Air Accidents Investigation Branch

AAIB Bulletin 11/2019

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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:	Luton LA4A Minor, G-AWMN
No & Type of Engines:	1 Volkswagen 1800 piston engine
Year of Manufacture:	1987 (Serial no: PFA 827)
Date & Time (UTC):	3 February 2019 at 1145 hrs
Location:	Near Belchamp Walter, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	UK Private Pilot's Licence
Commander's Age:	55
Commander's Flying Experience:	317 hours (of which 150 were on type) Last 90 days - n/k Last 28 days - n/k
Information Source:	AAIB Field Investigation

Synopsis

The pilot was conducting a test flight in G-AWMN to renew the aircraft's Permit to Fly. Whilst climbing away from the runway, the aircraft was observed to bank to the right and then descend steeply to the ground.

It was not possible to definitively determine the cause of the accident. It is possible that the engine stopped producing power due to carburettor icing which led to a stall from which the aircraft was not able to recover. The investigation also identified that, despite wire locking being present, the barrel from an aileron flight control turnbuckle was missing, but it could not be determined if this had been missing prior to the accident.

History of the flight

The pilot began operating G-AWMN from Waits Farm, near Belchamp Walter, Essex in July 2012. In recent months he had been completing test flights in G-AWMN to renew the aircraft's Permit to Fly following a period when it had not flown. It was reported that he had completed one test flight in December 2018 and a second in January 2019.

On the day of the accident the pilot arrived at the airfield at approximately 1030 hrs. He spoke to the airfield owner and another pilot. He told the other pilot that he did not intend to take off until approximately 1200 hrs. Before he took off in his own aircraft at 1100 hrs, the other pilot conducted a radio check with the pilot of G-AWMN. The pilot of G-AWMN did not mention what he intended to do on his flight to either person and no documents were found describing what tests the pilot intended to conduct.

No one witnessed G-AWMN taking off and it is not known exactly when the aircraft was started up. The airfield owner heard G-AWMN start up but was not sure exactly what time this occurred, but he was informed of the accident approximately 10 – 15 minutes later.

Figure 1

Waits Farm showing the accident and witness locations

A witness (Figure 1 – Witness 1), working in a nearby garden, thought he heard an aircraft start up, taxi and then take off. He first saw the aircraft climbing away from the airfield heading north-east and described it as “travelling quite slowly.” He then saw the aircraft bank sharply to the right and descend, at an approximate 45° angle, to the ground. He did not see the aircraft hit the ground, but he heard the impact. He recalled that he could hear the engine when the aircraft was climbing away from the airfield but did not remember hearing it after the aircraft banked right. During the period that he was able to hear the engine he did not remember it sounding unusual. He ran towards the accident site but, approximately three minutes after the impact and before he could reach the scene, the aircraft caught fire.

A couple walking in a nearby field (Figure 1 – Witness 2) heard an aircraft flying towards them from the airfield. When they looked in that direction, they saw the aircraft banked to one side and then descend to the ground. They heard, but did not see, the impact. They also ran to the scene but did not reach the aircraft before it caught fire.

Another couple who were working in a nearby garden heard the aircraft but did not see it. Their attention was drawn to it when they heard the engine noise suddenly stop. A few seconds later they heard a "dense thud" which they thought sounded like an aircraft crash.

The accident occurred at approximately 1145 hrs. The fire service, ambulance, police and air ambulance attended the scene promptly and the remaining fire was extinguished. The pilot was fatally injured.

Several other people reported seeing or hearing aircraft in the surrounding area which appeared to be having engine problems. However, the timings and descriptions suggest these were unlikely to be the accident aircraft.

Meteorology

The day of the accident was cold with a clear sky and light south-westerly wind. The nearest airfield that records weather reports is Stansted which is 17 nm south-west of the accident site. At 1150 hrs, Stansted recorded the surface wind as 220° at 7 kt, visibility greater than 10 km, no discernible cloud, temperature 4°C and dew point -2°C.

The pilot who took off from Waits Farm at 1100 hrs reported that, when he started his engine, the surface wind was west south-westerly at approximately 7 – 8 kt, the temperature was - 1°C and the grass was wet with melting frost.

Using the chart published in the CAA Safety Sense Leaflet 14 – '*Piston Engine Icing'*[1] the temperature and dew point is indicative of a relative humidity of 60 – 70%. The chart suggests that with these conditions there is a moderate risk of carburettor icing at cruise power and a serious risk at descent power. However, the leaflet highlights that with wet ground and light winds the local humidity could be higher and further increase the risk of icing.

Airfield information

Waits Farm (Figure 2) has a small privately-owned airfield with hangar space for a few light aircraft. The owner keeps his own aircraft there and rents hangar space and use of the airfield to a few other pilots. The airfield has a bulk fuel tank to store aviation fuel (100LL).

There is a single taxiway leading to the eastern end of a 500 m grass runway orientated approximately 07/25. Runway 07 has a slight up-slope. A prominent windsock is located to the north of the runway.

Aircraft normally take off and land into wind. The surface wind on the day of the accident was south-westerly which would suggest Runway 25 would be the preferred runway for takeoff and landing. The start of Runway 25 is closer to the hangar so requires less taxiing and no need to backtrack the runway. The aircraft that took off before the accident and

Footnote

[1] http://publicapps.caa.co.uk/docs/33/20130121SSL14.pdf [accessed 8 August 2019].

returned later in the day used Runway 25. As no one witnessed G-AWMN taking off, it is not known which runway was used. However, the aircraft was seen climbing away from Runway 07.

Figure 2
Waits Farm Airfield

The airfield owner reported that he inspected the runway after the accident and, despite the soft ground, found no tyre marks in the first third of Runway 07. This suggests that no aircraft had used this part of the runway recently.

Personnel information

The pilot held a UK Private Pilot's Licence with a valid Single Engine Piston rating. This licence allowed the pilot to operate non-EASA aircraft, such as G-AWMN, in UK airspace.

His logbook records that he had a total of 317 hours of flying experience, of which 150 hours were in G-AWMN.

It records that, on 6 July 2015, he had an engine failure in G-AWMN which resulted in a forced landing in a field. The logbook suggests that the aircraft flew again on 15 July 2015 and completed 18.5 hours of flying between July 2015 and October 2017. The last flight in G-AWNM was recorded on 17 October 2017.

There were no flights recorded between October 2017 and July 2018. In July and August 2018, the pilot completed two training flights in a Piper Warrior aircraft. The last entry in the pilot's logbook was a licence proficiency check (LPC) on 25 August 2018. The examiner who conducted his LPC commented that he was a safe and competent pilot.

Witnesses reported that the pilot flew G-AWMN on two occasions in the months before the accident flight, once in December 2018 and once in January 2019. No record was found of these flights. It is therefore not known exactly how many flying hours the pilot had completed in the last 28 or 90 days.

Medical and pathological information

The pilot had 'self-declared' that he was medically fit to fly on 17 September 2018; this declaration was valid at the time of the accident. Self-declaration allows the pilot to fly non-EASA aircraft, such as G-AWMN. The pilot had previously held a CAA class 2 medical but, this expired on 20 October 2018.

The post-mortem report stated that the cause of death was *'multiple traumatic injuries.'* There was evidence of '*significant bony trauma about both knees'* and of a *'significant head injury.'* The report found there was a *'small amount of carbon pigmentation within the airways suggesting there may have been some respiratory effort at the time of the onset of the fire.'* However, the report stated that this was '*most likely weak and not prolonged.'*

The post-mortem found no evidence of any significant underlying natural pathology or of an acute pathological event.

No drugs or alcohol were detected in the post-mortem blood or urine samples.

Accident site

The aircraft crashed in a harvested arable field close to the extended centreline of the landing strip from which it had departed (Figure 3). The surface of the field was bare earth which was extremely soft and wet. Activity of emergency services had disrupted the surface around the wreckage and obscured some impact marks.

Figure 3
Accident site

The engine was partly buried by the force of the impact, but its final orientation was consistent with the aircraft having descended steeply nose-down with the left wing hitting the ground just before the right wing. An intense post-impact fire had destroyed almost all the wooden structure, leaving only the extreme outboard section of the right wing and aileron unburnt. There was no evidence of impact damage in these unburnt areas. Charred remains of curved wooden members indicated that the tail-plane, rudder and elevators were present at the site but nothing identifiable as the wooden structure of the fuselage or of the left wing survived the fire. Numerous metallic components did survive including the highly disrupted fuel tank and various steel struts, brackets, hinges, bracing wires and control cables. The aluminium alloy cowling panels were severely disrupted and fire-damaged; a number of molten lumps of aluminium alloy were found at the scene.

One lightly damaged propeller blade protruded visibly upwards from the engine to which it was still attached, whereas the other blade, recovered from underneath the engine, had broken off at the root.

The accident site was compact with no evidence of any visible wreckage trail of items from, or parts of, the aircraft.

Recorded information

No radar returns for G-AWMN were recorded, either by civilian or military installations, covering the area of Waits Farm and neither were any radio transmissions from G-AWMN recorded.

A mobile phone was found at the accident site and a tablet device was recovered from the pilot's car. The phone was extensively damaged and, although communication records were obtained which showed the cell towers that the phone had connected to, the data was not of sufficient fidelity to determine the track of the accident flight. Examination of the tablet identified that typical aviation applications were installed but none provided any insight into the planning of the accident flight.

Aircraft information

General

The Luton LA4A Minor was designed in 1958 as an update of a legacy 1930's ultra-light aircraft. It was intended for amateur construction using commercially available drawings. An aircraft owner, from the design drawings, has responsibility for the building of an aircraft, and the Light Aircraft Association (LAA), through its inspectors and LAA Engineering, can provide guidance and processes to help the owner ensure that the aircraft build meets the minimum airworthiness requirements appropriate to the type.

Figure 4

G-AWMN before the accident (used with permission)

The LA4A has a largely wooden structure with fabric covering. It has a high ‘parasol’ type wing arrangement, the wing structure being mounted on a system of cable-braced, streamlined, metal tubular struts, well above the fuselage and its single seat open cockpit (Figure 5). The bracing cables incorporate turnbuckles to enable the wing rigging to be adjusted.

Figure 5

G-AWMN cockpit (used with permission)

Flying controls

The flying controls are conventional, with cables operating the control surfaces (rudder, elevators and ailerons). For each flight control, a number of turnbuckles are used to adjust rigging and alter cable tensions. Each turnbuckle (Figure 6) consists of a cylindrical barrel, which incorporates left and right hand threaded bores in opposite ends, and a hole bored at mid-length.

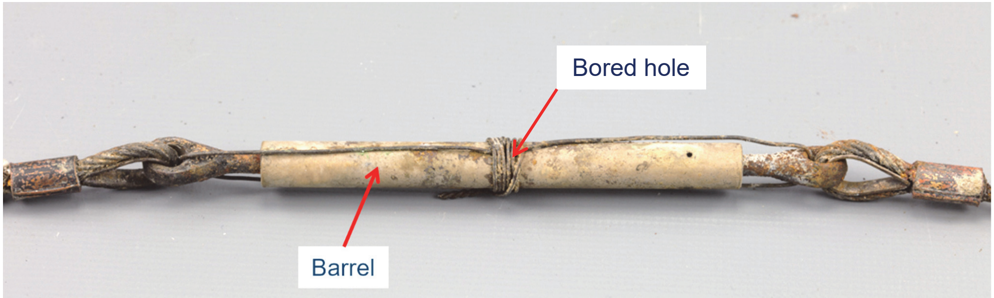

Figure 6

A typical turnbuckle recovered from G-AWMN

Threaded eye-bolts, each pair having respective left hand and right hand threaded portions, are screwed into the barrel ends. Rotating a barrel enables cable tension to be increased or decreased, depending on the direction of rotation, without twisting the eye-bolts or cables.

The cable ends pass through holes in each eye-bolt and are bent backwards around a protective metal member and secured to the parent cable by a swaged collar. Once adjusted for tension, the assembly's security is maintained by wire locking the eye-bolts to one another and to the barrel. This is achieved by passing locking wire through the holes in each of the eye-bolt ends. Rotation relative to the barrel is prevented by the wire being passed through the bored hole and the ends being twisted together. On all turnbuckles on G-AWMN the wire locking ends were repeatedly wrapped around the centre of the barrel.

As a result of its non-proprietary nature, considerable differences in detailed design and component selection can be found in examples of the LA4A type. Hence no surviving example can fully serve as a pattern for details of the pre-accident configuration of G-AWMN. In particular, the locations of the turnbuckles, so far as could be determined from the wreckage of G-AWMN, did not entirely replicate the locations shown on the only flying control cable drawing available.

Engine

The LA4A type is capable of being powered by a range of engine types. G-AWMN utilised a 1,766 cc horizontally opposed four-cylinder air cooled engine of the type used to power Volkswagen cars and camper vans. The engine drives a two-bladed propeller manufactured from a single continuous length of laminated timber, bolted to the drive flange on the forward end of the engine crankshaft.

The ignition system consisted of two 'Skycraft' ignition modules mounted on the rear of the installed engine. Carburation was by means of a single Zenith-Stromberg automotive carburettor. An air box, incorporating a controllable intake flap, was positioned upstream of the carburettor. The engine log book recorded that a modified air box was installed on or before 6 November 2018 following the installation of a different fuel pump whose geometry prevented fitment of the previous air box. The flap enabled direct ambient air delivery to the carburettor to take place but, when closed, caused heated air to be drawn into the air box via a section of hose from a single muffler surrounding one of the four individual exhaust pipes. This provided heated air to remove ice from the carburettor intake. The flap was controlled by a lever in the cockpit.

Aircraft performance

There are no published manuals describing the handling characteristic or performance of the LA4A and, as the aircraft are handmade from drawings, each is slightly different. As no other pilot regularly flew this aircraft, it is not possible to know the exact handling characteristic of G-AWMN.

However, pilots who have flown other Luton LA4A Minors describe them as having benign stall characteristics. There is no tendency to drop a wing if the aircraft is stalled in balance. Due to the high drag, the aircraft does require a steep nose-down attitude to maintain speed in a glide.

The CAA publish Handling Sense Leaflet 02 - '*Stall/Spin Awareness*'[2] which highlights the hazard of stalling following an engine failure shortly after takeoff or during a go-around. The leaflet states:

> *'One of the most critical phases of flight is just after take-off or when going around from an approach to land. At low level, at relatively low speed and with a high nose attitude, an engine failure will lead to a rapid deceleration and increasing angle of attack. To avoid any possibility of stalling and spinning, the pilot must promptly and positively select a lower nose attitude, to achieve and maintain a safe gliding speed. If the aircraft has already decelerated below the recommended gliding speed, this may initially require an attitude lower than normal.'*

History of G-AWMN

Construction of the original aircraft took place over an extended period; the maiden flight having taken place in 1987. Since then, according to its maintenance records, it had flown approximately 330 hours and had been owned by four different people. The accident pilot acquired the aircraft in 2007 after it had been damaged in a previous accident in Ireland[3]. He rebuilt the aircraft and first flew it on 4 December 2011.

Footnote

[2] https://publicapps.caa.co.uk/docs/33/ga_srg_09webHSL02.pdf [accessed 8 August 2019].

[3] The accident on 29 July 2007 was investigated by the Air Accidents Investigation Unit of Ireland. The report is available at http://www.aaiu.ie/sites/default/files/upload/general/9720-0.PDF [accessed 8 August 2019].

On 6 July 2015, the aircraft suffered an engine failure in flight and the pilot landed the aircraft in a field near Wickham St. Paul. Documentation submitted to the LAA states that the aircraft did not fly again until after the Certificate of Clearance was issued by the LAA on 30 November 2018. Similarly, neither the aircraft nor engine log books contain any reference to any flights after 6 July 2015. However, the pilot's logbook recorded that the aircraft flew again nine days after the engine failure and completed 18.5 hours of flying between July 2015 and October 2017.

The documentation submitted to the LAA shows that a programme of work was completed on the aircraft on 8 November 2018. A worksheet of that date shows that the wings had been removed for road transport and subsequently refitted, with fasteners checked and replaced as necessary. The aileron cables were inspected, reconnected, wire locked, and checked for correct operation and full movement. The wing strut bracing tension was adjusted and the turnbuckles wire locked. All control hinges were inspected and lubricated with full movement checked. The wheels were removed, the tyres inspected, and the brakes cleaned and adjusted. All of these were signed for by an engineer.

A final recorded action was a dual inspection of control cables which was signed for by the engineer and countersigned by the owner/pilot.

An application for Renewal (revalidation) of the Permit to Fly was signed by the owner/pilot on 10 November 2018 and received by the LAA on 13 November 2018.

On 30 November 2018, the LAA issued a Certificate of Clearance, valid until 28 February 2019. This was an authorisation to carry out test flights with the alternative fuel pump and air box fitted. The authorisation limited flight to within a 35 nm radius of Waits Farm and stipulated that the pilot conducting the test must have a minimum total experience of 100 hours, including 10 hours on type, and that they must be in current flying practice.

Aircraft examination

General

Due to the absence of the majority of the aircraft, the examination was necessarily limited in scope and almost entirely restricted to metallic components, in particular the power unit and the flying controls.

Engine

An external examination of the power unit indicated that the propeller remained correctly bolted to the drive flange on the forward end of the crankshaft. One blade was only lightly damaged whilst the other blade, recovered from underneath the engine, had failed at the root. The fracture was consistent with a backward bending load which was not the failure orientation to be expected from a propeller blade impact occurring with the engine delivering power. Although neither propeller blade showed any evidence of the chordwise scoring which could be expected with an engine delivering power, the impact and fire damage to the outer section of the broken blade precluded a reliable assessment of power at impact as this is the area where such evidence is normally most obvious.

The body of the engine-mounted fuel pump had broken away from the engine crankcase as a result of the impact. Part of the internal rocking lever remained attached to the surviving portion of the pump body adjacent to the mounting flange. The remainder of the body of the unit was not only separated, but a portion of it was not identified amongst the recovered items. The portion incorporating the main spring and diaphragm was nonetheless identified and dismantled. Both the spring and diaphragm were examined and found to be intact and capable of functioning correctly. As a result of the post-impact fire, a number of other parts of the aircraft fuel system could not be identified.

The two electronic ignition units were removed and subjected to rig testing at the premises of the supplier. Following rectification of a small impact damage feature, both units were mounted in the test rig and found to operate satisfactorily.

The carburettor was severely heat damaged and its examination revealed no useful evidence.

Strip examination of the engine unit involved removing the cylinder heads from both pairs or banks of cylinders, removing all four cylinders and splitting the crankcase into its two halves. All internal revolving and reciprocating parts of the engine were then examined. The internal condition of the engine was good, no defects were found amongst those components and all bearings, gears and moving surfaces showed no evidence of seizure or a lack of lubrication.

Examination of the combustion chambers and the piston crowns revealed an absence of the characteristic brown colouring normally found in aviation piston engine types which have operated for periods with the correct air/fuel mixture. Instead, all combustion chambers and piston crowns within all cylinders exhibited a distinctive black finish. The combustion chamber colouring was compared with that of a Volkswagen-derived aero-engine recently removed from an aircraft which was known to have had high power at impact. The normal characteristic brown colouring, mentioned previously, was present in the combustion chambers and on the piston crowns of this other engine.

Flying controls

The cables for the flying controls were severely disordered and only two of the many pulleys had survived the fire. The rudder control cables were identified as being complete from the rudder bar in the cockpit to the rudder bell crank, which is normally attached directly to the rudder. It was noted, however, that a turnbuckle barrel had fractured at mid-length (across the bored hole) but the turnbuckle remained capable of transmitting force as a result of the wire locking remaining intact (Figure 7).

The rear elevator operating bell crank was identified along with operating cables and turnbuckles. These were found to be almost entirely intact from the pilot's control column to the rear bell crank with the exception of a turnbuckle barrel that linked the control column to the elevator. The barrel had fractured as a result of bending and was severely affected by heat; all features which are consistent with impact and the effects of the post-impact fire.

