Air Accidents Investigation Branch

AAIB Bulletin 1/2020

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01252 512299

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

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

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MISCELLANEOUS

(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.

ACCIDENT

Aircraft Type and Registration:	Eurocopter EC135T1, VP-CPS
No & Type of Engines:	2 Turbomeca Arrius 2B1A turboshaft engines
Year of Manufacture:	1999
Date & Time (UTC):	26 February 2019 at 1631 hrs
Location:	Owen Roberts International Airport, Cayman Islands
Type of Flight:	Training and search
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - 3 (Minor) Passengers - N/A
Nature of Damage:	Damage to tail boom, landing gear and transmission deck
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	7,842 hours (of which 3,879 were on type) Last 90 days - 56 hours Last 28 days - 22 hours
Information Source:	AAIB Field Investigation

Synopsis

At the start of a 'training and search' detail in the Cayman Islands, the pilot lifted the helicopter to a height of approximately four feet and felt the cyclic control stick shake and exert a rearwards force. He immediately lowered the collective lever and the helicopter landed heavily, sustaining damage to the tail boom, landing gear and transmission deck. A subsequent inspection of the helicopter revealed the longitudinal axis of the main rotor actuator had failed. A tie bar within the actuator had suffered pitting corrosion, leading to intercrystalline corrosion and cracking which resulted in overload failure of the remaining material. It is possible that moisture penetrated into the actuator and allowed the tie bar to corrode. The environment conditions of the Cayman Islands may have contributed to the corrosion. Safety actions have been taken to ensure the continued airworthiness of the worldwide fleet and to review the design of the actuator to prevent moisture ingress.

History of the flight

On the day of the accident flight the helicopter had been prepared with dual controls, ready for a planned instrument-flying practice-mission. It was positioned on the dolly used for moving the helicopter in and out of the hangar at Owen Roberts International Airport, Cayman Islands. Prior to departure the crew were informed of a search requirement for a vessel in Cayman Island waters and so a Tactical Flight Officer (TFO) was added to the crew to enable both the search and the instrument-flying practice to be completed in the same mission. The commander was the Pilot Flying (PF) in the right seat and the safety pilot (Pilot Monitoring) was in the left seat, with the TFO in the rear of the cabin.

Pre-flight checks were completed by a challenge and response system between the commander and the TFO. The weather was partly cloudy, 29°C with 13 kt wind from 090°. At 1631 hrs local the pilot lifted the helicopter to a height of approximately four feet above the dolly and felt the cyclic control stick shake and then a strong rearwards force, which he was unable to overcome. The pilot immediately lowered the collective lever, landing heavily, and moved both throttle twist grips to idle, switched off the engines and applied the rotor brake. A PAN call was made to ATC requesting fire service assistance.

The crew exited the helicopter unaided and the aircraft was made safe without further incident. A maintenance team arrived at the helicopter and found damage to the landing gear, tail boom, Fenestron shroud and the transmission deck. Further investigation revealed that the tie bar of the longitudinal axis actuator had broken near the fork end (Figure 1).

Figure 1

Longitudinal axis actuator prior to removal from VP-CPS

Aircraft information

The Eurocopter EC135 (now Airbus Helicopters H135) is a light utility helicopter powered by two gas turbine engines, with over 1,300 aircraft flying with various operators worldwide.

The exterior of VP-CPS was regularly washed, using a corrosion inhibitor and an automotive/ marine shampoo. It was stated by the maintenance organisation that the main rotor blades were washed but no water or cleaning agents were directly sprayed on to the main rotor head or any area above the transmission cowling.

There are no routine maintenance tasks performed on the main rotor actuators while they are installed on the aircraft.

Main rotor control system

The main rotor swashplate is moved in the lateral, longitudinal and collective axes by three hydraulic actuators and together they comprise the Main Rotor Actuator (MRA). The actuators are located forward of the rotor mast between the engine air intakes (Figure 2) and are all similar in construction.

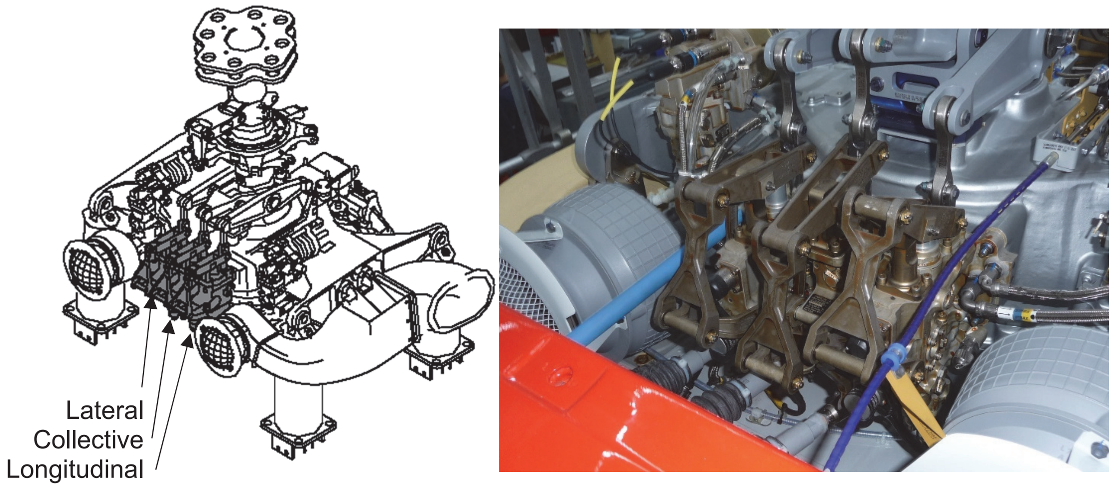


Figure 2

Typical installation of the MRA (not VP-CPS) - (Airbus)

The MRA is installed vertically and, depending on control input, the actuators either push upwards or pull downwards on the swashplate linkage. Inside each individual actuator are two axial pistons, one per hydraulic system, which are linked with a tie bar (Figure 3). This bar is manufactured from passivated, high-strength, corrosion-resistant steel, and attached to a fork end which connects to the swashplate linkage. Tension loads from the pistons are transferred to the fork end by the tension ring segments and compressive loads are transferred through the compression ring segments. Sealant is applied to the centre bore of the fork end to prevent moisture ingress into the upper piston through the tension ring segments.

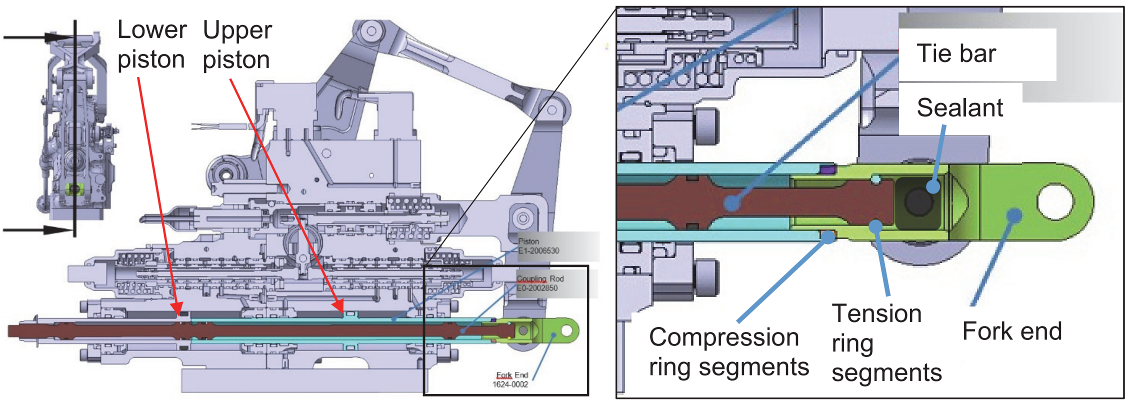


Figure 3

Cross section views of a single axis actuator from the MRA (rotated)

To enable the replacement of an actuator on the helicopter without the need to adjust the swashplate linkage, the length of the actuator is controlled to +/- 0.1mm. To achieve this tolerance, the completed actuator length is measured, and new compression ring segments (Figure 4) are fitted to achieve the length tolerance. The replacements are chosen from a group with a range of different lengths [X].

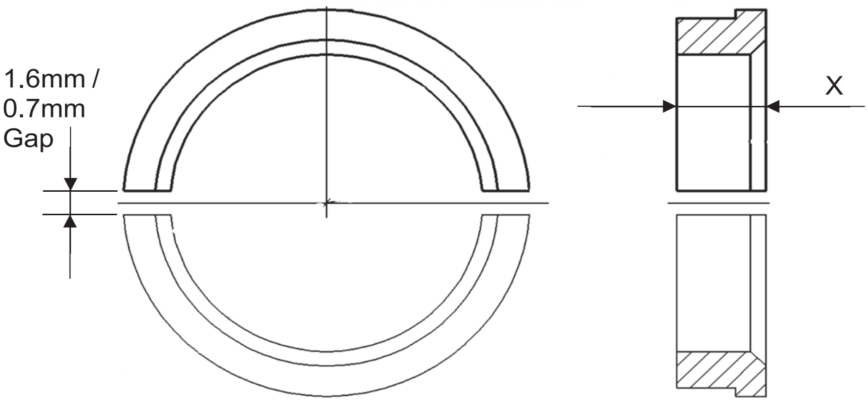


Figure 4

Compression ring segments

Two half-segments are used to remove the need to fully disassemble the actuator at the final stage of manufacture and no sealant is applied, to ensure ease of removal. The dimensional tolerances of each segment result in a gap between the segments of 1.6 mm to 0.7 mm on each side (Figure 4) when installed into the upper piston (Figure 5).

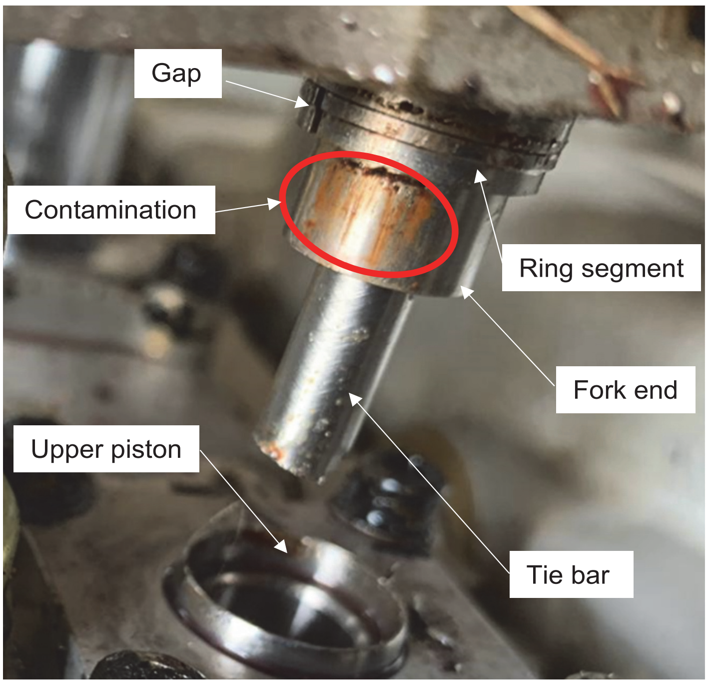


Figure 5

Compression ring segments gap

Aircraft examination

The MRA was removed from the helicopter and sent to the component manufacturer for disassembly and inspection. The overall external condition was typical for the equipment, which had completed 18 years in service and 6,561 flying hours. The lateral and longitudinal axis tie bars had been replaced in 2005 after 576 flying hours, due to damaged threads. The tie bar of the longitudinal axis actuator had fractured approximately 30 mm from the end attached to the fork fitting, where the cross-section changes for an 'O-ring' seal (Figure 6).

Figure 6
Tie bar fracture location

Analysis of the material found adjacent to the fracture on the tie bar (Figure 7) revealed a high sodium and chlorine content, amongst other chemical elements, with similar deposits found on the other actuator tie bars. There was evidence of the same material on the part of the fork end located within the upper piston (Figure 5).

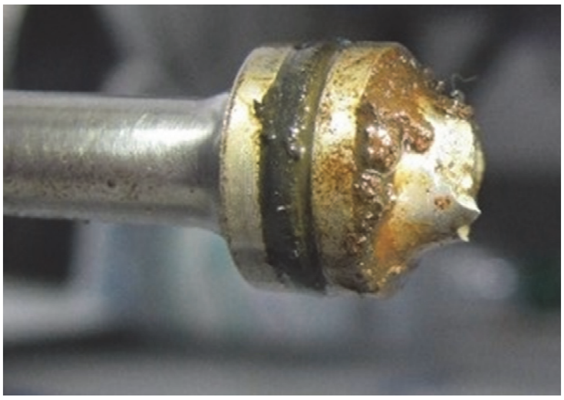


Figure 7
Material adjacent to tie bar fracture surface

The failed tie bar was removed from the actuator and the fracture surfaces were examined using Scanning Electron Microscopy with semi-quantitative Energy Dispersive X-ray (SEM-EDX) spectroscopy (Figure 8). On the surface of the tie bar local to the fracture there was evidence of pitting corrosion, with several pits extending into the material [1]. On the fracture surface there was evidence of intercrystalline corrosion with crack propagation covering approximately ¾ of the fracture surface and the fracture surface was lightly corroded [2]. The remaining region of the fracture surface demonstrated failure through overload [3]. The tie bars from the lateral and collective axis actuators also showed evidence of surface pitting corrosion but to a lesser extent. Pitting corrosion was also identified on the internal bore of the upper piston coincident with the location of the failure in the tie bar.

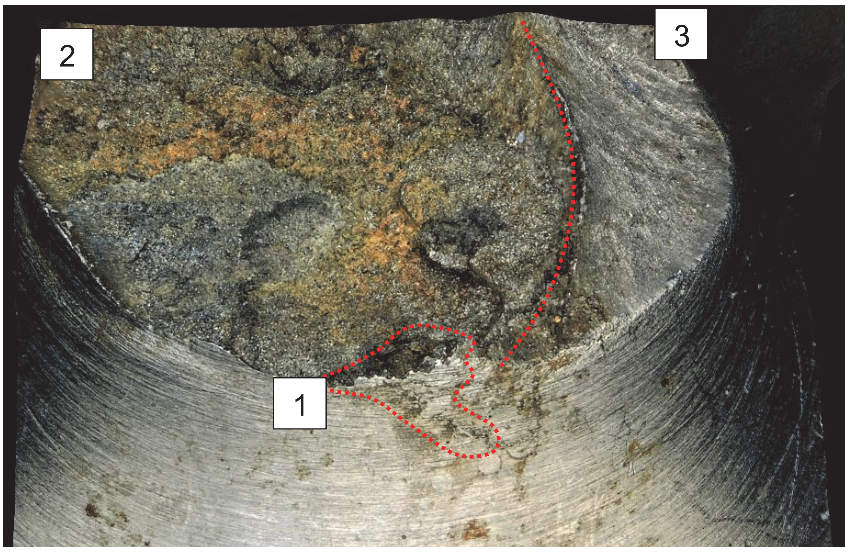


Figure 8
Microscope photograph of the fracture surface (Airbus)

Continued airworthiness

Following the discovery of the failed tie bar, the helicopter manufacturer and EASA issued an Alert Service Bulletin (ASB) and Emergency Airworthiness Directive (EAD) 2019-0087-E respectively, to inform operators of the need to perform a one-time visual inspection of the affected actuators. The EAD was applicable to a specific group of actuators and mandates replacement of the tie bar if corrosion is detected or if the actuators have exceeded a defined period since their last overhaul. A preliminary external assessment can be made on aircraft but the detailed inspection of the tie bar must be done in the workshop due to access requirements.

Analysis

The combination of the installation orientation of the main rotor actuator and an unsealed gap between the compression ring segments could lead to moisture penetrating into the upper piston. This moisture would then collect by the first 'O-ring' seal at the end of the tie bar and, over time, cause the tie bar and piston to corrode. Analysis of the material found adjacent to the fracture surfaces showed elevated levels of sodium chloride. The helicopter's normal operating environment over the Cayman Islands and its waters would expose it to high levels of salt. It is likely that this deposit caused the pitting corrosion found on the surface of the tie bar. The deposit would then cause further corrosion within the material along the intercrystalline boundaries. Normal operating loads on the tie bar would cause these small intercystalline corrosion cracks to coalesce, leading to a reduction in cross-sectional area. This would happen gradually over time, as evidenced from the light corrosion seen on the fracture face in VP-CPS. Finally, the remaining material would fail through overload.

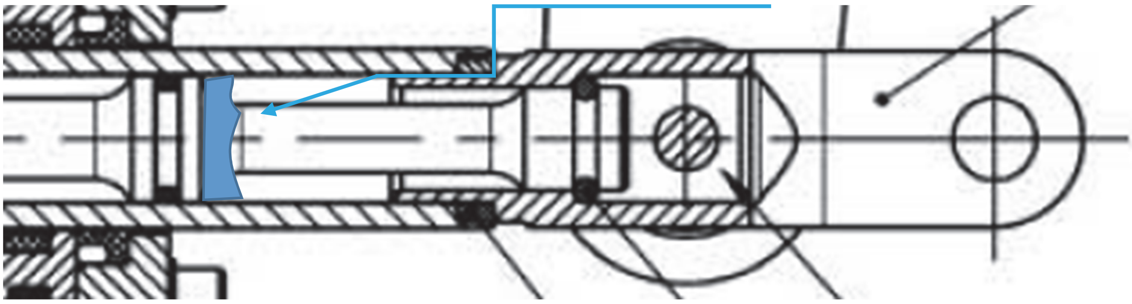


Figure 9

Possible moisture ingress path (rotated)

It should be noted that although the H145 helicopter shares a similar MRA with the H135, in the H145 it is installed horizontally below an aerodynamic cover. Therefore the risk of moisture migrating into the upper piston and causing corrosion pitting is reduced.

Conclusion

Following this accident, where longitudinal control of the helicopter was lost at low level, it was discovered that a tie bar within a main rotor actuator had fractured. This fracture was caused by the reduction in area of the tie bar through the propagation of a crack initiated by pitting corrosion. It is highly probable that the corrosion pits were caused by the accumulation of salt moisture in the end of the actuator, which had penetrated into the actuator through a gap.

Safety actions/Recommendations

The helicopter manufacturer has taken the following safety actions:

> To issue instructions for continued airworthiness in the form of a mandated (by EASA EAD) Alert Service Bulletin to inform all operators to inspect the main rotor actuators. If evidence of tie bar corrosion is found, or the time in service exceeds a defined period, then the tie bar is to be replaced.
>
> To initiate a review of the actuator design with the equipment supplier to identify changes that could be made to prevent moisture ingress and a corrosion-initiated failure of the tie bar.

