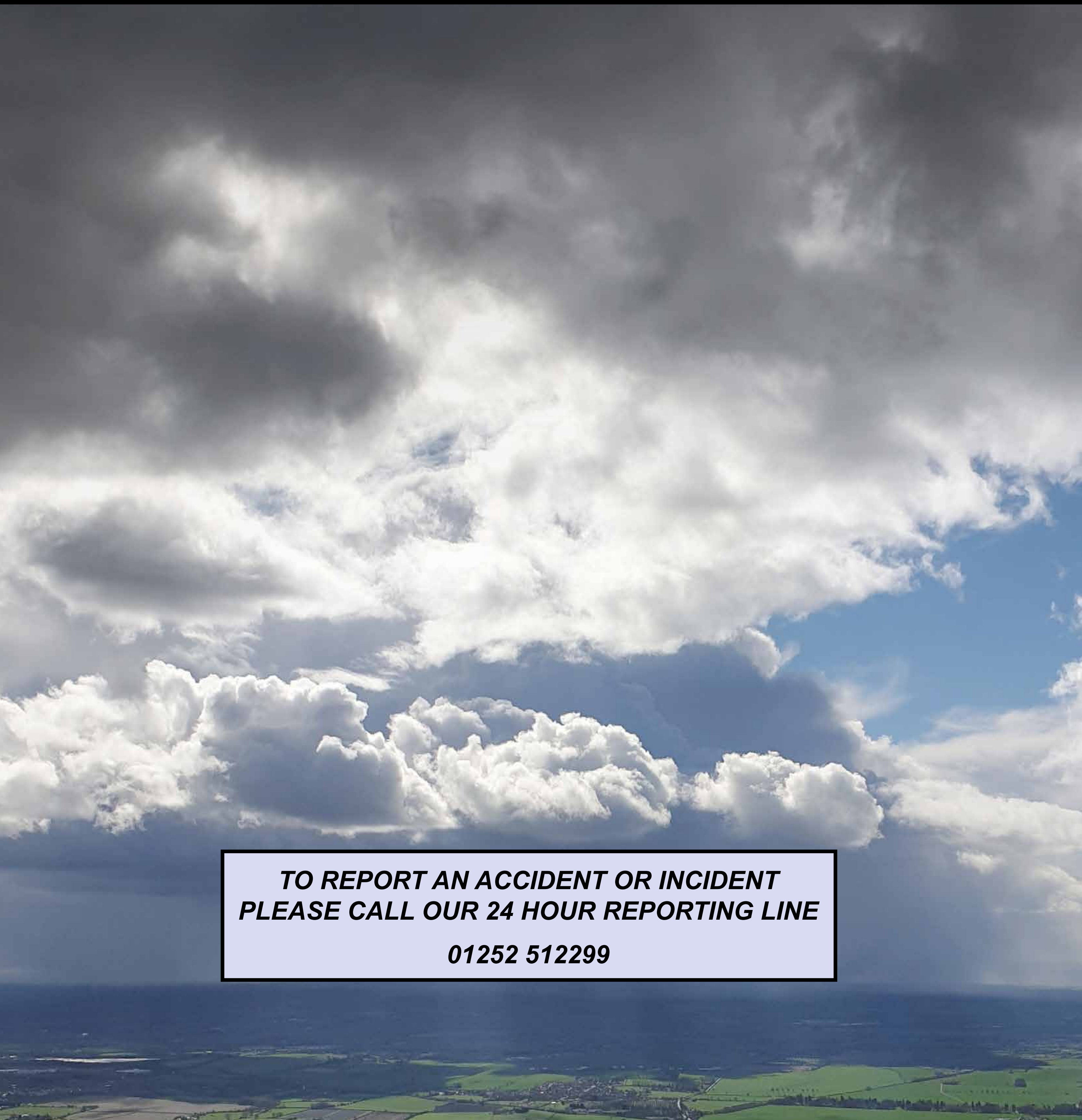
AAIB

Air Accidents Investigation Branch

AAIB Bulletin 2/2021



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

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RECORD-ONLY INVESTIGATIONS

MISCELLANEOUS

ADDENDA and CORRECTIONS

None

(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Field Investigation Reports

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

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

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

ACCIDENT

Aircraft Type and Registration:	Pitts S-2A Pitts Special, G-ODDS
No & Type of Engines:	1 Lycoming AEIO-360-A1E piston engine
Year of Manufacture:	1980 (Serial no: 2225)
Date & Time (UTC):	24 August 2019 at 1304 hrs
Location:	Stonor, Oxfordshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 2 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence (Class Rating Instructor)
Commander's Age:	35 years
Commander's Flying Experience:	Approximately 710 hours (of which about 172 hours were on type) Last 90 days - 35 hours Last 28 days - 12 hours
Student's Flying Experience:	197 hours (of which 1 hour 25 minutes were on type) Last 90 days - 34 hours Last 28 days - 8 hours
Information Source:	AAIB Field Investigation

Synopsis

During an aerobatics training flight, the aircraft struck the ground whilst in a spin. The aircraft was destroyed and both pilots were fatally injured. A definitive cause could not be determined, but it is likely that the commander became incapacitated during a spin and the student was unable to recover the aircraft in time. The aircraft had a Centre of Gravity (C of G) position that was out of limits aft, which would have reduced the capability of the aircraft to recover and extended the time to do so. Unapproved devices, which adjusted the rudder pedal positions, were found on the rudder cables but were unlikely to have been a contributory factor.

Safety action has been taken by the operator regarding aircraft weight and balance to ensure accurate weights are used.

History of the flight

The aircraft was engaged on an aerobatic training sortie. The objective of the training was to prepare the student to compete in Sports[1] level aerobatic competitions. The accident occurred on his third sortie of the training and the student was operating from the rear cockpit of the aircraft.

The exact content of the sortie is unknown, though the investigation was advised that the commander generally followed the Aircraft Owners and Pilots Association (AOPA) Standard Aerobatic Course syllabus. For the stage of training being undertaken, it is believed that upset recovery training and recovery from inadvertent spin entry would have been likely exercises.

The aircraft took off from White Waltham Airfield at approximately 1255 hrs. It flew to an area north of Henley-on-Thames and was seen manoeuvring by two eyewitnesses. The eyewitnesses described the aircraft as entering a spin and then recovering, climbing to gain more altitude and then entering another spin. The eyewitnesses were both over one mile from the accident site. Their statements differ significantly in the estimation of the height of the aircraft and the exact manoeuvres flown, though both recalled last seeing the aircraft in a spin. The second spin persisted for several turns and the aircraft was still spinning when the witnesses lost sight of it; neither witness saw the aircraft strike the ground. Both occupants were fatally injured.

Accident site

The accident site was approximately 1 mile south of Stonor village in an open field with livestock (Figure 1). The aircraft was disrupted, in an upright position and had struck the ground in a steep nose-down attitude. The ground marks showed the first ground contact was made by the leading edge of the right lower wing and the nose of the aircraft. The ground marks were short and although the ground was very hard, the aircraft had not travelled forward after the initial contact. However, there was evidence that the aircraft had moved to the left by approximately 1-2 m with a small rotation to the right which is consistent with spinning with right yaw. Both pilots were restrained within the aircraft but had suffered injuries which were not survivable.

Footnote

[1] There are four contest classes of aerobatic competition of which Sports is the lowest and requires only basic aerobatic manoeuvres.

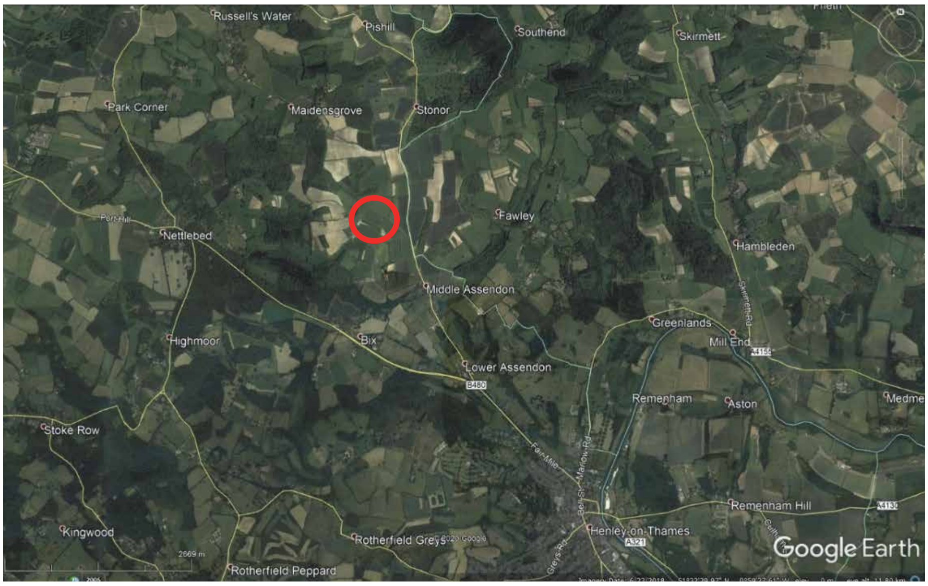


Figure 1
Accident site

Recorded information

The only sources of data relating to the flight were primary radar recordings (Figure 2). This provided the aircraft flight path but no altitude information. Radar contact was lost at 1304 hrs.