Figure 7

Fractured barrel in a rudder flying control turnbuckle

Examination of the roll control system revealed that, for the turnbuckle on the aileron balance cable, both eye-bolts and most of the locking wire was present but the barrel was absent (Figure 8).

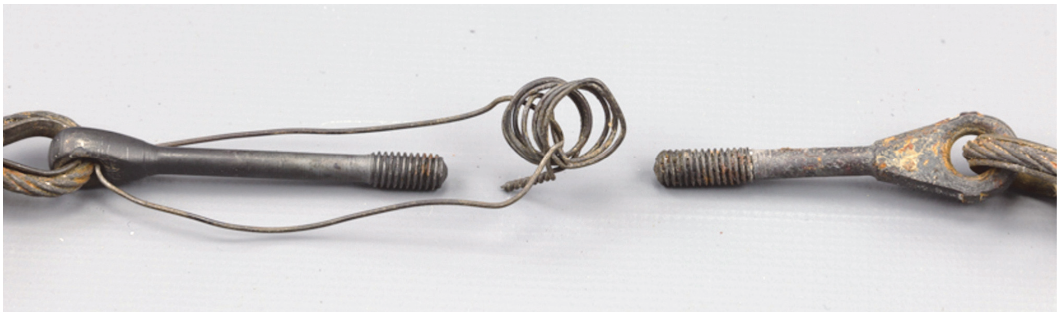

Figure 8

Aileron balance turnbuckle (barrel missing)

Neither threaded eye-bolt showed evidence of significant oxidation, and thus appear not to have been overheated. Lubricating grease was found on both threads but there were no traces of any metal from the barrel. Both corresponding cable ends appeared correctly swaged. The locking wire of one eye-bolt to the missing barrel was present and attached to the eye-bolt. It appeared to have been correctly routed through the hole in the now-absent barrel with multiple coils and the wire end visible where the mid-length bored hole in the barrel would have been. The portion of locking wire extending from the central hole to the other eye-bolt and back was absent. Both wire ends showed the characteristics of tensile failures and both failures were in the area where the mid-length hole in the barrel would have been.

Survivability

The cockpit area was substantially damaged in the impact and subsequent fire leaving no survival space. The accident was not survivable.

Analysis

Purpose of the flight

The pilot was conducting a test flight to renew the aircraft's Permit to Fly. The LAA requires pilots conducting test flights to be in current flying practice and have a minimum of 100 hours total time including 10 hours on type. The accident pilot had significantly more experience than these minimum hours, but it is not known how much recent flying he had completed. His logbook records that he last flew on 25 August 2018 in a different aircraft type. However, witnesses reported he flew G-AWMN in December 2018 and January 2019 although no records were found of these flights.

The aircraft had suffered an engine failure in July 2015. There was a discrepancy in the paperwork regarding whether the aircraft had flown between this engine failure and the recent test flights. The pilot's flying logbook suggested the aircraft had been flown whereas the aircraft log book, engine log book and paperwork submitted to the LAA suggested it had not. This discrepancy was not resolved.

It is not known what specific tests the pilot intended to conduct during the accident flight.

Accident Flight – direction of takeoff

No one witnessed the aircraft taking off from Waits Farm, so it is not known exactly what time the aircraft took off or in which direction. The aircraft was not recorded on radar and no radio transmissions were recorded, so it is not known where it flew after takeoff. The airfield owner heard the aircraft's engine start and remembered being informed of the accident 10 – 15 minutes later which implies the aircraft could not have flown far from the airfield.

The witnesses who saw the accident reported seeing the aircraft climbing away from Runway 07 and this could infer that the aircraft had just taken off from that runway. However, this would mean that the aircraft would have needed a longer takeoff run in order to depart with a tailwind on an up-slope. There were no tyre marks evident on the first third of Runway 07 and therefore, it seems unlikely that the pilot took off in this direction.

Conversely, if the aircraft took off from Runway 25, to arrive where it was seen by the witnesses, it would have needed to fly a 180° turn, return to approach the airfield in the opposite direction, and then climb away. This would be an unusual manoeuvre but one that the pilot may have elected to follow if he had had an aircraft problem and decided to attempt a tailwind landing onto Runway 07. From such an approach, it is possible that the tailwind caused the pilot to go-around and this was when the aircraft was first seen by the witnesses.

Accident Flight – loss of control

Eye witnesses report seeing the aircraft bank to the right then descend in a steep nose-down attitude before impacting the ground and ear witnesses report hearing the engine noise stop before the impact. The investigation found two possible explanations for these observations; either carburettor icing causing the engine to stop producing power or a flight control issue. Both of these possibilities are discussed further below.

Flying controls

The flying control cable system, although disrupted and with most of its pulleys destroyed by fire, appeared to have been intact before the accident with the possible exception of the turnbuckle barrel on the aileron balance cable. The process and sequence of separation of the eye-bolts from the turnbuckle barrel, the absence of the latter and the absence of a section of locking wire could not be explained.

The condition of the two eye-bolts, and in particular the absence of the significant oxidation seen on components of other turnbuckles known to have been severely fire affected, was not consistent with this assembly having been excessively heated in the post-impact fire. The presence of lubricant grease on the threads of both eye-bolts also indicated that the assembly had not been greatly affected by the fire. Therefore, it is unlikely that the turnbuckle barrel had melted and was thus absent.

One other turnbuckle barrel in the aircraft had failed at the mid-point locking wire hole. However, had this occurred on the barrel in question, it would have required both fractured ends of the broken barrel to be individually unscrewed from the eye-bolts. An absence of any material from the barrel in the eye-bolt threads indicates that it was unlikely that both eye-bolts had been pulled out of the threads in the barrel by tensile forces. In addition, no mechanism was identified that could leave most of the locking wire intact but result in both eye-bolts becoming unscrewed.

The reason for the loss of continuity at that location was not determined, but the investigation did consider the effect that such a loss of continuity might have had on aircraft handling.

If this turnbuckle barrel was missing prior to flight or failed in flight, it is possible that the aileron circuit would still have functioned whilst held together by the locking wire. However, once the locking wire failed, the pilot would have been left with very limited roll control, although directional control could have been maintained through use of the rudder. Had such a flying control failure occurred, it could support the theory that the pilot tried to return to the airfield. However, with limited roll control and with a tailwind, maintaining runway alignment would have been challenging and might have necessitated a go-around. The presence of such a flying control disconnect could have either directly caused a loss of control or distracted the pilot from the monitoring of his airspeed which could then have resulted in the aircraft stalling.

Engine

The condition of the propeller was consistent with an absence of power at impact. No evidence of pre-impact mechanical failure was identified in the engine. The combustion chambers and piston crowns lacked the brown coating generally associated with petroleum-fuelled piston engines operating normally. Examination of another Volkswagen-derived aero-engine had confirmed that such brown colouring was to be expected in the combustion spaces of a correctly functioning engine. Instead, all G-AWMN's piston crowns exhibited a black finish as normally found in engines which have operated for a period with an over-rich mixture. Such over-rich operation can result from a period of running with significant and increasing carburettor ice formation and which will, eventually, cause the engine to stop producing power. The low temperature and recent clearance of ground frost at the airfield at the time of the accident indicates that conditions conducive to carburettor icing near ground level would have been present.

It is possible that the pilot experienced a rough running engine due to carburettor icing. If the aircraft had taken off from Runway 25 this might be a reason for the pilot to return to the airfield for a landing on Runway 07. However, with the tailwind mentioned earlier, this may have necessitated a go-around during which the engine stopped producing power. It is also possible that, again due to carburettor icing, the engine lost power following a takeoff from Runway 07. Following either scenario, if the pilot attempted to make a forced landing in a field, it would be natural to reduce engine power, and this may explain why witnesses heard the engine noise stop.

It would normally be possible to glide an aircraft into a field if the engine fails, however, this can be particularly challenging when at low speed and with a high nose attitude on a go-around. Owners of other Luton Minors reported that the aircraft requires a steep nose-down attitude in a glide to maintain a safe airspeed. It is possible that the pilot was not able to react quickly enough to the loss of engine power and the aircraft then stalled. It is unlikely that it would have been possible to recover from such a stall at this low height. A loss of engine power due to carburettor icing followed by a stall would be consistent with the witness observations of the aircraft.

Conclusion

The aircraft was seen climbing away from Runway 07 at Waits Farm. It could not be determined if the aircraft had just taken off or if it was going around from an approach to land on Runway 07.

The aircraft was observed to bank to the right and then descend rapidly to the ground which it struck at a steep nose-down angle. The structure was almost totally destroyed by a post-impact fire. The accident was not survivable.

The investigation found that the engine may have stopped producing power due to carburettor icing. It is possible that the pilot was not able to lower the nose of the aircraft quickly enough to maintain adequate airspeed and the aircraft then stalled at a low height from which recovery was unlikely.

The investigation also identified that a turnbuckle barrel was missing from the aileron balance cable. It could not be determined how this component came to be absent nor whether it was missing prior to the accident.

Published 19 September 2019.

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:	1) Airbus A320, OE-IHD 2) Saab-Scania SS340B, G-LGNK
No & Type of Engines:	1) 2 International Aero Engines IAE 2500 S 2) 2 General Electric Co CT7-9B turboprop engines
Year of Manufacture:	1) 2008 (Serial no: 3270) 2) 1990 (Serial no: 340B-185)
Date & Time (UTC):	12 February 2019 at 1900 hrs
Location:	London Stansted Airport
Type of Flight:	1) Commercial Air Transport (Passenger) 2) Commercial Air Transport (Passenger)
Persons on Board:	1) Crew - 7 Passengers - 180 2) Crew - 3 Passengers - 18
Injuries:	1) Crew - None Passengers - None 2) Crew - None Passengers - None
Nature of Damage:	1) None 2) None
Commander's Licence:	1) Airline Transport Pilot's Licence 2) Airline Transport Pilot's Licence
Commander's Age:	1) 41 years 2) 42 years
Commander's Flying Experience:	1) 13,731 hours (of which 98 were on type) Last 90 days - 63 hours Last 28 days - 63 hours 2) 5,311 hours (of which 4,574 were on type) Last 90 days - 181 hours Last 28 days - 64 hours
Information Source:	Aircraft Accident Report Form submitted by the pilots

Synopsis

On short finals, the A320 initiated a go-around due to an unstable approach. During the go-around a delayed response to an ATC instruction caused a loss of planned separation and resulted in a Traffic alert and Collision Advisory System (TCAS) Resolution Advisory (RA) on the Saab 340.

History of the flight

G-LGNK

The aircraft was routing from Stansted to Dundee and cleared for an UTAVA 1R Standard Instrument Departure (SID) with a cleared altitude of 4,000 ft. As the aircraft approached holding point R1 for Runway 22, the crew reported to ATC that they were "READY FOR DEPARTURE". They were cleared for an immediate takeoff, and the departure was expeditious but routine. As the aircraft passed approximately 1,000 ft, the crew were advised by ATC that an aircraft on approach had initiated a go-around. ATC advised the crew to continue with the planned UTAVA 1R SID. Shortly after this, ATC instructed the crew to turn right onto a heading of 290º. By this point the autopilot (AP) was engaged so the commander initiated the turn using the AP. A further ATC instruction was then issued to "STOP CLIMB AT ALTITUDE 3,000 FT". This instruction was acknowledged by the co-pilot and the commander set the aircraft altitude select/alert system to 3,000 ft.

On passing approximately 2,500 ft, the aircraft TCAS issued an audio Traffic Advisory (TA) message and the associated amber indication on the pilots' displays. A few seconds later as the aircraft passed approximately 2,700 ft the TCAS issued a momentary "LEVEL OFF" RA instruction with the associated red indications on the pilots' displays.

The commander disconnected the AP and began to level the aircraft. Almost immediately the TCAS issued a "CLEAR OF CONFLICT" message. The commander subsequently climbed the aircraft to the cleared altitude of 3,000 ft and the AP was re-engaged. The co-pilot did not transmit a "TCAS RA" message to ATC due to his high workload at the time of the event. The crew continued the flight to Dundee and reported the event to Stansted ATC upon arrival.

OE-IHD

During the arrival into Stansted, while at approximately 14,000 ft, ATC gave OE-IHD a short-cut and a speed reduction to 250 kt. The reduction in track-miles available to the crew meant the aircraft was now above the descent profile for the runway in use. The situation was noted by both pilots, but the co-pilot, who was PF, felt the approach was still acceptable. At approximately 7,000 ft, ATC cleared OE-IHD to descend to 2,000 ft and the crew decided they could reach the final approach fix at 2,000 ft by using the speed brakes to increase the descent rate.

ATC restrictions led to further reductions in speed to 220 kt and then 200 kt with the consequent effect of a reduced descent rate. ATC offered to increase the distance to landing but this was declined by the co-pilot. At this point the commander pointed out that the aircraft was above profile and that he wanted to extend the landing gear to increase drag and hence increase the descent rate. This was done and the aircraft began returning to the profile.

As the aircraft approached the planned ILS glidepath intercept point, the glideslope indication was near the lower end of the scale (fly down indication). Before the AP captured the glideslope, the AP entered an altitude capture mode and began to level at 2,000 ft so, again, the descent rate was reduced. The commander directed the co-pilot to use a vertical speed mode to increase the rate of descent. However, the co-pilot inadvertently triggered a climb mode in the AP. The co-pilot wanted to re-attempt the vertical speed selection, but recognising there was no prospect of a stable approach the commander ordered a go-around.

The co-pilot set Take Off Go- Around (TOGA) for the flight director and autothrottle, while also disconnecting the AP. The commander set the go-around altitude in the Flight Control Unit

(FCU) and, very shortly afterwards, the aircraft was in altitude capture mode at 3,000 ft, the published go-around altitude. At 3,000 ft there was some confusion between the pilots over speed and flap selections, and the co-pilot reduced thrust to idle. The commander directed the co-pilot to "set thrust and Flap 1" but then, still not content, he took control of the aircraft.

As the commander took control, ATC instructed OE-IHD to climb to 4,000 ft and fly a heading of 135°M. This was shortly followed by a further turn to 090°M. The flight director was still giving directions to fly the aircraft along the planned navigation path for the published go-around so the commander did not engage the AP. He made a slight turn to the right and then immediately corrected to the left and ordered the co-pilot to set heading 090°M. At this point there was an audio callout of "PRIORITY RIGHT" which indicated the co-pilot had pressed the priority take over button on his sidestick. The commander re-iterated his control of the aircraft, brought the control priority to the left, turned left to 090° and climbed to 4,000 ft. The departing Saab 340 indicated on the TCAS as a TA with the associated amber visual indications. The crew believed the aircraft were approximately 900 ft apart vertically, and the TA disappeared during the climb to 4,000 ft. The commander retained control and subsequently flew an uneventful approach to land at Stansted.

Recorded Information

The radar and ATC transponder data from both aircraft were analysed. A digest of the analysis showing the closest point of approach is shown in Figure 1. The aircraft passed 87 m apart laterally and 600 ft vertically. A 3D representation is at Figure 2.

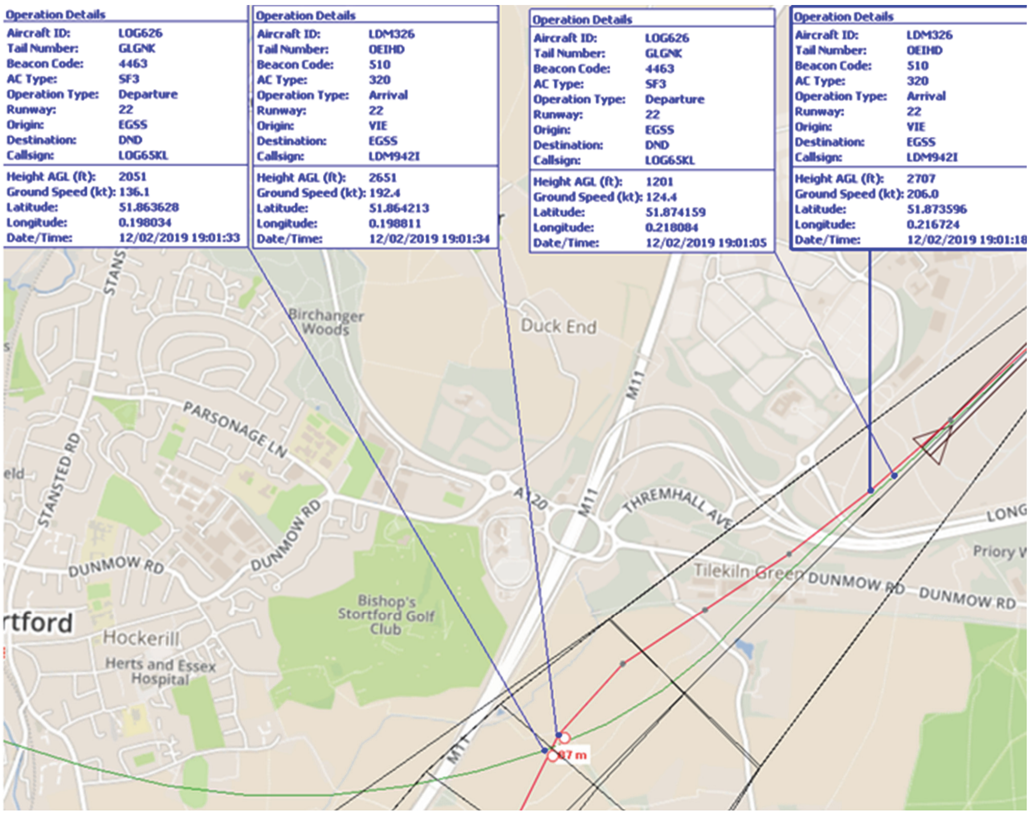

Figure 1
ATC Radar information

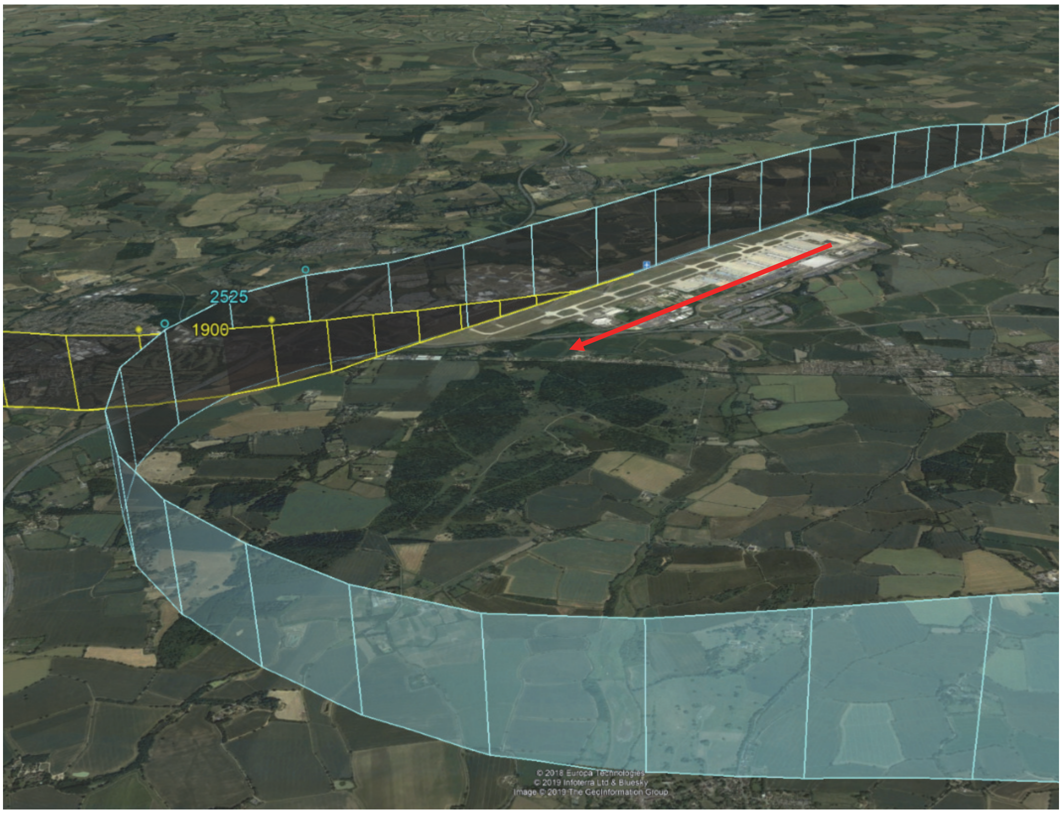

Figure 2

3D Tracks with the red arrow indicating the direction of travel
G-LGNK in yellow, OE-IHD in blue with altitudes based on 1013 mb

Human factors - OE-IHD

The crew of the A320 consisted of a commander under line training in the left seat with a line co-pilot in the right seat. A training captain was supervising the training from the flight deck jump seat. The commander was in a relatively unfamiliar role and being assessed on his performance. It is likely that he did not wish to be too overbearing on the co-pilot and so allowed the perceived excess energy situation to persist longer than he would in normal circumstances. This contributed to the aircraft being above the glideslope as the aircraft neared 2,000 ft. The AP capture of 2,000 ft during the approach surprised the co-pilot. The commander gave relevant and prompt instructions to recover the situation but these were not followed by the co-pilot, who was under pressure, and their actions triggered a climb. Though the co-pilot wanted to continue the descent, the commander recognised that there was no realistic prospect of a stable approach and ordered a go-around.