Published: 19 December 2019.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration N/A)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: 0G0DF8F0240057)
Date & Time (UTC):	16 March 2019 at 1310 hrs
Location:	Temple Newsam, Leeds, Yorkshire
Type of Flight:	Commercial Operation
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Damage to rotor arms, propellers, and camera payload
Commander's Licence:	Not applicable
Commander's Age:	42 years
Commander's Flying Experience:	67 hours (of which 67 were on type) Last 90 days - 17 hours Last 28 days - 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The DJI Matrice 210 small unmanned aircraft was being operated commercially to record video footage of an outdoor athletics event. The pilot started to position the aircraft back towards the landing site due to an increase in the rainfall. The pilot then saw the aircraft "wobble" slightly and as it neared the landing site it flipped over before descending rapidly to the ground from a height of about 3 m (10 ft). No one was injured. During the accident flight the aircraft had been operating at heights of up to about 30 m (100 ft) near to, and above people on the ground. This investigation reviewed other similar accidents and the risk of injury to people on the ground. Two Safety Recommendations are made to the UK CAA.

History of the flight

The DJI Matrice 210 small unmanned aircraft (SUA)[1] was being operated on a commercial[2] flight to record footage of an outdoor athletics event[3] that was taking place in the grounds of

Footnote

[1] A SUA is defined by the Air Navigation Order (ANO) 2016 (Amendment 13 March 2019) as '*any unmanned aircraft, other than a balloon or a kite, having a mass of not more than 20 kg without its fuel, but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight*.' This meaning includes traditional remotely controlled model aeroplanes, helicopters or gliders, as well as multirotor 'drones' and remotely controlled '*toy*' aircraft.

[2] A commercial operation involves a flight or flights '*in return for remuneration or other valuable consideration*.' The full definition is available at http://www.legislation.gov.uk/uksi/2016/765/article/7/made [accessed November 2019].

[3] English schools cross country championship 2019.

Temple Newsam House, Leeds. The event was attended by several hundred competitors and spectators. There had been intermittent rain showers throughout the day and the wind was from the west at about 10 kt, with gusts of approximately 22 kt.

Prior to the event, attendees had been made aware of the planned operation of an unmanned aircraft system (UAS)[4] by providing details of the intended operation in the 'event application form' and by briefings on the day. The pilot[5] of the aircraft stated that he had liaised with the event safety officer and considered that attendees were:

> *'under my control as they were part of the event, briefed about the operation, and able to be informed if an emergency situation occurred via the event staff over the tannoys'* [public address system].

A cordoned takeoff and landing site (TOLS) situated away from the public area was used. The aircraft was flown three times in the morning, during which it had rained lightly for about 20 minutes. The pilot advised that since purchasing the UAS from new in August 2018, the aircraft had been operated in light rain on several occasions without incident.

At 1303 hrs the aircraft took off from the TOLS and was positioned overhead the venue at a height of about 30 m (100 ft) agl, where filming took place (Figure 1). During the initial part of the flight it had been raining "lightly" but after about six minutes the rainfall started to increase. The pilot then decided to position the aircraft back towards the TOLS, which was about 400 m away, whilst also descending the aircraft.

Whilst en route to the TOLS, the aircraft passed overhead people at a height of about 10 m (~30 ft) agl (Figure 2 and Figure 3). At some point during this period the pilot saw the aircraft do "a little wobble" and became concerned that there was a problem and stopped filming. As the aircraft approached the TOLS at a height of about 3 m (10 ft) agl it suddenly "flipped itself upside down and drove itself into the ground". No person was injured, but the aircraft was severely damaged. The recorded flight time was about eight minutes.

Footnote

4 A UAS comprises a SUA with its controller..

5 The ANO refer to a person in control of an unmanned aircraft as a remote pilot. In this report, the remote pilot is referred to as 'pilot'.

Figure 1
Footage from aircraft at a height of about 30 m (100 ft) agl

Figure 2
Footage taken whilst en route back to the TOLS

Figure 3
Footage captured one minute before the accident

UAS information

The Matrice 210 is a quadcopter aircraft with a maximum takeoff mass of 6.14 kg (Figure 4). With its flight controller, the aircraft forms a UAS. During the accident flight the mass was 4.97 kg, which included an underslung camera mounted on a gimbal and two TB55 batteries. The Matrice 210 forms part of the manufacturer's model range referred to as the Matrice 200 series.

Figure 4

RTK version of the Matrice 210
The accident aircraft was fitted with one camera and
did not have external GPS antennas attached (two white circular components)

Electronic Speed Controller

Each of the four propeller motors was controlled by an associated electronic speed controller (ESC) that was fitted in a chamber located below each motor (Figure 5). The ESC consisted of electronic components soldered to a circuit board that was connected to the motor and main body of the aircraft using a push-fit connector and soldered connections. Fitted to each ESC was a label (Figure 6) that changed colour if it was exposed to moisture or liquids. Moisture can result in erroneous operation or failure of electronic components and/or electrical connections.

To prevent moisture and dust[6] ingress into the ESC chamber the UAS manufacturer advised that most of the chamber was sealed using adhesive and gaskets, but the attachment holes and seam between the antenna case and lower chamber were not sealed. The

Footnote

[6] Particles of up to 1 mm in diameter (refer to later section on environmental protection).

manufacturer advised that they were working on an improvement to seal this area but did not confirm if this had been introduced on new aircraft, or if it would be offered as a retrofit for aircraft already in-service.

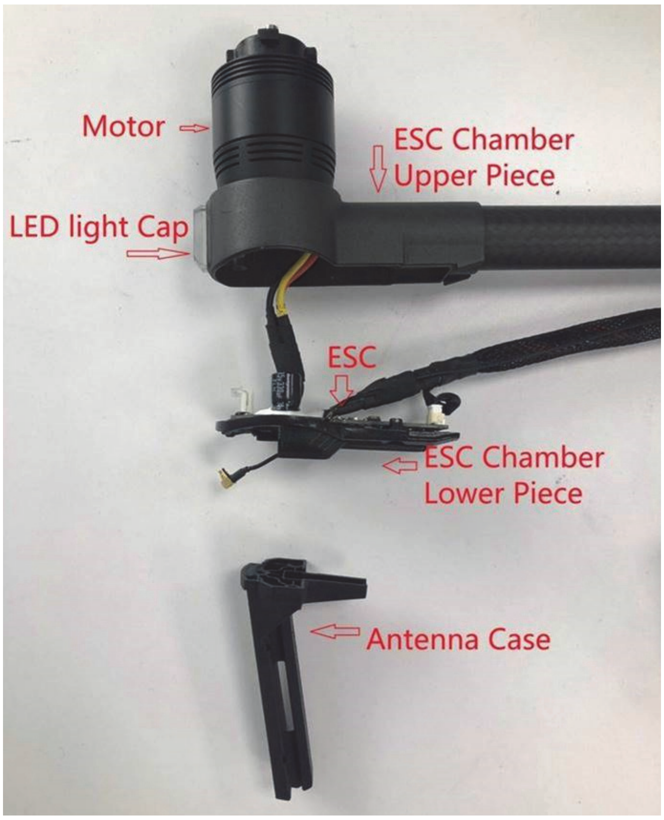


Figure 5
Motor, ESC, chamber and antenna

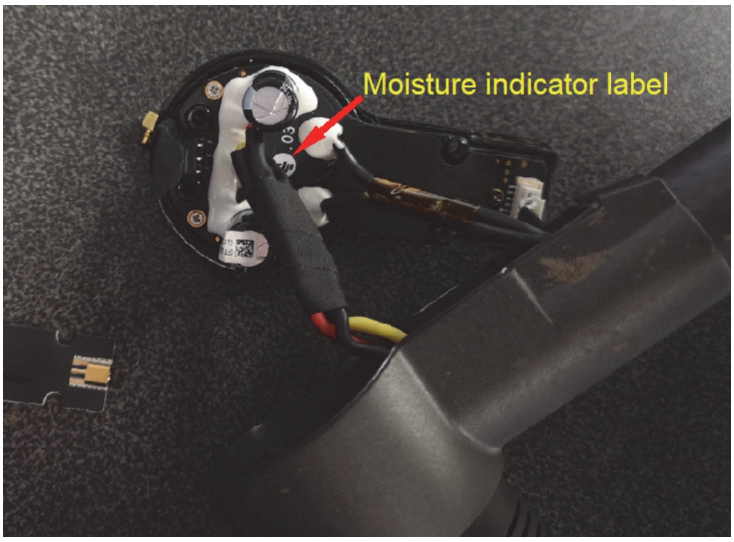


Figure 6
ESC moisture indicator position

Environmental protection

The UAS manufacturer stated that the Matrice 200 series had been tested to meet IP[7]43 standards, which included the following water and solid object ingress requirements:

- vertically dripping water shall have no harmful effect.
- vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle up to 15° from its normal position.
- water falling as a spray[8] at any angle up to 60° from the vertical for a duration of 10 minutes shall have no harmful effect.
- Solid objects with a diameter of 1 mm or more should not be able to enter the unit.

During IP43 accreditation testing, the propeller motors were operated but the propellers were not fitted. The manufacturer advised that the facility that carried out the testing could not accommodate the aircraft when these items were fitted. The manufacturer subsequently carried out its own in-house test with the propellers fitted whilst water was sprayed onto the aircraft. The manufacturer stated that no moisture was subsequently found within the unit.

Information on the operation of the Matrice 200 series aircraft in rain was available on the manufacturer's website. In the FAQ (frequently asked questions) section it was stated that the '*IP43 protection rating allows the Matrice 200 series to maintain stable flight in light rain weather conditions (less than 10 mm/h rainfall)'*. The guidance also stated that in rain, the frame (motor) arms should not be folded and the aircraft should not be operated at pitch angles of more than 60°. Users were advised to use either a TB55 or TB50-M200 battery and not to use an external GPS module.

The manufacturer's website also provided thirteen[9] 'documents and manuals' relating to the operation of the Matrice 200 series aircraft. The '*User Manual*' and '*disclaimer and safety guidelines*'[10] manuals contained the following information:

- *'Under stable laboratory conditions, the Matrice 200 series achieves IP43 rating by IEC60529 standards when equipped with TB50-M200 or TB55 intelligent Flight Batteries. However, this protection rating is not permanent and may reduce over time after long-term use.*
- *DO NOT fly when the amount of rainfall exceeds 10 mm/h.'*

Footnote

7 IP (International Protection Marking) IEC standard 60529 defines the degree of protection provided by mechanical casings and electrical enclosures against intrusion, dust, accidental contact, and water. The European equivalent standard is EN 60529.

8 A spray nozzle is used with a flow rate of 10 litres per minute at a pressure of 50 to 150 kPa. The duration of the test must be one minute per square metre of surface or a minimum of five minutes.

9 https://www.dji.com/uk/matrice-200-series/info [accessed September 2019]

10 https://dl.djicdn.com/downloads/M200/20170926/M200_210_210-RTK+Disclaimer+and+Safety+Guidelines+V1.2.pdf [accessed September 2019]

Reference to the longevity of the IP43 protection was not included in the manufacturer's information, and no guidance was provided as to how to ascertain if the IP43 protection had degraded, or what was considered to be '*long-term use*' of the system, or how to determine if the level of rainfall exceeded the recommended operating limit of 10 mm/h.

In addition to the information provided by the manufacturer, one of its approved Enterprise[11] dealer's in the UK provided the following information on its website:

- *'The Matrice 200 is the first DJI platform to feature IP43 Ingress protection. In practice - this means the Matrice 200 will be fully protected when flying in wet conditions, either through precipitation or moisture in the atmosphere.'*

The UK Met Office use various gauges to measure rainfall and provided the following definitions (Table 1):

Rainfall type	Description	Rainfall category
Drizzle	Water droplet size of < 0.5 mm	Not applicable
Rain	Water droplet size of > 0.5 mm	Slight = < 0.5 mm/h Moderate = 0.5 to 4 mm/h Heavy = > 4 mm/h
Rain showers	Water droplet size of > 0.5 mm Precipitation from convective cloud (cumulus or cumulonimbus) and often characterized by short duration and rapid fluctuations of intensity	Slight = 0 to 2 mm/h Moderate = 2 to 10 mm/h Heavy = 10 to 50 mm/h Violent = > 50 mm/h

Table 1

UK Met Office rainfall description

UAS examination

The pilot sent the aircraft to an Enterprise dealer in the UK for examination. It was found that the No 3 motor ESC moisture indicator had been activated and evidence of liquid residue was found on the ESC circuit board (Figure 7).

The No 3 motor arm had remained intact following the accident and the pilot stated that the arms had never been folded since the aircraft had been purchased from new in August 2018. The remaining ESC's were inspected, but no evidence of moisture ingress was found.

The onboard recorded data contained fault messages that coincided with the loss of control of the aircraft. These messages referred to a No 3 motor ESC '*link down*' and a fault with the No 4 motor ESC. The manufacturer reviewed this data and advised its Enterprise dealer that the accident had been caused by a fault with the No 4 ESC. The aircraft was subsequently

Footnote

[11] A manufacturer approved dealer that has access to commercial UAS platforms and equipment.

sent to the manufacturer for further evaluation. At the time of report publication, no further information had been provided by the manufacturer on the cause of the No 4 ESC failure or if the moisture found on the No 3 ESC had caused this ESC to also fail.

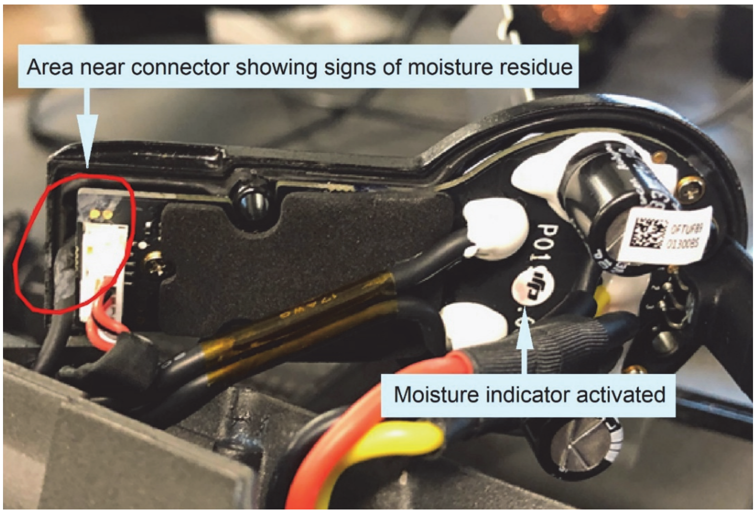


Figure 7

No 3 ESC from accident aircraft

UAS accidents

Matrice 200 series

The manufacturer provided information (Table 2) on the 'probable cause'[12] of 44 accidents involving the Matrice 200 series that had occurred internationally between October 2018 and March 2019. The manufacturer was asked to provide information on the number of Matrice 200 series aircraft sold in the UK and internationally, but this was not provided.

UAS component	Type of failure	Number of units	Percentage of units % (value is rounded)
ESC	Water damage Loss of PPM (pulse position modulation) signal Hardware damage	4 2 4	9 5 9
Non-ESC	Propeller motor Loss of propeller during flight Incorrectly installed propellers Propeller damage Excessive load/payload Unable to determine cause	12 2 1 1 1 17	27 5 2 2 2 39

Table 2

Manufacturer findings on Matrice 200 series failures

Footnote

[12] The manufacturer stated that the probable cause was identified by analysing the UAS and/or its recorded data. Where neither data nor the aircraft was available for evaluation, or where the results were inconclusive, 'educated guesses' were made as to the possible cause of the failure.

The manufacturer stated the following concerning ESC failures due to water ingress:

> *'Physical component analysis showed that water ingress points are close to the center part of the ESC board, which is close to the antenna, and damaged parts of the ESC are mostly located on the back side of the PCB board (the side of the antenna). Therefore, there is the possibility that water seeped in from the closing part of the antenna case. Water ingress will cause the ESC and other components to short circuit, causing complete damage and signal lost* [sic]*, or to send out abnormal signals causing abnormal motor behaviour* [sic]*, which may lead to an incident.'*

Non-ESC failures included malfunction of the propeller motors. The cause of these failures was considered by the manufacturer to have been caused by the motor either becoming 'clogged' by sand, dust or other small particles, or having been damaged prior to the accident, such as during a previous collision with a hard surface. The IP43 rating provided protection against entry of solid objects with a diameter of >1 mm but not smaller particles, such as dust or sand.

UAS accidents reported to the AAIB

Table 3 provides information on 59 UAS accidents[13] reported to the AAIB between February 2015 and 31 July 2019. This information included 18 accidents involving the Matrice 200 series aircraft.

UAS mass	Type of failure	Number of occurrences (all types)	Number of DJI Matrice 200 series occurrences
<20 kg	Technical fault resulting in loss of control of the aircraft	34	16
	Loss of aircraft control due to pilot action.	6	0
	CFIT[14]	5	1
	Mid-air collision	3	0
	Other[15]	4	1
>20 kg	Technical fault - resulting in loss of control of the aircraft.	3	
	Loss of control due to pilot action.	2	
	Other	2	

Table 3

UAS incidents and accident reported to AAIB between February 2015 and March 2019

Footnote

[13] The UAS was damaged during collision with the ground or water.
[14] CFIT - Controlled Flight Into Terrain – includes unplanned deviation from flight path due to excessive wind speed or gusts.
[15] Accidents caused by incorrectly fitted propellers and other causes.

Table 4 provides a detailed breakdown of the 16 Matrice 200 series accidents that involved technical failures.

