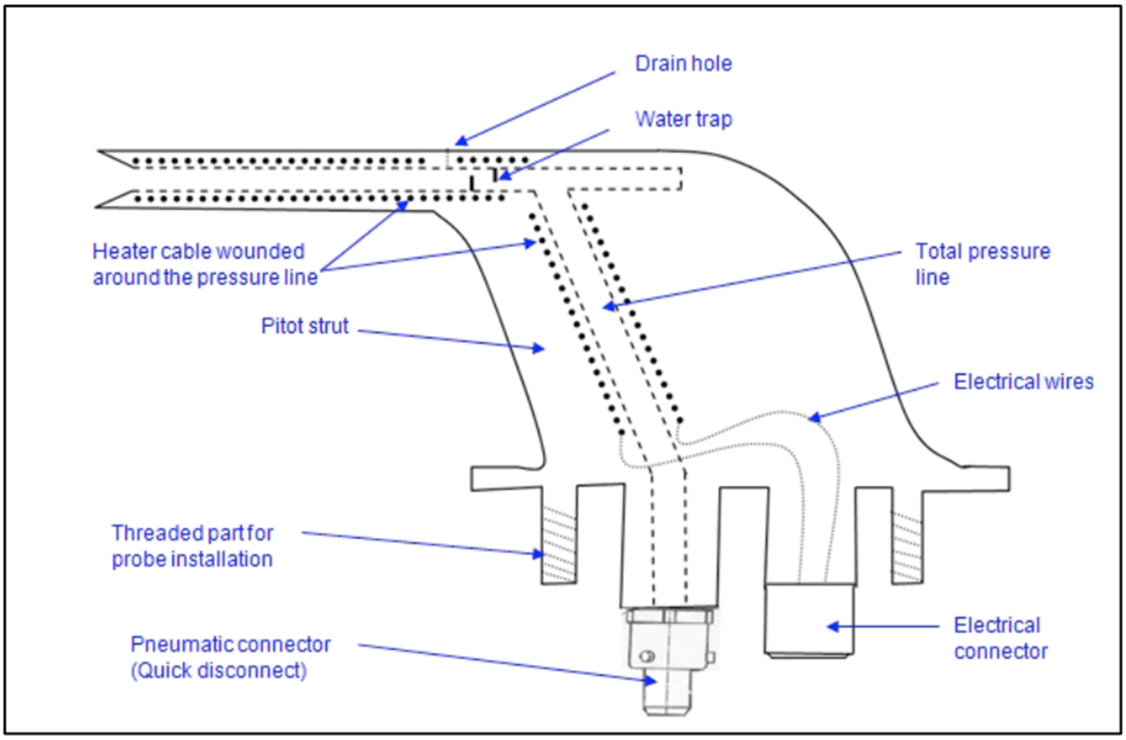

Figure 12

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.