For the go-around, the co-pilot inadvertently deactivated the AP although TOGA thrust was set. The crew workload was now significantly above normal. The go-around altitude was 3,000 ft and this was reached very quickly. As the aircraft levelled it accelerated quickly. The commander, cognizant of the increasing speed asked the co-pilot to confirm a selection of Flap 1. At this point the co-pilot retarded the thrust to idle as a reaction to the speed increase. The commander then directed "Set Thrust and Set Flap 1." Recognising the breakdown of situational awareness, the commander took control of the aircraft.

During this period ATC directed the turn to 135°M and then 090°M. The commander was aware of the requirement to turn but crew duties had changed, and the co-pilot's situational awareness appeared to have briefly broken down due to the high workload. The aircraft flight director was still commanding a turn to the right to follow the published go-around and so the commander could not immediately engage the AP to reduce workload. As the commander tried to fly the turn manually, the "PRIORITY RIGHT" callout indicated that the co-pilot was still using his flying controls. The commander repeated his order to take control and then flew the manoeuvre directed by ATC.

Analysis

The A320 was in a state of excess energy as it conducted its arrival to Stansted. This was recognised by the crew and by ATC, but all involved thought that the situation was manageable. ATC did offer extra distance to the crew to assist in resolving the situation but this was declined by the co-pilot of OE-IHD who was PF. The AP capture of 2,000 ft altitude triggered a situation which markedly and suddenly increased the crew workload. The crew actions triggered a climb which led to the commander ordering a go-around. During the go-around the commander recognised that the situational awareness of the co-pilot was low and he took control to resolve the situation. The high workload of the OE-IHD crew following the initiation of the go-around and the change of control led their focus to be inside the aircraft for a significant period. During this time their attention was directed at a safe recovery of the situation and the execution of the go-around. These factors contributed to their delayed response to ATC.

Conclusion

The go-around and the very high resultant workload, followed by a change of PF, led to a situation where the ability of one of the A320 crew to react to ATC instructions was reduced. Due to the delay in the response by the A320 crew there was a short term loss of separation between the aircraft. The Saab 340 crew received a TCAS RA which prevented a further degradation of separation.

ACCIDENT

Aircraft Type and Registration:	Airbus A320-214, G-EZWC
No & Type of Engines:	2 CFM56-5B4/3 turbofan engines
Year of Manufacture:	2012 (Serial no: 5236)
Date & Time (UTC):	3 April 2019 at 1410 hrs
Location:	Belfast International Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 180
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to leading edge of No 2 engine nacelle, underside of fuselage, leading edge of right wing, nose landing gear, and to tyre
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	11,886 hours (of which 7,943 were on type) Last 90 days - 58 hours Last 28 days - 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and a report into the incident by the ground handling agent

Synopsis

While being pushed back from Stand 18 at Belfast International Airport, the aircraft was stopped with the tug and tow bar positioned at a significant angle to the aircraft's nose. The tow bar disconnected from the nose landing gear, and the aircraft rolled forward and struck the tug.

The handling agent carried out an internal investigation and initiated Safety Action which is included at the end of the report.

History of the flight

The aircraft was scheduled for a flight from Belfast International Airport to Malaga Airport in Spain and was parked on Stand 18 at the terminal building. It was to depart from Runway 35, and clearance had been given to pushback to Spot L3 facing west and for engine start (Figure 1). It was raining, and the parking area was wet with the pushback being carried out in daylight.

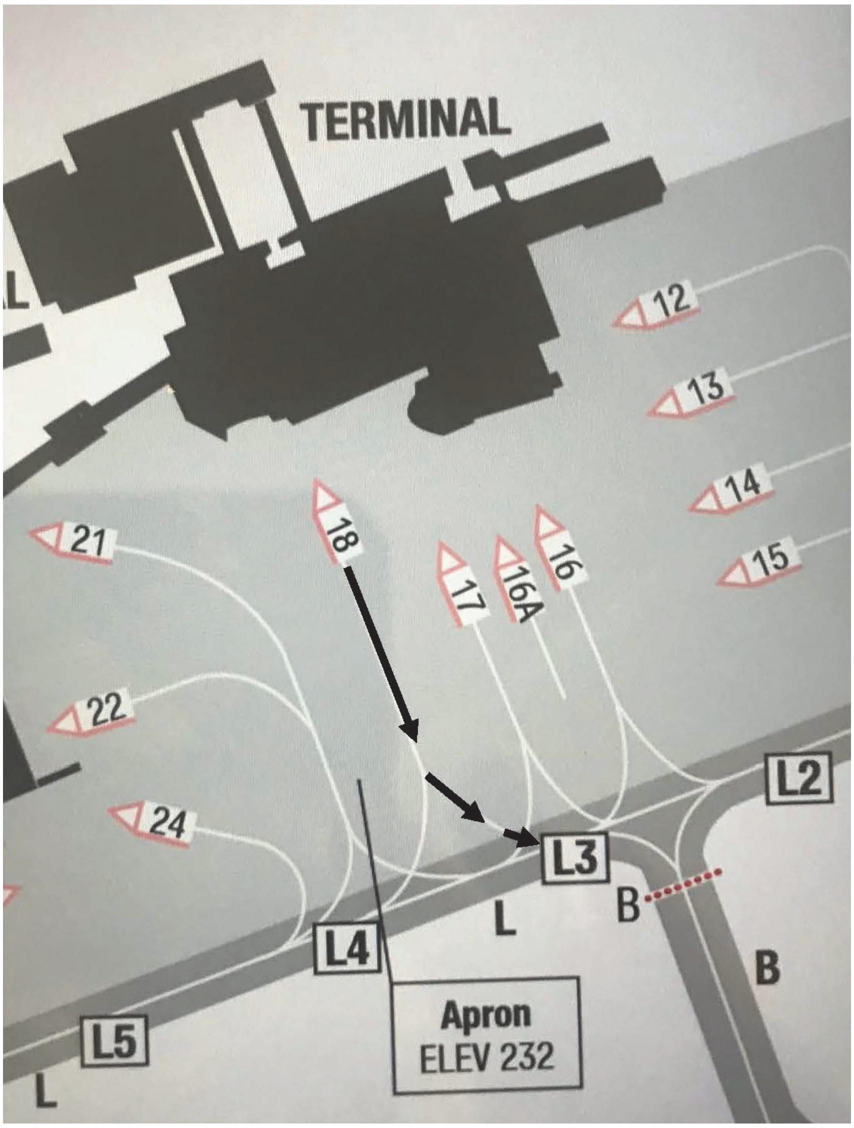

Figure 1

Parking Stand 18 showing the taxi line for the pushback to position L3

Both engines were started during the pushback, which appeared normal to the flight crew until, part of the way around the 90° turn to face west, the commander became aware that the aircraft was close to the edge of the apron. He questioned the situation with the member of the groundcrew on the headset and was told the situation was "OK". The aircraft stopped at an angle to the taxiway centreline with the nose pointing towards the grass area beyond the edge of the apron. It then started to move forward which the commander thought was to align it with the taxiway centreline, but he quickly became concerned about the direction of travel, which was towards the grass, and called the groundcrew to "STOP, STOP, STOP". There was no reply to his instruction, but he did not apply the aircraft's wheel brakes because the operator's SOPs prevented him from doing so while under tow (to prevent damage to the nose landing gear by the tug pushing or pulling against the aircraft brakes). Shortly afterwards the aircraft stopped, accompanied by an unfamiliar noise which was the underside of the aircraft contacting the roof of the tug cab (Figure 2).

Figure 2

The aircraft with the tug beneath it showing the close proximity to the edge of the apron

The commander applied the parking brake and asked the groundcrew for information as to what had happened. He found it very difficult to understand what the groundcrew was saying but he understood the right engine had been damaged and told them that he was shutting it down. He started the Auxiliary Power Unit (APU), informed ATC of the situation and requested assistance from airport ground operations.

The Cabin Manager (CM) entered the flight deck and provided an update on the passengers and what some of them had seen. The commander used the Public Address (PA) system to inform them of the situation and explained that they would have to return to the terminal to disembark them. He then shut down the left engine. At this point, there were two fire vehicles and several operations vehicles present and the commander was surprised by how many people were taking photographs, especially when he still had no clear idea of the situation. He contacted ATC on the ground frequency to try and establish what had happened to ensure that any potential hazards were identified. The airport Rescue and Fire Fighting Service (RFFS) inspected the damage and the fire crew informed him that the number two engine was damaged (Figure 3) but there was no fuel leak and no need for an evacuation.

The fire crew advised the commander that the aircraft had rolled forward over the tug which was wedged under the fuselage. Following a discussion with the operator's Base Captain, it was decided to disembark the passengers through the rear right door because the front left door was close to the edge of the apron and the front right door was close to the tug and debris. The commander made a PA announcement to that effect, whilst emphasising that the disembarkation must be carried out in an orderly manner to avoid there being too much weight at the rear of the aircraft at any one time. The passengers left the aircraft and were then taken to the terminal building in coaches.

Figure 3
The damage to the right engine intake caused by the initial impact with the tug

Report by the ground handling agent

The ground handling agent carried out an investigation into the incident and their report is summarised below.

The pushback groundcrew comprised a tug driver and headset man who was in direct contact with the aircraft's flight crew, but there was no radio communication between the tug driver and the headset man. There was also a third person who was observing the pushback for training purposes. The aircraft was close to maximum all up weight and the latter part of the pushback was uphill which, when combined with the engine start and wet surface, increased the workload on the pushback groundcrew. The tug driver had difficulty seeing the taxi line due to the wet reflective surface of the apron and the tug was struggling to move the aircraft due to a high gear having been selected. The turn to L3 was made late and the aircraft's position was closer to the edge of the apron than normal (Figure 4).

Figure 4

Images showing the normal and incident pushbacks

The tug driver attempted to correct the situation by stopping the pushback and selecting a lower gear on the tug. When the pushback was stopped, the tug was at an acute angle to the aircraft and the tow bar angle was possibly close to the 75° maximum angle to the aircraft's centreline. The aircraft, which was at idle power and facing down-slope, moved forward and, at some point, the shear pin in the tow bar failed disconnecting the tow bar and tug from the aircraft (Figure 5).

Figure 5

The tow bar to nose landing gear attachment unit with the shear-bolt circled

With the aircraft's brakes released, the combination of the aircraft facing downslope and both engines running at idle, meant that it moved forward impacting the tug with the right engine nacelle, which caused the aircraft to yaw to the right as it moved forward and overran the tug, wedging it under the aircraft. Given the unusual situation, the headset man and tug driver were slow to react but the rate of forward movement of the aircraft was at a speed consistent with towing and the tow bar disconnect may not have been immediately apparent.

Recorded information

Both the CVR and FDR were downloaded, and the airport CCTV recorded images showed the pushback and point at which the tow-bar separated. This information supported the descriptions provided by the flight crew and ground staff involved in the incident.

Analysis

The pushback was a frequently-conducted procedure with two experienced groundcrew members performing it. The late turn towards L3 was caused by the tug driver not being able to see the taxi line clearly due to the wet reflective surface of the apron. The commander, who had been monitoring the engine start as well as the progress of the pushback, was concerned with the closeness to the edge of the apron but was reassured by the headset man responding that the situation was "ok".

The aircraft came to a halt pointing downhill towards the grass but then began to move forward slowly under idle thrust and with the tow bar having detached from the tug. Given the low speed, it appeared to the flight crew that the aircraft was still under tow and that they should not, therefore, apply the brakes. Despite the commander's repeated instructions for the tow to be stopped, the aircraft continued moving, turning to the right because of the impact with the tug, until the impact caused it to a stop.

Conclusion

During the pushback, the left turn was made beyond the correct turning point because the tug driver had difficulty seeing the taxi line in the wet reflective surface of the apron. The aircraft was stopped with the tug and tow bar positioned at a significant angle to the right of the aircraft's nose and, at some point, the tow bar disconnected from the nose landing gear. The aircraft rolled forward slowly, and the flight crew believed it was still under tow and they could not apply aircraft brakes. The aircraft was brought to a halt when it struck the tug.

Safety action

Following this incident, the handling agent took action to prevent a reoccurrence of the incident:

1. A Safety Alert was issued to all staff regarding the incident.
2. A training awareness training module was developed covering the use of pushback tugs and gear selection.
3. Refresher training was instigated for headset procedures and action to be taken in the event of a shear pin to bar head separation.
4. A Safety App was developed that all managers and supervisory assessment staff could use on pushback and/or headset evaluation.
5. Bluetooth headsets would be issued to tug drivers to improve communication with the flight deck.

ACCIDENT

Aircraft Type and Registration:	Airbus A330-243, G-MLJL
No & Type of Engines:	2 Rolls-Royce RB211 Trent 772B-60 turbofan engines
Year of Manufacture:	1999 (Serial no: 254)
Date & Time (UTC):	2 August 2019 at 23:54 hrs
Location:	In flight from Varadero Airport, Cuba, to Manchester Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 11 Passengers - 320
Injuries:	Crew - 2 (1 serious) Passengers - None
Nature of Damage:	Radome damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	12,136 hours (of which 5,300 were on type) Last 90 days - 205 hours Last 28 days - 93 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

While avoiding observed weather radar returns the aircraft encountered unexpected severe turbulence. The encounter lasted for approximately 90 seconds during which two cabin crew members received injuries, one of which was later classified as 'serious'. After consulting with Medlink[1] the aircraft commander elected to continue to destination.

History of the flight

During the climb from Varadeo the flight crew could see that several significant thunder clouds in their vicinity were not painting on the aircraft's weather radar displays. Changing the weather radar selection from System 1 (WRS1) to System 2 (WRS2) appeared to solve the problem.

Approaching SUMRS waypoint (Figure 1) the aircraft was in cloud cruising at FL370 and avoiding weather radar returns. The seat belt signs had been selected 'ON' five minutes earlier as a precaution during light turbulence. The aircraft was 30 nm clear of the closest weather painting on its radar when it entered a denser area of cloud and the turbulence increased. The commander made a PA for the cabin crew to immediately take their seats. Less than

Footnote

[1] In-flight medical advisory service.

5 seconds later the aircraft encountered severe turbulence resulting in a 500 ft altitude gain and autopilot disconnection. The severe turbulence encounter lasted for approximately 90 seconds and was accompanied by the sound of hail striking the aircraft's nose. After the turbulence subsided the autopilot was reconnected and the aircraft returned to its assigned cruising level. Light to moderate turbulence was experienced for the following hour, during which time WRS2 failed. The degraded WRS1 was used for the remainder of the flight.

The severe turbulence encounter resulted in one cabin crew member receiving injuries to their left ankle. The individual had been in the aft galley when the commander gave the instruction for the crew to take their seats. Unable to immediately stow their catering cart, the crew member applied the cart's brakes and attempted to wedge it in a safe place. While securing the cart the crew member's foot and ankle became trapped beneath it. Their foot remained wedged until the turbulence subsided sufficiently to allow other crew members to help free them.

After consulting with Medlink, the commander decided to continue the flight to Manchester where the injured party received hospital treatment for a broken ankle. It later emerged that one other cabin crew member had suffered bruising to their back and shoulders that had not been apparent at the time.

Post-flight checks revealed minor surface damage to the aircraft's radome.

Meteorology

The significant weather forecast chart for the flight (Figure 1) indicated that occasional, isolated and embedded cumulonimbus (CB) clouds could be expected until passing waypoint DRYED, approximately 2 hours and 30 minutes into the flight. The presence of CB clouds implies a risk of thunderstorms and hail as well as moderate or severe turbulence and icing.

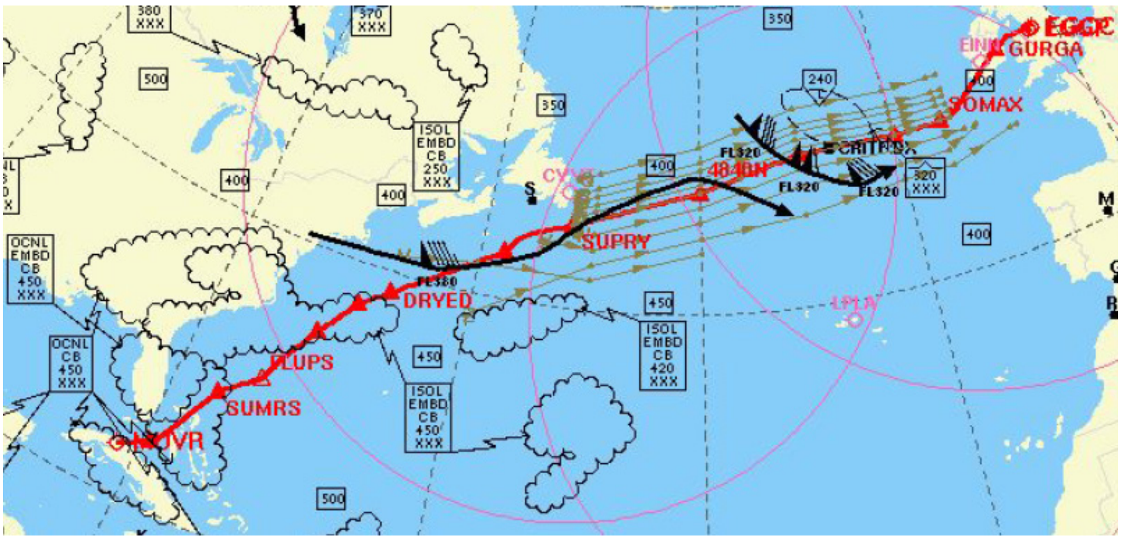

Figure 1

North Atlantic Significant Weather Chart valid 00 UTC 3 Aug 2019

Analysis

The flight crew were aware of the risks associated with CB clouds and were using their aircraft's weather radar to plan avoidance routings. The onset of severe turbulence was rapid and unexpected. Had the seat belt signs not already been illuminated, it is possible that more people would have been injured in the incident.

Conclusion

This was an unexpected turbulence encounter while avoiding areas of known CB activity. It is likely that the number of injuries would have been greater had passengers been moving around the cabin at the time.