Date	Location	UA Type	Description of accident	AAIB Bulletin Number	AAIB File Reference
20/12/2017	La Route de la Trinite, Jersey	Matrice 210	At a height of 84 m all four motors stopped and the UA fell to the ground due to a battery firmware issue.	10/2018	EW/G2017/12/07
18/07/2018	Keith, Aberdeenshire	Matrice 210 RTK	At a height of 25 m all four motors stopped and the UA fell to the ground due to a battery firmware issue.	11/2019	EW/G2018/07/43
04/09/2018	Tilbury Docks, London	Matrice 210	At a height of 20 m all four motors stopped and the UA fell to the ground due to a battery firmware issue.	11/2019	EW/G2018/09/04
15/10/2018	Brierley Hill, West Midlands	Matrice 210	At a height of about 50 m over a building the UA suddenly dropped vertically and struck the roof of the building. The No 4 ESC had failed. Light drizzle was reported.	01/2020	EW/G2018/10/23
20/10/2018	Manchester	Matrice 210 RTK	At a height of 80 m all four motors stopped and the UA fell to the ground due to a battery firmware issue.	11/2019	EW/G2018/10/09
26/10/2018	Ledbury, Herefordshire	Matrice 210	At a height of 4 m all four motors stopped and the UA fell to the ground due to a battery firmware issue.	11/2019	EW/G2018/10/17
14/01/2019	Colwyn Bay, Conway	Matrice 210 RTK	From a height of 70 m the UA entered a rapid uncontrolled descent until it struck the ground. The UA was overweight with a non-standard payload but cause unknown.	7/2019	EW/G2019/01/05
19/01/2019	Clevedon, Somerset	Matrice 210	From a height of 120 m the UA fell vertically to the ground while flying in light drizzle. The No 2 ESC had failed.	01/2020	EW/G2019/01/14
29/01/2019	Little Hulton, Manchester	Matrice 210	From a height of 69 m the UA entered a tight spiral descent to the ground. One motor had a propulsion error.	4/2019	EW/2019/01/02
18/02/2019	Feltham, London	Matrice 210	Following a loud mechanical noise the UA descended rapidly to the ground in light rain. The ESC had failed, possibly due to an earlier accident.	5/2019	EW/G2019/02/23
03/03/2019	Leicester	Matrice 210	From a height of 90 m the UA started spinning and rapidly fell to the ground. It was raining and the No 3 motor had failed.	01/2020	EW/G2019/03/03
16/03/2019	Temple Newsham, Leeds	Matrice 210	This report. Rapid descent from a height of 3 m in rain.	01/2020	EW/C2019/03/02
18/03/2019	Manchester	Matrice 210	At a height of 2 m the UA wobbled, slewed sideways and then struck the ground inverted. The manufacturer determined that a motor had failed.	01/2020	EW/G2019/03/08
20/04/2019	Dearne Old Moor, S. Yorkshire	Matrice 210	At a height of 5 m the UA became unstable and one of the motor arms broke causing the UA to drop to the ground. Data showed that the No 2 and No 3 motors had stalled. It could not be determined if this occurred before or after the arm failed.	01/2020	EW/G2019/04/14
11/06/2019	Hammon Court, Norfolk	Matrice 210	From a height of 80 m the UA started spinning and descended rapidly to the ground. Cause unknown.	01/2020	EW/G2019/06/08
28/07/2019	Chedburgh, Suffolk	Matrice 210	The aircraft dropped vertically from 71 m and hit a building, damaging its roof. There was light rain. The manufacturer reported an issue with the No 2 motor.	01/2020	EW/G2019/07/40

Table 4

Matrice 200 series UAS accidents reported to AAIB between
December 2017 and July 2019 which involved technical failures (16 in total)

The majority of UAS accidents reported to the AAIB have involved quadcopters. In the event of a motor failure, the configuration of a quadcopter means it is unlikely to remain controllable. The evidence available to the AAIB shows that, in these cases, the UAS tumbles and falls rapidly to the ground. Where electrical power has been lost to all motors, the UAS will free fall to the ground.

UAS regulations

At the time of the accident the UK CAA defined three categories of UAS:

- *'20 kg or less - Small Unmanned Aircraft (SUA) - this class covered all types including traditional remotely controlled model aeroplanes, helicopters or gliders, as well as multirotor 'drones' and remotely controlled 'toy' aircraft. They were subject to some parts of UK aviation law, which is discussed in the following sections of this report.*
- *>20 kg to 150 kg - Light Unmanned Aircraft (LUA) - this class covered larger and potentially more complex types of unmanned aircraft (UA) and large model aircraft. They were subject to all aspects of UK aviation law, but exemptions could be granted to some requirements.*
- *Over 150 kg – aircraft operating within this class would normally be subject to the same level of regulatory approval requirement as would be used for traditional manned aircraft.'*

The CAA stated that they had not carried out a risk assessment concerning the overflight of people by an SUA. The Air Navigation Order (ANO) required a pilot operating a SUA (commercially or for private use) that was equipped to undertake any form of surveillance[16] or data acquisition to comply with the following requirements, unless in accordance with a permission[17] issued by the CAA:

- *'Must not operate an aircraft over or within 150 metres of any congested[18] area;*
- *Must not operate an aircraft over or within 150 metres of an organised open-air assembly of more than 1,000 persons;*
- *Must not operate an aircraft within 50 metres of any vessel, vehicle, structure or person which is not under the control of the pilot of the aircraft;*
- *Must not operate an aircraft within 30 metres of any person (except the pilot) during takeoff or landing unless a person is under the control of the pilot.'*

Footnote

16 An aircraft fitted with a camera or other sensor that can collect information.

17 The CAA advised that if a pilot wanted to operate a SUA closer to people (not under the control of the operator) than the limits set out in the ANO article 95, an operating safety case with appropriate mitigating actions would need to be submitted and agreed with the CAA.

18 The ANO defines a congested area '*in relation to a city, town or settlement, means any area which is substantially used for residential, industrial, commercial or recreational purposes*'.

The ANO also included several articles relevant to the safe operation of a UAS, which included:

- Article 241 '*a person must not* recklessly *or negligently cause or permit an aircraft to endanger any person or property*'
- Article 94 '*(2) The remote pilot of a small unmanned aircraft may only fly the aircraft if reasonably satisfied that the flight can safely be made'*

On 11 June 2019 regulations relating to the harmonized use of UAS within Europe were published. This contained the following regulations (the CAA has also issued CAP1789[19] that summarises these):

- Commission Implementing Regulation (IR) (EU) 2019/947 on the procedures and rules for the operation of a UA.
- Commission Delegated Regulation (DR) (EU) 2019/945 on a UA and on third country operators.

The DR became applicable on 1 July 2019 and the IR becomes applicable on 1 July 2020.

Operations of UAS will then be placed into one of three categories:

- *'Open category (less than 25 kg) – operations that present a low (or no) risk to third parties. Operations are to be conducted in accordance with basic and pre-defined characteristics and are not subject to any further authorisation requirements. The open category is divided into operational 'subcategories' A1, A2 and A3. Within each subcategory are classes of UAS that include C0, C1, C2, C3 and C4 (Table 4).*
- *Specific category – operations that present a greater risk than that of the open category, or where one or more elements of the operation fall outside the boundaries of the open category. Operations will require an operational authorisation from the national aviation authority (i.e. the CAA in the UK) based on a safety risk assessment.*
- *Certified category – operations that present an equivalent risk to that of manned aviation and will be subject to the same regulatory regime (i.e. certification of the aircraft, certification of the operator, licensing of the pilot).'*

Footnote

[19] Available from https://www.caa.co.uk/Our-work/Publications/Publications/ [accessed September 2019]

Operation		UAS			UAS Operator	Remote pilot	
Subcategory	Operating Area	Class	Mass/KE/Speed	Operating Date limitations	Registration	Min Age (solo flight)	Competency
All	- Max height 120m/400ft (see UAS.OPEN.010 [3] & [4] for specific obstacle and sailplane limits) - No dropping of articles - No carriage of dangerous goods					If directly supervising another remote pilot - 16	
A1	Fly over uninvolved people, but not over crowds	Privately built	<250g and <19m/s	Nil	Only if 'camera' equipped (but not toys)	Nil	Read user manual
		Legacy (placed on market before 1 Jul 22)	<250g			UK – 12 EU – 16 (unless reduced in State)	
		C0 (toy)	<250g and ≤19m/s			Nil	
		C0 (not a toy)				UK – 12 EU – 16 (unless reduced in State)	User manual - Online training - Online (foundation) test
	No intentional flight over uninvolved persons	C1	<900g or <80 J	Nil	Yes	UK – 12 EU – 16 (unless reduced in State)	- User manual - Online training - Online (foundation) test
		A1 Transitional (Article 22)	<500g	Not after 30 Jun 22			To be defined by the State
A2	No closer than 30m horizontally from uninvolved persons (5m in 'low speed' mode)	C2 (can also be used in A3)	<4kg	Nil	Yes	UK – 12 EU – 16 (unless reduced in State)	- User manual - Online training - Online (foundation) test - Self-practical training - A2 CofC Theoretical test
	No closer than 50m horizontally from uninvolved persons	A2 Transitional (Article 22)	<2kg	Not after 30 Jun 22			
A3	- No uninvolved people present within the area of flight - No flight within 150m horizontally of residential, commercial, industrial or recreational areas	C3	<25kg	Nil	Yes	UK – 12 EU – 16 unless reduced in State)	- User manual - Online training - Online (foundation) test
		C4					
		Privately built					
		Legacy (placed on market before 1 Jul 22)					
		A3 transitional (Article 22)	>2kg to <25kg	Not after 30 Jun 22			

Table 5

CAP 1789 Annex C, open category and subcategories A1, A2 and A3

The open category is expected to apply to hobbyist users and some commercial operators. In this category, only a UA with a mass of less than 250 grams and, for UA's introduced after 1 July 2022, a maximum velocity of 19 m/s, is permitted to fly over '*uninvolved people'* but it must never be flown over an assembly of people (crowd). A UA of 250 grams or more must not be flown over '*uninvolved people*'.

The Europen Union (EU) implementing regulations define uninvolved people as '*persons who are not participating in the UA operation or who are not aware of the instructions and safety precautions given by the UA operator*'. In order to be an involved person, they need to have been given explicit consent to be part of the UA operation and have received some form of safety precautions/instructions.

The definition provided in the EU Implementing regulations for an assembly of people (crowd) is '*gatherings where persons are unable to move away due to the density of the people present'*.

The CAA also provided the following clarifications to the AAIB:

- Informing an assembly of people, such as at a concert, that a UA will be flying overhead is not sufficient and these people would be considered to be 'uninvolved'.
- In the A1 subcategory, a UA must never overfly an assembly of people (either involved or uninvolved).

The specific category will typically apply to commercial operations in the UK. This category introduces the concept of 'standard scenarios' of use, for which a risk assessment has already been made and mitigating safety actions provided relative to the task involved.

If a scenario matches the intended task, the operator will make a statement of declaration to the CAA that includes the need to comply with any mitigating safety actions. If the intended task is not covered by the scenarios, the operator is required to carry out a risk assessment and apply to the CAA for operational authorisation. The scenarios are expected to be published by the European Commission (EC) in early 2021. Discussions with the CAA indicate that one of several mitigating actions could include the fitment of an aircraft parachute recovery system.

The EU regulations also make provision for an optional light UAS operator certificate (LUC) scheme, which allows the CAA as a national aviation authority to issue privileges to UAS operators, including the possibility of authorising their own operations.

CAA guidance on UAS overflight of people, built-up areas and crowds

In October 2019, the CAA published The Drone and Model Aircraft Code[20]. This provided the following guidance on operating a UAS of 20 kg or less near to people:

- *'Never fly closer to people than 50m. Even when your drone is more than 50m away from people, it's safer to avoid flying or hovering directly over them. You're responsible for flying safely whenever you fly.'*

The code also included the following examples of built-up and busy areas, and where crowds of more than 1,000 people shall not be flown near to or over by a UAS of 20 kg or less.

- *'cities and towns, villages, beaches and recreational parks that are part of a city, town or village, housing estates, schools and offices, retail, warehouse, industrial and business parks, theme parks, sports events, music festivals or concerts, marches or rallies or carnivals.'*

UAS design, production and maintenance

A SUA (a mass of 20 kg or less) operating in the UK does not require airworthiness approval or require CAA oversight of its design, production or maintenance. However, manufacturers can declare that their UAS meets European Standards (EN). Relevant EN's include 60950-1 and 62311:2008 that include risk of fire, electric shock or injury to the operator and exposure to electromagnetic fields. The manufacturer of the Matrice 200 series had declared that it was compliant with six EN's, however EN's do not assure product reliability or that a fault will not cause loss of control of the aircraft.

The rules introduced in DR 2019/945 and IR 2019/947 require that a UAS operating in the open category will be subject to a set of product standards similar to the 'Conformité Européene (CE)'[21] marking scheme. It will require that all UAS operating in this category must be marked with the appropriate UAS class number (C0, C1, C2, C3 or C4) by 01 July 2022. A UAS sold for use in the specific category will come under a different set of requirements that are still to be developed, but have been outlined as being:

- set out in the operational authorisation issued to the operator;
- set out in the standard scenario that the operator has declared will be used;
- set out in the LUC.

The regulations also introduce transitional arrangements that enable a UAS that does not comply with the new requirements to continue to be operated, but under a more restrictive set of requirements concerning flight near to people.

Footnote

[20] https://register-drones.caa.co.uk/drone-code [accessed November 2019]

[21] Conformité Européene means European Conformity and by affixing the CE marking to a product, a manufacturer declares that the product meets all the legal requirements for CE marking and that it can be sold throughout the European Economic Area (EEA). CE marking applies to products made in Europe and other countries that are sold in the EEA

Overflight of people and property by manned aircraft

Prior to 2010, Permit to Fly manned aircraft, under the conditions of their permit, were not allowed to fly over congested areas. This was understood to have been put in place as the airworthiness of aircraft in this category were not considered to have been to an equivalent standard as aircraft with a Certificate of Airworthiness. In 2007, The Popular Flying Association made a recommendation to the CAA asking for the restriction to be removed. The recommendation was supported by a safety case that showed Permit to Fly aircraft were not a higher risk than Certificate of Airworthiness aircraft.

In July 2010, CAA exemption (E3175) was issued to allow certain permit aircraft (microlight aeroplanes, amateur-built aeroplanes up to 1,500 kg, and factory-built aeroplanes up to 1,500 kg that were previously on a Certificate of Airworthiness) to overfly congested areas, subject to the normal rules of the air. These rules included retaining the capability of a single engine aircraft to glide clear and maintain minimum clearances with obstacles. The exemption did not apply when test flying or check-flying the aircraft. In February 2012, the exemption was superseded by Information Notice IN-2012/003 which made the arrangement permanent.

Risk of injury due to falling objects

The AAIB is not aware of any research relating to the potential for injury from a falling UAS. However, in the 1990's a dropped object prevention scheme (DROPS)[22] was introduced as part of a safety initiative by the UK Oil and Gas industry. The program has since expanded to include about 200 organisations, with the development of a DROPS analysis tool. This tool provides an indication as to the possible[23] outcome of a blunt object in free fall striking a person wearing personal protective equipment (i.e hard hat, eye protection).

Analysis using the DROPS calculator[24] indicated that a blunt object with a mass of 4.97 kg (the mass of the accident aircraft) falling from a height of more than about 3 m (~10 ft) agl could result in a fatal injury to someone wearing a hard hat. It also indicated that a 1 kg blunt object could cause a fatal injury from a height of 11 m.

The rules introduced by DR 2019/945 and IR 2019/947 for the open category state that aircraft able to impart 80 joules of kinetic energy shall not be operated intentionally over '*uninvolved people*'. The kinetic energy of the accident aircraft in free fall from about 3 m (10 ft) would be about 140 joules.

A Matrice 200 series aircraft in free fall from a height of 50 m (164 ft) would take about three seconds before it reached the ground. At its maximum takeoff mass, which was 6.14 kg,

Footnote

[22] https://www.dropsonline.org/ [accessed September 2019]
[23] It is not possible to be definitive due to varying factors such as where an object strikes a person or if it penetrates the body.
[24] https://www.dropsonline.org/resources-and-guidance/drops-calculator/e-drops-calculator/ This calculator calculates the potential energy of an object (Mass(m) x Height(h) x Gravitational Acceleration). The DROPS Calculator is a guide only and is intended to give a general idea of the potential severity of a dropped object. [accessed September 2019]

the aircraft would have a kinetic energy of approximately 3,000 joules when it reached the ground. Reducing this height to 30 m (~100 ft), it would take about 2.5 seconds for the aircraft to reach the ground and impart about 1,800 joules.

Analysis

Failure of DJI Matrice 210 SUA at Temple Newsam

The manufacturer stated that the accident had been caused by the failure of the No 4 ESC, but no information was made available as to why this component had failed. When the No 4 ESC had failed, a No 3 ESC '*link down*' message was also recorded. The manufacturer did not confirm what this message meant, or if this ESC had also failed.

Subsequent inspection of the aircraft found that moisture had entered the No 3 ESC chamber and residue was present on the ESC circuit board. No evidence of moisture was found on the other ESC's. Since owning the aircraft from new, the pilot had followed the manufacturer's guidelines to prevent moisture entering the aircraft and during the accident the No 3 motor arm had remained intact. It is therefore more likely that the moisture entered the No 3 ESC chamber during the last three minutes of the accident flight when the rainfall increased rather than during previous operation or following the accident.

The lower section of the ESC chambers adjacent to the antennas were not sealed and this could have provided an entry path for rainwater. The IP 43 accreditation testing was also not performed with the propellers installed and so it is possible that these tests did not fully reflect in-service operation in rain. It is also possible that rainwater entered the unit due to rainfall exceeding the manufacturer's limitation of 10 mm/h or that the IP 43 protection had degraded over time.

Although it was not confirmed if moisture ingress caused this accident, information shows that other Matrice 200 series accidents have been caused by moisture entering the aircraft. The manufacturer's analysis also showed that 27% of accidents were attributed to a loss of propeller motor propulsion that were for reasons other than a fault with the ESC. The manufacturer did not provide guidance on ascertaining if the rainfall exceeded limitations, or the duration that the IP 43 protection may remain in place. It is therefore possible that pilots of the Matrice 200 series could operate the aircraft in rain without knowing that it could result in the loss of control of the aircraft due to moisture ingress. The following Safety Recommendation is therefore made:

Safety Recommendation 2020-001

It is recommended that the Civil Aviation Authority notify users of the DJI Matrice 200 series of the possibility of moisture entering the aircraft when operating in rain and that this could result in a sudden loss of control of the aircraft.

Operation of UAS over persons

The ANO allows a UA with a mass of up to 20 kg to be flown over assemblies of up to 1,000 people as long as the aircraft maintains a height of at least 50 m. UA's such as the DJI Matrice 200 series rely upon their propulsion system for lift. If propulsion is lost, aircraft of this type typically fall vertically to the ground. From a height of 50 m, the descent would take about three seconds, which would provide limited time for a pilot to warn people and for them to take avoiding action if possible. The risk of injury to a person on the ground if struck by a falling UA is high, with the DROPS analysis indicating that a UA with a mass of only a few kg falling from a height of just several metres could result in a serious or even fatal injury.

In accordance with the ANO, a person must not 'permit an aircraft to endanger any person' and may only fly the aircraft 'if reasonably satisfied that the flight can safely be made'. It is therefore up to the operator or remote pilot to decide if flying a UA over people will endanger them. However, there is no guidance available from the CAA on how to make that assessment. This could include consideration of standards of safety, reliability, UA mass and type, the operational environment and whether any secondary safety systems are fitted.