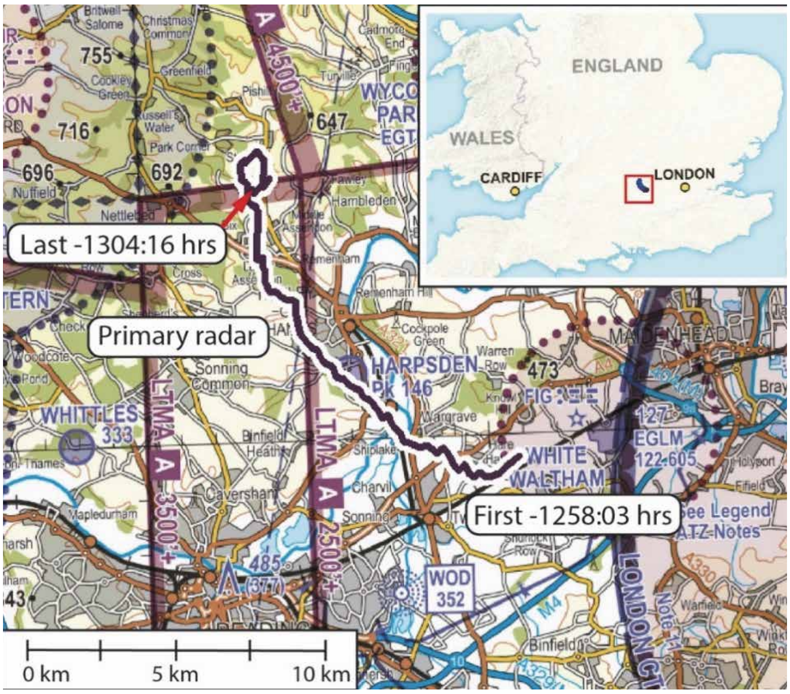


Figure 2
Radar data

Airspace information

The aircraft was being flown in Class G airspace. However, the London TMA, Class A airspace, lies over the area in which the aircraft came to rest and has a lower level of 3,500 ft amsl. The terrain at the accident site rises to approximately 500 ft amsl, so the base of the Class A airspace is approximately 3,000 ft agl. The Benson Military Air Traffic Zone and further Class A airspace at 4,500 ft amsl lies to the west of the accident site. Approximately 500 m north of the accident site the base of Class A airspace rises to 5,500 ft amsl.

Meteorology

The Met Office conducted an analysis of the meteorological situation. A summary is as follows:

> *'From the information available, it can be concluded that weather conditions around the Stonor area in Oxfordshire, on Saturday 24th August 2019 at around 1305 UTC were very benign. Visibility was likely to be greater than 10KM, likely up to 30KM, and there would have been very little cloud, if any. Although neither RAF Benson, nor RAF Northolt reported any low or medium cloud, there is a chance that at the location of interest, there could have been some Cumulus or Stratocumulus between 2000FT and 5000FT.'*

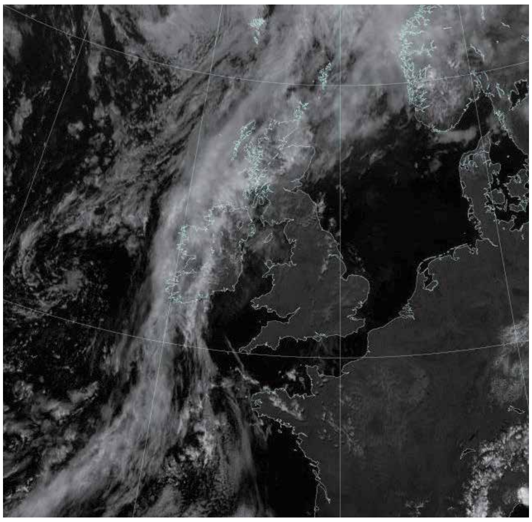


Figure 3

Visible Light Satellite images 1300 hrs, 24 August 2019

Personnel

The commander was a PPL(A) holder with a current Class 2 medical, an aerobatics rating, a Class Rating Instructor and was an Unlimited Category competition aerobatics pilot. The results of an electrocardiogram (ECG) examination, carried out in 2001, were acceptable for all classes of aviation medical[2]. The commander's previous logbook was not found and

Footnote

[2] The commander had a Class 2 Medical for which a retest of the ECG was not required until age 40.

so the flying hours experience on the Pitts Special is an approximation based on the active logbook and information provided by the operator.

The student was a PPL(A) holder, endorsed with night and aerobatic ratings, with a current Class 2 medical. The aerobatic rating course requires a minimum of 5 hours or 20 flights of airborne instruction in aerobatics[3] ; the syllabus included spin training. The student only flew with the accident commander as the operator had assessed that flying with any other instructor would have resulted in their combined weights exceeding the weight limit for aerobatics for the aircraft.

Medical aspects

The post-mortem for the student indicated no issues that would have been a factor in the flight while that for the commander revealed a significant cardiac condition. While there were no indications of a previous heart attack, there was significant narrowing of a cardiac artery. The level of coronary disease could have placed the commander at risk of sudden death due to cardiac dysrhythmia. Most cases of such disease in young people are generally only identified at post-mortem with no history of previous symptoms. The condition is not common and particularly rare in those under 40. The commander had shown no history of illness and it is unlikely the condition would have been revealed by an ECG unless a significant physiological burden[4] was applied at the time. Such testing is only required for pilots over 65 for a Class 1 aviation medical.

It is possible that the commander could have suffered a significant alteration of cardiac output, sufficient to prevent further control of the aircraft. In this eventuality it would be likely that the commander would have collapsed with little or no warning.

Aircraft information

The Pitts Special S-2A is a two-seat aerobatic biplane designed in the 1940s and has a proven record in aerobatic competition flying. G-ODDS was built in 1980 and was fitted with a Lycoming AEIO-360-A1E engine.

Fuel consumption

The AOPA Technical Companion for the Pitts S-2A gives an approximate fuel burn of 50 litres per hour for aerobatic training and a minimum fuel for aerobatics of 20 litres. There is approximately 3.8 litres of unusable fuel.

Rudder system

The rudder is operated by two steel cables running the length of the aircraft, which are connected to two sets of pedals, one set in each cockpit. When the left pedal is pushed forward, the cable pulls on a lever attached to the rudder and moves the rudder to the left, and visa-versa. As the left pedal is pushed forwards, the right pedal will be pulled backwards, with the pedals in both cockpits moving simultaneously. Figure 4 shows the system with an inset view, looking forward on the front cockpit, from an exemplar aircraft.