ACCIDENT

Aircraft Type and Registration:	1) Boeing 737-73S, EI-SEV 2) Boeing 737-33A, G-GDFB
No & Type of Engines:	1) EI-SEV: 2 CFM56-7B turbofan engines 2) G-GDFB: 1 CFM56-3B2 turbofan engine, 1 CFM56-3C1 turbofan engine
Year of Manufacture:	1) EI-SEV: 1999 (Serial no: 29078) 2) G-GDFB: 1992 (Serial no: 25743)
Date & Time (UTC):	30 April 2019 at 0647 hrs
Location	Stand 24, East Midlands Airport
Type of Flight:	Positioning flight (non-revenue)
Persons on Board:	1) Crew - 2 Passengers - None 2) Crew - None Passengers - N/A
Injuries:	1) Crew - None Passengers - None 2) Crew - N/A Passengers - N/A
Nature of Damage:	1) Right winglet partially detached 2) Damage to underside of right horizontal stabiliser
Commander's Licence:	1) Airline Transport Pilot's Licence 2) N/A
Commander's Age	1) 35 Years 2) N/A
Commander's Flying Experience:	1) 6,500 hours (of which 2,650 were on type) Last 90 days - 140 hours Last 28 days - 62 hours 2) N/A
Information source:	Aircraft Accident Report Form submitted by the pilot, internal investgation reports by the Operator and Air Traffic Service Unit and further enquiries by the AAIB

Synopsis

EI-SEV was taxiing to park on Stand 22 (S22) at East Midlands Airport (EMA) and the routing passed behind G-GDFB on Stand 24 (S24). As EI-SEV passed behind G-GDFB its winglet struck the other aircraft's right horizontal stabiliser.

Low Visibility Procedures (LVPs) were in force, and controllers could not see the apron area and were unaware that S24 was occupied. Neither the UK Aeronautical Information Publication (AIP) nor the pilots' airfield charts indicated that wingtip clearance could be compromised when taxiing behind parked aircraft in that location.

Following the accident, the airport operator closed S22 pending a safety review and conducted a survey of parking stands across the airport to identify any similar aircraft taxi-separation hazards. The operators of both aircraft alerted their EMA-based flight crew to the hazard of reduced aircraft separation when using Stands 20-25 (S20-25). EI-SEV's Operator also issued a Company NOTAM to alert all their pilots using EMA to the hazard identified through this accident.

History of the flight

At the time of the accident EMA was operating under LVPs. The reported Runway Visual Range (RVR) was 300 to 325 m. EI-SEV arrived from Stansted Airport (STN) and landed on Runway 27 before following Taxiway Alpha eastwards to the Central Apron.

Due to the poor weather and their elevated position in the control tower, air traffic controllers could not see the aircraft, taxiway or apron. G-GDFB was not painting on the Controllers' Surface Movement Radar (SMR) display. With no other information about stand occupancy available to them, ATC were unaware that S24 was occupied. Accordingly, the ground movements controller cleared EI-SEV to taxi the shortest route to S22 which was via Quebec (Q), the western entry point to the apron (Figure 1). The EMA ATC Final Investigation Report into the accident concluded that:

> *'The poor visibility rendered the parked aircraft on stand 24 invisible to ATC. Had visibility been better, ATC would have had an opportunity to visually acquire the obstruction and offer a different route.'*

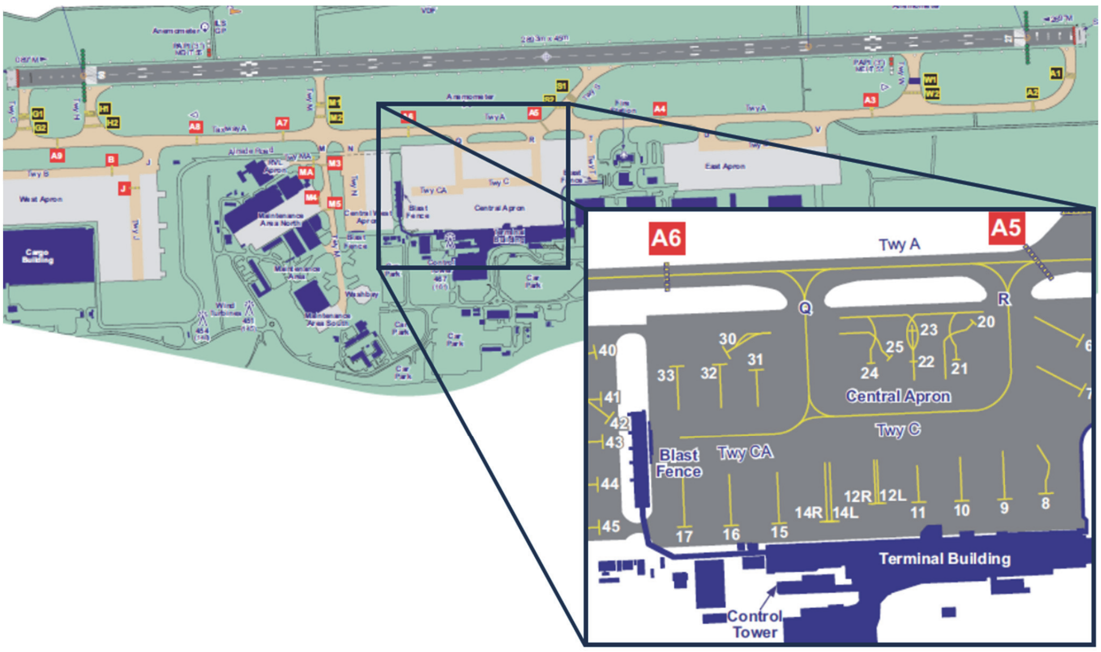

Figure 1

East Midlands Airport Chart with zoomed image of the Central Apron

The aircraft commander taxied EI-SEV as cleared, turning left from Taxiway Quebec towards Stand S22. The flight crew became aware of an aircraft parked on S24 and noted that the space available to pass behind it looked “tight”. Seeing that the parked aircraft was on its stop bar (Figure 2), they were reassured that there would be enough room to pass behind, provided they accurately tracked the stand taxi-lane centreline.

As EI-SEV crossed behind G-GDFB the commander brought the aircraft to a slow walking pace and the co-pilot monitored the right wing tip. From his perspective it appeared to be clear, but as they overlapped EI-SEV’s winglet struck G-GDFB’s right horizontal stabiliser (Figure 3). The commander brought the aircraft to a halt and reported the collision to ATC.

Figure 2

G-GDFB nosewheel position after the collision

Figure 3

EI-SEV’s winglet in contact with right horizontal stabiliser of G-GDFB

Recorded information

Airport CCTV and SMR footage revealed that, in the conditions prevailing at the time, neither system was capable of alerting the ATC controllers to the collision risk. The CCTV view of the apron was obscured by fog and the SMR was not designed to show stationary targets (Figure 4). The EMA ATC report noted that:

> *'The East Midlands Surface Movement Radar (SMR) does not show stationary objects or parked aircraft...When aircraft are taxiing they display but as they stop, either to park or to hold, they disappear from SMR...in times of poor visibility* [SMR] *becomes the 'eyes' of the controller. More modern SMRs show stationary targets and would have shown the aircraft parked on stand 24... Whilst it cannot be guaranteed that a better SMR/ASMGCS*[1] *system would have prevented the collision, it would have provided the controller with much needed information as to the presence of an obstruction on* [EI-SEV's] *taxi route.'*

Figure 4

Screenshots of the SMR display (left) and the Central Apron CCTV camera (right)

Prior to this accident the airport operator had started scoping for the procurement of an improved SMR or an ASMGS installation.

Airfield information

G-GDFB was a Boeing 737-300 (B733) series aircraft but S24 only had stop lines for Airbus A321 and Boeing 737-800 (B738) aircraft. The B733 is approximately 6 m shorter than a B738. With a B738 parked on S24 the available clearance to taxi behind it would have been approximately 12 m. The commander considered it likely that had it been a B738 on S24 it would have been more apparent that insufficient clearance existed.

Footnote

[1] Advanced Surface Movement Guidance Control System.

Neither the AIP nor the airfield charts available to the pilots contained any restrictions, warnings or guidance relating to wingtip/tail clearance on the implicated stands.

EMA ATC's final report highlighted discrepancies in three documents[2] regarding the requirement for follow-me vehicles during LVPs. The discrepancies related to whether follow-me vehicles were mandatory in RVRs of less than 300 m. Due to the RVR being not less than 300 m the report did not consider these findings directly relevant to the accident.

Personnel

It was the first flight of the day for the flight crew who had stayed overnight at STN in a hotel provided by their operator. Their previous rest period was 11 hours 43 minutes which complied with Airline's flight time limitations for temporarily detached crew. They reported being well rested and did not believe that fatigue played a part in the accident. Both pilots were based at EMA but had not previously operated from the remote stands in question (S20-25).

Human factors

Commercial flight crew routinely operate on airfields where following established taxiway markings generates safe separation. Repeated achievement of safe outcomes through compliance builds confidence and trust that airfield markings are safe to follow.

The Air Accident Investigation Unit Ireland published a synoptic report[3] into a similar ground collision between two B738 aircraft which occurred in October 2014. The report highlighted the limitations of the human eye in judging relative distance at ranges above 10 m. It noted that the visual perception challenge was increased on aircraft where winglets have a blended, rather than angular, appearance when viewed from the flight deck. The investigation concluded that:

> *'…for pilots operating winglet equipped aircraft and/or aircraft with large wingspan, it is not possible to accurately judge absolute distance between the wingtip and another object. Therefore, regardless of experience, there is a risk that in attempting to judge separation distance at close quarters to another object, a collision may occur. As such pilots should err on the side of caution and if doubt exists as to whether an aircraft can be passed safely, the flight crew should stop, advise ATC, and request alternative instructions if available.'*

Footnote

2 MATS Pt2 SI no 05 of 2018: Low Visibility Procedures; EMA Airside Operational Instruction (AOI) 21: Low Visibility Instructions; and EMA AOI 05: Apron Management.

3 Air Accident Investigation Unit Ireland Synoptic Report, Accident, Boeing 737-8AS, EI-EMH/EI-EKK, Link 2, Dublin Airport, Ireland 7 October 2014, http://www.aaiu.ie/node/860 accessed 02 September 2019.

Other information

Aerodrome licensing standards

EMA is an EASA[4] Certificated Aerodrome. It operates in accordance with Commission Regulation (European Union) No 139/2014 (CR 139/2014) which details the requirements and acceptable means of compliance for Certificated Aerodromes. Topic areas relevant to this accident include operational procedures, aerodrome physical characteristics, assessment and treatment of obstacles and visual aids. The document details minimum separation distances between taxiways, including stand taxi-lane centrelines, and fixed objects (Figure 5). If separation distances are not achieved, operational restrictions, such as limiting the size of aircraft using an affected taxiway, may be imposed to mitigate safety risks. EI-SEV and G-GDFB were both Aerodrome Reference Code C (Code C) aircraft[5] with wingspans just less than 36 m. EI-SEV had turned off the taxiway and was following the stand taxi-lane centreline to S22.

	Distance between taxiway centre line and runway centre line (metres)								Taxiway centre line to taxiway centre line (metres)	Taxiway, other than aircraft stand taxilane, centre line to object (metres)	Aircraft stand taxilane centre line to aircraft stand taxilane centre line (metres)	Aircraft stand taxilane centre line to object (metres)
	Instrument runways Code number				Non-instrument runways Code number							
Code letter	1	2	3	4	1	2	3	4				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
A	77.5	77.5	—	—	37.5	47.5	—	—	23	15.5	19.5	12
B	82	82	152	—	42	52	87	—	32	20	28.5	16.5
C	88	88	158	158	48	58	93	93	44	26	40.5	22.5
D	—	—	166	166	—	—	101	101	63	37	59.5	33.5
E	—	—	172.5	172.5	—	—	107.5	107.5	76	43.5	72.5	40
F	—	—	180	180	—	—	115	115	91	51	87.5	47.5

Note 1: The separation distances shown in columns (2) to (9) represent ordinary combinations of runways and taxiways.
Note 2: The distances in columns (2) to (9) do not guarantee sufficient clearance behind a holding aeroplane to permit the passing of another aeroplane on a parallel taxiway.

Table D-1. Taxiway minimum separation distances

Figure 5

CR 139/2014Table D-1 Taxiway minimum separation distances

CR 139/2014 states[6] that:

> *'The safety objective of minimum taxi separation distances is to allow safe use of taxiways and aircraft stand taxilanes* [sic] *to prevent possible collision with other aeroplanes...The separation distance between the centre line of a taxiway and…an object should not be less than the appropriate dimension specified* [at Figure 5]*'*

Footnote

4 European Union Aviation Safety Agency.
5 Wingspan ≥24 m but <36 m or outer main gear wheel span ≥6 m but <9 m.
6 CR 139/2014 dated May 2019, CS ADR-DSN.D.260 https://www.easa.europa.eu/document-library/regulations/commission-regulation-eu-no-1392014 accessed 2 September 2019.

In relation to clearance distances on aircraft stands[7] the regulation states that:

> *'Any aircraft passing behind an aircraft parked on an aircraft stand should keep the required clearance distances defined in* [Figure 5]*.'*

It further states that there should be a minimum clearance of 4.5 m between Code C aircraft entering or exiting a stand.

Guidance for pilots

CAP 637: Visual Aids Handbook[8], is a UK CAA publication intended to explain in general terms the meaning and purpose of visual aids at UK licensed airports. The handbook covers lighting, surface markings, signs and signals and contains guidance for pilots and personnel engaged in the handling of aircraft. At paragraph 2.3.1.a, CAP 637 states:

> *'Taxiway centrelines are located to provide safe clearance between the largest aircraft that the taxiway is designed to accommodate and fixed objects such as buildings, aircraft stands etc, provided that the pilot of the taxiing aircraft keeps the 'Cockpit' of the aircraft on the centreline and that aircraft on a stand are properly parked.'*

Analysis

Due a combination of poor weather and the limitations of the EMA SMR, ATC were unaware that G-GDFB was parked on S24. EI-SEV was given a taxi clearance that required it to pass directly behind G-GDFB. EI-SEV was accurately maintaining the stand taxi-lane centreline and G-GDFB was parked at an appropriate stop line on S24.

Based on known dimensions, G-GDFB's tail was less than 18 m from the S22 taxi-lane centreline. Had the minimum separation from the S22 taxi-lane centreline to G-GDFB been in accordance with CR 139/2014 there would have been at least 4.5 m clearance between the aircraft. Neither the AIP nor the pilots' airfield charts contained any limitation, warning or guidance relating to taxi separation distances on S20-25 at EMA.

To the flight crew of EI-SEV the clearance behind G-GDFB looked "tight" but passable. Routinely operating on airfields where following the taxiway lines assures safe separation, commercial flight crew can come to trust the markings. This is further reinforced by the wording of CAP 637, albeit not targeted at EASA certificated aerodromes, which infers that safety is assured by accurate taxiing and parking. It is possible that this combination of factors had desensitised the crew to the risk of ground collision.

The commander considered it unlikely he would have attempted to taxi behind a B738 on the same stand.

Footnote

7 CR 139/2014 dated May 2019, CS ADR-DSN.E.365

8 CAP 637 Visual Aids Handbook Issue 2 dated May 2007, https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=136 accessed 15 July 2019.

The aircraft was traveling slowly and the co-pilot was visual with both EI-SEV's winglet and G-GDFB's stabiliser. From his perspective, it appeared that the winglet would remain clear of the other aircraft's tail. That the aircraft collided demonstrated that visually judging relative distance between two objects at range is prone to error.

Conclusion

Due to the poor weather conditions and limitations of the SMR, EI-SEV was given an unachievable taxi clearance. The fallibility of the human eye in accurately judging relative distance at range seduced the crew into thinking that safe separation had been achieved. Less than minimum standard taxi separations existed on S20-25 but there were no published warnings, limitations or guidance to alert ATC or flight crews to the risks. Flight crew need to remain alert to the potential for consistently safe outcomes desensitising them to latent airfield hazards.

Safety action

Following this event:

The airport operator closed Stand 22 pending a safety review and conducted a survey of parking stands across the airport to identify any similar aircraft taxi-separation hazards.

The operators of both aircraft alerted their EMA-based flight crew to the hazard of reduced separation when using Stands 20 to 25.

The operator of EI-SEV issued a Company NOTAM to alert its pilots to the reduced separation hazard on Stands 20 to 25 at EMA.

INCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8, G-ECOC
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2007 (Serial no: 4197)
Date & Time (UTC):	13 December 2018 at 2105 hrs
Location:	En route from Aberdeen to Birmingham
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 77
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	7,655 hours (of which 7100 were on type) Last 90 days - 204 hours Last 28 days - 49 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During the climb to cruising altitude the flight crew took the precautionary action of using the fixed oxygen system following a pressurisation event. The aircraft pressurisation system was reset and functioned normally, however the oxygen system failed to provide the pilots with oxygen. The oxygen cylinder regulator was later disassembled, and the crew oxygen supply port was found blocked with a piece of debris. It is suspected that the debris was the tip of a screw extraction tool, but no evidence could be found to explain how it came to be in the regulator. The operator has changed the 'first flight' checks to ensure the flight deck emergency oxygen system is functioning correctly.

History of the flight

Prior to departure from Aberdeen Runway 16 for Birmingham Airport, the flight crew completed the safety checks satisfactorily, including verification that the flight crew oxygen system was pressurised. The altimeter checks and cabin pressure were indicating normally as the aircraft climbed through 10,000 ft (FL100) but at approximately 18,000 ft (FL180) a loud noise was heard on the flight deck which the pilots associated with a decompression event. They checked the cabin altitude, which showed normal, but saw that the MAX DIFF (maximum differential) cabin pressure warning was displayed. The aircraft was levelled off at FL190 and ATC were informed of the situation. Due to the MAX DIFF being reached the aircraft was slowly depressurising and as a precautionary measure the pilots decided to don their oxygen masks. When the oxygen supply was activated the headbands did not inflate and no oxygen was available, which startled the pilots and delayed the completion of the QRH card. There were no standard operating procedures which covered the failure of the crew oxygen system. The pilots decided to continue without their masks and actioned the QRH, resetting the pressurisation system which functioned normally for the remainder of the flight.

As a precautionary measure, the rest of the flight was made at FL190 and they requested portable oxygen from the cabin to be made available. The cabin crew were unaware of any pressurisation issues until informed by the flight crew.

On arrival at Birmingham Airport, the pilots re-checked their masks and found that although the pressure gauge showed normal, when oxygen was demanded the pressure reduced to zero.

Aircraft information

The De Havilland Canada (DHC) Dash 8 Q400 is a high-wing regional airliner type powered by twin turboprop Pratt and Whitney Canada PW150A engines.

Crew fixed oxygen system

The flight crew fixed oxygen system consists of a single pressurised oxygen cylinder assembly in the lower nose fuselage, three full-face oxygen masks, equipped with microphones and oxygen diluting regulators, a pressure gauge and the associated connecting pipes (Figure 1). Further portable oxygen cylinders are stored in the passenger compartment for cabin crew.

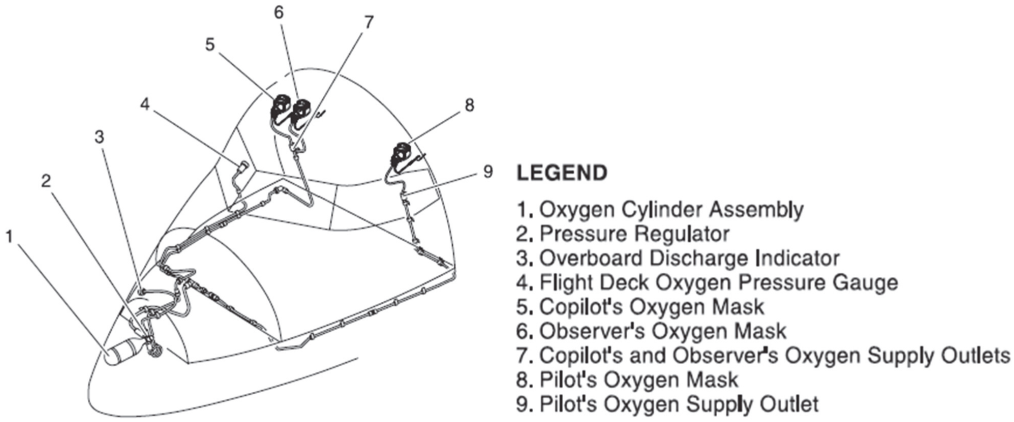

Figure 1

Crew fixed oxygen system

The oxygen cylinder assembly (Figure 2) has sufficient capacity for a descent to FL140 in 4 minutes followed by continued flight at FL140 for a further 116 minutes. The cylinder assembly consists of a composite bottle and a regulator assembly attached to the outlet (Figure 3).