IR (EU) 2019/947 is due to come into force in July 2020 and will require that a UA operating in the open category with a mass of more than 250 grams must not be flown over 'uninvolved persons'. If operating a UA in the specific category, the operator will need to comply with mitigating safety actions to prevent injury to people. However, these actions are not due to be published by the EC until 2021 which leaves an unresolved hazard prior to publication. The following Safety Recommendation is therefore made:

Safety Recommendation 2020-002

It is recommended that the Civil Aviation Authority specify the conditions that must be met for an unmanned aircraft to be flown safely over people.

Conclusion

The DJI Matrice 210 crashed whilst operating in rain. The manufacturer stated that the accident had been caused by a fault with the No 4 motor ESC. Moisture was also found on the No 3 motor ESC, but it was not established if this contributed to the accident. However, information showed that other Matrice 200 series accidents involving aircraft operating in rain had been caused by ESC failures due to moisture ingress. Other types of DJI Matrice 200 series failures included contamination of the motors by fine particles that the IP43 rating did not provide protection against.

Failures of the Matrice 200 series aircraft resulted in a loss of power and control, with the aircraft typically falling vertically to the ground. This poses a risk of injury to people on the ground which is not mitigated by the current UK regulations or the published guidance material. To address this, two Safety Recommendations have been made to the CAA.

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.

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A319-131, G-DBCD
No & Type of Engines:	2 International Aero Engine V2522-A5 turbofan engines
Year of Manufacture:	2005 (Serial no: 2389)
Date & Time (UTC):	2 April 2019 at 2150 hrs
Location:	En route London Gatwick Airport to Palma De Mallorca Airport, Spain
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 63
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	10,296 hours (of which 2,931 were on type) Last 90 days - 122 hours Last 28 days - 45 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and the operator's safety report

Synopsis

During pre-departure maintenance activity to resolve a flight control status message, the No 1 spoiler was unintentionally left in the MAINTENANCE position with the maintenance key installed. During the flight, the spoiler was able to 'float' up resulting in uncommanded left roll and vibration. The crew landed the aircraft without further incident.

The operator's internal investigation identified a number of factors which contributed to the maintenance error and it made 11 internal recommendations.

History of the flight

Following a flight control status message prior to departure, maintenance activity intended to deactivate the No 1 spoiler on the left wing was completed. This was undertaken to allow the aircraft to depart with the defect deferred in accordance with the Minimum Equipment List.

The departure was normal but whilst in the cruise, the crew noticed that the aircraft was flying 2º left wing down with 2.4 units of right rudder trim; a light "rumble" was apparent.

As the flight progressed, the crew monitored the situation and consulted with the operator's maintenance control. The senior cabin crew member was asked to visually check the wing and its control surfaces for anything unusual. In the absence of any warnings or confirmed abnormalities, the crew decided to continue the flight to the planned destination.

During the approach with the autopilot engaged, when FULL flap was selected the aircraft rolled noticeably to the left and deviated from the flight director command bars. This was accompanied by buffeting and vibration which felt like "light turbulence". The crew observed the operating spoilers on the right wing were repeatedly extending and retracting and that the autopilot had applied 6.6 units of right rudder trim as it regained the approach profile.

The crew reviewed the situation and decided to continue the approach. At 1,000 ft agl, the stable approach criteria were met and at 800 ft agl the handling pilot disconnected the autopilot. This introduced a further roll to the left which was contained by the pilot. The aircraft was out of trim and required continual sidestick input, sometimes to nearly full extent, to maintain the approach profile. The crew reviewed the situation again and decided to land. The landing and taxi to stand were without incident.

On arrival, maintenance staff inspected the aircraft and found that instead of the No 1 spoiler being deactivated it had been left in the MAINTENANCE position with the maintenance key still installed. The '*remove before flight*' flag attached to the maintenance key had been cable tied to the spoiler actuator, Figure 1. In this configuration the spoiler could move away from its stowed position in an uncontrolled manner which would cause the anomalies experienced by the crew.

The spoiler was then correctly deactivated, and the aircraft returned to Gatwick Airport without further incident.

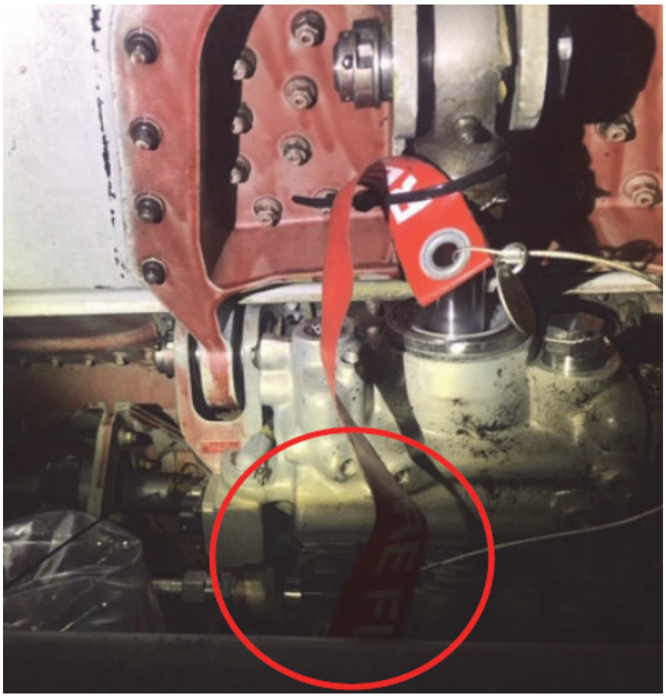


Figure 1

Spoiler maintenance key and flag as found on arrival

Maintenance activity

The aircraft had returned to stand due to a flight control (FLT CTL) status massage which had been displayed to the flight crew whilst taxiing. Two licensed aircraft engineers (LAEs) were sent to meet the aircraft and investigate the cause of this message. They had just commenced their shift. On arrival at the aircraft, they debriefed the flight crew and began their fault finding. During this process, they had to go outside of the aircraft to restore ground power after it had failed.

Both LAEs had been issued with tablet devices containing approved aircraft maintenance data which was accessed via an APP. After some confusion surrounding the fault codes and difficulty with the Trouble Shooting manual (TSM), it was confirmed that the No 1 spoiler actuator was not operating correctly.

The LAEs then referred to the paper copy of the Minimum Equipment List (MEL), kept in the flight deck, to see if the aircraft could be dispatched with this defect. Dispatch of the aircraft was allowable with the No 1 spoiler deactivated providing the appropriate procedure in the Aircraft Maintenance Manual (AMM) had been completed. This procedure required the use of a special tool, a spoiler maintenance key, which had to be collected from the engineering stores. Both LAEs returned to the engineering offices to collect the tool and their wet weather clothing due to the worsening weather conditions.

On returning to the aircraft the LAEs completed the deactivation procedure. It was now cold and raining. An operational test was carried out and indications from the ground and on the flight deck displays were as expected. A check to see if the spoiler could be manually raised was not carried out.

The LAE who had completed the deactivation was unable to complete the technical log as his hands were too cold and he “could not feel his fingers”, so the other LAE completed the certification; which was outside the scope of his approval. The aircraft then departed.

Review of Maintenance Activity by the LAEs

When the LAEs later learnt of the flight crew reports of a control anomaly, they realised that the spoiler had been incorrectly locked out and they reviewed the deactivation procedure on a desk top computer.

During their review, the LAEs identified the following issues that may have contributed to their error:

- The tablet device did not allow multiple tabs to be used in the APP which made navigation between the TSM and the AMM “clunky”.
- The APP does not remember the last location so every time a manual is re-opened, the user must scroll repeatedly to find the page previously being used.

- The AMM procedure for spoiler deactivation contains references to all the spoiler positions and the different modification states that are available for the spoiler actuator. This made it difficult to identify the relevant sections of the procedure to use, relating to the modification status and position of the actuator, on the tablet device they were using.
- Post-modification spoiler actuators have an identification plate indicating the OPERATIONAL and MAINTENANCE positions; pre-modification actuators do not.
- The instructions in the AMM clearly indicate the installation of the spoiler maintenance key, but due to the sentence construction the removal instruction is not as clear, Figure 2 and 3.

> (a) Install the (98D27603002000)**KEY-SPOILER MAINTENANCE**, (98D27603002001)**KEY-SPOILER MAINTENANCE** (3) on the servocontrol and turn it a quarter turn counterclockwise to the 'M' position (Maintenance).
> The servocontrol is in maintenance position.

Figure 2

Instruction to install spoiler maintenance key

> (f) Turn the (98D27603002000)**KEY-SPOILER MAINTENANCE**, (98D27603002001)**KEY-SPOILER MAINTENANCE** (3) a quarter turn clockwise to the 'O' position (Operation) and remove it.
> The servocontrol is in operational position.

Figure 3

Instruction to remove spoiler maintenance key

The weather conditions were reported as "very bad", it was raining hard and there was a driving wind. The tablet device is housed in a rubberised case with a lip surrounding the screen, this collected rain water which had to be tipped away before each use and the remaining water residue made the screen less responsive to the touch commands. This made scrolling through the pages difficult.

Neither LAE had deactivated a spoiler actuator for aircraft dispatch before, although both had fitted the spoiler maintenance key during hangar maintenance where it is left in place, along with a 'gag' on the actuator rod to ensure the spoiler does not move if hydraulic power is inadvertently applied during the maintenance activity.

Operator's internal safety investigation

Staff from the Operator's Engineering Quality department conducted an internal 'formal' safety investigation. The stated intention of the investigation was to determine the cause or causes of the incident with a view to eliminating or minimising the probability of recurrence. It was not intended to be critical of individuals or apportion blame.

This internal investigation included:

- interviews with the engineering staff involved in the maintenance activity to deactivate the spoiler;
- a review of the AMM task and its presentation;
- a review of how the maintenance information was accessed using the software and devices supplied by the operator;
- an inspection of the spoiler maintenance key and a review of its use; and
- a review of previous similar events involving spoiler deactivation.

This internal investigation found the following:

- The LAEs did not completely follow the AMM procedure to de-activate the No 1 spoiler and they were convinced the spoiler maintenance key should remain in the actuator, as it does in hangar maintenance situations and with other systems they had worked on.
- The maintenance information, although complete, was difficult to follow as the task included instructions for differing spoiler actuator modification states and for every spoiler position, so the applicable sections had to be identified from the main large body of text.
- The information platform and tablet used by the maintenance staff was more difficult to use in the heavy rain and did not allow more than one document to be open at a time.
- The information platform timed-out after a period of time which required the user to log-in after moving between locations and rather than going to the page being used, it would default to start of the document.
- The performance of information platforms and checklists used by flight crew were more succinct and the information relevant to tasks was easier to access and follow than those supplied to maintenance staff.
- No final or independent physical check to confirm the spoiler lockout was performed.
- The engineers referred to the approved data, but it was primarily to locate part numbers of tooling and to access function check sequences.

The internal investigation report made the following observations:

'There are several learning points from this event which from an organisational perspective reflect those raised in a similar event in 1993[1]*.*

Footnote

[1] AAIB note -This event to G-KMAM on 26 August 1993 was investigated by the AAIB, see Formal Report AAR 2/1995.

As aircraft technology evolves, we somewhat remove some of the potential maintenance errors, however this evolvement also brings an increased reliance of the importance to adhere to maintenance procedures. Those maintenance procedures from a human factor perspective, need to be concise and user friendly. Of a standard which can be followed easily and safely in a time pressured environment. We need to take away or support more, some additional single reliance we put on the certifiers to make safety critical decisions under pressure. As an organisation we rely solely on the certifier in an unscheduled maintenance environment to make decisions on duplicate inspections, where guidance within the approved data would be best place to offer organisational support.'

It went on to review other similar maintenance lapse events and identified five causal factors from the AAIB report AAR 2/1995 in to a similar incident involving an Airbus A320-212, G-KMAM in 1993 that have a direct correlation to the causal factors identified in this event:

- *'During the flap change compliance with the requirements of the Maintenance Manual was not achieved in a number of directly relevant areas.*
- *The re-instatement and functional check of the spoilers after flap fitment were not carried out.*
- *A rigorously procedural approach to working practices and total compliance with the Maintenance Manual was not enforced by local line management.*
- *It is not possible for maintenance staff working on the current generation of aircraft to have enough information about the aircraft and its systems to understand adequately the consequences of any deviation from approved maintenance procedures.*
- *The avoidance of future unnecessary maintenance related accidents with high technology aircraft depends on an attitude of total compliance with approved procedures being developed and fostered within the industry.'*

Operator's additional comment

'Approved data presented by a manufacturer is not always in alignment with good human factor principles. This report demonstrates the importance of how task data is presented to an engineer. In this case, the majority of the task data is not directly related to the deactivation of No.1 spoiler. This led the engineers involved to scroll through several paragraphs of inapplicable data in order to identify the specific parts of the task that applied to them. This can, as it did in this case, lead an engineer to miss essential safety information or critical parts of the task.'

Conclusion

Following maintenance action intended to deactivate a spoiler, the aircraft departed with the spoiler in the maintenance position. This allowed the spoiler to 'float' up in the airflow causing an uncommanded roll input. The aircraft landed without further incident and the spoiler was correctly deactivated for the return flight.

The operator's safety investigation identified that the LAEs had not followed the AMM procedure correctly. The maintenance activity was, by necessity, being conducted in bad weather and it was an unfamiliar task. They were distracted during the task and had difficulty using the APP on the tablet device which was provided to display the required maintenance information.

The LAEs had difficulty interpreting the modification status of the actuator and identifying the relevant sections of the procedure to use, relating to the modification status and position of the actuator, on the tablet device they were using. They were not clear on how the maintenance key was to be used to deactivate the spoiler actuator for dispatch. A physical check for correct deactivation was not completed and an independent check for correct deactivation was not required to be carried out. The log book entry for the deactivation was incorrectly certified.

The operator's report also identified a number of contributory factors including how the maintenance information was accessed and presented to the engineers, and differences in how similar information is presented more effectively to flight crews.

Safety actions/recommendations

The operator's investigation report contained eleven internal recommendations intended to prevent a recurrence. These were made in the following topic areas:

- Improving the ease of access to, and the presentation and clarity, of maintenance information.
- Discussion with EASA and Airbus about the possibility of having critical lock out tasks clearly defined within the MEL in the style of a QRH for use alongside the crew OPS procedures.
- Reviewing the policy and standards for duplicate inspection to clearly identify that this deactivation task should require a duplicate inspection.
- Reviewing the effectivity of current line manager's task audits at the Maintenance Safety Group.
- Highlighting to other engineers the importance of fully understanding the AMM and Trouble Shooting Manual tasks.

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A321, YL-LCQ
No & Type of Engines:	2 International Aero Engine V2533-A5 turbofan engines
Year of Manufacture:	2004 (serial number 2211)
Date & Time (UTC):	22 July 2019 at 2319 hrs
Location:	On approach to London Stansted Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 8 Passengers - 211
Injuries:	Crew - None Passengers - None
Nature of Damage:	None reported
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	13,468 hours (of which 3,095 were on type) Last 90 days - 222 hours Last 28 days - 74 hours
Information sources:	Aircraft Accident Report Form submitted by the pilot, Mandatory Occurrence Report submitted by ATC and further enquiries by the AAIB

Synopsis

London Stansted Airport (STN) was operating with a displaced threshold on Runway 22 (RW22) while repairs were carried out at the normal threshold. RW22 ILS was unavailable during the works period. A revised RNAV approach (RNAV22C), which was steeper and based on the displaced threshold, had been promulgated for RW22. YL-LCQ was observed to be lower than expected during its approach and over the works area.

The pilots of YL-LCQ had not realised that a revised approach was required and flew the standard RNAV arrival. Radar data indicated that the aircraft was low over the works area and touched down close to the displaced threshold. Temporary approach plates were available to the pilots in their electronic flight bags (EFB), but the stated work-in-progress (WIP) active periods on the temporary airfield chart were incorrect. ATC had made repeated references to the displaced threshold and the RNAV22C arrival during the period when YL-LCQ was on the terminal controller's frequency.

After the incident, the operator highlighted the WIP implications to all their pilots operating from STN. The chart manufacturer reviewed their processes to address the issues which had resulted in incomplete information being presented on the temporary airfield chart.

History of the flight

STN had begun a works programme to carry out repairs to the runway near the eastern threshold (THR 22). To facilitate continued flight operations the work was to be carried out only at night and employed a displaced maintenance threshold to permit safe overflight of the works area. The works rendered the ILS unusable but a revised RNAV approach to the displaced threshold was published for use when reduced runway length operations were in force.

YL-LCQ was the first aircraft to make an approach to the airfield after the displaced threshold had been established on the evening of Monday 22 July 2019. The pilots did not realise that they were required to follow the RNAV22C procedure and flew the standard RNAV arrival anchored at THR 22. The Aerodrome Tower Controller thought that the aircraft looked "slightly lower than the traffic on final approach during the previous night's reduced distance operation", but they were "not sure". As the aircraft approached 4 miles the controller issued landing clearance and added "CAUTION, DISPLACED THRESHOLD AND REDUCED LANDING DISTANCE AVAILABLE…DO NOT FLY BELOW PAPI INDICATIONS". The airline reported that their pilots had misinterpreted the controller's instruction to "not fly below the PAPIs" as "do not follow the PAPIs".

The aircraft was seen to be lower than expected over the works area.

The crew did not see any obstructions on the runway and did not notice anything untoward during their approach and landing.

Airfield information

UK AIP Supplement 24/2019 (SUP 024/2019), published 6 June 2019, provided details of the intended works and the associated displaced maintenance threshold (THR 22C). The works were planned for two blocks of four consecutive nights between Sunday 21 July and Thursday 1 August. On nights when works were scheduled the runway was to be closed for 15 minutes from 2300 hrs to allow time for airfield ground lighting changes to be made and to establish the displaced threshold (Figures 1 and 2). As part of the lighting changes, temporary PAPIs were deployed; these were set to indicate a 3.5° approach angle. The normal approach to RW22 is flown with PAPIs set at 3.0°.