Footnote

3 Part FCL 800.b.2.ii

4 https://www.bhf.org.uk/informationsupport/tests/exercise-ecg [accessed 16 October 2020]

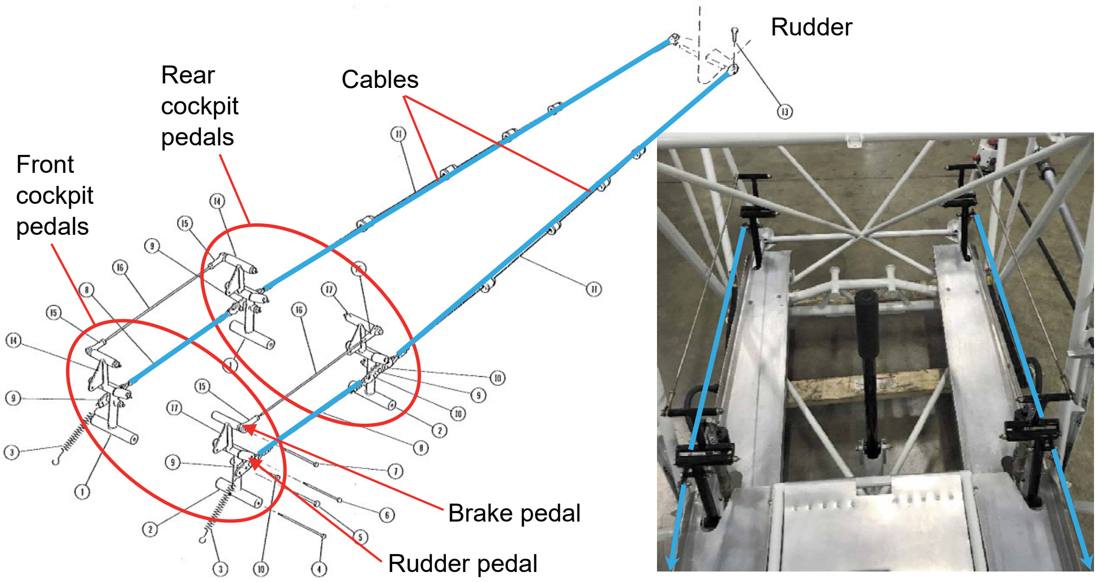


Figure 4

Rudder control system schematic and cockpit view looking forward in an exemplar aircraft

The airframe is a welded tubular steel construction with a fabric covering and sheet aluminium trays in the cockpits for the pilot's feet to rest upon. The rudder pedal hinges are welded to the frame and there are cut-outs in the trays to allow for pedal movement (Figure 5). The cut-outs in the trays allow for the full movement of the pedals and the rudder of +/- 30° without restriction. The brake pedals, which actuate the hydraulic brake system, are mounted on top of the rudder pedals. No adjustment of the pedal position or seat position to suit the pilot is possible.

Figure 5

Front rudder and brake pedal and heel tray cut-out (side and top view of exemplar aircraft)

Aircraft examination

The aircraft was recovered to the AAIB facilities for detailed examination of the airframe and engine. No anomalies were found with the airframe structure or with the engine. It was not possible to examine the accessories fitted to the rear of the engine as they were all extensively damaged. The three-bladed propeller had sustained damage to one blade (which had lost its outer third), one entire blade was missing, and the third blade was undamaged. In the rear cockpit, in the top of the airframe, was a storage locker which contained several items that weighed 1.36 kg (3.0 lb) in total.

Both pilots were sitting on top of additional seat cushions made from layers of firm closed-cell foam approximately 25 mm thick per layer. In the front cockpit, seven cushions were present and, in the rear cockpit, three cushions were used. All the additional cushions were retained by the five-point seat belts and, in total, weighed 1.9 kg (4.2 lb).

All the control cables were inspected and found intact. However, the control column in the rear cockpit had become detached near the hinge point. It was observed that there was impact damage to the left rudder surface (Figure 6) with corresponding damage to the left elevator. The rudder stops were present and undamaged, and the trim tab was set to neutral.

Figure 6

Elevator and rudder damage (circled)

Rudder cable devices

During the initial examination of the aircraft at the accident site it was noted that there were four unidentified devices fitted onto the rudder cables. They were left in place for further examination at the AAIB facilities. A device was fitted on each of the cables between the forward and rear rudder pedals and on the cables aft of the rear rudder pedals. After removal, it could be seen that each device constituted an aluminium block, aluminium semi-circular wedge, steel cotter pin and steel retaining pin (Figure 7) with the forward devices a matching pair and the aft pair matching. Each pair was similar in construction and design however there were some minor dimensional differences.

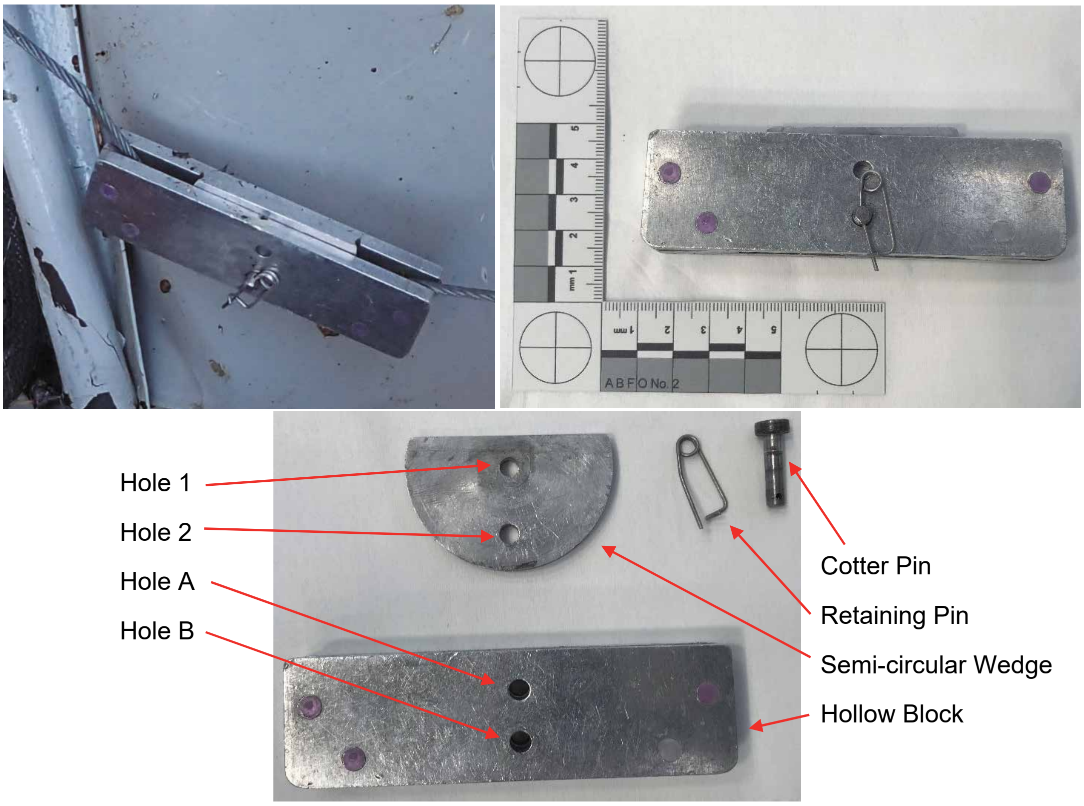


Figure 7

Rudder cable device shown in situ,
removed for examination and constituent parts

When fitted, they effectively shorten the cable by diverting it around the semi-circular wedge. In the block and the wedge, are two cotter pin holes (Figure 7) that make it possible to install the devices in different configurations. Each configuration will shorten the cable by a different amount. Table 1 shows some of the configurations and the effect they had on the rudder pedal neutral position, in terms of movement towards the seat. The aircraft was in configuration B2+B2 for the accident flight.

Device Settings		Rudder Pedal Movement	
Front	**Rear**	**Front**	**Rear**
A2	Not fitted	3 mm	None
B2	Not fitted	11 mm	None
A1	Not fitted	25 mm	None
B2	**B2**	**33 mm**	**22 mm**
Not fitted	A2	6 mm	6 mm
Not fitted	B2	22 mm	22 mm
Not fitted	A1	34 mm	34 mm

Table 1

Effect on rudder pedal movement in various device configurations

With only the front devices fitted, the front rudder pedals move aft by 3, 11 and 25 mm for the configurations shown and there is no movement of the rear pedals. When only the rear devices are fitted, both sets of pedals move by 6, 22 and 34 mm. With the devices set as they were on the accident flight, the front pedals were 33 mm aft from their nominal position and the rear pedals were 22 mm aft. This cumulative effect on the front pedals is because the rear devices also affect the front rudder pedals due to the cable layout.

A change of more than 30 mm in the front pedal neutral position when using the devices, caused the retreating pedal to come into contact with the end of the heel tray cut-out, thus preventing full pedal and rudder deflection. In the accident flight configuration (B2+B2), this interference restricted rudder movement by 3° (ie reduced the rudder movement from +/-30° to +/-27°) and the maximum device setting restricted the rudder by 10° (from +/- 30° to +/-20°). In April 2019, the aircraft had a 50-hour maintenance check and, during the check, the devices were found already fitted to the rudder cables. While inspecting the rudder travel, the engineer noticed that there was a 6 mm gap between the rudder lever and the fuselage stop when the pedals were at the limit of their travel. This 6 mm gap at the rudder stop equated to approximately 3° of rudder travel. The devices were removed, and it was noted in the maintenance documentation that '*Non-approved rudder cable devices found fitted. Once removed rudder travel then is satisfactory*'. There was no discussion about this note between the operator and the maintenance organisation.