Figure 2

Oxygen cylinder assembly

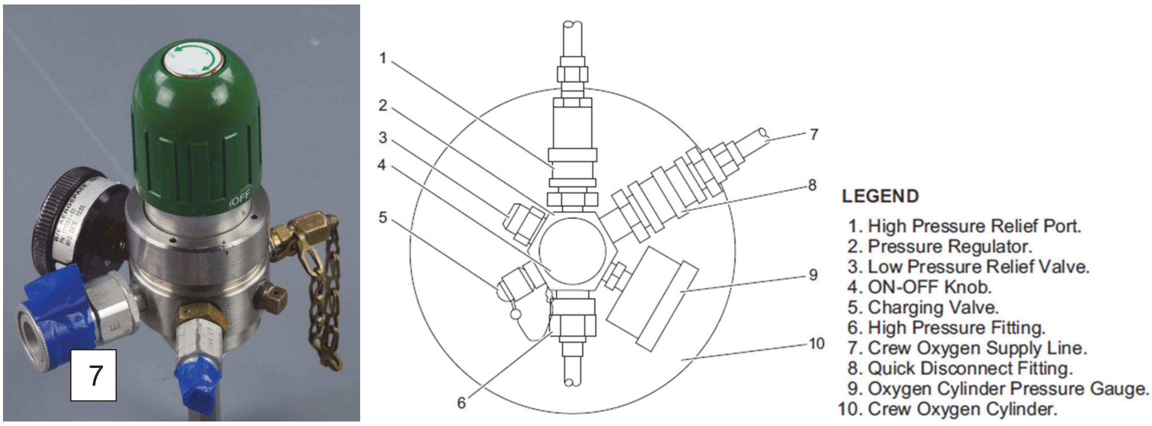

Figure 3

Oxygen cylinder regulator assembly

The operator had a contract with an equipment pool supplier to ensure that replacement cylinder assemblies were always available. The pool supplier had a contract with a maintenance and repair organisation (MRO) to replenish and re-certify depleted cylinder assemblies which could then be returned to service. The cylinder assembly from the incident flight was last certified in February 2015 and passed a flow rate test. It had subsequently been returned to the MRO on three separate occasions since then for minor rework and refill & leak checking. The operator's maintenance organisation is only authorised to attach the regulator outlet (crew oxygen supply line [7] in Figure 3) to the aircraft and are not authorised to remove or disassemble the regulator.

Aircraft examination

Following the incident on 13 December 2018, the oxygen cylinder assembly was removed from the aircraft and taken to a laboratory for further analysis. The regulator was removed from the bottle and a visual examination revealed debris blocking the crew oxygen supply line port (Figure 4).

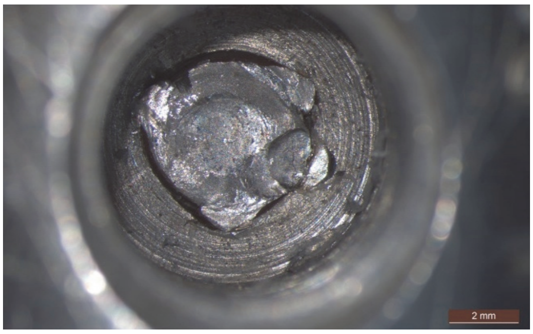

Figure 4

Debris blocking port with regulator partially disassembled

The regulator was fully dismantled, and abrasion damage was observed to the valve pin when viewed through the low-pressure relief valve port ([3] in Figure 3). The valve body was sectioned at right angles to the port and further visual examination of the debris revealed that it was threaded. Energy dispersive x-ray (EDX) analysis of the metal attached to the end of the debris confirmed that the debris had damaged the valve pin (Figure 5). EDX analysis of the debris showed it to be a low alloy steel containing chromium and molybdenum, whereas the valve pin and the regulator body are manufactured from a corrosion-resistant steel.

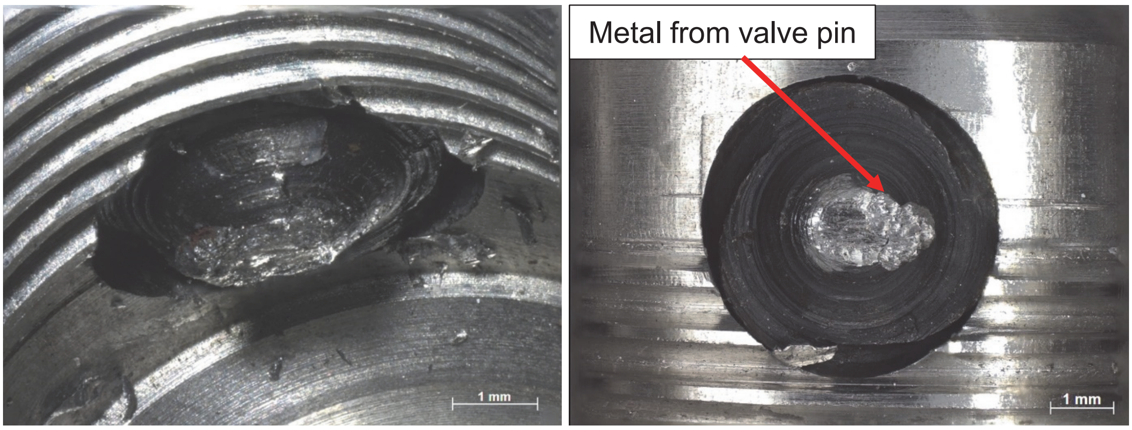

Figure 5

Debris blocking port (regulator sectioned)

Examination of the outer end of the debris using a scanning electron microscope (SEM) showed that the surface had been extensively mechanically damaged by contact with another body. Analysis of undamaged areas of the surface showed a fracture surface consistent with torsional overload in shear. An attempt was made to remove the debris using a screw extractor, however the debris was too hard to drill using a standard drill bit.

The regulator body was further sectioned along the axis of the port and revealed the debris to have a left-hand thread and that it had cut into the smooth bore section of the crew oxygen supply port (Figure 6). The debris was tapered and was approximately 6 mm in length.

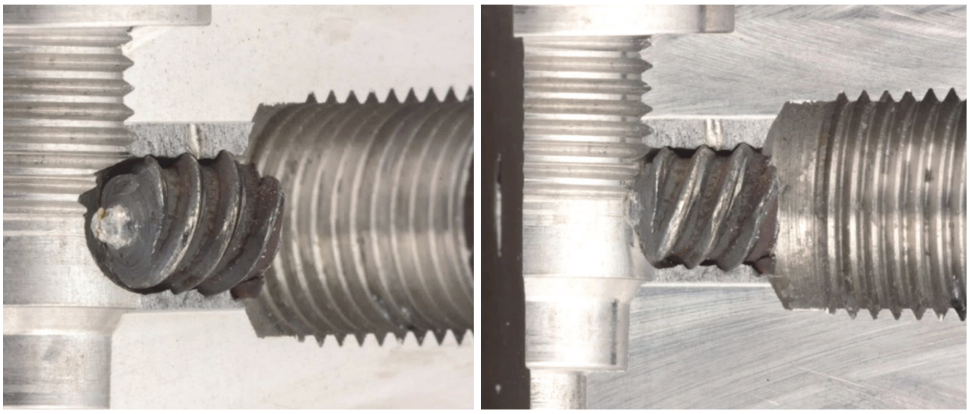

Figure 6
Debris blocking port [7] (regulator sectioned)

Analysis

The tapered geometry and left-hand thread of the debris is similar to a screw extractor tool (Figure 7) and these are typically manufactured from a steel with high hardness, which would explain the difficulty in drilling it during the examination process.

Figure 7
Example of screw extractor tool

It is possible that a screw extractor tool had been inserted into the crew oxygen supply port at some point and turned until it contacted the valve pin and cut into the wall of the port. If torque continued to be applied to the tool it would result in overload failure of the tool in shear. The subsequent damage to the fracture surface may have been the result of attempts to remove the debris. With the debris in place normal oxygen flow would have been restricted but it did not fully block the port therefore allowing, over time, for the system pressure to read normally on the flight deck gauge.

The equipment pool supplier and the MRO participated in the investigation and no evidence could be found to explain the presence of the debris. The acceptance test certificate was obtained demonstrating that oxygen flow was within limits when the cylinder assembly was last certified in February 2015. It would not have been possible to pass the test with the debris in position.

The crew oxygen system check, which is performed before the first flight each day, is to verify using the cockpit pressure gauge that the system is pressurised. Following this incident, the operator has changed the 'first flight' procedure to include a momentary flow of oxygen to ensure that the system can maintain pressure whilst supplying a flow.

Conclusion

For reasons unknown, a tapered screw extractor tool had been inserted into the flight crew oxygen supply port until it failed through torsional overload. Despite possible attempts to remove the debris from the cylinder assembly, the oxygen bottle was subsequently installed onto G-ECOC. The blockage was sufficient to restrict the flow of oxygen flow when demanded on the incident flight, however it did allow the cylinder pressure to register on the flight deck pressure gauge until the system was turned on.

No explanation could be found to explain the presence of the debris.

Safety action

The operator has taken the following safety action:

> The Operations Manual for the Flight Deck Fixed Oxygen Checks has been updated to include a one-second flow of oxygen to ensure that system pressure is maintained during the first flight check.

ACCIDENT

Aircraft Type and Registration:	Cessna F177RG Cardinal RG, G-AYSY
No & Type of Engines:	1 Lycoming IO-360-A1B6 piston engine
Year of Manufacture:	1971 (Serial no: 26)
Date & Time (UTC):	16 June 2019 at 0933 hrs
Location:	Leicester Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Damage to propeller and fuselage
Commander's Licence:	Light Aircraft Pilot's Licence
Commander's Age:	30 years
Commander's Flying Experience:	63 hours (of which 28 were on type) Last 90 days - 30 hours Last 28 days - 14 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot was unable to lock the landing gear in the down position. He landed on the grass runway at Leicester Airport, the landing gear retracted, and the aircraft exhaust and propeller dug into the ground. The pilot suffered minor injuries.

The hydraulic landing gear-up pressure line had become detached at the fitting, allowing the hydraulic fluid to escape.

History of the flight

The aircraft departed from Leicester Airport on a short flight to Sywell Aerodrome. After departure the pilot noticed that it took a much greater time for the landing gear to retract than was normally the case. At Sywell, the pilot positioned for landing and selected the landing gear down. He noticed that neither the green light, which indicated the landing gear was down and locked, nor the red light, which indicated the landing gear was up, was illuminated. He commenced a go-around from his approach and circled near the airfield whilst completing the emergency checklist. The pilot attempted to manually extend the gear using the emergency hand pump, but the pump had no pressure and the pilot felt no resistance to his movements.

The pilot decided that he would return to Leicester because he was more familiar with that airport and was aware that it had a smooth grass strip he could land on. Having returned to

Leicester, he completed a low approach and go around so that people on the ground could confirm the position of the landing gear, which was seen to be hanging down but not locked, as shown in Figure 1.

Figure 1

Photograph showing the landing gear position

The pilot then commenced an approach to land onto grass Runway 16. At approximately 100 ft aal he shut down the engine but the propeller continued to windmill. The touchdown was smooth, but the exhaust and propeller dug into the runway bringing the aircraft to an abrupt stop. The pilot received minor injuries and was taken to hospital as a precaution. Figure 2 shows the final position of the aircraft.

Figure 2

Photograph showing the final position of the aircraft

The aircraft was recovered to a local maintenance facility where an examination revealed that the landing gear-up pressure line had separated from its fixing, as shown in Figure 3. The hydraulic pipework is aluminium and uses flare fittings with flare nuts to attach them to the power pack.

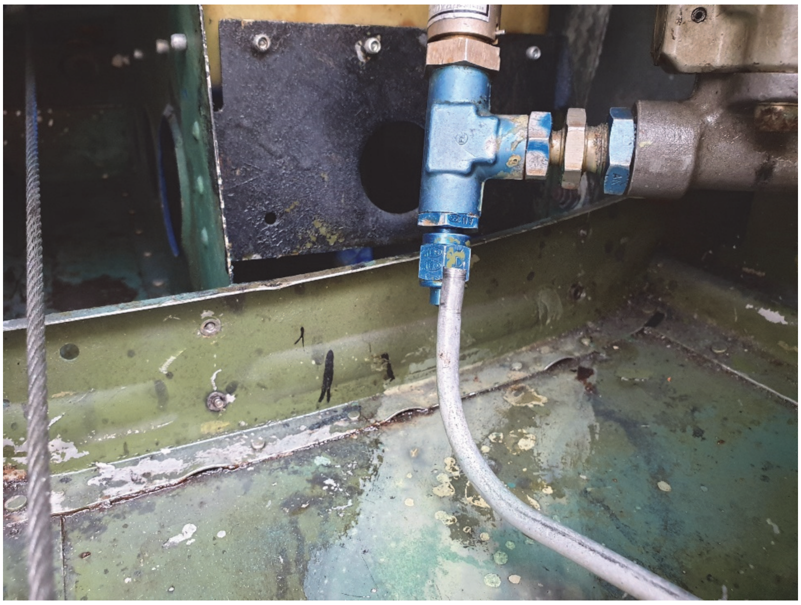

Figure 3
Hydraulic line separated from its fixing

The aircraft itself suffered slight damage to the exhaust and propeller. The engine required an examination for shock loading.

Aircraft information

G-AYSY is fitted with retractable tricycle landing gear. The landing gear is extended and retracted by hydraulic actuators powered by an electrically-driven hydraulic power pack. The main gear is held up by hydraulic pressure whilst the nose gear has a mechanical lock. When the gear is selected down, the hydraulic fluid is returned to the reservoir through the landing gear-up pressure line. When the landing gear locks down the hydraulic pump is switched off by a micro switch on an over-centre lock on the nose landing gear. In the case of G-AYSY, the landing gear did not reach this position, so the pump continued to run and the hydraulic fluid was lost. The aircraft is fitted with an emergency hand pump, located on the cockpit floor between the front seats, which extends the landing gear in the event of a hydraulic pump failure but it requires hydraulic fluid to function. If the fluid is lost, the hand pump cannot extend the gear.

The aircraft had been at a maintenance facility until a few days before the accident due to a problem with the hydraulic pressure in the landing gear system: the landing gear had not been staying retracted because of a loss of system pressure. The fault was traced to an internal leak in the power pack and, following a thorough clean and seal renewal, the power pack was re-installed and tested. Repeated extension and retractions showed that the fault was fixed, and the landing gear system worked correctly. Between the leak being fixed and the accident flight, the gear extension and retraction had been tested or used without fault at least 18 times.

The aluminium tubing in this system is relatively thin-walled. Using flare fitments with this piping can present problems as the flare joint can be fragile. Overtightening, repeated movement or even age can cause the pipe to fail at the flare joint as in this case.

Analysis

Having had previous issues with the landing gear remaining retracted, the hydraulic system had been examined and an internal leak in the powerpack rectified. Repeated testing of the system showed that the fault had been fixed and the system was working correctly. Aluminium pipes, as used in this system, can be weakened by overtightening, repeated movement or age and at some point, when the gear was selected down, the landing gear-up pressure line failed at the flare. The outcome was the total loss of hydraulic fluid from the system which subsequently prevented the landing gear from locking down.

The pilot assessed the situation and elected to return to an airfield he was familiar with, and that he knew had a smooth grass strip for his landing. Having shut the engine down, he performed a successful landing causing limited damage to the aircraft and only minor injuries to himself.

Aluminium tubing with flare fittings can be vulnerable if the fitting is overtightened. Repeated removal and re-fixing of such fittings with aluminium tubing should be treated with caution to ensure that the tubing is not damaged or weakened in the process.

ACCIDENT

Aircraft Type and Registration:	Colomban MC-30 Luciole, G-CIBJ	
No & Type of Engines:	1 Briggs And Stratton 0114-E1 piston engine	
Year of Manufacture:	2013 (Serial no: LAA 371-15002)	
Date & Time (UTC):	10 April 2019 at 1815 hrs	
Location:	Farm strip at Thankerton, South Lanarkshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Destroyed	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	83 years	
Commander's Flying Experience:	15,324 hours (of which 60 were on type) Last 90 days - 1 hour Last 28 days - 1 hour	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

After a local flight, the ground taxi route back to the hangar involved several tight turns and when full left rudder pedal was applied the cockpit filled with smoke. The pilot exited the aircraft without injury and the ensuing fire consumed the aircraft. It is suspected that the terminals of the starter solenoid were not insulated, and the rudder pedal created an electrical short circuit which damaged a fuel pipe and ignited the fuel. Several Safety Actions have been taken to prevent recurrence.

History of the flight

The pilot had returned to the farm strip in Thankerton, where the aircraft was based, after an uneventful local flight. After landing the pilot taxied the aircraft to the hangar. The route from the airstrip to the hangar involved several tight turns (Figure 1) and it was following a left turn, where the pilot applied full left rudder pedal, that he felt a restriction. Shortly afterwards the cockpit filled with smoke and the pilot quickly exited the aircraft. In his haste to exit he did not wait for the aircraft to come to a halt, turn off the fuel or turn off the ignition. The aircraft was destroyed by fire (Figure 2) but the pilot did not suffer any injuries.

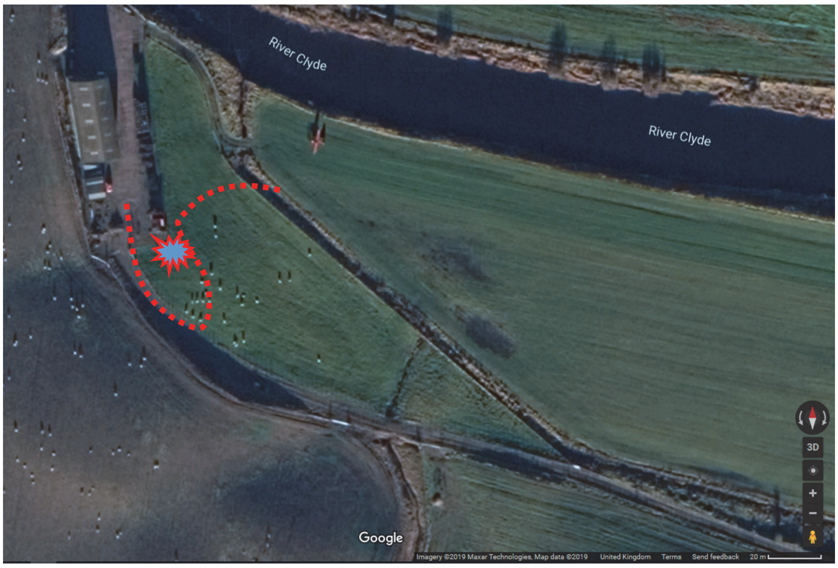

Figure 1
Thankerton farm strip – taxi route and accident location

Figure 2
G-CIBJ shortly after the pilot had evacuated

Aircraft information

The Colomban Luciole is an ultra-lightweight single-seat aircraft, home built from plans and is powered by a V-twin four-stroke petrol engine. The construction is a mixture of wood, plywood, metal, foam and carbon reinforced plastic and has a maximum takeoff weight of 200 kg.