2.1 Timetable for 2019 Works

TIMINGS (All times ZULU)						OPERATIONAL IMPACT		
Date	Runway Closure Time	Runway Closed for Lighting Changeover	Runway Open With Reduced Distances Available	Runway Closed for Lighting Changeover	Runway Open Full Length	Runway Configuration During Reduced Distances	TORA	LDA
Sunday – Thursday	2259	2300-2315	2315-0445	0445-0500	0500	Phase 3	2200 M	1900 M

PHASE 3: Displaced Threshold 22C – Sunday to Thursday Nights 21 July until 1 August 2019

CIVIL AVIATION AUTHORITY SUP 024/2019-1

Figure 1

SUP 024/2019 works timetable and operational impact

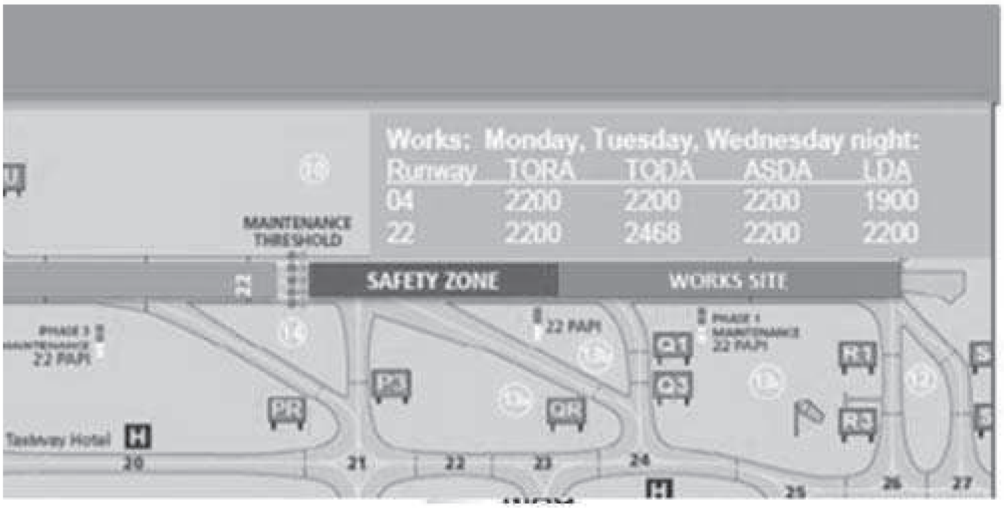


Figure 2

SUP 024/2019 overview of runway works plan showing displaced maintenance threshold

With vehicles planned to be operating in its normal beam path, the ILS was unavailable during the works period. An alternative RNAV procedure, designated RNAV22C and generating increased flightpath clearance above the works area, was promulgated in SUP 024/2019. Notable differences between the RNAV22 and RNAV22C procedures were the following:

- RNAV22 began at waypoint TOTVO while RNAV22C began at UPGIR.
- The RNAV22 approach angle was 3.0°, but the RNAV22C final approach was 3.5°.
- RNAV22 targeted a threshold crossing height (TCH) of 49 ft over THR 22 while RNAV22C targeted a TCH of 50 ft over THR 22C.

Meteorology

At the time of the incident STN was reporting good visibility with a gentle westerly breeze. The final approach was flown clear of cloud.

Personnel

Neither pilot was a native English speaker. The aircraft commander's flight crew licence was issued by the Irish Aviation Authority and contained a valid English Language Proficiency Level 5 endorsement.

Recorded information

Transcript from Essex Radar

YL-LCQ was initially instructed to hold at reporting point ABBOT while the runway was closed for the WIP lighting changeover. During the time that YL-LCQ was holding ATC gave another aircraft on the same radio frequency details about the runway opening time and the reduced runway operations. They then checked that the pilots of YL-LCQ had heard the information:

ATC: "[YL-LCQ] I TAKE IT YOU COPIED THAT THE RUNWAY IS DUE TO OPEN AT 2315. VECTORS FOR RNAV APPROACH RW22C DISPLACED THRESHOLD."

YL-LCQ: "COPIED OPEN AT 15, RNAV APPROACH."

YL-LCQ: "JUST CONFIRM RNAV APPROACH RW22."

To which ATC responded:

ATC: "AFFIRM, VECTORS FOR RNAV APPROACH RW22C IT WILL BE A DISPLACED THRESHOLD WHEN THE RUNWAY OPENS."

This was acknowledged by the flight crew. After initial vectoring from the ABBOT hold, YL-LCQ was cleared direct to UPGIR, the start of the RNAV22C approach:

ATC: "[YL-LCQ] ROUTE DIRECT UPGIR DESCEND ALTITUDE 2,500 FT CLEARED RNAV APPROACH RW22C."

Based on their planned RNAV22 arrival, the pilots should have expected to route via TOTVO; UPGIR was not in their active flight plan. They did not query the routing and replied:

"[CALLSIGN] DESCEND 2500 CLEARED FOR ILS, SORRY, RNAV APPROACH RW22C"

ATC did not ask the flight crew to confirm the routing to UPGIR. Shortly afterwards YL-LCQ was transferred to Stansted Tower frequency. The pilot of YL-LCQ spoke with a thick accent which may have contributed to a slight lack of clarity in transmissions from the aircraft.

The Air Traffic Service provider conducted an internal Unit Investigation into the occurrence. Their report concluded that the most likely explanation for the incident was that the pilots flew the RNAV22 rather than RNAV22C procedure. It also highlighted that incomplete readbacks by the pilots of YL-LCQ were not challenged by the Terminal Control (TC) controller. The Unit's TC airports interface manager was tasked to '*raise the issue of incorrect or incomplete readbacks with TC controllers, ensuring that TC controllers are robust in challenging these types of events*'. The report noted that some operators at STN questioned '*the need to use phraseology such as "do not fly below PAPI indications" as they believed this could be distracting in the latter stages of an approach*'. The airport's user safety group was tasked to conduct a full review of the phraseology used for the reduced runway operations.

ATC radar

Radar data for the incident aircraft and the two aircraft that landed after it revealed that YL-LCQ was consistently lower during the approach than the following aircraft which had both flown the RNAV22C procedure (Figure 3).

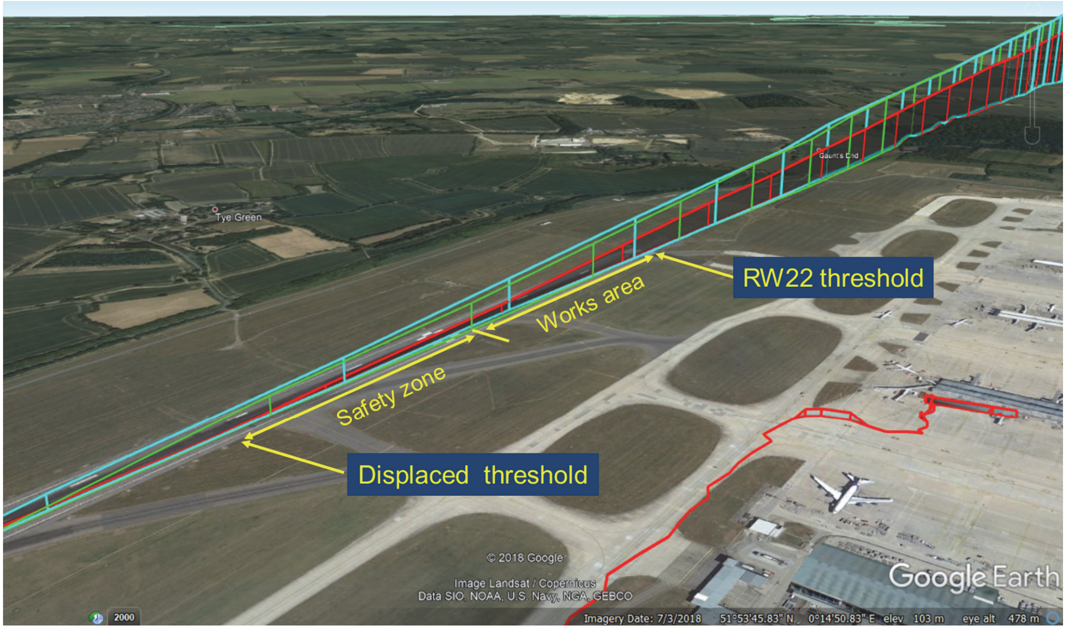


Figure 3

Comparative radar traces (YL-LCQ trace in red)

Other information

NOTAMS

The flight documentation pack issued to the pilots contained two NOTAMs relating to the runway works at STN (Figure 4). While the second NOTAM referenced Sup 024/2019, the pilots did not have access to that document.

Destination airport EGSS - STN - LONDON/STANSTED RWY 04 04C 22 22C [rwy | NEW TODAY]
A2293/19 NOTAMN
Q) EGTT/QMRLC/IV/NBO/A/000/999/5153N00014E005
A) EGSS B) 1907212300 C) 1907312315 D) SUN-WED 2300-2315
E) RWY 04/22 CLSD TO PREPARE FOR REDUCED DISTANCE OPERATIONS [rwy | 1]

A1701/19 NOTAMN
Q) EGTT/QMRTT/IV/BO/A/0/999/5153N00014E5
A) EGSS B) 1907210000 C) 1908012359
E) TRIGGER NOTAM - REDUCED RUNWAY OPERATIONS. SUP 024/2019 REFERS [rwy | 2]

Figure 4

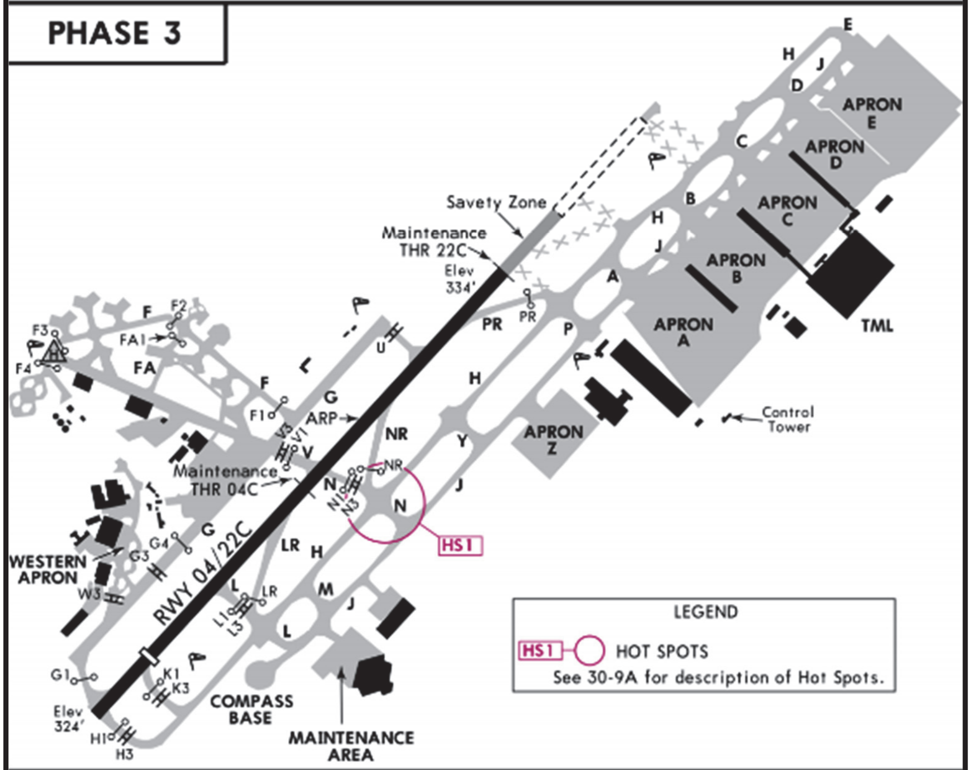
NOTAMs relating to STN runway repair works, as issued to pilots of YL-LCQ

Airfield charts

The pilots had up-to-date airfield databases on their EFBs, a recent update to which had introduced temporary charts issued to reflect pertinent information from SUP 024/2019. Included in the database was a chart for the RNAV22C procedure as well as a temporary '*Reduced Rwy Operations*' airfield chart (Figure 5).

REDUCED RWY OPERATIONS
REFER ALSO TO LATEST NOTAMS

Overnight reduced Rwy operations will take place to carry out required Twy maintenance at Twys R and S.



The works will be carried out Sunday and Wednesday night until the next morning and require Phase 3 reduced rwy operations. Phase 1 and 2 will not be utilised.

During Phase 1: THR 04C (maintenance threshold) and THR 22 (normal threshold) will be in operation.
During Phase 2: There is a full Rwy closure.
During Phase 3: THR 04 (normal threshold) and THR 22C (maintenance threshold) will be in operation.

Phase 3 restrictions affect the Rwy declared distances, ground lighting, navigational aids and instrument flight procedures available at night. There will be block closures on the Twy system to safeguard the closed section of Rwy and facilitate contractor access. At the beginning and prior to the end of each nights's working period the Rwy will be closed for approximately 15 minutes. Unless otherwise informed, outside of the working period all Rwy distances and lighting will be fully available
Throughout the working period each night the section of Rwy between Rwy THR 04 and the edge of the works area (abeam Twy PR) will remain operational for ACFT. A maintenance threshold will be introduced for Rwy 22C.

RWY	APCH and RWY lights			LDA	TORA
04	HIRL (60m)	HIALS	PAPI-L (3.0°)	6234' 1900m	7218' 2200m
22C	HIRL (60m)	ALS ❶	PAPI-L (3.5°)	7218' 2200m	

❶ Configuration unknown; length 689'/210m

Figure 5

Temporary airfield chart available to the pilots

The wording on the temporary airfield chart stated that works would be carried out on '*Sunday and Wednesday night*' rather than Sunday through to Thursday night. Having been made aware of the incorrect data after the incident, the chart manufacturer conducted an internal investigation. They identified how the error in data transposition had occurred and took steps to prevent similar slips in the future.

Human factors

The pilots had reviewed the NOTAMs and airfield charts, the wording of which led them to believe that the STN runway works would not affect them on a Monday night. While ATC referred several times to RNAV22C and the displaced threshold, this did not alert YL-LCQ's flight crew to the requirement to fly the revised approach.

Analysis

Radar data and eye witness testimony confirmed that YL-LCQ was lower than expected over the THR 22 works area at STN. The aircraft appeared to have touched down close to the displaced threshold. Flying the RNAV22C procedure would have placed YL-LCQ 50 ft higher over THR 22C and thus greater clearance over the works area would have been achieved.

An error in the temporary airfield chart available to them misled the pilots into thinking that the runway works were not active on the night of the incident. They planned for and flew a standard RNAV22 approach. Neither holding during the temporary runway closure nor ATC's repeated references to reduced runway operations and the displaced threshold triggered a realisation that the works were taking place. The crew appeared to have exhibited a degree of confirmation bias; they were expecting a standard RNAV arrival and did not perceive the cues directing them to fly the alternative procedure.

While the controller consistently referred to the RNAV22C approach, the pilots of YL-LCQ replied with "RNAV APPROACH" to all bar the final approach clearance readback. The flight crew did not query or repeat the clearance to proceed direct to UPGIR, and ATC did not challenge their incomplete clearance readbacks. The pilot's thick accent may have contributed to a slight lack of clarity in radio transmissions from the aircraft. Confirmation bias may also have influenced the terminal controller's understanding of the flight crew's intentions.

The tower controller advised the pilots to avoid flying below PAPI indications because the aircraft was low on the approach. The pilots were unaware that they were lower than anticipated, hence did not expect to be reminded to maintain the correct glidepath. They misinterpreted the controller and believed that they were to ignore PAPI indications.

Conclusion

Having read the relevant flight documentation paperwork, the pilots' mindset was that the runway works at STN were not active during their approach. Confirmation bias appears to have played a part in the pilots' selection of the wrong approach procedure and may have contributed to ATC not detecting the error. The reminder to follow PAPI indications was misinterpreted as an instruction to ignore them. The incident highlighted the importance of correct and complete radio transmission phraseology.

Safety actions

Following this serious incident, the following safety actions were taken:

- The aircraft operator alerted their crews to the error in the temporary airfield chart and the requirement to fly the revised RNAV procedure when the THR 22 works were active.
- The Stansted Airport air traffic services unit terminal control interface manager was tasked to raise the issue of incorrect or incomplete readbacks with the terminal control unit; the aim being to ensure that future poor radio phraseology would be robustly challenged.
- The airport's user safety group was tasked to conduct a full review of the phraseology used for the reduced runway operations.
- The chart manufacturer undertook an investigation into how the works scheduling had been incorrectly represented on the temporary airfield chart and took remedial action to prevent similar data transposition errors in the future.

SERIOUS INCIDENT

Aircraft Type and Registration:	Agusta A109E, G-ETPI
No & Type of Engines:	2 Pratt & Whitney Canada PW206C turboshaft engines
Year of Manufacture:	2001
Date & Time (UTC):	27 June 2019 at 0820 hrs
Location:	In flight North of Seaton, Cornwall
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Loss of window
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	4,736 hours (of which 847 were on type) Last 90 days - 35 hours Last 28 days - 11 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, maintenance organisation investigation and AAIB enquiries

Synopsis

During a post-maintenance flight, the left cockpit door window separated from the helicopter. The window had been removed and reinstalled during recent maintenance. The investigation determined that insufficient adhesive had been applied to the rubber retaining seal. In addition, liberal application of high-concentration soap solution during reinstallation likely contributed to the loss of the window, by reducing the frictional ability of the rubber seal to retain the window. As a result of the findings of this investigation, the maintenance organisation has taken four safety actions.

History of the flight

Following completion of a lengthy base maintenance input, the helicopter was scheduled to perform a post-maintenance flight which included a track-and-balance check of the main rotor. It departed from Liskeard Heliport, with the commander occupying the right seat and an engineer in the left seat to record the track-and-balance data. The aircraft ventilation system was set to maximum as it was a hot day.

The track-and-balance check required data to be gathered in the hover, at 80 kt and at 140 kt. The flight initially proceeded uneventfully but as the helicopter was accelerated towards 140 kt, there was a loud bang and a substantial increase in wind noise. It was immediately apparent to the commander that the window transparency from the left cockpit door had separated from the aircraft. There was no resulting increase in vibration, nor any indication that tail rotor control had been adversely affected. The track-and-balance check was terminated, and the helicopter returned to Liskeard, landing without further incident.

Maintenance history

During the recent maintenance input, the helicopter had undergone a full external repaint, which necessitated the removal and disassembly of all cockpit and cabin doors and windows. These tasks were documented as a single item on a maintenance worksheet, which was signed-off by the certifying engineer on 21 March 2019.

Following completion of the helicopter base maintenance and repaint, the doors and windows were reassembled and refitted by an engineer. The associated worksheet stated '*Cockpit, cabin and baggage compartment doors reassembled and reinstalled ….*' The worksheet did not record the date on which the task had been completed but indicated that it had been inspected and certified by the certifying engineer on 9 April 2019.

Installation of cockpit door windows

The A109E cockpit doors are of a composite construction and include a non-opening single acrylic window transparency. The window is attached to the door by an extruded rubber seal channel. The rubber seal has three separate grooves to accommodate the window, the door frame and a seal filler strip which locks the seal and window in place.