The fitting of these devices to the aircraft changes the definition of the rudder system as specified in the aircraft type design documentation submitted at the time of certification. The Certification of Airworthiness for G-ODDS was issued by EASA and the installation of these devices should have been achieved by an approved design change to the type design in accordance with EASA part 21.A.91 '*Classification of changes to type design*'[5]. The AAIB was unable to find an approved modification for the fitting of these devices to the aircraft rudder cables, and the aircraft manufacturer confirmed that there was no such modification or Supplemental Type Certificate modification.

The designer of the devices, a pilot and professional aeronautical engineer, stated that the devices were to allow for adjustment of the rudder pedals when using the aircraft for teaching students of different stature. It is understood that the devices were fitted and removed depending upon which pilot was flying; the commander always used them, but another pilot stated that he never used them. Their installation or removal was not recorded in the aircraft's technical logbook. The designer also stated that only the two sets fitted to G-ODDS were made. He explained that an alternative to moving the rudder pedals would be to use extra cushions between the pilot and the seat back, but this moves the pilot forward and can restrict the amount of aft control column movement and therefore the ability to pitch the aircraft up. He further stated that, in his opinion, they were "personal role equipment" and as such did not require a modification. It should be noted that these devices had been used in G-ODDS by many pilots over many years, in training and competition flying, without incident.

Footnote

[5] https://www.easa.europa.eu/acceptable-means-compliance-and-guidance-material-group/part-21-airworthiness-and-environmental [Accessed 16 October 2020]

Brake pedals

The geometry of the brake master cylinder and pedal connecting linkages means that, as the rudder pedal moves towards the rear of the aircraft, the brake pedal does not move as much (Figure 8 left and middle). The brake pedal position influences the pilot's foot posture and, with soft soled shoes as both pilots were wearing, extension of the toes would result in an optimal direction of force applied to the rudder pedal (Figure 8 right) with minimal force applied to the brake pedal. However, it has been stated that, whilst flying aerobatic manoeuvres, it is not uncommon for pilots to inadvertently apply the wheel brakes. Despite this small application of the brakes, the main application of force is through the rudder pedal.

Figure 8

Rudder / brake pedal relative movement and foot posture

Aircraft performance

The aircraft manufacturer was asked to provide information regarding flight characteristics in a spin. The manufacturer stated that the aircraft has no adverse spinning characteristics and that it is cleared for upright, inverted and accelerated spinning. The investigation spoke to a number of pilots whose experience was that the spin characteristics of the Pitts were predictable.

Spin characteristics

Spin characteristics vary significantly depending on pilot inputs so, to determine performance in a spin, the assumption was made that a conventional technique to induce and maintain a spin was used, ie full rudder and control column held fully back with ailerons neutral. Information provided by the manufacturer indicated that a 10-turn upright spin incurred a height loss of 3,400 ft in an elapsed time of 32 seconds. Therefore, each spin rotation takes approximately three seconds and incurs a loss of 340 ft with a rate of descent of approximately 6,800 fpm.

The manufacturer advised that, with full opposite rudder deflection and neutral (or released) control column, it would take approximately 500 ft to stop the rotation and then another 500 ft to level flight with a 4 g acceleration.

It is not possible to determine what control inputs were made during the spins on the accident flight but deviations from the conventional technique outlined above would affect spin rate, rate of descent and time for recovery. The ground marks were consistent with a right-hand upright spin and the following information, provided by a test pilot, indicates how the spin may vary if the controls are not held in the conventional pro-spin positions:

a. Increased power would have an anti-spin effect and could be expected to lower the pitch attitude, increase the spin rotation rate and reduce the number of turns and time to recover.

b. Left or out-spin aileron would have a pro-spin effect which would result in a flatter, more wings-level spin and possibly a higher spin rotation rate. Even if the ailerons were set to neutral during the recovery, the number of turns and time to recover would both increase, compared to a neutral aileron spin. If out-spin aileron was maintained during the recovery, the pro-spin effect could overpower the anti-spin effect of the recovery rudder and the aircraft may not recover.

c. Right or in-spin aileron would have an anti-spin effect which could result in a steeper nose-down spin. If the ailerons were then set to neutral during the recovery, the aircraft would recover from the spin in fewer turns and less time than from a neutral aileron spin. However, if in-spin aileron was maintained during the recovery the aircraft could potentially enter another spin, possibly inverted, in the opposite direction.

d. If the rudder remained fully deflected in the direction of the spin it would be highly unlikely for the aircraft to recover from the spin irrespective of the aileron and elevator positions.

The manufacturer supplied the investigation with a flight test report for spinning. The flight test was conducted in 1971 at the maximum takeoff weight and with a C of G position 97.7 inches aft of the datum. The aircraft entered left and right-hand spins using conventional pro-spin controls. Using a conventional recovery technique, the aircraft stopped the rotation to the right in one half turn and in one turn from a spin to the left. When the controls were released during a spin, the aircraft recovered by itself within one and a half turns. When aileron was applied in the opposite direction to the spin, the spin became flatter. Ailerons were then neutralised, and, with the conventional recovery technique, the spin stopped in less than three rotations.

The test pilot also advised that:

'In a spin, a pilot will experience multiple visual, rate and acceleration cues about multiple axes, and the motions may be steady or oscillatory. The body is more sensitive to some of these cues than to others and, therefore, the perception of the motion may not be representative of the actual motion of the aircraft. In particular, conflicting acceleration and visual cues can cause marked disorientation. Roll direction is a very powerful visual cue if a good horizon is present. However, yaw (and hence spin) direction may be wrongly identified due to visual cues possibly being blurred at high yaw rates plus variations in

yaw rate causing sensory confusion (analogous to being on a swivel chair and stopping suddenly). There can also be an unconscious perception of spin direction driven by the roll direction, especially if roll direction changes. Overall, the best single and simple cue to ascertaining spin direction is to interpret the turn needle.'

G-ODDS had a turn indicator fitted in the front cockpit but not in the rear. Both cockpits were fitted with a slip indicator[6].

Weight and Balance

The aircraft departed White Waltham with 64 litres of fuel on board. This was the operator's standard fuel load for aerobatic sorties. A climb to an altitude of 3,500 ft and transit to the area of the accident would use approximately 11 litres of fuel and take under 10 minutes.

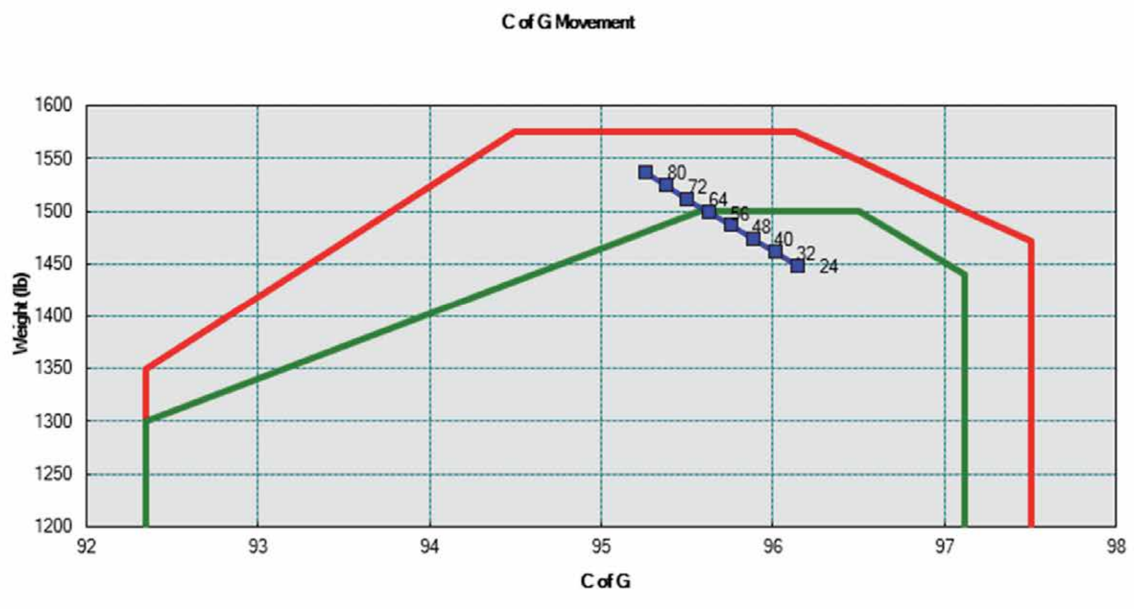
The operator had created a spreadsheet to calculate aircraft weight and C of G position. A copy of the spreadsheet was obtained from the commander's computer. The total aircraft weight used in that copy was 1,097 lb and a C of G position 88.00 inches aft of the datum. The operator stated that the figures '*were supplied with the aircraft and were in the tech log at the time of purchase*'. These figures came from weighing the aircraft in 2005.