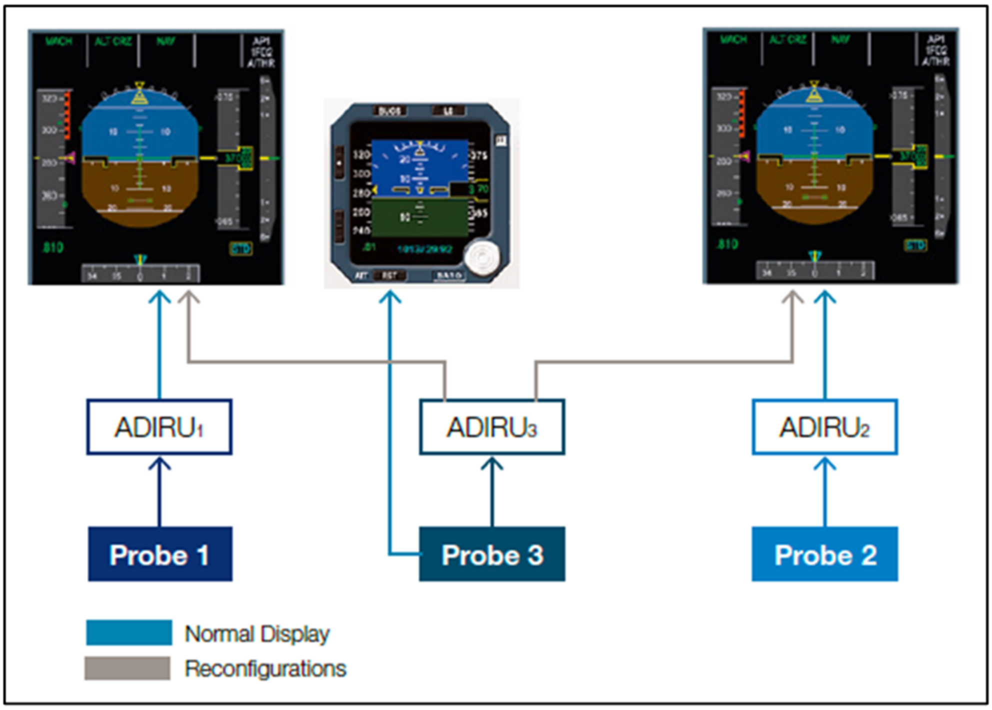

Figure 13

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.

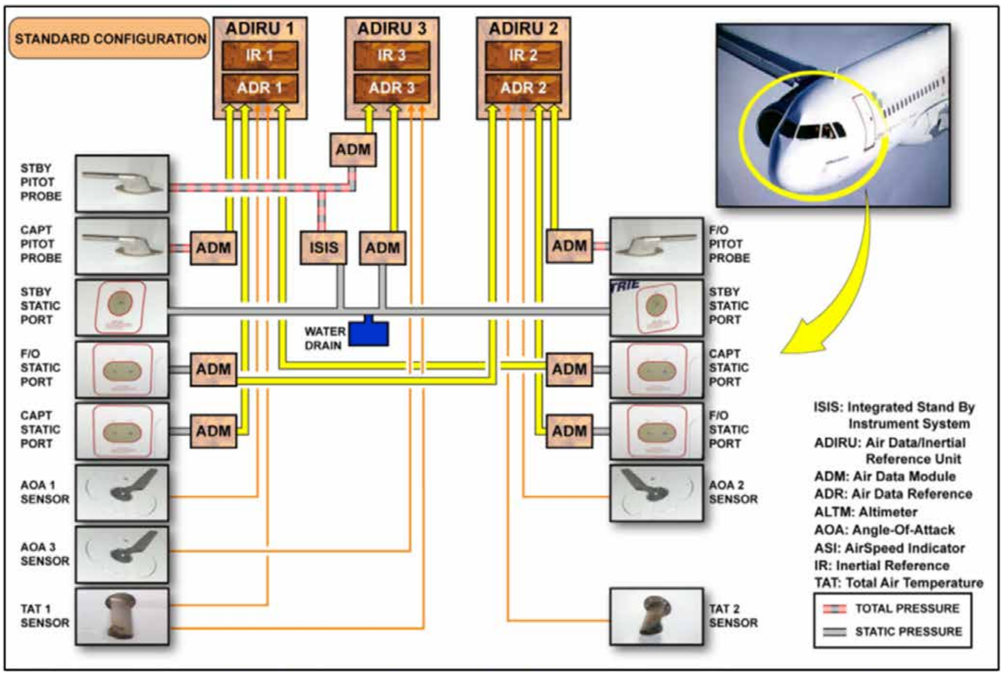

Figure 14

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.