Chapter 56-31-7 of the A109E maintenance manual describes the procedure for installation of the cockpit door windows as follows. The numbers in parenthesis refer to the numbered items in Figure 1.

C. Installation procedure

(1) Apply a layer of adhesive ...C537 (5) into the grooves of the seal channel (3) as shown in the section A-A.

(2) Install the transparent panel (2) and the seal channel (3) into the door frame (1).

(3) Using a small brush, apply a soapy solution into the groove of the seal channel (3) where the seal filler (4) will be installed.

NOTE: make sure to install the seal channel and the seal filler as detail in [Fig 1].

(4) Insert the seal filler (4) into the seal channel (3). When starting, hold the end of the seal filler (4) in position with a thumb and, if a new seal filler is being used, provide a slight overlap before cutting the seal filler strip to allow for a tight joint when both ends are forced into placed.

(5) Butt ends and compress seal filler (4) into the seal channel (3).

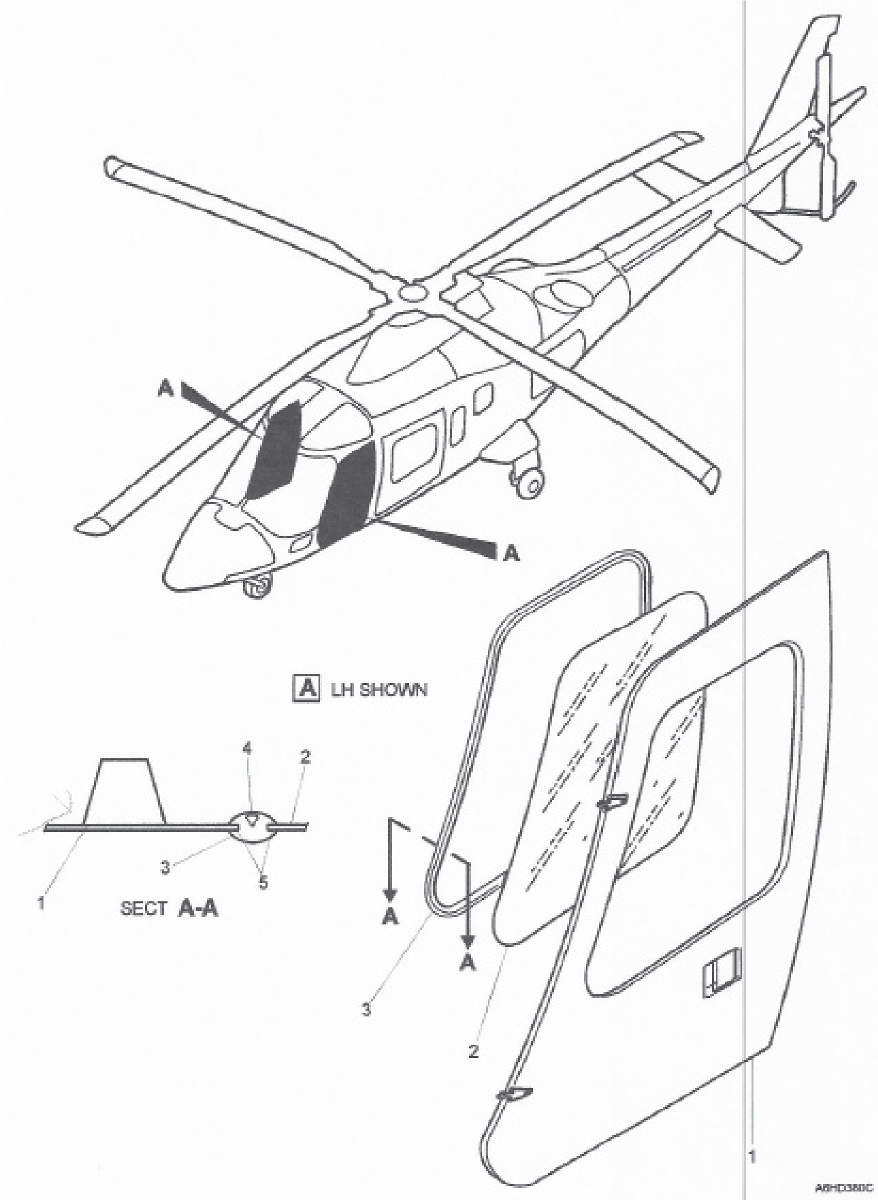


Figure 1

Illustration showing installation of A109E cockpit doors

Inspection of the helicopter

Following the incident, inspection of the helicopter's external surfaces did not reveal any secondary damage.

The left cockpit door was inspected and the associated maintenance worksheet stated that the inspection *'…did not reveal sufficient (residual) presence of adhesive on the door structure.'* The engineer performing the inspection also noted the presence of a greasy residue around the window aperture. A photograph taken during the inspection (Figure 2) shows no evidence of adhesive residue. The window and retaining seal were not recovered following the incident, so it was not possible to confirm whether sufficient adhesive had been applied to the window side of the seal.

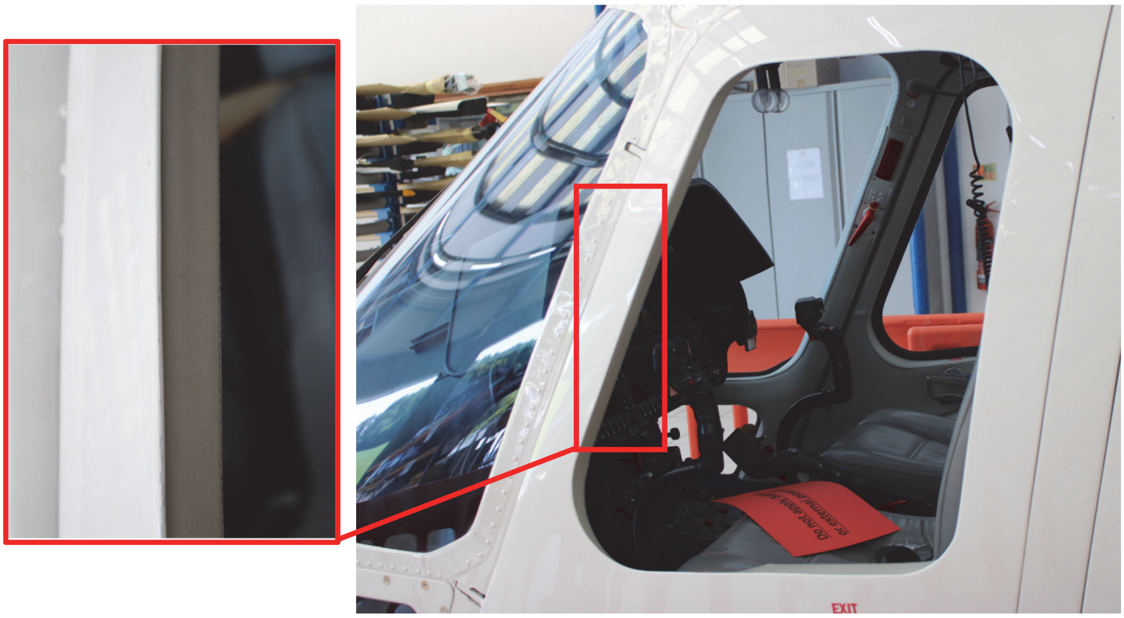


Figure 2

Window aperture of left cockpit door, showing no evidence of adhesive

The right cockpit door window was removed for inspection and this revealed the correct presence of adhesive in the grooves of the seal.

The cockpit, cabin and cabin door windows were also inspected for correct installation and security. Maintenance worksheets for these inspections indicate that no defects were noted with the cockpit windows. Although adhesive was present on the cabin windows and cabin door windows, it was noted that there was '*minimal squeeze-out.*' In each case, additional adhesive was subsequently applied to ensure positive adhesion of the seal to the door structure and window.

The post-incident inspection and reinstallation of the cockpit, cabin and cabin door windows were carried out by the same engineer and certifying engineer who had completed the original window installations.

Internal investigation

The maintenance organisation undertook an internal safety investigation following the incident. It identified that the engineer who installed the left cockpit door window had experienced some difficulty fitting the seal filler strip to the seal channel. The engineer had used a soapy solution to insert the filler strip but acknowledged during the investigation that the solution was applied liberally, such that it covered the window and the concentration of soap had been stronger than might normally be used.

The C537 adhesive specified in the A109E maintenance manual is a multi-purpose silicone adhesive/sealant which adheres to most surfaces and cures to form a tough flexible rubber. A single 310 ml tube of adhesive was issued to G-ETPI during its original maintenance input. During the safety investigation a similar tube of adhesive with approximately 1 inch of adhesive remaining was found in the hangar. It was determined that this was the originally-issued tube of adhesive and that it had been used during the original and post-incident window installations on G-ETPI. The maintenance organisation considered that, applied in correct quantity, the original and post-incident installation of all the cabin, cockpit and cockpit door windows would have required more adhesive than that which appeared to have been used. It would also have expected to see residual adhesive on the door frame.

The maintenance organisation's safety investigation concluded that the steps taken during reinstallation of the cockpit door windows differed from those prescribed in the A109E maintenance manual. It determined that little or no adhesive had been applied to the door side of the left cockpit door seal and that excessive use of an overly soapy solution to fit the seal filler strip had reduced the ability of the seal to retain the window due to friction alone. It considered the fact that the helicopter's ventilation system was set to maximum during the incident flight would have created a cabin pressure differential as the helicopter accelerated and this may have been a contributory factor. It believed the ram air effect of the ventilation system may have pushed the window outwards and caused the seal to roll off the door aperture, assisted by the lubricating effect of the soapy residue.

The maintenance organisation also determined that the certifying engineer did not perform a staged inspection during the task to confirm the presence of adhesive prior to installation of the window and seal. This was based on a perception that the task was relatively simple and that the engineer performing the task was fully competent to perform it correctly. The maintenance organisation also identified that its procedures did not make it clear that maintenance tasks involving steps which cannot be visually inspected or otherwise verified upon final completion, should be subject to a staged inspection.

The maintenance organisation did not identify any individual human performance issues with either engineer which may have contributed to the maintenance error.

Discussion

The A109E maintenance manual indicates the need for a thin layer of adhesive to be applied in the window and door grooves of the seal. Post-incident inspection revealed no evidence of adhesive on the left cockpit door window surround, which suggests that little or no adhesive had been applied to the corresponding seal groove during installation of the window. The window and seal were not recovered so it could not be determined whether adhesive had been applied to the window groove of the seal.

The A109E maintenance manual indicates that a small brush should be used to apply a soapy solution within the grooves of the seal filler channel. This suggests the need for precise application of the solution within this area. While the maintenance manual does not specify the concentration of soap to be used, other engineers in the maintenance organisation, indicated that one would normally use water with a light concentration of soap.

Using an excessive amount of soap solution would have allowed the solution to migrate into the window and door grooves on the seal (item 5 in Figure 1). In the 11 weeks that had elapsed between installation of the window and the incident, the water would likely have evaporated leaving a soapy residue. This may have acted as a lubricant, which in combination with the absence of adhesive allowed the window to separate from the cockpit door.

Reduced supervisory oversight by the certifying engineer, based on their evaluation of both the task and staff competence, meant that stage checks were not conducted throughout the window installation task. Such checks may have identified and addressed the difficulties that the engineer experienced while installing the windows and/or the absence of adhesive on some of the window seals.

The maintenance organisation's internal investigation also identified that the maintenance paperwork relating to the installation of the cabin, cockpit and cockpit door windows task did not include adequate detail. Specifically, a collection of separate tasks had been documented as a single task and only the date of certification was recorded rather than date of completion. Although not directly relevant to the incident, this made it difficult to identify who was involved in which task and the order in which they had been done.

The post-incident inspection and reinstallation of the cockpit door windows was undertaken by the same engineer and certifying engineer who had done the original window installation in April 2019. The maintenance organisation's internal safety investigation was not commenced until several days later. The fact that the same engineers undertook the same task, on the same aircraft could have adversely affected their recollections of the original installation, when interviewed during the subsequent safety investigation. This may have affected the quality of information available to the investigation.

Conclusion

The left cockpit door window separated from the helicopter during a post-maintenance flight. The investigation determined that little or no adhesive had been applied to the door side of the rubber retaining seal during installation of the window. In addition, excessive use of an overly soapy solution to fit the seal filler strip may have reduced the ability of the seal to retain the window, which in combination with the absence of adhesive allowed the window to separate from the cockpit door. Deviation from the prescribed maintenance manual procedure and lack of effective supervisory oversight were identified as contributory factors.

Safety actions

Following its internal safety investigation, the maintenance organisation debriefed all involved staff on the findings of the investigation. On 28 August 2019 it issued a temporary notice to all engineers informing them of the incident and requiring the installation of windows to be considered as a critical maintenance task, requiring an independent inspection to be performed during the installation of any acrylic window. The task was subsequently included on the organisation's formal list of critical maintenance tasks, when it was next updated. The details of the incident are also to be included in company continuation training, with a focus on the requirements for effective supervision, stage checks and adherence to procedure.

The maintenance organisation has undertaken to review its Emergency Response Plan (ERP) and to consider implementing a process to ensure that staff involved in maintenance activity prior to a suspected maintenance error, incident, or accident are stood down from duty, and are not allocated to be part of the maintenance response team. It indicated that the review of the ERP would be completed by the end of October 2019.

In September 2019 the maintenance organisation introduced a new production planning tool across all its maintenance bases to control and monitor to allocation of manpower, including supervisory staff, to aircraft undergoing base maintenance.

ACCIDENT

Aircraft Type and Registration:	Cessna 441 Conquest II, EI-DMG
No & Type of Engines:	2 Honeywell (Garrett Airesearch) TPE 331-10-534S turboprop engines
Year of Manufacture:	1980
Date & Time (UTC):	25 June 2019 at 0800 hrs
Location:	Glasgow Prestwick Airport
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - 7
Injuries:	Crew - None Passengers - None
Nature of Damage:	Engines, propellers and right-hand nose locker door damaged
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	4,563 hours (of which 1,035 were on type) Last 90 days - 40 hours Last 28 days - 11 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent AAIB enquiries

Synopsis

While landing at Prestwick International Airport it became apparent that the nose landing gear had not fully extended. The aircraft's landing gear indication and warning system had not alerted the pilots to this unsafe condition. Upon realising the aircraft's nose was dropping lower than normal, the pilots increased engine power and raised the aircraft nose while they activated the landing gear emergency blow-down system. The nose landing gear fully extended and the remainder of the landing was uneventful.

At the time of publication of this report, the aircraft had not been examined but it was considered likely that a faulty downlock switch on the nose landing gear actuator could provide an explanation for the failure of the nose landing gear to deploy and the absence of appropriate indications and warnings.

History of the flight

The company-owned aircraft was operating a private flight from Waterford Airport, Ireland to Prestwick International Airport, UK. Although EI-DMG was certified for single-pilot operations it was company practice to always operate with a second pilot on board. The aircraft was being flown by the commander seated in the left seat and the company's senior pilot occupied the right seat.

The ILS approach to Runway 30 at Prestwick was uneventful. The 'Before landing checks' were carried out and the commander recalls that all three green landing gear DOWN AND LOCKED lights were illuminated. Full flap was selected for landing.

Following a smooth touchdown on the main landing gear, as the aircraft's nose began to lower both pilots noticed that it continued to lower beyond its normal position. A "scrubbing/ scratching" sound was also heard. The pilots had a momentary discussion about flying a go-around but considered that this was not feasible due to the possibility of damage having been sustained. They increased the engine power, applied back pressure to the control column to keep the nose "flying" while they activated the landing gear emergency blow-down system. Upon reducing power and relaxing pressure on the control column, it was evident to the pilots that the nose landing gear had extended and the remainder of the landing roll continued uneventfully.

While taxiing to the parking area, a passenger alerted the commander to fuel leaking from the right engine. The taxi was expedited and the firewall shutoff valves were then activated. There were no injuries and the occupants disembarked normally without assistance. The aircraft sustained damaged to the engines and propellers. Subsequent inspection of the runway showed propeller strike marks over a distance of several metres in the touchdown zone.

The commander advised that no anomalies with the nose landing gear were noted during the pre-flight inspection, or during landing gear retraction following takeoff from Waterford. The landing gear warning horn did not sound during the approach.

A photograph taken of EI-DMG prior to touchdown (Figure 1) shows that the nose landing gear was partially extended prior to landing.

Figure 1

EI-DMG nose landing gear partially extended prior to touchdown
(image used with permission)

Figure 2

EI-DMG after landing showing fuel leak and damage to propellers
(image used with permission)

Landing gear system description

General

The Cessna 441 has a retractable tricycle landing gear which is electrically controlled and hydraulically actuated. It is operated by the landing gear selector switch, which depending on whether selected UP or DOWN, energises either the retract or extend solenoid in the landing gear control valve.

Landing gear extension

Normal extension and retraction of the landing gear is accomplished by hydraulic actuators, one for each landing gear. During extension, hydraulic pressure is routed from the landing gear control valve to release the uplock hooks and then to the extension side of the actuators. Once the landing gear reaches the extended position, an internal spring-loaded mechanical lock will engage to hold it in the extended position. An electrical downlock switch on each actuator indicates when the piston is locked. Once the downlock mechanisms are engaged, the hydraulic bypass valve will open and allow hydraulic fluid to be routed back to the hydraulic reservoir.

A landing gear emergency blow-down system is fitted to allow landing gear extension in the event of a hydraulic problem. It is activated by pulling the emergency landing gear extension T-handle mounted under the instrument panel. Pressurised nitrogen is discharged into the hydraulic system to release the uplock hooks and then into the landing gear cylinders to drive the landing gear into the down and locked position.

Landing gear indication and warning

The landing gear position and warning system provides a visual and audible indication of the safe or unsafe position of the landing gear. Three green landing gear DOWN AND LOCKED lights, one for each landing gear, are located on the instrument panel and illuminate when the downlock switch on the respective landing gear indicates that it is fully down and locked. A single red landing gear IN TRANSIT light illuminates when any, or all, of the landing gear are unlocked or in transit.

The landing gear warning system sounds an intermittent audible warning if one or both power levers are retarded to flight idle and at least one landing gear is not down and locked. The warning horn may be silenced for this condition and will be reset when the power lever is advanced. The warning horn will also sound if the flaps are extended beyond the approach condition and at least one landing gear is not down and locked; the warning cannot be silenced in this condition.

Electrical power is continually present at all the landing gear position indicator lights when the landing gear circuit breaker is closed. An individual ground circuit for each light will cause the light to illuminate when it senses an electrical ground. The nose landing gear downlock switch is a two-pole switch. One side of the switch provides the ground circuit for the nose landing gear DOWN AND LOCKED light and the other side provides the ground circuit for the landing gear warning horn.