Following the fitting of a new propeller, the aircraft was reweighed in 2007 and its mass had increased to 1,124 lb and the C of G position had moved further aft to 89.79 inches aft of datum. The operator stated they were unaware of the most recent weight report at the time of the accident and only found the most recent weight and balance report after the event. In addition, the pilots' weights used in the calculations were significantly less than their actual weights; the commander's weight was underestimated by 6.35 kg (14 lb) and the student's weight by 9.98 kg (22 lb). The source of these figures is unknown. A copy of the Weight and Balance calculation believed to have been used by the commander prior to the accident flight is shown in Figure 9. The numerals on the blue line corresponds to a range of possible fuel quantities in litres.

The use of incorrect figures could have misled the commander into thinking that the aircraft was within its flight envelope for the planned sortie. Figure 10 shows a more accurate result with figures from the most recent weight and balance report. The actual pilot weights, the weights of the additional seat cushions and the miscellaneous equipment found in the aft cockpit locker have also been included.

Footnote

[6] A turn indicator is used to indicate the rate at which the aircraft changes heading. The instrument is helpful whilst in a spin, as it indicates the direction of yaw. The slip indicator shows whether corrective rudder is required to achieve balanced flight.



Utility envelope < 3.8g

Aerobatic envelope

Figure 9

Commander's Weight and Balance spreadsheet

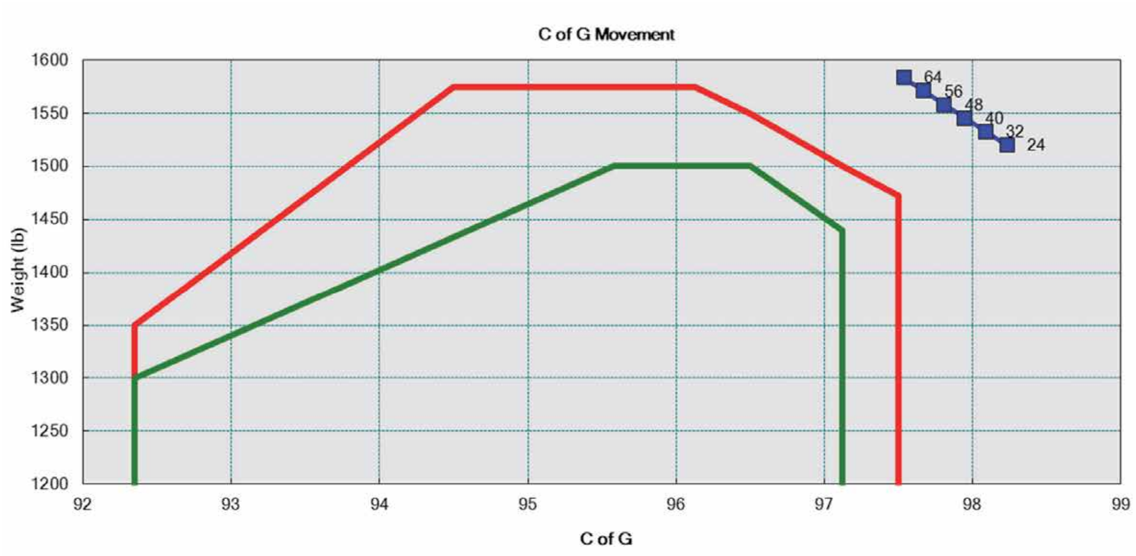


Figure 10

Revised Weight and Balance spreadsheet

With these figures the aircraft was overloaded for both the aerobatic and utility flight envelopes. The most rearward C of G limit for aerobatics is 96.5 inches at a gross weight of 1,500 lb increasing to 97.12 inches at 1,440 lb. For the utility category the limits are 96.13 inches at 1,575 lb increasing to 97.5 inches at 1,472 lb. The aircraft manufacturer stated that the overload condition would not have affected the aircraft's capacity to recover from a spin. Having been advised that, at the time of the accident, G-ODDS's C of G position was further aft than the limit, the manufacturer stated that:

> *'The AFT C.G. limit is the aft most point that the aircraft should be operated in. This data was the direct result of FAA flight testing during certification that resulted in the limits depicted in the flight manual.'*

Movement of the position of the C of G affects the positive longitudinal stability of the aircraft and it also affects the handling characteristics in pitch. If the C of G is moved aft, outside the permitted limits, the positive stability of the aircraft in pitch is reduced and the reduction in the moment arm of the rudder and elevators reduces their effectiveness. The flight test report referred to earlier, stated that the C of G used for the test was 97.7 inches.

Survivability

Neither pilot wore a parachute so abandoning the aircraft was not an option. The forces exerted on both pilots during the impact resulted in injuries that were not survivable. Despite the high impact forces, the fuselage remained largely intact and the cockpit spaces were preserved. However, it was noted that the rear cockpit seat, along with its seat belts, had detached from the airframe. The front cockpit seat was still attached but despite wearing a five-point harness, the occupant sustained severe facial injuries through impact with the edge of the cockpit.

Organisational information

The operator specialises in aerobatic, formation flying and vintage aircraft training. It also provides private flying displays and conducts event days for corporate clients.

The operator stated that they wrote to all students prior to the start of their training to indicate that 89 kg was the maximum acceptable weight for pilots. The Skyway Code (CAP1535) contains extensive information on aircraft mass, balance and performance. Of note it states:

> *'Account for everything – when adding up the mass of the aircraft make sure you account for all items onboard. Miscellaneous things such as bags should be included in whichever loading point they are closest to.*
>
> *Passenger mass – ensure you know the mass of your passengers, including clothing and other accessories they may be carrying.'*

Aerobatic training

The operator did not have standardised sortie plans for aerobatic instruction, with sortie content decided for each individual student by each individual instructor. The objective was to prepare pilots for the Sport level of aerobatic competition. For spin recovery, the operator taught the Beggs/Mueller method, which is as follows:

- Power to idle.
- Release the control column.
- Apply full opposite rudder until rotation stops.
- Neutralise rudder and recover to level flight.

The advantage of this method is that it works for either an upright or inverted spin and so reduces the likelihood of a disorientated pilot taking incorrect actions.

AOPA Syllabus

The operator stated that the commander, when instructing, '*would invariably follow the AOPA Standard Course Syllabus*'. The AOPA syllabus states '*Recoveries from all manoeuvres must be completed by a minimum of 1000 feet above the surface, and a maximum height must also be observed of 500 feet below the base of regulated airspace. Greater margins are likely to be wise until adequate experience has been gained*.' The operator stated that the 500 ft below regulated airspace, specified in the AOPA syllabus, was not considered as a standard operating procedure. For Sport level aerobatics, the base height is 1,000 ft agl and there is no upper limit in the British Aerobatic Association Rules.

Pre-flight briefing

The operator used a generic briefing outline from another organisation. It consisted of '*Aim, Briefing, Air Exercise*' followed by '*Threat and Error Management*'. The actual content was decided for each sortie and student. A pre-flight briefing is an opportunity to address issues, such as a loss of communication, but it is not known if these were discussed by the crew. The operator stated that the commander habitually gave thorough pre-flight briefings and believed that contingencies were routinely covered.

Parachutes

The operator had parachutes available and stated that pilots are given the option of wearing one. However, the operator also stated that '*the weight of the parachutes increases the cockpit weights significantly, and therefore operate to limit the aircraft's operational weight and balance capability*.' Neither pilot involved was wearing a parachute.

Other training organisations

The investigation contacted another training organisation which advised that it provides a standard briefing for commanders to cover eventualities such as loss of communication, abandoning the aircraft and the initiation of recovery actions. However, that organisation requires the use of parachutes and so the briefing text reflects their use in abandoning an aircraft in an emergency. The briefing does address the issue of loss of communication between the pilots but, as it uses aircraft with side-by-side seating, not all of the briefing is appropriate or relevant to the accident aircraft.

That operator uses a Minimum Abandon Height (MAH) of 3,000 ft agl. An allowance of 2,000 ft is made for recovery so the minimum height to commence recovery would be 5,000 ft agl. A further allowance of 400 ft per turn is added to derive an entry height. Therefore, using a four turn spin as an example, the minimum height for spin entry would be 6,600 ft agl or, in the vicinity of the accident site, 7,100 ft amsl and provides for significant safety margins in terms of altitude.