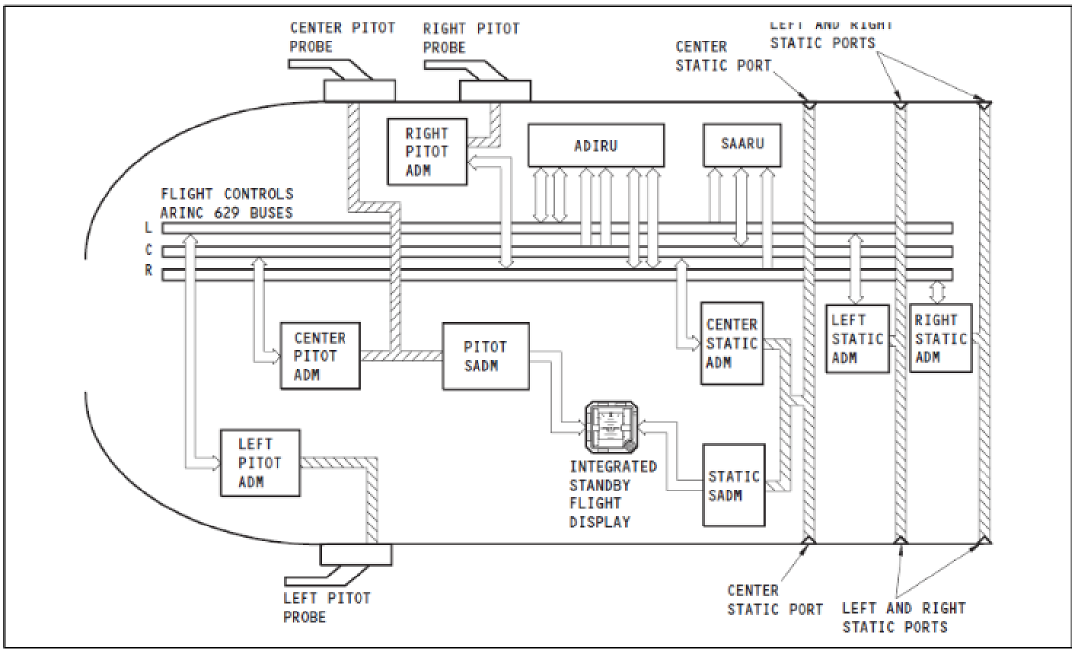

Figure 15

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).

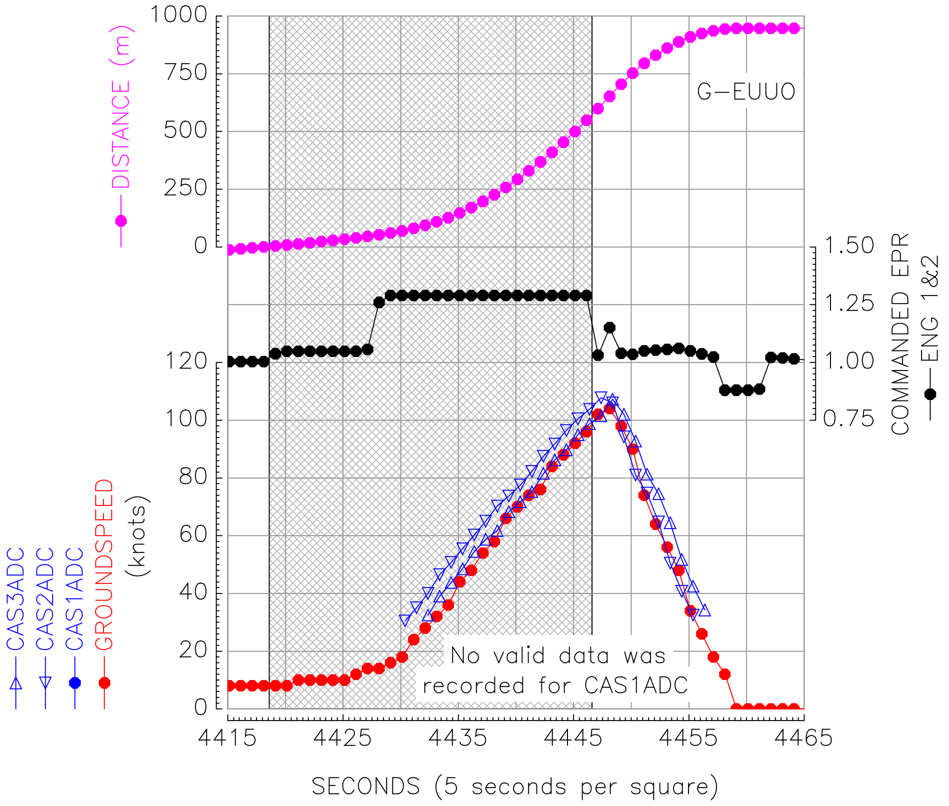

Figure 16

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.