Examination of the aircraft

At the time of publication of this report, the maintenance agency had only conducted a preliminary examination of the aircraft's nose landing gear system, with further, detailed, examination scheduled for a later date. Neither the cause of the nose landing gear's failure to deploy, or the failure of the landing gear indication and warning system to alert the pilots to the unsafe condition had been determined, but the maintenance agency suspected it was related to a failure of the downlock switch on the nose landing gear actuator.

Information from aircraft manufacturer

The aircraft manufacturer identified several possible conditions which could explain why the nose landing gear DOWN AND LOCKED light was illuminated despite the nose landing gear not being fully extended.

The manufacturer confirmed that if the nose landing gear DOWN AND LOCKED light senses an electrical ground, it will illuminate regardless of the nose gear downlock switch position (Figure 3). It was therefore possible that a faulty downlock switch could provide a continual ground to the DOWN AND LOCKED light. Other potential sources of electrical ground could include an electrical short in the wire between the DOWN AND LOCKED light and the downlock switch; inadvertent grounding of post 9 on terminal board 1; incorrect wiring on terminal board 1; or a defect within, or shorted wire from, the annunciator logic module to post 9 on terminal board

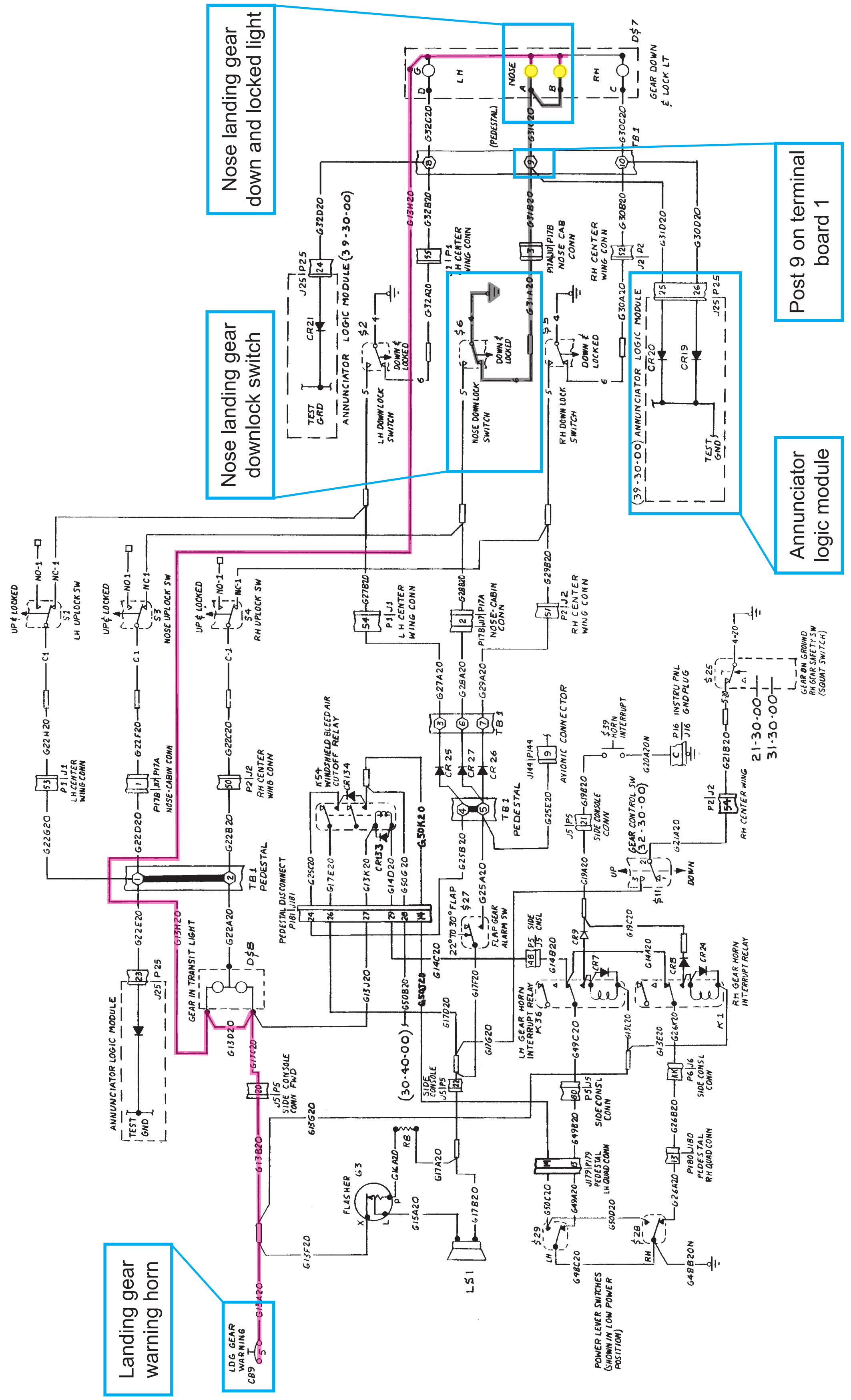


Figure 3
Landing gear and flap warning system from Cessna 441 Wiring Diagram Manual

The manufacturer also indicated that a faulty downlock switch could provide a possible explanation for the failure of the nose landing gear to fully extend. If the nose landing gear downlock switch had failed in the DOWN AND LOCKED position, when the landing gear selector switch was selected to DOWN, an immediate path to ground would exist for the nose landing gear DOWN AND LOCKED lights and also for the hydraulic bypass valve. This would cause the bypass valve to open and allow hydraulic fluid to be routed back to the hydraulic reservoir, returning the system to its 'at rest' position. The main landing gear of the Cessna 441 are assisted by airflow to reach the down and locked position. The nose landing gear is extended against the airflow and may take longer to extend. Therefore, it may be possible for the main landing gear to be driven by hydraulic power to the down and locked position but, upon receipt of an erroneous ground signal from the downlock switch, for hydraulic pressure to be prematurely removed before full extension of the nose landing gear is achieved. A failure of the downclock switch in this manner would also remove the path to ground for the landing gear warning horn, preventing its operation.

Landing gear downlock switches

Cessna Service Letter SNL89-3 *'Main and nose landing gear actuator switch sealing'* dated 17 March 1989 and Cessna Service Bulletin CBQ90-1 *'Landing gear actuators microswitch inspection and sealing procedures'* dated 23 March 1990 indicate that the downlock switch on the Cessna 441 main and nose landing gear can be susceptible to ingress of moisture or other contaminants. This can contribute to switch malfunctions and possible incorrect landing gear indications. EI-DMG was among the aircraft serial numbers identified as requiring the downlock switches to be inspected and sealed.

Discussion

The commander reported that upon selecting the landing gear down during the approach to Prestwick all three landing gear DOWN AND LOCKED lights were illuminated green. There was no activation of the landing gear warning horn and the landing gear IN TRANSIT light was not illuminated. Neither had there been any anomalies noted with the landing gear before or during the flight. The pilots were not therefore aware until landing that anything was amiss with the nose landing gear.

Although acting in a mainly observational capacity, the senior pilot instinctively acted to assist the commander when it became apparent that the nose landing gear was not down and locked. Both pilots reacted promptly to keep the aircraft nose off the runway and to activate the landing gear emergency blow-down system. Their recognition of the need to extend the emergency blow-down system during the landing roll ensured a successful outcome and minimised damage to the aircraft.

The aircraft manufacturer described several possibilities which could create an erroneous ground signal at the nose landing gear DOWN AND LOCKED light causing it to illuminate even though the nose landing gear was not fully extended. It was determined that one of these, a nose landing gear downlock switch failed in the down and locked position, could also account for improper extension of the nose landing gear and absence of the landing gear warning horn activation.

While at the time of publication it had not been determined if the nose landing gear downlock switch on EI-DMG had failed, the Cessna 441 landing gear downlock switches are known to be susceptible to moisture and/or other contaminant ingress. Although downlock switches are required to be sealed, a degraded or damaged seal could provide a path for moisture to enter the switch.

Conclusion

As the aircraft had not been examined by the maintenance agency at the time of publication, it was not possible to determine why the nose landing gear failed to deploy correctly, nor why the pilots were not alerted to this unsafe condition by the landing gear indications and warnings. However, a faulty nose landing gear downlock switch was suspected as a potential cause.

ACCIDENT

Aircraft Type and Registration:	Learjet 45, C-GMCP
No & Type of Engines:	2 Honeywell TFE731-20BR-1B turbofan engines
Year of Manufacture:	2000 (Serial no: 45-126)
Date & Time (UTC):	4 May 2019 at 2159 hrs
Location:	Edinburgh Airport
Type of Flight:	Commercial Air Transport (Non-Revenue)
Persons on Board:	Crew - 2 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to nose landing gear leg and its support and actuating mechanism
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	12,920 hours (of which 2,669 were on type) Last 90 days - 152 hours Last 28 days - 57 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The nose landing gear leg collapsed aft during pushback which was most likely caused by inadvertent brake application.

History of the flight

The flight crew started both engines at the gate. The aircraft was then pushed back using a TLD 150 Max tug[1]. As the aircraft was being turned to line up on the taxiway the nose landing gear (NLG) suddenly collapsed aft and the aircraft came to rest (Figure 1). During the pushback the co-pilot had been carrying out checks and had started adjusting the position of his rudder pedals. He was bringing the pedals aft and he said there was a possibility he might have tapped the brakes but he was not aware of having done so.

Aircraft examination

The NLG on this aircraft type retracts in the forward direction. The NLG actuator is attached to the front of the nose leg at a bracket. This bracket had failed allowing the NLG to collapse aft. The bracket was examined at a metallurgical lab which revealed that it had failed due to overload. There was no evidence of material defects or fatigue.

Footnote

[1] The heaviest aircraft this tug can handle is a Boeing 757.

Figure 1
C-GMCP nose gear collapse

The aircraft manufacturer examined photographs of the structural damage to the NLG bay and stated that this damage and the damage to the bracket was similar to the damage that occurred to a Learjet 45 (MSN 2129) at their production facility, which occurred during pushback with brake application. The manufacturer stated that it was also aware of two in-service events (Learjet 45 MSN 181 and Learjet 45 MSN 202) in which brake application during pushback resulted in the same rearward NLG collapse as in this accident.

Conclusion

The NLG collapse on aircraft C-GMCP was most likely caused by inadvertent brake application during pushback.

ACCIDENT

Aircraft Type and Registration:	Enstrom 280FX Shark, G-WPKR
No & Type of Engines:	1 Lycoming HIO-360-F1AD piston engine
Year of Manufacture:	1986 (Serial no: 2012)
Date & Time (UTC):	27 July 2019 at 1330 hrs
Location:	Tongwynlais, Caerphilly
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Lower fuselage, landing skids and tail rotor damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	440 hours (of which 45 were on type) Last 90 days - 16 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

While conducting a steep approach to a private landing site, the helicopter overshot the helipad, descending into an adjacent quarry. After hovering above the bottom of the quarry, the pilot attempted to climb out at full power, but during the climb ran out of power and the low rotor rpm warning activated. The helicopter narrowly managed to clear the lip of the quarry but landed on a fence and some ballast bags, sustaining extensive damage.

History of the flight

During the descent towards a private landing site near Tongwynlais, Caerphilly the pilot contacted Cardiff Radar and the wind was given as 260/10 kt. He approached the landing site from the east for a steep descent onto the helipad, during which the high rotor rpm warning alarm activated. In his attempt to reduce the rotor rpm the pilot over-corrected and the low rotor speed warning alarm then sounded. The pilot reported that he pushed the cyclic forward to increase the rotor speed but in doing so overshot the helipad pad into the neighbouring quarry, where the helicopter descended to approximately 50 ft above quarry floor.

The pilot hovered the helicopter above the quarry floor to recover and then started to climb out at full power but during the climb it became apparent to him that there was insufficient power available to sustain the climb. The helicopter's climb rate reduced and the low rotor rpm warning sounded. The pilot reported that he was unable to either turn or descend without colliding with the rock face, as the helicopter was close to the side of the quarry.

He continued to apply full power hoping that he could clear the quarry lip and boundary fence, to land on the helipad. As the helicopter came over the lip of the quarry it started to descend and landed on the fence and some bags of ballast. The helicopter came to rest approximately 0.5 m from the quarry edge. Having landed with full power still applied, the engine was over-speeding, so the pilot turned the throttle to idle, disengaged the clutch and turned the fuel off. He was uninjured and was able to exit the helicopter without assistance.

Based on his assessment of the damage sustained by the helicopter, the pilot believes it may have pivoted backwards causing the tail rotor blades to strike the fence and the helicopter to come to rest partly on the fence and partly on the ballast bags (Figure 1).

The pilot subsequently commented that he had misjudged the approach. He considered the approach to be challenging in normal circumstances and particularly so on the day of the accident, because he had not flown G-WPKR for some time as it had been undergoing maintenance. With hindsight, he believes that he should have waited until he could fly G-WPKR with a safety pilot. He also indicated that it might have been preferable to approach the landing site from the north-west as the wind was light and the approach would have been less challenging.

Figure 1

G-WPKR after coming to rest on the lip of the quarry

Discussion

Over-pitching is a phenomenon which occurs when maximum power is achieved from a helicopter's engine and the collective pitch on the main rotor blades continues to be increased. The engine does not have enough power to keep the rotor blades spinning at the required speed, so a reduction in rotor rpm occurs.

Over-pitching can occur following a low rotor rpm situation. As rotor rpm decays, the coning angle of the rotor blades will increase. This causes the rotor disc to become smaller such that the total rotor thrust reduces and the drag on the blades increases. Large blade coning angles prevent the available engine power from increasing the rotor rpm. If the rotor rpm continues to drop it can reach a point where it cannot be restored, even by application of full engine power it; this is known as over-pitching. The reduced rotor rpm and subsequent loss of lift due to reduced airflow over the blades will cause the helicopter to descend when the engine cannot supply the power required.

The recovery actions for over-pitching are to lower the collective lever and simultaneously increase the throttle. Lowering the collective flattens the pitch angle and thereby reduces the drag of the main rotor blades, allowing the engine power to recover and the rotors to spin at full speed. The helicopter will lose height during the recovery.

CAA Safety Sense Leaflet 17 *'Helicopter Airmanship'* emphasises the importance of maintaining rotor rpm at all times together with proficiency at recognising and recovering from low rotor rpm conditions.

Having found himself at the bottom of the quarry, the pilot applied full power to climb out of the quarry and back towards the landing site. With the throttle fully open, he would not have been able to demand any additional power from the engine once he encountered a low rotor rpm situation. Due to his position relative to the quarry wall, the pilot reported that he did not have an option to turn or descend. Unable to execute any of the required recovery actions, it was fortuitous that the helicopter managed to clear the lip of the quarry before it began to descend.

The pilot acknowledged that had he considered aspects such as the challenging nature of the chosen approach to the landing site, the prevailing wind and his recency on type, he may have avoided a situation where it was necessary for the helicopter to climb out of the quarry.

Conclusion

While attempting to recover from overshooting the landing site the helicopter encountered a low rotor rpm situation from which the pilot did not consider it possible to effect the necessary recovery actions. This accident demonstrates the importance of preparation for helicopter operations in to challenging or confined sites. It further highlights the importance of maintaining rotor rpm and proficiency at recognising and recovering from low rotor rpm conditions.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-181 Cherokee Archer II, G-BSIM
No & Type of Engines:	1 Lycoming O-360-A4M piston engine
Year of Manufacture:	1986 (Serial no: 28-8690017)
Date & Time (UTC):	20 August 2019 at 1355 hrs
Location:	Branscombe Airfield, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - None Passengers - None
Nature of Damage:	Substantial
Commander's Licence:	Private Pilot's Licence
Commander's Age:	30 years
Commander's Flying Experience:	136 hours (of which 60 were on type) Last 90 days - 7 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot had lined up on Runway 28 at Branscombe Airfield for a return flight to his home base at RAF Henlow. The reported wind was from 180° at 9 kt, although a windsock, visible in a moving image recording of the takeoff, indicated that it was gusting considerably higher than this. The maximum demonstrated cross wind for the aircraft is 17 kt.

As the takeoff commenced the pilot's directional control of the aircraft was not steady, and the nose of the aircraft lifted at low speed. The aircraft then became briefly airborne and 'weathercocked' in to the wind and towards the airfield boundary hedge. The pitch angle continued to increase, and the aircraft sank back on to its main wheels and its tail contacted the ground, Figure 1.

Figure 1

G-BSIM 'weathercocked' and at a high pitch angle, during the takeoff

The aircraft then became airborne again in a nose-high, low speed condition. The pilot attempted to turn towards the runway and the aircraft 'mushed' on to the boundary hedge. There were no injuries, but the aircraft was substantially damaged, Figure 2.

AAIB comment

Proper technique and practice are vital to achieve a safe cross wind takeoff, especially when the wind speed is close to the demonstrated maximum.

Figure 2

The aircraft's position after impact with the hedge

ACCIDENT

Aircraft Type and Registration:	Quik GT450, G-CGNK
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2010 (Serial no: 8536)
Date & Time (UTC):	19 October 2019 at 0945 hrs
Location:	Beccles Aerodrome, Suffolk
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	Severe damage to airframe and wing
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	2,605 hours (of which 1,000 were on type) Last 90 days - 111 hours Last 28 days - 25 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The accident occurred during a training flight with an instructor, who was pilot flying and seated in the rear, and a passenger in the front. Having flown a go-around due to turbulence experienced on the first approach to Runway 27, the aircraft was re-established on short final for a second approach, which was stable. However, at a height of less than 10 ft above the runway, the aircraft suddenly pitched down and rolled right. The pilot was unable to prevent the aircraft touching down firmly, following which the trike tipped onto its right side and slid for about 20 ft along the runway before coming to a stop. Both occupants had to be helped from the aircraft by airfield staff.

History of the flight

The Quick GT 450 is a two-seat, weight-shift microlight. It is normally flown from the front seat but may be flown from the rear seat when instructing. The front seat position is fitted with a foot operated engine throttle and a hand throttle is positioned to the left of the front seat so that it could be used by both front and rear seat occupants.

The reported weather was from the south-west at about 7 kt, which was within the aircraft's crosswind landing limit. The pilot commented that when the wind had a southerly component at Beccles Aerodrome, nearby buildings and trees could result in turbulence during landing. The pilot also referred to reduced control authority when flying the aircraft from the rear seat that had led to lessons being cancelled due to non favourable wind conditions, but he considered that the weather on the day was suitable.