Tests and research

A specialist anthropometrics consultancy service was engaged to assist in understanding the effect that the rudder cable devices and the extra seat cushions might have had on the controllability of the aircraft. The consultants were supplied with a digital representation of an exemplar aircraft and used measurements of the pilots to construct digital mannikins. In this digital environment they assessed the pilots' ability to operate the controls through their full range of movement.

To construct a digital representation of the G-ODDS airframe, another Pitts S-2A airframe of the same build standard was scanned using the GOM structured light scanning system[7] (Figure 11). An SAE H-point machine[8] was placed in the cockpit (Figure 12) and scanned to fix the key datums and enable positioning of the pilot mannikins in the digital environment. The consultants were also able to observe a pilot in the cockpit who was familiar with flying the Pitts Special to gain an understanding of posture and position when flying.

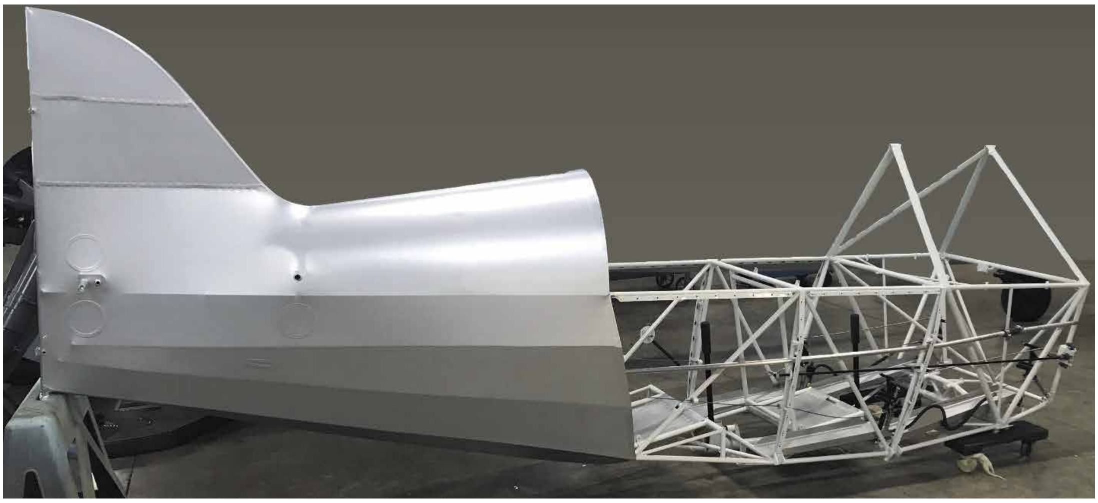


Figure 11
Representative airframe ready to be GOM scanned

Footnote

7 https://www.gom.com/metrology-systems/atos/atos-triple-scan.html [Accessed 16 October 2020]
8 https://www.sae.org/standards/content/j4002_200508/ [Accessed 16 October 2020]

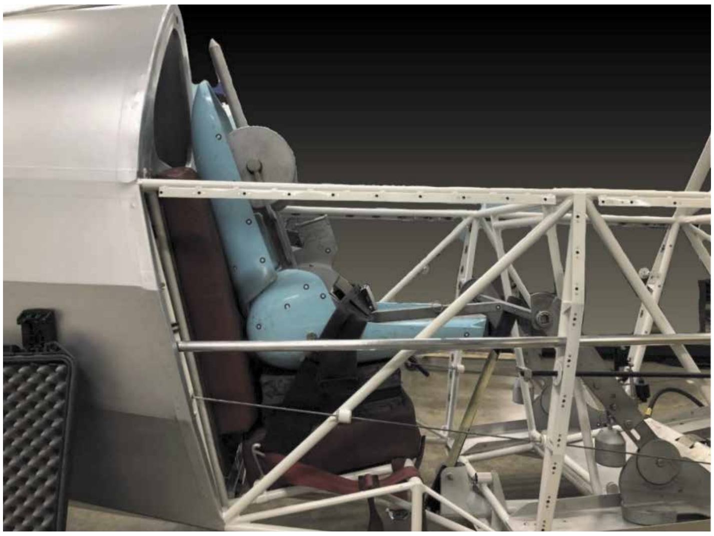


Figure 12
SAE H-point machine installed in the rear cockpit

Where required body dimensions were not available, the anthropometric consultants estimated figures based on other known proportions and photographs[9]. The measurement data was then imported into the System for Aiding Man Machine Interaction Evaluation (SAMMIE) Digital Human Modelling software tool and a digital mannikin was created for each pilot. Using the scanned digital cockpit environment and the H-point machine, the SAMMIE digital mannikins were then positioned in the cockpit and the Seating Reference Points (SgRP) were defined (Figure 13).

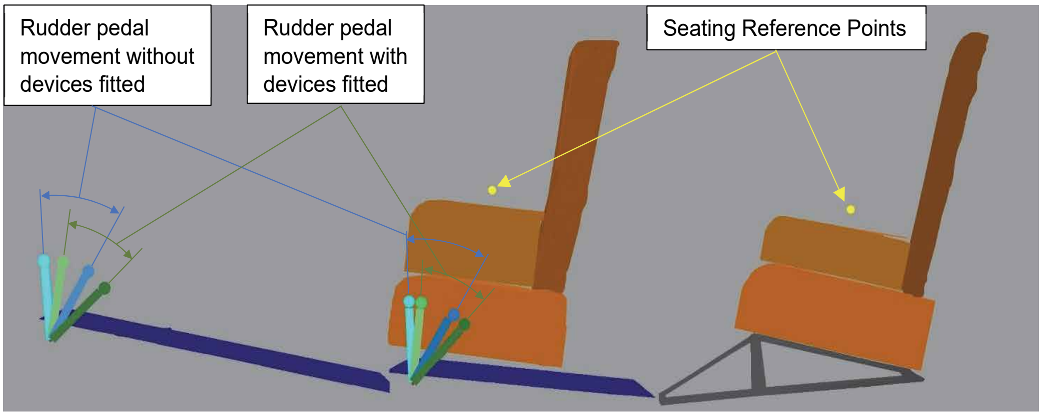


Figure 13
SgRPs and rudder pedal movement

Footnote

[9] Human body dimensions are usually described in terms of percentiles which show where a measurement lies within the distribution of that measurement for the population of interest. For example, stature may be expressed as 5th percentile UK male which means that 5% of the population are smaller than this value and 95% of the population are taller. The same convention can be used for any body dimension and those that were estimated were based on the same percentile as the stature of the pilots. This is a simplification because bodies vary, and people can have relatively larger or smaller individual body dimensions than would be expected if all were exactly in proportion to their stature.

An assessment was made of the ability of each pilot to achieve full rudder pedal deflection without any rudder cable devices fitted and with the devices installed as per the configuration used during the accident flight. Figure 14 shows the digital mannikins located on the SgRPs and positioned for full forward travel of the right rudder pedal without any devices fitted.

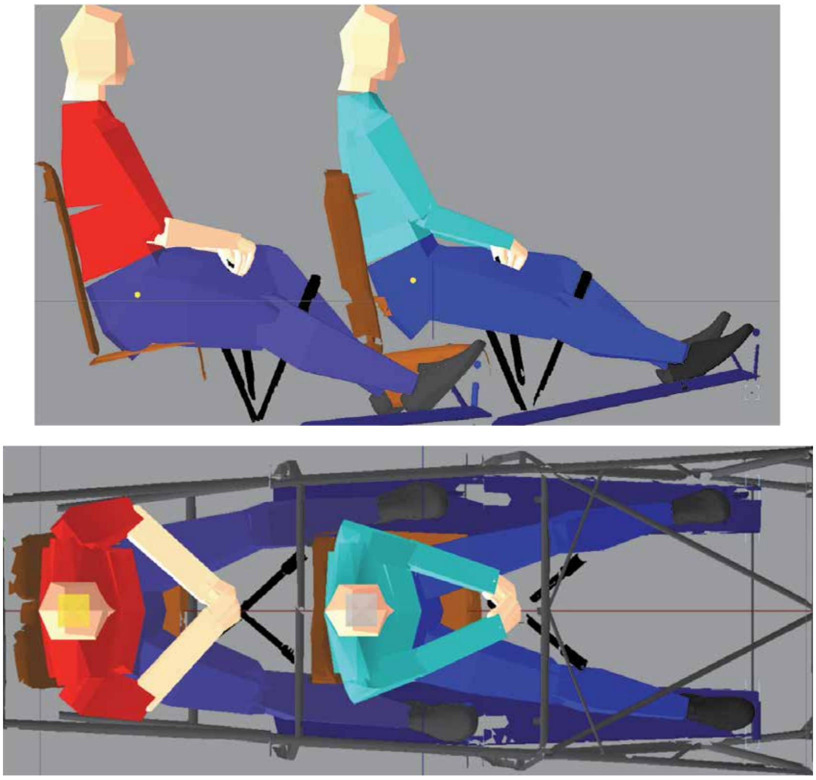


Figure 14

Right rudder pedals full forward without the devices fitted
(brake pedals omitted for clarity)

The assessment showed that the commander was unlikely to have been able to move the pedal to this position because the leg is fully extended with only the tip of the toes in contact with the pedal. The student was likely to have had better foot contact on the pedal and the leg is only slightly bent, but this position may have been uncomfortable due to the additional seat cushions digging into the thigh and the front seat back on the inside of the calves. The assessment showed that the receding pedal position was unlikely to pose a problem for either pilot to exert the force necessary to return the rudder to the neutral position.