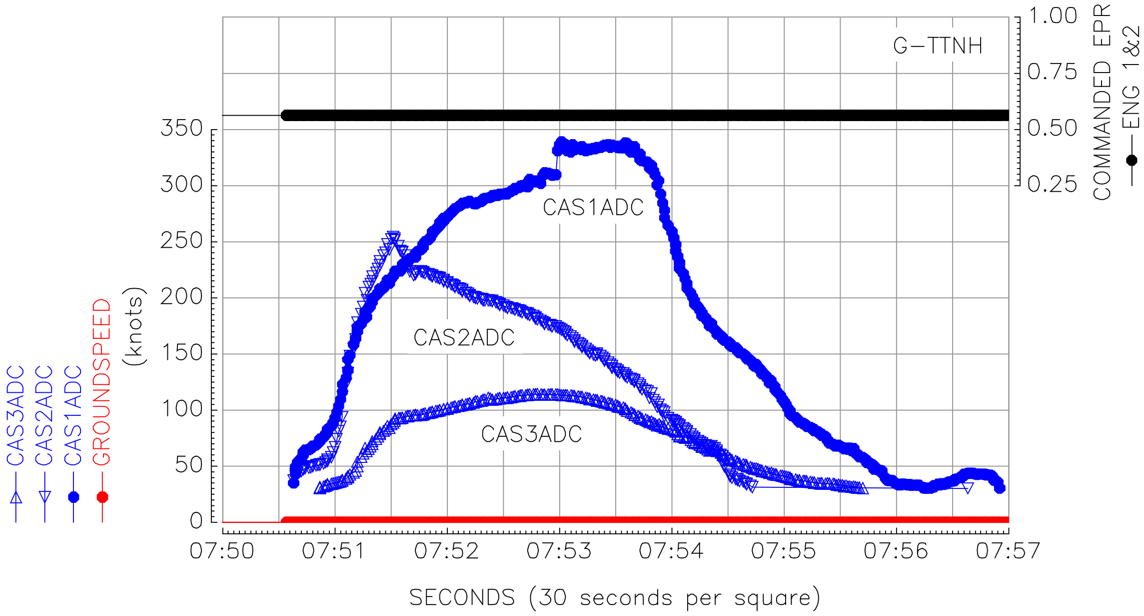

Figure 17

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.