The compact cockpit footwell has the battery on the floor of the left side with the starter solenoid mounted forward on the engine bulkhead. The fuel tank is behind the instrument panel with the fuel supply pipes, associated electrical pump and filter routed along the right side of the cockpit, going forward and through the engine bulkhead just beneath the starter solenoid. The rudder pedals are adjustable fore and aft on a moveable carriage to suit the pilot and are centralised using elastic cords (Figure 3). During the accident flight the rudder pedals were adjusted fully forward.

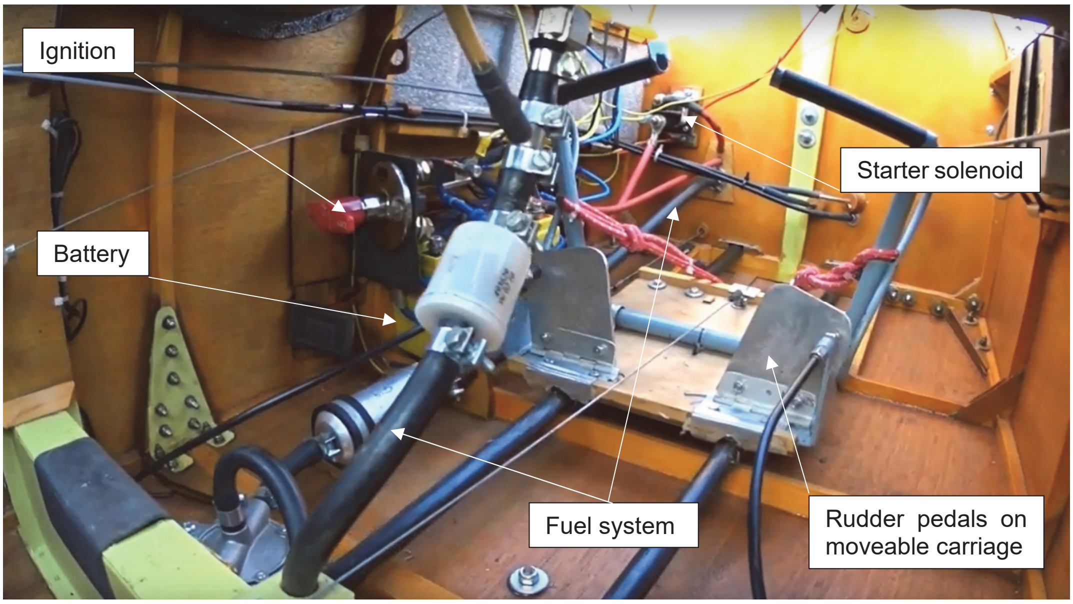

Figure 3
Cockpit interior (not G-CIBJ)

Analysis

During the taxi manoeuvres the pilot noted a restriction when he applied full left rudder pedal and shortly afterwards smoke was seen in the cockpit. It is probable that, as the rudder pedal carriage was in the fully forward position, the metal pedal contacted the exposed terminals of the starter solenoid. The solenoid is connected directly to the battery and the metal rudder pedal created a short circuit to earth, resulting in rapid discharging of the battery and overheating of the electrical system. Evidence was found of local heat damage to the engine bulkhead around the starter solenoid. This overheating may have caused the fuel pipe to melt, with a spark igniting the fuel and the aircraft was then consumed by the fire.

The plans for the aircraft state that the terminals of the solenoid should be "*perfectly isolated*". The Light Aircraft Association (LAA) has examined all other Luciole aircraft registered in the UK and confirmed that all the terminals are insulated (Figure 4). It is suspected that only G-CIBJ did not have this insulation and awareness of this issue has been raised by the LAA in their June 2019 "*Safety Spot*" publication and Technical Leaflet TL3.26. The LAA intends to mandate a change to the specification of the fuel pipe in the cockpit to one that is more heat resistant and will require all UK owners to modify their aircraft to this new fuel pipe specification.

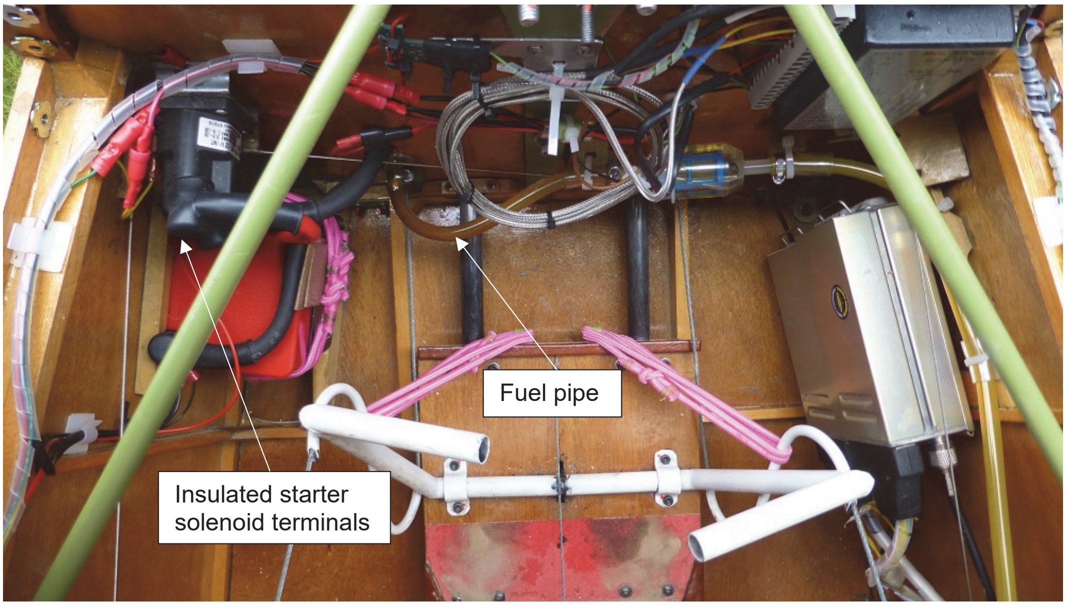

Figure 3
Cockpit interior (not G-CIBJ)

The LAA will mandate that all UK-registered Colomban Luciole aircraft be modified to the higher heat resistant fuel pipe specification.

Conclusion

The source of the fire which consumed the aircraft was the electrical system, which had overheated due to a short circuit. The short circuit was made by the metal rudder pedal contacting the exposed terminals of the starter solenoid mounted to the engine bulkhead. The rudder pedals had been adjusted to the fully forward position and due to the pedal inputs required for the taxiing manoeuvres, the left pedal had contacted the exposed terminal. The plans for the aircraft required the terminals to be insulated; however, the insulation had not been fitted to G-CIBJ. The LAA will mandate that the fuel pipes on all UK-registered Luciole aircraft be modified to a higher heat resistant specification.

Safety actions/Recommendations

> The LAA has recommended that all UK-registered Colomban Luciole aircraft be modified to the higher heat-resistant fuel pipe specification.

ACCIDENT

Aircraft Type and Registration:	DHC-1 Chipmunk 22, G-BXHF
No & Type of Engines:	1 De Havilland Gipsy Major 10 MK.2 piston engine
Year of Manufacture:	1953 (Serial no: C1/0808)
Date & Time (UTC):	4 March 2019 at 1027 hrs
Location:	Redhill Airfield, Surrey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	16,883 hours (of which 167 were on type) Last 90 days - 107 hours Last 28 days - 31 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The pilot stated that he was planning on flying the aircraft to Solent Airport, Hampshire, for its annual inspection. After two failed attempts to start the engine, which involved priming the engine by rotating the propeller by hand, the pilot vacated the cockpit for a third time to prime the engine again. However, when he rotated the propeller the engine kicked over and it struck his hand causing serious injuries. A doctor and paramedic from the resident air ambulance were quickly in attendance and the pilot was subsequently flown to a specialist trauma hospital, where he stayed for 10 days.

It was subsequently discovered that prior to the third prime the pilot had not turned the magnetos OFF; he was not able to explain this omission.

ACCIDENT

Aircraft Type and Registration:	Jodel D120 Paris-Nice, G-BKCW
No & Type of Engines:	1 Continental Motors Corp C90-14F piston engine
Year of Manufacture:	1965 (Serial no: 285)
Date & Time (UTC):	19 June 2019 at 1100 hrs
Location:	Perth Aerodrome, Perth and Kinross
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to landing gear, propeller, left wing skin and woodwork
Commander's Licence:	Private Pilot's Licence
Commander's Age:	34 years
Commander's Flying Experience:	72 hours (of which 10 were on type) Last 90 days - 9 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During the takeoff from Runway 27, the engine lost power but the pilot managed to climb to 2,400 ft aal. He carried out performance checks, which appeared normal, and returned to the airfield circuit where, once again, power reduced. He turned onto the final approach but, at about 10 ft above the runway, power increased, the aircraft yawed left and, because the pilot was applying right rudder as the aircraft touched down, it departed the right side of the runway.

History of the flight

The weather for the intended flight from Perth to Kingsmuir was good with a surface wind at Perth of 240° at 10 kt, visibility greater than 10 km, clouds FEW at 3,200 ft, OAT +18°C and dew point +12°C, QNH 1006 hPa and 70% humidity. The aircraft started normally, and all the checks were carried out before taxing to a position just short of holding point Charlie. There was a delay of twenty minutes due to other traffic, during which carburettor heat was selected ON. Once cleared for departure, the carburettor heat was selected OFF and the aircraft entered Runway 27 for departure.

Full power was selected and the aircraft accelerated normally, lifting off at about 45-50 kt. With the aircraft less than 5 ft above the runway, engine rpm reduced and the airspeed decreased. The aircraft drifted left which meant the pilot was unable to abandon the take off due to other aircraft on the adjacent taxiway Charlie. He set a level attitude and the aircraft accelerated and gradually climbed to 1,000 ft where the engine performance recovered. The climb was continued to 2,400 feet aal, and the aircraft was flown in an orbit to the southwest of the airfield to confirm normal engine operation and that all checks had been correctly completed. The pilot decided to return to Perth to carry out a precautionary landing and joined the circuit at 1,000 feet aal to land on Runway 21.

The engine performance reduced again and it was difficult to maintain height, but the aircraft was positioned onto short finals for Runway 21 and the engine set to idle power. At approximately 10 ft above the runway, engine rpm increased and the aircraft yawed left. The pilot attempted to correct the left yaw by applying right rudder, at which point the aircraft touched down and veered right. It departed the right side of the runway and the landing gear collapsed, which caused the propeller to strike the ground before the aircraft came to rest. The pilot switched off the fuel and electrical power before leaving the aircraft.

Analysis

The temperature of 18°C combined with a dew point of 12°C and 70% humidity meant there was a high possibility of carburettor icing at low power settings. The pilot considered that even using carburettor heating during the 20 minutes holding may not have prevented carburettor icing during the take off in the prevailing conditions. Icing was also a possible reason for the power reduction in the circuit. He thought that increasing power occasionally while holding might have been beneficial. Also, with the reduced and unreliable engine performance, positioning for a glide approach might have been a better option.

Bulletin Correction

In the Synopsis and the first paragraph of the History of Flight the report incorrectly states that the pilot took off from Runway 21, this should have read Runway 27.

The online version of this report was amended prior to publication on the 14 November 2019.

ACCIDENT

Aircraft Type and Registration:	Luscombe 8A Silvaire, G-AKVP
No & Type of Engines:	1 Continental Motors Corp A65-8 piston engine
Year of Manufacture:	1948 (Serial no: 5549)
Date & Time (UTC):	19 April 2019 at 1225 hrs
Location:	Baxterley Aerodrome, Warwickshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	2,366 hours (of which 1,500 were on type) Last 90 days - 3 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

On takeoff from Baxterley Aerodrome, the aircraft climbed normally but drifted to the left of the intended takeoff track. The pilot attempted to turn to the right in order to avoid a tall tree, but the left wingtip struck the top branches causing the aircraft to enter a spin to the right. It struck the ground heavily, trapping the pilot who had to be released from the wreckage by the Fire Service.

History of the flight

The pilot had planned to carry out a flight from Baxterley Aerodrome in Warwickshire to Old Warden Airfield in Bedfordshire. He had operated from Baxterley for 15 years and was familiar with the trees on the southern side of the runways and at the western end. The weather was good with a light surface wind from 075° at less than 5 kt, CAVOK, OAT 22°C and QNH 1030 hPa. The pilot elected to depart from Runway 25, which is 450 m long by 15 m wide. Although the takeoff was downwind, the wind was light and the pilot considered it was compensated for by the downslope. The layout of the aerodrome is shown below as Figure 1.

Figure 1

Aerodrome plan showing the runway alignment and the tree struck by the aircraft's left wingtip

Following the normal pre-takeoff checks, which included the engine power checks, the aircraft was lined up some 50 m north-east of the beginning of Runway 25 along the Runway 24 extension. Full throttle was set, and the acceleration appeared normal with the aircraft becoming airborne at about the normal point on the runway. The climb was shallow as the aircraft accelerated to its climb speed of 70 mph during which it drifted to the left of the runway towards some trees. The pilot could see a tree which was on the left side of a gap in the trees at the end of the runway. He applied right bank but no rudder to avoid it, but the aircraft continued towards the top of the tree, which he thought it would clear by some 10 to 15 feet. It then became apparent that the aircraft may hit the tree and so the pilot applied a further 15° of bank to try and avoid it. The left wingtip struck the tops of the tree with a "bang" and, in seconds, the right wing dropped and the aircraft spun through 180°, impacting the surface of the field adjacent to the aerodrome.

Although the pilot was not seriously injured, which he thought was due to the energy absorption of the seat cushions and his harness, he was trapped in the wreckage by his leg which was beneath the instrument panel. He was unable to turn off the fuel but turned off all the other switches, including for the electrical system. The Fire Service arrived and were able to release him.

Analysis

The pilot considered that the aircraft performance had been normal, and he was aware of the trees to his left and those at the end of the runway. The slight tailwind component possibly reduced the angle of climb which reduced his normal vertical separation from the obstacles, which he could see and initially thought he would clear. When it became apparent that he would not clear them, his attempt to turn away to the right was not made early enough and the left wingtip contacted the upper branches.

Conclusion

The pilot concluded that an early decision to avoid an obstacle is better the waiting to see if the aircraft will clear it.

ACCIDENT

Aircraft Type and Registration:	Ikarus C42 FB80, G-CDSW
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2006 (Serial no: 0511-6772)
Date & Time (UTC):	5 April 2019 at 1150 hrs
Location:	Deanland Airfield, East Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller, fuselage, wings, landing-gear damaged
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	83 hours (of which 83 were on type) Last 90 days - 8 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot lost control during an unexpectedly strong crosswind landing and crashed into a hedge.

History of the flight

The pilot planned a triangular cross-country flight beginning at Headcorn Airfield and landing sequentially at Lydd and Deanland Airfields, before returning to Headcorn. He had obtained PPR[1] for Deanland the day before. The flight to Lydd was uneventful and after a short break, he commenced the next leg of his flight. The pilot was aware from the windsock as he departed Lydd that the wind had freshened.

The pilot had flown to Deanland once before and had planned to land on Runway 24 but on arrival found that Runway 06 was in use and the wind was variable. On turning onto final he became aware that there was a strong crosswind, with turbulence, and he was only able to maintain the inbound track by crabbing approximately 40º to the centre line. The pilot switched to a wing-down approach, but this did not reduce the crab angle and he perceived that the aircraft was now slipping and had lost height. He therefore reverted to the crab approach. During the flare the pilot closed the throttle and aligned the aircraft

Footnote

[1] Prior permission required.

with the runway which resulted in the aircraft drifting to the left. He attempted to counter the drift by applying opposite rudder, but the aircraft bounced on touchdown, veered off the runway and struck a runway marker before passing through a hedge. While the aircraft was damaged, the pilot was uninjured.

The pilot considered that in planning his cross-country flight he had paid too much attention to communications and circuit preparations at the expense of giving due consideration to the possibility of varying weather conditions. He further considered that once underway, he missed several opportunities to revise his flight plan.

AAIB comment

This accident highlights the importance of initiating a go-around if the aircraft is not stable on the approach. Moreover, when planning a multi-leg flight it is important to consider possible adverse changes in the weather and the effect it might have on all the legs.

Bulletin Correction

The report states that the pilot obtained prior permission for the landing at Deanland Airfield while at Lydd Airport during the cross-country flight. The pilot has confirmed that prior permission for landing at Deanland had been obtained during the day preceding the flight.

The report incorrectly states that Runway 26 was in use when the aircraft arrived in the vicinity of Deanland Airfield. The correct designation for the runway in use at the time of the accident was Runway 06.

The online version of the report was amended prior to publication.

ACCIDENT

Aircraft Type and Registration:	Mainair Rapier, G-MZIM
No & Type of Engines:	1 Rotax 462 piston engine
Year of Manufacture:	1997 (Serial no: 1124-0697-7-W927)
Date & Time (UTC):	16 May 2019 at 1655 hrs
Location:	Newtownards Airfield, Co. Down
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Severe damage to pod, main keel and the wing
Commander's Licence:	Private Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	550 hours (of which 528 were on type) Last 90 days - 15 hours Last 28 days - 10 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot had completed an uneventful flight from St. Angelo Airfield to Newtownards Airfield, Co. Down which was the pilot's 'home' airfield. The weather was good with visibility more than 10 km, high cloud and an OAT of 15°C. The pilot carried out an overhead join for Runway 15 (grass), with a surface wind of 150°/8 kt. There was some slight turbulence on the approach, but it did not cause any difficulty in maintaining the desired approach path. On touchdown or just before, the aircraft suddenly turned left and the pilot was not able to regain control before it struck a fence, which ran parallel to the grass runway. The pilot was unclear as to what had caused the aircraft to turn so suddenly and surprised at the lack of control, which prevented him from avoiding the fence. He suffered a significant foot injury but was able to get out of the aircraft without assistance.

The pilot did not think he had struck an obstacle just before or after touchdown which might have caused the sudden turn. He considered that the turn may have been due to wake turbulence from another flex wing aircraft that landed ahead of him, but there appeared to have been a safe distance between them. He reported that, in future, he would leave a greater distance between his aircraft and traffic landing ahead of him.

ACCIDENT

Aircraft Type and Registration:	DJI Inspire 2 (UAS, registration n/a)	
No & Type of Engines:	4 electric motors	
Year of Manufacture:	2017 (Serial no: 095XDAX002027D)	
Date & Time (UTC):	25 March 2019 at 1444 hrs	
Location:	Chobham Common, Surrey	
Type of Flight:	Aerial Work	
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:	33 years	
Commander's Flying Experience:	76 hours (of which 7.5 were on type) Last 90 days - 2.2 hours Last 28 days - 0.4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The DJI Inspire 2 UAS was returning from a surveillance flight when it unexpectedly yawed and uncontrollably descended, contacting the ground. An object was seen to be released from the aircraft prior to the loss of control which was thought to be a part of a propeller blade. The operator has implemented safety action as a result of this investigation.

History of the flight

The operator was conducting a surveillance operation of a heathland fire utilising a DJI Inspire 2 which was able to stream footage to observers on the ground. Prior to the flight the operator's standard checklist was followed to check the aircraft ready for flight. Two successful flights were completed with no incident. Between each flight the pilot changed the battery, which is known as a 'warm start'.

During the third flight, the DJI Inspire 2 ascended to 365 ft whilst travelling in a south eastern direction from the Take-Off and Landing Site (TOLS). It then held station surveying the site 1,635 ft from the TOLS. Approximately four minutes later a decision was made to return the UAS to the TOLS so it could operate from a different location. As the aircraft returned it was seen to yaw suddenly to the right whilst rapidly descending. The pilot attempted to regain control but did not get any response. Both the pilot and spotter shouted warnings to those in the vicinity of the falling aircraft. An observer who was not part of the operating team heard the warnings and took cover in undergrowth near-by. The UAS crossed a road and struck the verge approximately 5 m from him. Both the pilot and the spotter reported seeing an object fly off the aircraft moments before control was lost, they also heard a loud high pitch squeal as the UAS fell.