With the devices fitted as they were on the accident flight (Figure 15), the assessment showed that the commander would be able to reach the extreme of pedal travel more easily. Full extension of their leg was still required but instead of the toe, the ball of their foot would likely have been on the pedal affording more control.

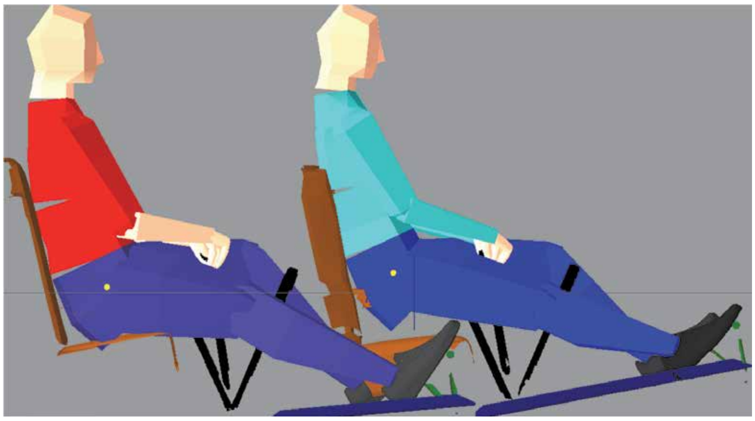


Figure 15
Right rudder pedals fully forward with the devices fitted
(brake pedals omitted for clarity)

Further assessment of this configuration suggested that it would probably have been more comfortable for the student because of the increased bend in the leg. It would also reduce the pressure of the seat cushion on the back on the thighs and allow an improved position for the calves around the front seat back.

The investigation considered the scenario that the commander had become incapacitated during the spin manoeuvre and so could have impeded the recovery of the aircraft. It was assumed that the spin was entered using full right rudder (and control column held fully back with ailerons neutral) and the commander would have a fully extended right leg on the rudder pedal when they became incapacitated. Spin recovery would require the student to apply full opposite (left) rudder.

Digital modelling and practical assessment of this scenario was made using the SAMMIE tool and an exemplar aircraft and it was found that it was possible to apply the required rudder input even against a 'locked' straight leg. The commander's joint mobility was explored via digital modelling (Figure 16) and although the ankle is nearing the limits of extreme movement, it is possible for full opposite rudder to be applied. Typically, an external force would be required to extend the ankle to this position but a further 6° of extension is possible in the extreme range.

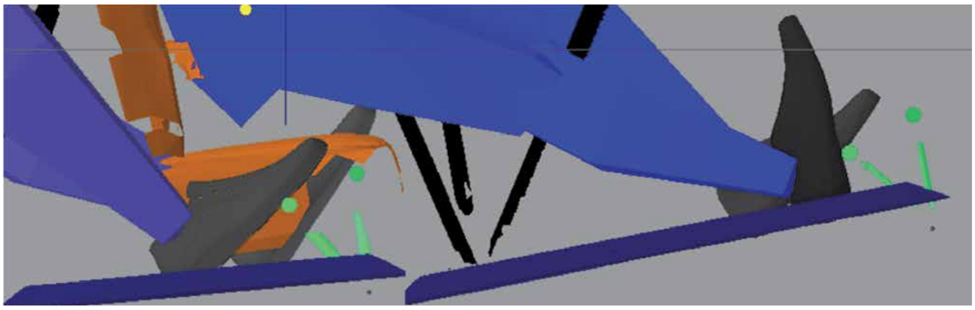


Figure 16
Commander ankle movement with full opposite rudder
(brake pedals omitted for clarity)

Analysis

Introduction

From the limited evidence available, it is likely that the commander of the aircraft became incapacitated in flight, probably at the start of, or during, the second spin sequence that was observed by witnesses. Ground impact marks indicate that the aircraft was still in a spin as it struck the ground and there was no indication of successful recovery action.

Both pilots had been trained in spin recovery and so if the controls were not restricted, they had the skills and knowledge necessary to affect a safe recovery. As there was a qualified pilot in the rear seat, the investigation considered the reasons why the student did not, or was unable to, recover the aircraft to level flight with the commander incapacitated.

Control restrictions, reaction to a loss of communication between commander and student, and the time available to recover to level flight are discussed in further detail below. Pre-flight planning is also discussed.

Rudder/elevator damage

It is considered that, at the time of impact, the rudder was in the neutral position or towards the right. The contact damage on the left side of the rudder and the deformation to the left elevator would require a significant impact force. The left rudder stop was intact, and, after the accident, it was not possible to move the rudder far enough to touch the elevator, therefore the rudder must have deformed. The lightweight rudder is stiff, and it would need a lot of momentum to deform significantly which could not be achieved if the rudder was against the left stop. If the pedals were holding the rudder neutrally or to the right, it is still possible for the rudder to move. As the fuselage deformed during the impact, the bending would have released the tension in the rudder cables, thereby allowing free movement of the rudder.

Pre-flight preparation – discussion

The content of the pre-flight briefing is unknown so it cannot be confirmed what was discussed with regard to actions for loss of communications and definition of recovery altitudes. Discussion of such actions in pre-flight briefings could, in general, assist in reducing the effect of any surprise or distraction that students may suffer. It may also encourage prompt action at a time when sufficient height remains to carry out a recovery.

Area of operation

The area of the accident was approximately 8 miles from White Waltham and although constrained above by the London TMA, offered more altitude than would be required for competition aerobatic manoeuvres. Slightly further north, the base of controlled airspace increases to 5,500 ft amsl although it is constrained laterally by the RAF Benson Military Aerodrome Traffic Zone. A transit flight of 20 nm would have taken the aircraft to an area where the base of controlled airspace is 8,500 amsl. Based on the albeit erroneous weight and balance calculated figures which limited the fuel load available, the commander may have chosen the accident locale to maximise aerobatic training time.

Weight and Balance

The aircraft departed with 64 litres of fuel which was a standard load intended to ensure that the aircraft was within its C of G envelope. As each of the operator's instructors had an idea of the limitations because of their own weight, it was not usual for them to calculate the exact C of G prior to each flight. The operator had created a spreadsheet to automate the C of G calculations, which calculated the mass and balance for a range of fuel loads. Figures obtained from the commander's computer showed a calculation with incorrect weights for both the pilots and the aircraft. Using the accurate weights, the aircraft was overloaded, and the C of G was further aft than both the published limit and the 97.7 C of G position in the flight test report. The aircraft manufacturer did not consider that the overloading would have impeded any spin recovery. However, the aft C of G position would have reduced the moment arm of the rudder and elevator controls, making a recovery more difficult.

Spinning

Once in a spin the aircraft descends at approximately 6,800 fpm. Directly above the accident site, the base of controlled airspace was 3,000 ft agl. Had the aircraft entered the spin at this height, a maximum of approximately 26 seconds would have been available before the aircraft would have struck the ground. If the commander had considered that the aircraft was clear of the lower band of controlled airspace and entered a spin at 5,000 ft agl, a maximum of approximately 44 seconds would have been available. If the commander had followed the AOPA guidance to remain 500 ft clear of controlled airspace these maximum times would be reduced by approximately four seconds.

From 3,000 ft agl, with 500 ft needed to arrest rotation and 500 ft to level, spin recovery would have needed to be initiated within 17 seconds to just avoid contacting the ground. From 5,000 ft agl, a maximum of 35 seconds would have been available. The durations are a maximum and make no allowance for a planned number of turns before recovery action is initiated. It is not known what manoeuvres or how many turns of spin were planned.