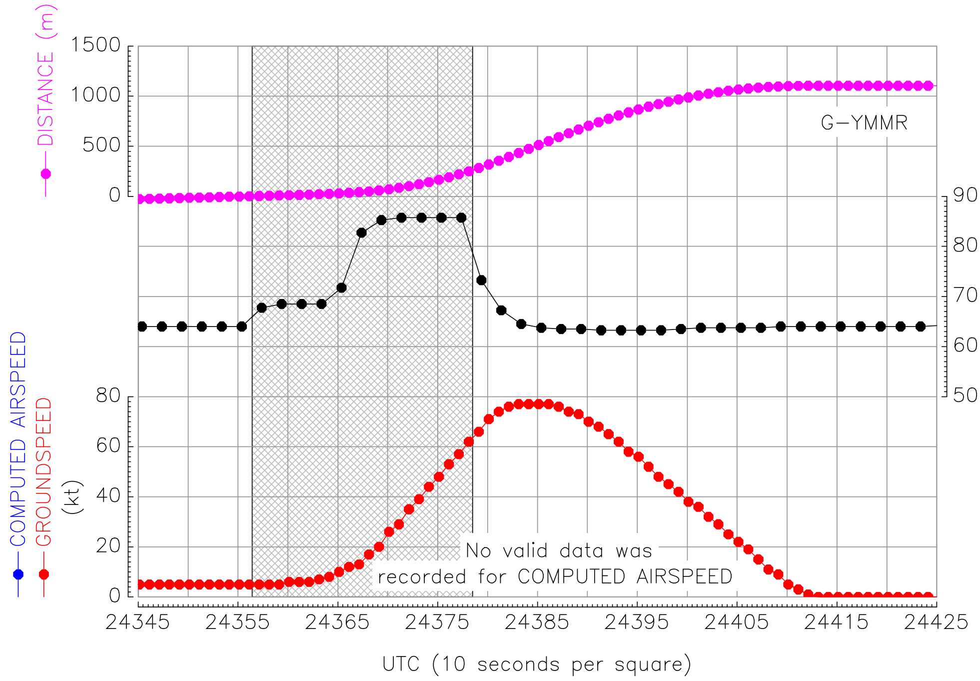

Figure 18

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).

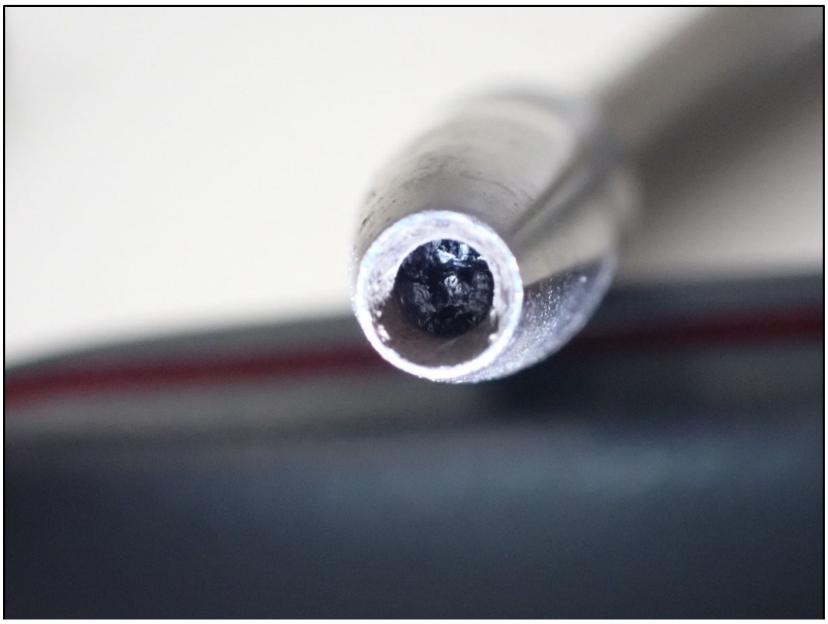

Figure 19

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].

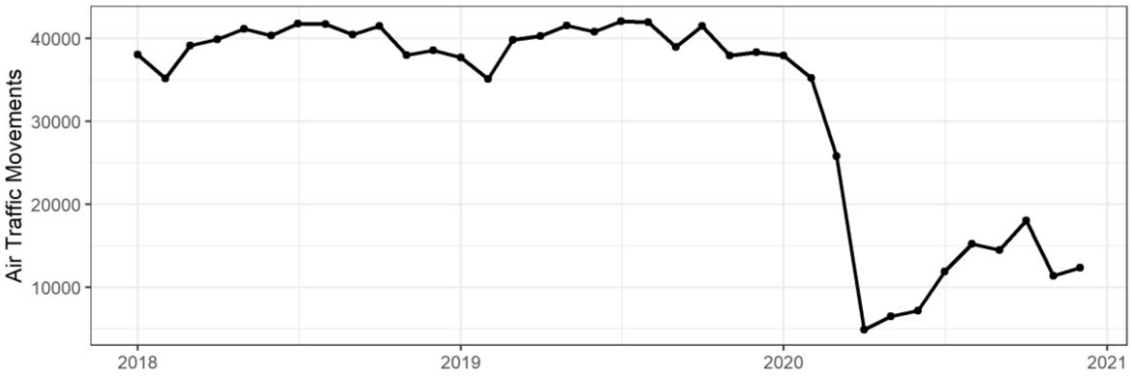

Figure 22

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.

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