Aircraft examination

Examination of the UAS, by the operator, confirmed that all four propellers had been fitted correctly to their hubs, however of the eight propeller blades, only two remained intact and connected to the hubs. The remainder of the blades had fractured at or near to the propeller hubs. An examination of the fracture surfaces of the propeller blades was not made.

The investigation completed by the operator concluded that the likely cause of the accident was as a result of an inflight propeller blade failure, however a speed controller failure could not be ruled out.

Analysis

When a warm start was carried out by the operator, there was no requirement for an inspection, similar to that completed prior to the first flight, to be done. It as considered that if an inspection had been carried out during each battery change a cracked propeller blade may have been detected.

Safety actions/Recommendations

As a result, the operator has taken the following safety action.

> During warm starts the operator has introduced physical checks, including an inspection of the propellers, before the next flight.
>
> The operator has also instructed its pilots not to overfly people.

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: 0GODF4R023001)
Date & Time (UTC):	4 September 2018 at 1451 hrs
Location:	Tilbury Docks, Essex
Type of Flight:	Emergency services operation
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Destroyed
Commander's Licence:	N/A
Commander's Age:	42 years
Commander's Flying Experience:	11 hours (of which 11 were on type) Last 90 days - 2 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

After about six minutes into the flight, a battery low voltage condition was detected by the UAS causing it to enter an automatic landing mode. Shortly afterwards, while the aircraft was 20 m above the ground, it powered down and the electric motors stopped, causing it to fall to the ground. An investigation of this and similar accidents was conducted by the manufacturer which found that the batteries' State of Charge (SOC) was indicating an erroneously high level of charge remaining. Safety actions were taken by the CAA to introduce operational restrictions while a fix was being found, and by the manufacturer to develop and 'push out' firmware changes to the battery and aircraft.

History of the flight

The accident occurred on the third flight of the aircraft that day. The aircraft was being operated in a cordoned-off area to maintain a safe distance (ie at least 50 m) from persons, vehicles, vessels and structures not under the operator's control, as per their procedures. Between each flight the batteries powering the aircraft were changed – the batteries installed for the accident flight were new, with the latest firmware installed (v01.00.00.71), and fully charged. Six and a half minutes into the accident flight, with the aircraft about 20 m above the ground, the pilot, who was visual with the aircraft, saw a battery system error displayed on the controller. The pilot then selected the HOME button on the controller; however, the aircraft appeared not to respond. A few seconds later, while the aircraft was above a road within the cordoned-off area, the motors stopped and it fell to the ground.

The damaged aircraft was sent to the manufacturer for repairs and analysis of the recorded onboard data. A copy of the recorded data was subsequently provided to the AAIB for further analysis.

Aircraft description

The DJI Matrice 210 is an Unmanned Aircraft System (UAS). The aircraft (Figure 1) is a quadcopter fitted with dual smart TB50 or TB55 batteries and has a maximum takeoff mass of 6.14 kg. It is controlled on the ground using a handheld flight controller via radio frequency with a maximum transmission distance of 7 km and a software application (app) running on a tablet device attached to the controller. The app on the tablet device offers touch-screen controls and shows live HD images from the aircraft's camera.

Safety modes include features such as Return to Home (RTH) to ensure the safe return of the aircraft to the takeoff point if the control signal is lost or if the batteries' remaining State of Charge (SOC) reduces to a pre-set level. It will also automatically initiate a landing if there is insufficient SOC to reach home. Battery voltage is also monitored and an RTH or landing will be initiated if the voltage becomes critically low; however, as battery voltage does not fall linearly as the battery is discharged, it is not a reliable means of predicting the capacity required to ensure a safe return or landing. A storage device in the aircraft is used to record flight data for each flight.

Figure 1

DJI Matrice 210

(This depicts the RTK version of the Matrice 210 –
the accident aircraft did not have the two white external GPS antennas attached.)

Recorded information

The recorded data showed that at the start of the flight, both batteries had a voltage of 22.5 VDC but an erroneous SOC of 100% which is normally associated with a battery voltage of 26.3 VDC. Nine seconds before the end of the flight, with both battery voltages at about 18 VDC (but indicating a SOC of 77%), a battery low-voltage condition was detected by the aircraft causing it to go into an automatic landing mode three seconds later. The aircraft powered down and the motors stopped while it was still airborne at a height of 20 m above the ground. The manufacturer's initial analysis concluded that landing was initiated 'due to critically low voltage'. This was confirmed by the AAIB's separate analysis of the recorded data (Figure 2).

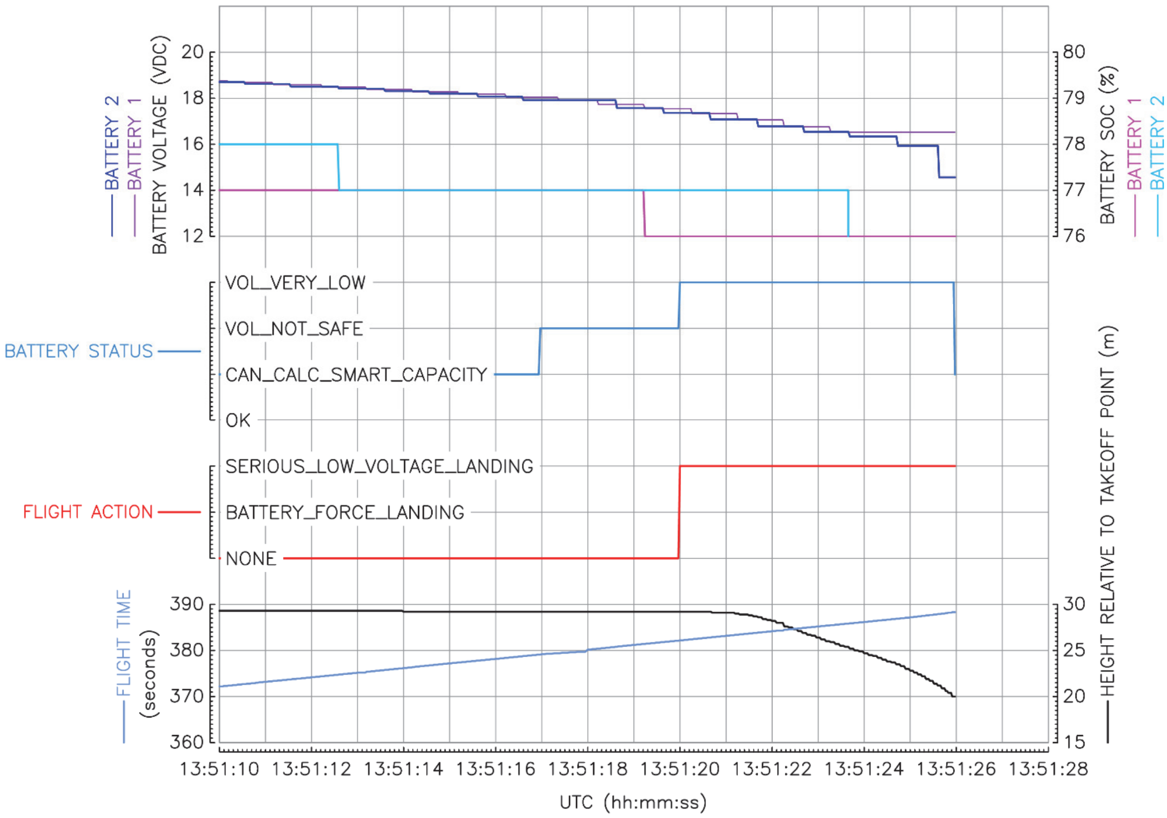

Figure 2

Plot of salient data for last 16 seconds of the recorded data

Similar Matrice 210 UK accidents

Between 9 July and 26 October 2018, the AAIB was made aware of another three Matrice 210 accidents, each of which crashed due to a loss of power, and which the manufacturer concluded were a result of landings being initiated due to critically low battery voltages. The batteries in these accidents (all TB55s) were indicating an erroneously high SOC. (See reports on DJI Matrice 210 RTK - EW/G2018/07/43, DJI Matrice 210 RTK - EW/G2018/10/09 and DJI Matrice 210 - EW/G2018/10/17 in this AAIB Bulletin 11/2019.)

Investigation by the UAS manufacturer

To understand the problem highlighted by these accidents and by a handful of similar cases worldwide, a comprehensive investigation, starting October 2018, was undertaken by the manufacturer to determine the root cause of the battery voltage and SOC mismatch of the smart batteries at fault.

Smart batteries and State of Charge

A smart battery is a rechargeable battery with a built-in management system that can monitor the battery status (such as current, voltage, charge level and state of health parameters). This information can then be used by a charger or UAS, for example, to intelligently manage their use.

Battery voltage is not an easy-to-interpret measure of the battery capacity remaining as voltage reduces non-linearly as current is drained. Therefore, the battery calculates a SOC which is a measure of its short-term (ie current charge) capacity and often called the 'gas gauge' or 'fuel gauge' function. The units of SOC are expressed as a percentage where 0% = empty and 100% = full. The SOC, rather than actual battery voltage, is used by the UAS to calculate battery 'fuel' trigger levels against which automatic actions such as Return to Home (RTH) or Automatic Landing can be set, so that these actions can be carried out safely.

For the SOC to be calculated, a battery capacity algorithm is used that integrates the total current flowing in and out of the battery to obtain the battery net charge. Batteries in storage, however, can generate an infinitesimal voltage which the battery capacity algorithm will detect and interpret as an apparent 'ghost' current. Over time, this can result in the battery SOC increasing even though the actual capacity has not changed. To stop this happening, an Open-Circuit Voltage (OCV) correction in the algorithm is used to compensate for any 'ghost' currents detected.

Investigation findings

The TB50 and TB55 batteries have a battery capacity calculation register that is used to configure the algorithm. One of the bits of the register (the 'DoDWT' bit[1]) is used for turning on the OCV correction in the algorithm. The battery manufacturer's default setting for the 'DoDWT' bit is 1 which disables the OCV correction (this setting is needed for batteries with different chemical compositions to the Li-ion composition of the TB50 and TB55 batteries). The aircraft manufacturer was aware of this setting and made the decision to not change it as it was not expecting the 'ghost' current of these batteries to be very high, and therefore not to be an issue.

The investigation found, however, that for some batteries the 'ghost' current was higher than expected but within the design variance of the battery. When these batteries were subsequently subject to long-term storage (such as new batteries shipped and then stored

Footnote

[1] Depth of Discharge WeighTing, Depth of Discharge (DOD) of a battery is the inverse of SOC (so 100% = empty and 0% = full).

by a retailer), the capacity algorithm slowly summed up the 'ghost' current as a charge, resulting in the generation of the false high SOC value. When the batteries were then recharged for use, the charging would have stopped once the SOC value reached 100%, but essentially before the batteries had reached their maximum charge capacity.

Battery firmware updates

Battery firmware version v01.00.00.71 was released by the manufacturer in August 2018 to set the 'DoDWT' bit to 0. For the update to work correctly, an internal flag was monitored to confirm that the new firmware had been installed; however, it was later realised that for some batteries, this flag was not being set even though the firmware was installed correctly.

Battery firmware version v01.00.00.77 was subsequently released in November 2018 that forcibly set the 'DoDWT' bit to 0 to enable OCV correction in the battery capacity algorithm for all TB50 and TB55 batteries.

Aircraft firmware updates

As an additional redundant safety mechanism to the v01.00.00.77 battery firmware update, aircraft firmware v01.02.0000 was also released in November 2018 that introduced within the aircraft's flight controller a method to estimate the SOC. With the updated firmware, the software compared the controller-estimated SOC at the trigger points for an RTH or Automatic Landing with that calculated by the battery and, in the event of a difference of greater than 10%, trigger an RTH or Automatic Landing.

Aircraft firmware v01.02.0301 was then released in December 2018, which introduced within the flight controller a current integration method to estimate the SOC with better accuracy to the method used in the v01.02.0000 update.[2]

Issues with the user manual and the apps used to control the Matrice

The Matrice 210 user manual (current version November 2018) does not specify that the batteries have their own firmware. It only describes the aircraft firmware and remote controller firmware. The aircraft firmware does not automatically install the latest battery firmware into a battery pair that is connected to the aircraft. If an operator has multiple sets of batteries, they might not have known that they needed to install each set of batteries into the airframe and conduct a firmware update on each set[3]. The manufacturer is planning an update to the user manual which will state:

> *'The battery firmware is included in the aircraft firmware. Be sure to update all the batteries' firmware.'*

Footnote

2 The release was in conjunction with the release of battery firmware v01.00.00.84 that added a battery heating safeguard to ensure that the temperature of the batteries is higher than 61°F (16°C) before takeoff. This was to prevent cold battery use when the battery performance is sub-optimal due to decreased chemical activity in the battery.

3 If an operator had consulted the firmware release notes on the manufacturer's website, then from August 2018 onwards they would have seen a note referring to updating all batteries with the firmware. However, it was not until December 2018 that the manufacturer included the battery firmware version in the release notes.

The Matrice 200 series aircraft can be controlled using the DJI Pilot app or the DJI Go 4 app. The DJI Pilot app is only available on Android whereas the DJI Go 4 app is available on Android and iOS. The user manual does not specify which app should be used but it states that the DJI Pilot app needs to be used to control two cameras. At the time of this accident and until 14 November 2018 the DJI Pilot app was in beta release[4]. For this reason, some operators chose to use the DJI Go 4 app. However, the DJI Go 4 app[5] cannot display the battery firmware version. Operators needed to know to use the DJI Pilot app to check the battery firmware version, but this was not specified in the user manual or the firmware release notes. Both apps had a system to warn the user if the battery firmware was not up-to-date. However, if after opening the apps, the user made a quick selection to enter flight mode, these messages would not appear; and once within the app it appeared that the firmware was up to date.

The manufacturer has made improvements to the DJI Pilot app (Android V1.1.0) to address these issues and is also planning improvements to the DJI Go 4 app. The planned update to the user manual will also specify that the DJI Pilot app is the recommended app to use (it is no longer in beta release).

The manufacturer stated to the AAIB that it is considering and designing 'push notifications' to users to notify them of emergency firmware upgrades without the user needing to upgrade the app first.

CAA Safety Notices

To raise awareness of the battery issues and firmware updates to DJI Matrice 200 series users, and introduce operational limits depending on the version of firmware installed, the CAA issued the following Safety Notices:

Reference:	*SN-2018/008 (dated 26 October 2018)*
Title:	*Small Unmanned Aircraft - DJI Matrice 200 Series In-Flight Power Failures*
Description:	*The purpose of this Safety Notice is to raise the awareness for DJI Matrice 200 series users of a small number of in-flight power failures which have led to a complete power loss and the aircraft have fallen to the ground. The SN gives guidance on how to complete the latest firmware update and also suspends any permissions based on an Operational Safety Case.*

Reference:	*SN-2018/009 (dated 31 October 2018)*
Title:	*Small Unmanned Aircraft - DJI Battery TB50 and TB55 In-Flight Power Failures*
Description:	*This SN gives guidance on DJI Battery TB50 and TB55 In-Flight Power Failures that supersedes SN-2018/008.* *Version 2 has been issued to clarify queries from industry relating to the suspension of permissions and exemptions issued to operators of the affected DJI platforms until further notice by the CAA*

Footnote

4 Android V0.6.3 (beta) until 14 November 2018. Beta release implies that there might be some bugs in the app.
5 iOS V4.2.24, Android V 4.2.21 up to latest versions iOS V4.3.3 and Android V4.3.2 (19 December 2018).

Reference:	*SN-2018/010 (dated 9 November 2018)*
Title:	*Small Unmanned Aircraft - DJI Battery TB50 and TB55 In-Flight Power Failures*
Description:	*This Safety Notice provides updated instructions and guidance regarding the DJI TB50/55 series of batteries and supersedes SN-2018/009 version 2.* *While a number of the previous suspensions relating to operational authorisations remain in place, those relating to operations within congested areas and EVLOS flights have now been lifted.*

Reference:	*SN-2018/011 (dated 21 November 2018)*
Title:	*Small Unmanned Aircraft - DJI Battery TB50 and TB55 In-Flight Power Failures*
Description:	*This Safety Notice provides updated instructions and guidance regarding the DJI TB50/55 series of batteries and supersedes SN-2018/010.* *The text highlights the updated battery firmware that has was released by the manufacturer on 16 November to correct previous instances where power has been unexpectedly lost. The aircraft operating restrictions that must now be observed are dependent on whether or not the manufacturer's recommended updates have been successfully installed.*

In addition, the CAA have published two alerts on its Skywise website[6], Alert SW2019/067 on 22 March 2019 which stated:

> *'The CAA has received six Mandatory Occurrence Reports in the last three months affecting the DJI Matrice 210 series drone.*
>
> *The reports have indicated that on each occasion the DJI M210 has malfunctioned resulting in rapid uncontrolled descent and consequent damage to the airframe upon impact with the ground. Reports suggest the issue may lie with one of the airframe's motors. We are working with the manufacturer and monitoring the situation.*
>
> *All users of the DJI M210 series are advised to consider their obligations under Art. 241 of the ANO[7] and avoid flying over people or property until further notice.'*

This was superseded by Alert SW2019/116, published on 30 May 2019 which said:

> *'On 22 March 2019 the CAA released a Skywise update regarding the DJI M210 series drone and a number of reported failures.*
>
> *The manufacturer has been unable to identify a common root cause and continues to investigate whether the failures are related. The CAA has received no further similar reports.*

Footnote

6 http://skywise.caa.co.uk/dji-matrice-210-series-drone/ [accessed September 2019]

7 Article 241 of the Air Navigation Order 2016 (ANO), amendment 28 September 2018, states: 'A person must not recklessly or negligently cause or permit an aircraft to endanger any person or property.'

No additional restrictions beyond those in the Air Navigation Order 2016 are in place for the use of a DJI M210.

However, the CAA reminds operators to have appropriate mitigation's in place if flying over persons or property in accordance with the Air Navigation Order, as was the case prior to this reported issue.'

Previous Matrice 210 AAIB investigation

In October 2018, the AAIB reported on another DJI Matrice 210 accident[8] that occurred on 20 December 2017 where power to the motors were cut when the system calculated that the battery levels were too low. Although the manufacturer could not explain the anomalies seen in the behaviour of one of the batteries (and different to the battery issue discussed in this report), it was aware of a battery firmware issue that resulted in the actual battery levels being ignored and power to the motors being cut because the system considered the battery level too low. It subsequently released a battery firmware update on 29 December 2017 (DJI Matrice 200 Series Release Notes for the '*Optimisation of battery level display*') to resolve this issue.

Other Matrice 210 AAIB investigations

In addition to the accidents discussed in this report, the AAIB has investigated seven Matrice 210 accidents that occurred in the UK between 14 January 2019 and 18 March 2019. All involved the aircraft falling to the ground for technical reasons; some relating to electronic speed controller failures and motor failures, but none relating to the battery issue discussed in this report.

Analysis

The manufacturer's investigation into this accident and the three others described in this report revealed that some TB50 and TB55 batteries could generate erroneously high SOCs when left in long-term storage.

For the affected batteries, it was found that they were generating higher than expected (but within the design variance) 'ghost' currents, which the battery capacity algorithm slowly summed up as an apparent charge. As these higher 'ghost' currents had not been anticipated, the manufacturer decided that the OCV compensation was not needed.

This resulted in the batteries registering a higher charge than they actually had, such that, when taken out of storage and subsequently recharged for use, the charging would stop before their maximum charge capacity had been reached.