Following an uneventful training sortie, the aircraft was positioned onto the approach for Runway 27, but a go-around was flown due to turbulence on short final. The second approach was described by the pilot as being stable but, when the aircraft was between 6 and 10 ft above the runway, it experienced "strong sink" that caused the aircraft to rapidly pitch down and roll to the right. The pilot described this as happening very quickly and he was unable to prevent the aircraft from landing firmly. The trike then tipped onto its right side and slid along the runway for about 20 ft before coming to a stop. The pilot and passenger were released from the aircraft with assistance from airfield staff.

The pilot believed that had he been able to quickly increase engine power he may have been able to arrest the rate of descent at touchdown and prevent the accident. However, the position of the hand throttle and need to reposition his hand from the control bar meant that this was unlikely to have been possible in the time available. The pilot suggested that a modification to install a throttle control closer to hand when flying from the rear seat would be advantageous when instructing.

Figure 1

G-CGNK after being recovered from the runway

ACCIDENT

Aircraft Type and Registration:	Zenair CH 601UL Zodiac, G-CDFL
No & Type of Engines:	1 Rotax 912-S piston engine
Year of Manufacture:	2004 (Serial no: PFA 162A-14309)
Date & Time (UTC):	13 July 2019 at 1345 hrs
Location:	Caunton Airfield, Nottinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Substantial airframe damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	264 hours (of which 21 were on type) Last 90 days - 9 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During an overhead join, the pilot became distracted by other traffic in the circuit. While he manoeuvred his aircraft to ensure safe separation with the other aircraft, the airspeed decayed to a point where the left wing dropped and the aircraft entered a steep nose-down turn or incipient spin. The aircraft struck the ground in a level attitude and the pilot was uninjured.

History of the flight

The pilot was carrying out a flight from Netherthorpe Airfield to Caunton Airfield in good weather with a wind of 020° at 6 knots, visibility in excess of 10 km and scattered cloud at 2,400 ft amsl. As the aircraft approached Caunton, the pilot saw an aircraft depart from Runway 03 and turn right, which was not the correct circuit direction for that runaway.

The pilot transmitted his intentions to join overhead for Runway 03 and, although momentarily uncertain as to the circuit direction due to seeing the departing aircraft turn right, he confirmed it was a left-hand circuit for Runway 03. He descended on the dead side and joined the downwind leg, transmitting his circuit-position on the radio. The ground radio operator informed him of possible conflicting traffic, which he eventually saw was on base leg for Runway 03 but flying a right-hand circuit.

The pilot, aware of a possible conflict, watched and assessed where the conflicting aircraft was going. Once it had passed well ahead of his downwind track, he decided to turn onto base leg slightly earlier than normal in order to maintain a safe distance between the two aircraft. Having become unsettled by the events, the pilot continued the turn onto the final approach but did not notice that his airspeed had reduced significantly. The left wing began to drop and he could not correct the situation before the aircraft entered a steep turn or incipient spin to the left. The aircraft struck a hedge before impact with the surface of an adjoining field in virtually a wings level attitude. The pilot was uninjured and able to leave the aircraft unassisted.

The pilot considered that his loss of attention to monitoring the airspeed led to the wing-drop during the turn, and this might have been avoided if the aircraft had been fitted with a stall warning device.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: 0GODF680230091)
Date & Time (UTC):	15 October 2018 at 1245 hrs
Location:	Merry Hill Shopping Centre, Brierley Hill, West Midlands
Type of Flight:	Emergency services operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Destroyed
Commander's Licence:	Not applicable
Commander's Age:	38 years
Commander's Flying Experience:	6 hours (of which 6 were on type) Last 90 days - n/k hours Last 28 days - n/k hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

Whilst hovering at a height of about 50 m over a building, one of the propeller motor electronic speed controllers failed, causing the aircraft to drop vertically and crash into the roof of the building.

History of the flight

The DJI Matrice 210 quadcopter small unmanned aircraft (SUA)[1], with a takeoff mass of 5.83 kg, was being used in support of an operation to target vehicle crime at a shopping centre. All flights were to be conducted over buildings to reduce risk to the public. It was reported that it was drizzling with a light wind. It was considered that the weather did not preclude flight as the aircraft had an IP43[2] rating.

The accident occurred during the second flight of the day. After takeoff the pilot checked the controls and the aircraft responded normally. After about 8 to 10 minutes of flight the

Footnote

1 A SUA is defined by the Air Navigation Order (ANO) 2016 (Amendment 13 March 2019) as '*any unmanned aircraft, other than a balloon or a kite, having a mass of not more than 20 kg without its fuel, but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight*.' This meaning includes traditional remotely controlled model aeroplanes, helicopters or gliders, as well as multirotor '*drones*' and remotely controlled '*toy*' aircraft.

2 Refer to DJI Matrice 210 - EW/G2019/03/12 in this AAIB Bulletin 1/2020 for information on IP43 environmental protection.

pilot brought the aircraft to a hover about 50 m above the roof of a shopping centre building. About one minute later, the aircraft suddenly dropped vertically and crashed into the roof of the building (Figure 1). The pilot had not made any control inputs and it was stated that there had been no warnings on the controller. The aircraft suffered severe damage (Figure 2).

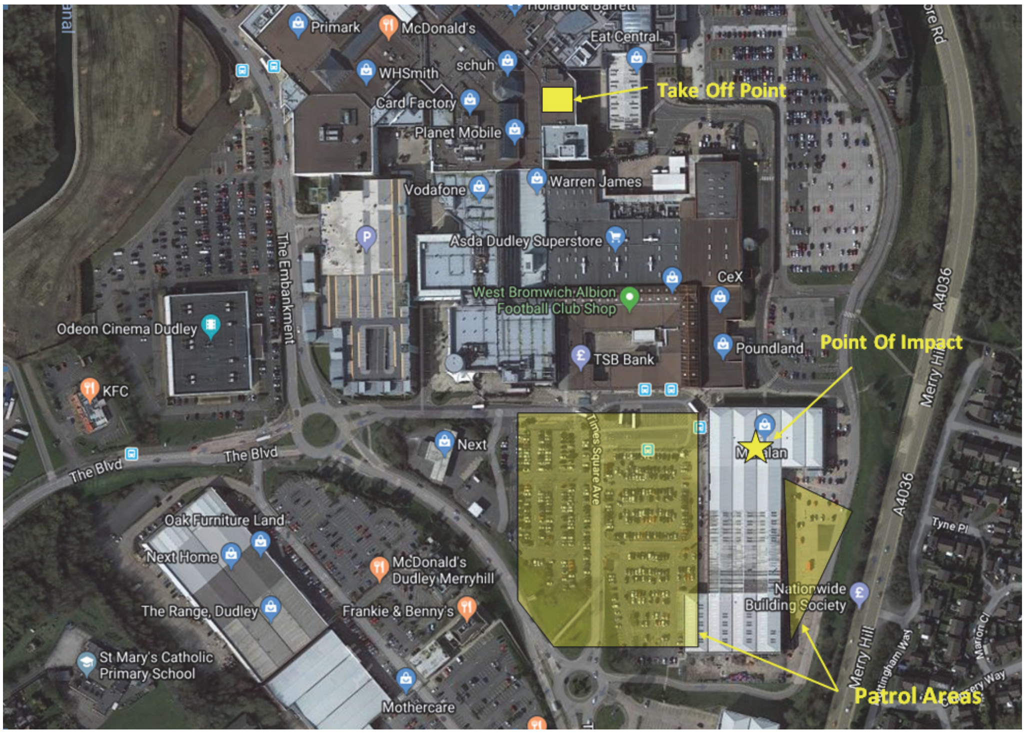


Figure 1

Accident site location

Figure 2

Damage to the aircraft

Recorded information

The recorded data from the aircraft indicated that the batteries were functioning normally and there was 22.8 V and 65% charge remaining on both batteries when it had hit the building. The manufacturer reviewed the data and confirmed that the loss of power which led to a loss of lift and control was caused by failure of the No 4 (right front) motor electronic speed controller.

Refer to report on DJI Matrice 210 - EW/C2019/03/02 in this AAIB Bulletin 1/2020 for information on other accidents involving the DJI Matrice 210 and Safety Recommendations concerning the safe operation of a UAS near to people and congested areas.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: 0GODF860240214)
Date & Time (UTC):	19 January 2019 at 1300 hrs
Location:	Clevedon, Somerset
Type of Flight:	Emergency services operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Destroyed
Commander's Licence:	Not applicable
Commander's Age:	39 years
Commander's Flying Experience:	38 hours (of which 5 were on type) Last 90 days - 4 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The DJI Matrice 210 quadcopter small unmanned aircraft (SUA)[1] was conducting a check flight to test, among other things, a camera for water intrusion following a flight the previous day. With the batteries fully charged the aircraft took off and after a successful systems check was flown to a position 500 m north of the takeoff site where it ascended to a height of 120 m (~390 ft) agl. The visibility was good, wind steady at 16 mph and light drizzle. The aircraft then hovered for approximately five minutes whilst conducting the intended checks before returning towards the takeoff and landing site (TOLS). When the aircraft was about 360 m from the TOLS it fell vertically to the ground, where it landed in an empty field. The aircraft was destroyed on impact (Figure 1).

Recorded data from the aircraft was analysed by the manufacturer who determined that the No 2 (front left) electronic speed controller had failed, likely as a result of water ingress.

Refer to report on DJI Matrice 210 - EW/C2019/03/02 in this AAIB Bulletin 1/2020 for information on other accidents involving the DJI Matrice 210 and Safety Recommendations concerning the safe operation of a UAS near to people and congested areas.

Footnote

1 A SUA is defined by the Air Navigation Order (ANO) 2016 (Amendment 13 March 2019) as '*any unmanned aircraft, other than a balloon or a kite, having a mass of not more than 20 kg without its fuel, but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight*.' This meaning includes traditional remotely controlled model aeroplanes, helicopters or gliders, as well as multirotor '*drones*' and remotely controlled '*toy*' aircraft.

Figure 1
Wreckage of the SUA

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: 0N4DF6L0210036)
Date & Time (UTC):	3 March 2019 at 1125 hrs
Location:	Maidstone Road, Leicester
Type of Flight:	Emergency services operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Destroyed
Commander's Licence:	Other
Commander's Age:	26 years
Commander's Flying Experience:	57 hours (of which 10 were on type) Last 90 days - 13 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The DJI Matrice 210 quadcopter small unmanned aircraft (SUA)[1] was being operated by the Police as part of a training exercise. The pilot had checked the weather as part of his preparations and although rain was forecast, it was considered the conditions were suitable as the aircraft had an IP43[2] rating.

After lift-off and control checks were completed satisfactorily, the aircraft was ascended to 90 m (300 ft) to maintain safe separation from nearby buildings. It was still raining but as the flight progressed the rain eased to drizzle.

After approximately five minutes and whilst the aircraft was being repositioned, it suddenly started to spin rapidly and fell to the ground. The pilot attempted to warn people by shouting "look out, move". It took an estimated five seconds for the aircraft to fall to the ground, where it was destroyed on impact (Figure 1). No person was injured.

Footnote

1 A SUA is defined by the Air Navigation Order (ANO) 2016 (Amendment 13 March 2019) as '*any unmanned aircraft, other than a balloon or a kite, having a mass of not more than 20 kg without its fuel, but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight*.' This meaning includes traditional remotely controlled model aeroplanes, helicopters or gliders, as well as multirotor '*drones*' and remotely controlled '*toy*' aircraft.

2 Refer to DJI Matrice 210 - EW/G2019/03/12 in this AAIB Bulletin 1/2020 for information on IP43 environmental protection.

Examination of the recorded data showed that a MOTOR BLOCKED warning message had been activated and the No 3 (rear left) motor had failed.

Refer to report on DJI Matrice 210 - EW/C2019/03/02 in this AAIB Bulletin 1/2020 for information on other accidents involving the DJI Matrice 210 and Safety Recommendations concerning the safe operation of a UAS near to people and congested areas.

Figure 1

Wreckage of the SUA

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: 0KGDF89DP100GF)
Date & Time (UTC):	18 March 2019 at 2010 hrs
Location:	Lathbury Road, Manchester
Type of Flight:	Emergency services operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Extensive damage
Commander's Licence:	Not applicable
Commander's Age:	Unknown
Commander's Flying Experience:	33 hours (of which 33 were on type) Last 90 days - 17 hours Last 28 days - 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The operator prepared the unmanned air system (UAS) for flight and all indications were normal. Once airborne, at a height of approximately 2 m, the operator released the control stick and there was an immediate high pitch noise from the SUA[1], which "wobbled". The operator increased the power to gain additional height but the SUA made a similar noise, slewing sideways and striking the ground upside down.

The manufacturer reviewed the flight data and concluded that one of the motors failed.

Refer to report on DJI Matrice 210 - EW/C2019/03/02 in this AAIB Bulletin 1/2020 for information on other accidents involving the DJI Matrice 210 and Safety Recommendations concerning the safe operation of a UAS near to people and congested areas.

Footnote

[1] A SUA is defined by the Air Navigation Order (ANO) 2016 (Amendment 13 March 2019) as '*any unmanned aircraft, other than a balloon or a kite, having a mass of not more than 20 kg without its fuel, but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight*.' This meaning includes traditional remotely controlled model aeroplanes, helicopters or gliders, as well as multirotor '*drones*' and remotely controlled '*toy*' aircraft.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 electronic motors
Year of Manufacture:	Unknown (Serial no: 0G0DF5Q0230132)
Date & Time (UTC):	20 April 2019 at 1436 hrs
Location:	Dearne Old Moor, South Yorkshire
Type of Flight:	Emergency services operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Rotor arms and rotor blades damaged
Commander's Licence:	Not applicable
Commander's Age:	46 years
Commander's Flying Experience:	7 hours (of which 7 were on type) Last 90 days - 7 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The DJI Matrice 210 small unmanned aircraft (SUA)[1] was performing a daylight survey exercise in light winds. After the pre-flight checks were completed, the aircraft was ascended to a height of around 5 m (~15 ft) to perform further checks. The pilot commanded small control inputs after which the aircraft became unstable and one of the motor arms broke where it attached to the aircraft. The pilot lost control and the aircraft crashed into the ground. No person was injured.

Subsequent analysis of recorded data from the aircraft identified that the No 2 (front left) and No 3 (rear left) motors had stalled, leading to a loss of lift on the left side of the aircraft. It could not be established whether the motors stalled prior to or after the failure of the motor arm.

Refer to report on DJI Matrice 210 - EW/C2019/03/02 in this AAIB Bulletin 1/2020 for information on other accidents involving the DJI Matrice 210 and Safety Recommendations concerning the safe operation of a UAS near to people and congested areas.

Footnote

[1] A SUA is defined by the Air Navigation Order (ANO) 2016 (Amendment 13 March 2019) as '*any unmanned aircraft, other than a balloon or a kite, having a mass of not more than 20 kg without its fuel, but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight*.' This meaning includes traditional remotely controlled model aeroplanes, helicopters or gliders, as well as multirotor '*drones*' and remotely controlled '*toy*' aircraft.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: OGODF6C0230006)
Date & Time (UTC):	11 June 2019 at 1458 hrs
Location:	Hammond Court, Norwich, Norfolk
Type of Flight:	Emergency services operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Motor arms, body, battery casing and cameras damaged
Commander's Licence:	Not applicable
Commander's Age:	43 years
Commander's Flying Experience:	100 hours (of which 100 were on type) Last 90 days - 6 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The DJI Matrice 210 quadcopter small unmanned aircraft (SUA) [1] was being operated by the Police over a congested[2] area. It was fitted with optical and a thermal imaging cameras. The pilot had checked the weather and although very light rain was forecast, it was considered that the conditions were suitable as they were within the manufacturer's parameters[3].

The takeoff and ascent to the operating height of 80 m (~260 ft) agl were normal and the aircraft remained static and stable for nearly 10 minutes; the battery level was 68%. The cameras then started to rotate and a 'motor overload' message was displayed. The aircraft then began to spin anticlockwise whilst rapidly descending. It subsequently crashed in an open space and was destroyed on impact. There was no damage to persons or property.

The pilot considered the accident was caused by either a motor or ESC failure and commented that the extra weight and position of the thermal camera away from the centre

Footnote

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2 The ANO defined a congested area " in relation to a city, town or settlement, means any area which is substantially used for residential, industrial, commercial or recreational purposes".

3 Refer to report EW/G2019/03/12 for information on the manufacturers limitations of operation during rainfall.

of gravity may have caused extra load on the propulsion system. He added that he thought restrictions on operating a UAS in congested areas should be reintroduced as he had one second's warning of the failure before control of the aircraft was lost.

Refer to report on DJI Matrice 210 - EW/C2019/03/02 in this AAIB Bulletin 1/2020 for information on other accidents involving the DJI Matrice 210 and Safety Recommendations concerning the safe operation of a UAS near to people and congested areas.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 DJI 3515 Electric motors
Year of Manufacture:	2017 (Serial no: 0G0DF6G0230142)
Date & Time (UTC):	28 July 2019 at 0300 hrs
Location:	Bury Road, Chedburgh, Suffolk
Type of Flight:	Emergency services operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Destroyed
Commander's Licence:	Not Applicable
Commander's Age:	55 years
Commander's Flying Experience:	23 hours (of which 18 were on type) Last 90 days - 3 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The DJI Matrice 210 quadcopter small unmanned aircraft (SUA) [1] was being operated at night over a small industrial estate in light rain. About 20 minutes into the flight the aircraft dropped suddenly without warning from a height of 70 m (230 ft). The aircraft hit the corrugated roof of a building and was destroyed; there was some impact damage to the roof.

The remains of the aircraft were sent to the manufacturer for examination. They determined that the accident was caused by a propulsion error of the No 2 motor but were unable to determine the reason for it.

Refer to report on DJI Matrice 210 - EW/G2019/03/12 in this AAIB Bulletin 1/2020 for information on other accidents involving the DJI Matrice 210 and Safety Recommendations concerning the safe operation of a UAS near to people and congested areas.

Footnote

[1] A SUA is defined by the Air Navigation Order (ANO) 2016 (Amendment 13 March 2019) as '*any unmanned aircraft, other than a balloon or a kite, having a mass of not more than 20 kg without its fuel, but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight*.' This meaning includes traditional remotely controlled model aeroplanes, helicopters or gliders, as well as multirotor '*drones*' and remotely controlled '*toy*' aircraft.

Miscellaneous

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

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

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

Published June 2014.

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

Published September 2014.

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

Published July 2015.

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

Published August 2015.

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

Published October 2015.

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

Published March 2016.

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

Published September 2016.

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

Published March 2017.

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

Published March 2018.

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

Published November 2018.

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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 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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