When these batteries were then used, the aircraft was monitoring and seeing what it thought was sufficient charge capacity in the batteries for continued flight with enough reserve to fly back home. However, the charge capacity was actually less than this, allowing the

Footnote

8 AAIB Bulletin 10/2018 pages 81-82: Accident to DJI Matrice 210 – EW/G2017/12/017 https://www.gov.uk/aaib-reports/aaib-investigation-to-dji-matrice-210-registration-n-a [accessed September 2019]

aircraft to continue flying until the battery low-voltage condition was detected triggering an RTH quickly followed by an Automatic Landing command. There was, however, insufficient voltage to continue powering the aircraft as the low-voltage RTH condition was set too low. At this point the motors stopped and the aircraft fell to the ground.

For this accident, the operational procedures meant that the aircraft was being operated in a cordoned-off area clear of people, vehicles, vessels and structures not under the operator's control, so that when it fell to the ground, there was no danger of it falling on someone. However, this is just one of 12 Matrice accidents with a similar outcome mentioned in this report that the AAIB has investigated, which highlights the potential danger, following a technical failure, for an unmanned aircraft to fall uncontrollably to the ground.

Ballistic recovery parachute systems

The Matrice 210 which has a maximum takeoff mass of 6.14 kg could cause a serious injury or a fatality if it fell on someone. The best way to mitigate the risk to people from an unmanned aircraft falling uncontrollably to the ground is to avoid flying over people. An alternative or additional way to mitigate against the risk of an unmanned aircraft falling to the ground is to install a ballistic recovery parachute system (BRPS). After-market BRPS are available for the Matrice 200 series aircraft.

There is a standard, ASTM F3322[9], which specifies requirements for the design, manufacturing and testing of Small Unmanned Aircraft System parachutes[10].

Safety actions

A number of safety actions have been made by the aircraft manufacturer and UK regulator. These are summarised as follows:

The manufacturer issued a number of firmware updates for the batteries, aircraft and controller apps as follows:

- Provided battery firmware updates to correct the erroneously high SOC issue.
- Provided aircraft firmware updates to perform a gross check of the batteries' SOC and trigger a RTH or Automatic Landing if a difference of greater than 10% is detected at specified trigger points.
- The DJI Pilot app has been updated to provide a clear warning when the battery firmware is out of date. The manufacturer is also planning improvements to the DJI Go 4 app.
- A planned update to the Matrice 200 series user manual will specify that the DJI Pilot app is the recommended app to use, and will specify that the batteries contain firmware that must be individually updated.

Footnote

9 https://www.astm.org/Standards/F3322.htm [accessed September 2019]

10 Compliance with this specification is intended to support an applicant in obtaining permission from a national aviation authority (NAA) to fly a small UA over people.

The CAA issued four safety notices and Skywise Alert SW2019/067 to raise awareness of the battery issues and firmware updates to DJI Matrice 200 series users, as well as introducing operational limits depending on the version of firmware installed. These limitations have now been removed with the publication of Skywise Alert SW2019/116 which also reminded operators to have appropriate mitigations in place if flying over persons or property.

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2017 (Serial no: 0G0DE8CLD30020)
Date & Time (UTC):	26 October 2018 at 1255 hrs
Location:	Ledbury, Herefordshire
Type of Flight:	Emergency services operations (Training)
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Damage to front motor arms, gimbal mount, propellers and camera
Commander's Licence:	N/A
Commander's Age:	40 years
Commander's Flying Experience:	4 hours (of which 0 were on type) Last 90 days - 4 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The aircraft dropped to the ground from a height of 4 m when the electric motors shut down due to insufficient battery charge remaining. The batteries' State of Charge (SOC) was indicating erroneously that 75% charge remained. The cause of the erroneously high SOC is discussed in the report on the accident to DJI Matrice 210 on 4 September 2018 (ref EW/G2018/09/04, AAIB Bulletin 11/2019).

History of the flight

The pilot was receiving instruction on how to operate the Matrice 210 Unmanned Aircraft System (UAS). The aircraft was fitted with two TB55 batteries and a Zenmuse Z30 Camera. The latest aircraft firmware v01.01.0913 and battery firmware 01.00.00.71[1] were loaded and the pilot was using the DJI Go 4 app to operate the aircraft.

Both batteries had been fully charged during the morning of the accident and some power had been used during ground training. Following a pre-flight inspection and a 3-minute test flight by the instructor the controller was passed to the pilot. The batteries' SOC was indicating about 80% charge remaining. Following a normal takeoff in an open field the

Footnote

[1] The battery firmware version was confirmed from the aircraft log file. Battery firmware v01.00.0071 and aircraft firmware v01.01.0913 were released on 13/08/2018 and were the latest versions at the time of the accident.

aircraft was flown to a height of 4 m where control checks were carried out. At the end of the checks the aircraft's tail indicator lights changed from green to red indicating an issue. The controller screen indicated 'Battery Error' and then all four motors stopped simultaneously, causing the aircraft to fall to the ground. The aircraft hit the ground inverted about 1 m in front of the takeoff area.

Recorded data

The log file from the aircraft revealed that when the aircraft took off both batteries were indicating 76% SOC and 20.1 V. A fully charged battery is about 25.5 V.

16 seconds after takeoff, at a height of 4 m, the voltage had dropped to 17.4 V and 17.7 V on batteries 1 and 2 respectively, and the 'Vol Not Safe' battery status was triggered. The batteries SOC was still indicating 75% charge remaining. Eight seconds later, when the voltage had reduced to 14.4 V and 15.2 V on batteries 1 and 2 respectively, the 'Vol Not Safe/Dangerous' battery status was triggered and the 'flightAction' parameter changed from 'NONE' to 'BATTERY_FORCE_LANDING'. According to the aircraft manufacturer this triggered an auto-land. The log file ends less than 1 second later when the aircraft shuts down.

Analysis

The data indicated that the aircraft dropped to the ground from a height of 4 m when the aircraft shut down, due to insufficient battery charge remaining. The batteries' SOC was indicating erroneously high for the voltage. The cause of the erroneously high SOC is discussed in the report on the accident to DJI Matrice 210 on 4 September 2018 (ref EW/G2018/09/04, AAIB Bulletin 11/2019).

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 RTK (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: 0N4DF6L021005)
Date & Time (UTC):	20 October 2018 at 1340 hrs
Location:	Manchester Piccadilly Gardens
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 to the airframe, batteries and cameras
Commander's Licence:	N/A
Commander's Age:	44 years
Commander's Flying Experience:	19 hours (of which 1 was on type) Last 90 days - 14 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The operator deployed the DJI Matrice 210 RTK unmanned aircraft system in the City Centre of Manchester. Whilst the aircraft was in a static hover at 260 ft above the takeoff point with an estimated remaining flight time of 12 minutes and 9 seconds displayed on the controller, the aircraft suddenly descended and slewed sideways uncontrollably. It hit the ground causing extensive damage to the airframe, batteries and cameras. No persons or other property were hit by the aircraft.

Analysis confirmed that one of the batteries was indicating an erroneously high state of charge (SOC) and the aircraft had initiated automatic landing due to critically low battery voltage. It subsequently lost all power less than 2.5 seconds later, which resulted in an uncontrolled descent followed by impact with the ground.

The cause of the erroneously high SOC is discussed in the report on the accident to DJI Matrice 210 on 4 September 2018 (ref EW/G2018/09/04, AAIB Bulletin 11/2019).

History of the flight

On 20 October 2018, the operator deployed to Manchester City Centre to operate a series of flights above the rooftops, using the Matrice 210 RTK. The weather at the time was dry, with a wind speed of about 5 kt, and visibility in excess of 10 km. The takeoff mass was 6.14 kg. During the series of flights, the pilot landed the aircraft and changed out the batteries for a fresh pair of fully-charged TB55 batteries and, on carrying out the pre-flight check, the pilot did not receive any error messages; the voltage displayed by the DJI Pilot app on the tablet computer linked to the remote controller (RC) at start-up for the accident flight was 26.0 VDC, with an estimated flight time of 29 minutes.

Figure 1

Plot of flight path of the flight

The accident flight started at 1325 hrs. The pilot was operating the aircraft up to heights of 79.2 m (260 ft) above the takeoff point. At 1340 hrs, while the aircraft was in a static hover at a height of about 168 ft (51.2 m) above the takeoff point, it started suddenly to descend and slew uncontrollably sideways, and hit the ground. The pilot briefly noticed the solid green battery indicator switch to flashing red; the observer noticed a BATTERY SYSTEM ERROR which flashed up on the RC. At the time of the sudden descent, the RC indicated that the battery voltage was 21.9 VDC with an estimated flight time remaining of 12 minutes and 9 seconds. The airframe and batteries, as well as both cameras incurred extensive damage. The aircraft did not hit any other persons or property on impact.

The operator sent the damaged aircraft, batteries and cameras to the manufacturer for repairs and analysis of the recorded on-board data.

Recorded information

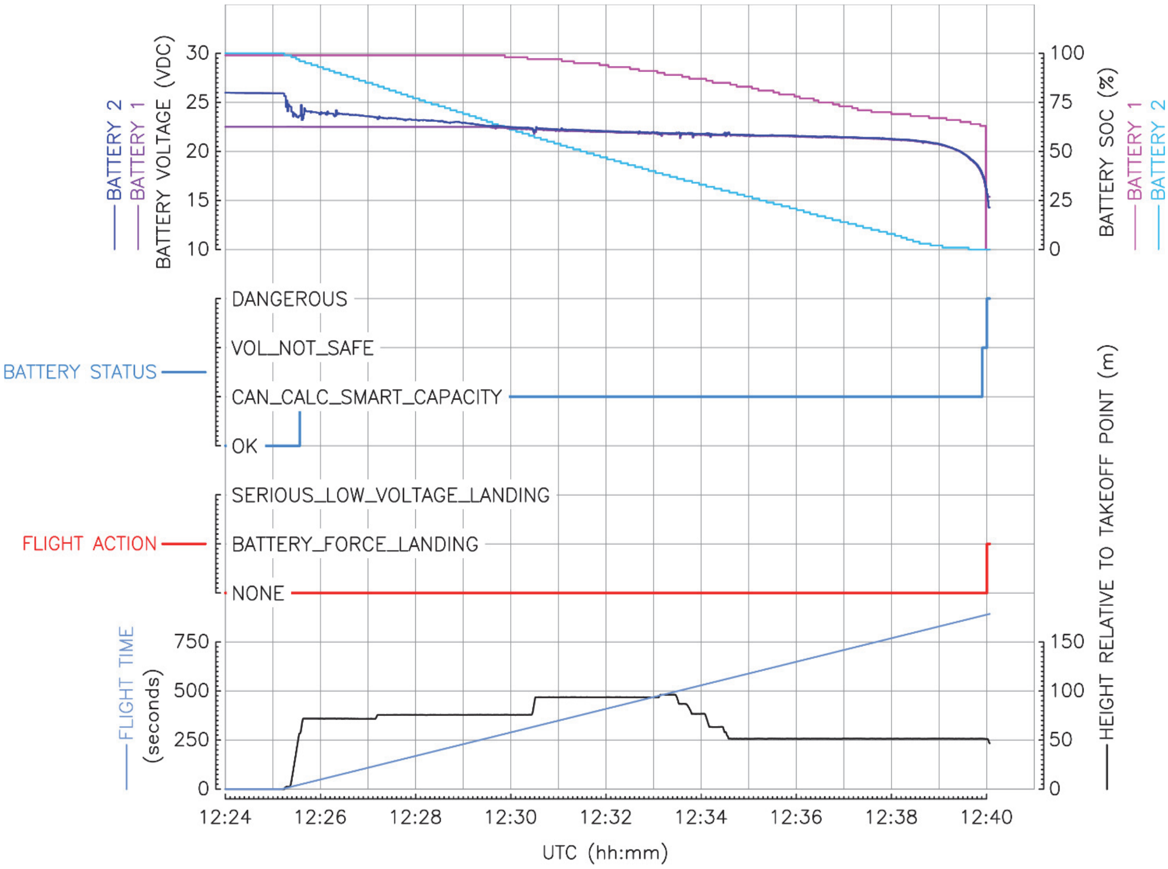

Figure 2

Plot of salient recorded data for the flight

The initial analysis by the manufacturer confirmed that the battery firmware was the latest version (v01.00.00.71). The log file from the aircraft recorded the battery voltages at the start of the flight as 22.5 VDC for battery 1 and 26.0 VDC for battery 2, yet, the SOC was 99% for battery 1 and 100%[1] for battery 2. Once airborne, the aircraft only drew current from battery 2 until the voltage matched that of battery 1; both batteries then discharged uniformly (Figure 2).

9.5 seconds before the end of the data, both batteries had a recorded voltage of 17.6 VDC. However, battery 1 had an SOC of 68% and battery 2 had an SOC of 0%. Seven seconds later, when battery 1 was fully discharged with an SOC recorded of 0% at 15.4 VDC, the aircraft initiated an automatic landing while at a height of 51.2 m (168 ft) above the take-off point.

The end of data, at 1240:03 hrs, with the aircraft at a height of 46.7 m (153 ft) above the takeoff point, marks the time at which the aircraft lost all power and it descended uncontrollably to the point of impact.

Footnote

[1] Battery SOC of 100% is normally associated with a battery voltage of 26.3 VDC.

Analysis

The manufacturer's initial analysis confirmed that the battery firmware was the latest version v01.00.00.71; it concluded that the aircraft had initiated landing automatically '*due to critically low voltage'* and the subsequent uncontrolled descent, which resulted in impact with the ground, occurred once the aircraft had lost all power. The manufacturer identified that the firmware of one of the batteries was reporting an erroneously high SOC for the voltage. The cause of the erroneous SOC is discussed in the report on the accident to DJI Matrice 210 on 4 September 2018 (ref EW/G2018/09/04, AAIB Bulletin 11/2019).

ACCIDENT

Aircraft Type and Registration:	DJI Matrice 210 RTK (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: ON4DEAQ0210210)
Date & Time (UTC):	18 July 2018 at 1147 hrs
Location:	Farmer's field, Keith, Aberdeenshire
Type of Flight:	Commercial Operation
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Destroyed
Commander's Licence:	N/A
Commander's Age:	42 years
Commander's Flying Experience:	20 hours (of which 18 were on type) Last 90 days - 0 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After about five minutes into the flight, a battery low voltage condition was detected by the UAS causing it to go into an automatic landing mode. Seventeen seconds later, while the aircraft was 25 m above the ground, it powered down and the electric motors stopped, causing it to fall to the ground. The batteries' State of Charge (SOC) was indicating that an erroneously high amount charge remained. The cause of the erroneously high SOC is discussed in the report on the accident to DJI Matrice 210 on 4 September 2018 (see EW/G2018/09/04, AAIB Bulletin 11/2019).

History of the flight

The DJI Matrice 210 RTK is a Matrice 210 Unmanned Aircraft System (UAS) using Real Time Kinematic (RTK) GPS correction technology to provide real-time corrections to its location data. It has a maximum takeoff mass of 6.14 kg. For the accident flight the takeoff mass was 4.57 kg.

The accident occurred on the fourth survey flight of the UAS that day. Each of the first three flights was no more than 20 minutes in duration and between each flight the batteries powering the aircraft were changed with fully charged ones. After about five minutes into the fourth flight, with the aircraft at a height of about 60 m, the pilot noted a battery low voltage message on the controller. Shortly afterwards, when the aircraft was above a farmer' s field, its four electric motors simultaneously stopped, and it fell to the ground.

The damaged aircraft was sent to the manufacturer for repairs and analysis of the recorded onboard data. The AAIB was unable to obtain a copy of the recorded data (it had been deleted by the time it was requested); however, it did receive a copy of the manufacturer's analysis report. This stated that at 5.5 minutes into the flight, about 60 m agl, an automatic landing was triggered by an abnormally low battery voltage. Seventeen seconds later, about 25 m agl, data recording onboard the aircraft stopped.

Similar Matrice 210 UK accidents and investigation by the UAS manufacturer

During 2018, another three Matrice 210 accidents were reported to the AAIB, all of which had similarities with this accident and which the manufacturer concluded were a result of landings being initiated due to critically low battery voltages.

A comprehensive investigation, starting in October 2018, was undertaken by the UAS manufacturer. The findings and subsequent safety actions are detailed in the report on the accident a DJI Matrice 210 - EW/G2018/09/04 found in this AAIB Bulletin 11/2019.

See reports DJI Matrice 210 RTK - EW/G2018/10/09 and DJI Matrice 210 - EW/G2018/10/17 in this AAIB Bulletin 11/2019 for details of the other two accidents.

INCIDENT

Aircraft Type and Registration:	DJI Phantom (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2018 (Serial no: 0HACFIT0A2001)
Date & Time (UTC):	25 April 2019 at 1030 hrs
Location:	Generals Lane, Chelmsford, Essex
Type of Flight:	Aerial Work
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Damage to arm, rotor, and gimbal
Commander's Licence:	Other
Commander's Age:	33 years
Commander's Flying Experience:	13 hours (of which 13 were on type) Last 90 days - 3 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The operator walked the area for the planned survey and programmed the drone using Drone Deploy software. Flight parameters were set using the software and the operator allowed a buffer zone from the trees that surrounded the field being surveyed. However, towards the end of the flight the drone struck a tree. The operator stated that the buffer zone had not been sufficient to allow for the turning circle of the drone at the end of one of the flight legs. The damaged drone was recovered from the tree.

ACCIDENT

Aircraft Type and Registration:	Parrot (UAS, registration n/a)
No & Type of Engines:	2 electric motors
Year of Manufacture:	Unknown (Serial no: D000316)
Date & Time (UTC):	6 August 2019 at 1557 hrs
Location:	Industrial Road, Halifax, Yorkshire
Type of Flight:	Aerial Work
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Damage to propellers and camera mount
Commander's Licence:	Other
Commander's Age:	36 years
Commander's Flying Experience:	22 hours (of which 6 were on type) Last 90 days - 5 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The UAS was being operated by the emergency services in response to a serious incident requiring an urgent search for a missing person along a canal path. An elevated position in a small, quietly populated cul-de sac was chosen from which to operate the UAS, with a good line of sight visibility of the search area. The weather was good, clear and sunny with a wind of about 14 kt, gusting 28 kt and an OAT of 22°C. There were no pedestrians in the operating area and no vehicular traffic.

The UAS made a normal takeoff and responded correctly to the control inputs made by the operator. It was manoeuvred towards the canal area at an altitude of about 60 m, continuing to respond correctly to the control inputs. It was brought to a hover for the operator to survey the general area and select a suitable flight area to clear the canal towpath.

Whilst surveying the area, and approximately 45 seconds into the flight, the operator experienced vibrations from the UAS which were evident in the camera image feed. The operator performed a 360° turn of the UAS in order to check control, which was effective. However, seconds later, control inputs did not have the desired or expected response from the UAS. It continued to vibrate heavily and began to move erratically and manoeuvre itself without control inputs. With the UAS facing away from him, the operator attempted to manoeuvre it backwards towards him, but it flipped uncontrollably resulting in an uncontrolled descent, impacting a small residential street. The total flight time was 1 minute and 21 seconds. There were no injuries to persons or damage to property on the ground, but the UAS suffered extensive damage. No cause for the loss of control was identified.

Miscellaneous

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

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

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.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

aal	above airfield level
ACAS	Airborne Collision Avoidance System
ACARS	Automatic Communications And Reporting System
ADF	Automatic Direction Finding equipment
AFIS(O)	Aerodrome Flight Information Service (Officer)
agl	above ground level
AIC	Aeronautical Information Circular
amsl	above mean sea level
AOM	Aerodrome Operating Minima
APU	Auxiliary Power Unit
ASI	airspeed indicator
ATC(C)(O)	Air Traffic Control (Centre)(Officer)
ATIS	Automatic Terminal Information Service
ATPL	Airline Transport Pilot's Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot's Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European 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

Air Accidents Investigation Branch