Incapacitation

The commander had, unknowingly, a serious cardiac condition, with the potential to cause incapacitation with little or no warning symptoms. The coronary pathology indicated that, while the condition would have taken months or indeed years to develop, it could have been completely asymptomatic. Even had the commander undergone a recent ECG, it would have been difficult to detect the condition due to the inherent circulation reserves of the cardiac tissues. Only a 'stress test' ECG such as that conducted during physical exercise to elevate the heart rate is likely to have revealed the condition.

Student response

The student had an aerobatic rating. The training for this included spinning and spin recovery, and so the student would have had the skills and knowledge to recover from a spin. Had the aircraft entered a spin from 3,000 ft agl, the student would have had a maximum of 17 seconds in which to initiate recovery actions from commencement of the spinning manoeuvre. This would be enough time for an appropriately trained pilot to take corrective action unless impeded by another factor.

Following the likely incapacitation of the commander, the student either did not attempt to recover the aircraft in time or tried but was unable to do so. It is possible that a physical control restriction impeded or prevented the student from taking recovery action, but this is considered unlikely.

If recovery was physically possible, then there may have been circumstances that reduced the time available for the student to recover, or his ability to do so. Apart from the eyewitness accounts and radar recording, there was no evidence to inform the investigation about the exercise being flown or any of the interactions between the commander and student. The following discussion outlines some plausible scenarios.

The Pitts Special has tandem cockpits so the student's view of the commander would have been restricted and communication between the two of them relied on intercom. If the student was awaiting an instruction from the commander to recover from the spin it is likely that their recognition of the situation would have been delayed. If the student thought communication had been lost, it is probable that attempts to re-establish communication with the commander would have been made to ascertain if there was a problem. If recognition of the need to act took too long, or too much of the limited time available was spent trying to re-establish communication, it could account for why the aircraft was still spinning at impact. There may also have been factors that impaired the student's ability to respond in the event that the commander was incapacitated during the spinning; the situation in the aircraft could have caused startle, surprise, confusion or panic and the motion of the aircraft may have caused disorientation. If the student was disorientated, they could have misidentified the yaw direction and it is possible they could have maintained or applied right rudder believing that it was the appropriate corrective action. Reference to a turn indicator, such as was fitted in the front cockpit only, would have helped to counter disorientation in a spin. Any one or combination of these factors could have reduced the student's ability to make a recovery in the limited time available.

Rudder cable devices

G-ODDS had been used as a school and competition aircraft for many years and had been flown by a lot of different pilots of varying stature and build. The design of the cockpit of the Pitts Special does not allow for personalised adjustment of the flight controls, specifically the rudder pedals, and so some devices had been designed and constructed for use in G-ODDS which, when installed would effectively move the rudder pedals aft. The devices enabled shorter pilots to achieve full rudder deflection without compromising the aft movement of the control column. The alternative to moving the rudder pedals aft would be move the pilot forward which, as the seat positions are fixed, would require additional seat cushions behind the pilot. This could compromise the aft movement of the control column against the pilot's torso and therefore the rudder devices could be seen by pilots to be a preferential option.

The fitting of such devices should be an EASA approved modification so that their operation and effects can be tested and documented. The investigation was unable to locate any approval for a modification to fit these devices. It was noted during a maintenance check that the devices, which were fitted at the time, restricted the rudder travel by 3° (10% of travel).

The devices allowed for a variety of settings and, in the most extreme configuration, restricted rudder movement by 10° (33% of the rudder travel). Although the investigation did not explore the effect of all the possible configurations, anecdotal evidence suggests that the devices had been used on many previous occasions without any adverse effects being reported. No records were kept detailing their installation or removal.

By building a digital representation of the cockpit environment it was possible to analyse the position of the pilots in the aircraft's fixed seats and what effect the rudder pedal devices had. Certain estimates had to be made to construct the digital representation of the pilots, but the analysis showed that, without the devices fitted, the commander, seated on a number of cushions to improve external visibility, probably would not have been able to achieve the fully-deflected rudder pedal position. Using the devices enabled the commander to do so. The student did not need to use the devices but, with them fitted, it probably would have allowed for a more comfortable position as the pedals are either side of the front seat.

Conclusion

It is likely that the commander was incapacitated by an undiagnosed cardiac condition while conducting a spinning exercise, though it is unlikely that such an incapacitation would impede the controls and prevent recovery action by the student. The evidence of the witnesses and the ground marks indicate that the aircraft was still in a spin, and both pilots were fatally injured when it struck the ground.

The rear seat student was a qualified pilot with an aerobatic rating and there was sufficient time to recover if prompt action was taken. However, a loss of communication between the pilots could have delayed recognition of the situation. The aft C of G position would have reduced the capability of the aircraft to recover from a spin and extended the time required for recovery. It is also possible that a combination of any or all of disorientation, startle, surprise, confusion or panic prevented the student from taking effective recovery actions in the limited time available.

Unapproved devices, which adjusted the rudder pedal positions, were found on the rudder cables but were unlikely to have impeded the recovery from the spin.

Safety action

Since the accident the operator has taken the following safety actions:

- The use of spreadsheets has been discontinued and Aircraft Flight Manual (AFM) weight and balance charts are used instead. A current weight and balance report is now included in the aircraft technical log.
- The operator has circulated the AFM weight and balance charts together with current weight and balance reports to all instructors.
- Scales are now provided so pilots can weigh themselves. The operator has found large discrepancies between given and actual weights among its pilots and no longer accepts assumed or estimated weights.

- The operator has encouraged pilots and instructors to continue to take notice of weight and balance placards in the aircraft, which require confirmation that the weight and balance has been checked before flight.
- Electronic copies of flight manuals have been circulated to all instructors (and are available for students) to provide reference material on weight and balance.

Published: 21 January 2021.

Bulletin Correction

The report first published on 21 January 2021, contained the sentence on page 11:

> In April 2019, the aircraft had a 50-hour maintenance check and the devices were fitted to the cables during the check.

To provide clarity that it was not the maintenance organisation that fitted the devices, this sentence has been changed to:

> In April 2019, the aircraft had a 50-hour maintenance check and, during the check, the devices were found already fitted to the rudder cables.

The online version of this report was corrected on 28 January 2021.

AAIB Correspondence Reports

These are reports on accidents and incidents which were not subject to a Field Investigation.

They are wholly, or largely, based on information provided by the aircraft commander in an Aircraft Accident Report Form (AARF) and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

ACCIDENT

Aircraft Type and Registration:	DHC-1 Chipmunk 22, G-BCKN
No & Type of Engines:	1 Lycoming O-360-A4A piston engine
Year of Manufacture:	1952 (Serial no: C1/0707)
Date & Time (UTC):	17 October 2020 at 1050 hrs
Location:	Blackpool Airport, Lancashire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor damage to right wing surface and flap
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	83 years
Commander's Flying Experience:	957 hours (of which 35 were on type) Last 90 days - 20 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft swung off the runway onto the grass during a landing at Blackpool Airport and struck a Precision Approach Path Indicator (PAPI) light causing minor damage to the right wing.

History of the flight

The pilot reported that he was intending to conduct circuits at Blackpool Airport. He took off on Runway 28 but, due to the light and variable winds, ATC changed the runway to Runway 10. The wind was reported as coming from 040° at 7 kt. The pilot reported that he encountered no difficulty during the approach but following a straight three-point touchdown at 50 kt the aircraft swung to the left. Despite the application of full right rudder, the aircraft departed the runway onto the grass. The aircraft came into contact with a PAPI light on the left side of the runway resulting in damage to the right wing surface and flap. The pilot did not use differential braking during the landing roll because he assessed the wind to be calm to very light. He could not account for why the aircraft unexpectedly swung to the left on landing. He stated that he had considered carrying out a go-around but chose to commit to controlling the ground roll from the runway onto the grass to avoid a propeller strike on the soft ground.

Aircraft examination

An engineering inspection commissioned by the aircraft owner reported that the main wheel braking system and tail wheel were free from defects and all system perishables were found to be in good condition.

Wheel brake system description

The Chipmunk is equipped with a hand-operated wheel brake system. A lever on the left sidewall of the cockpit is pulled rearwards to apply the brakes. For manoeuvring on the ground, differential braking is available by action on the rudder pedals. If the wheel brake lever is in the OFF (fully forward) position, no braking is applied to either main wheel, even if full pedal is applied in one direction. As the lever is pulled to the rear, progressively more brake pressure is applied to the wheel corresponding to the rudder pedal that is held forward.

A finger-operated collar at the base of the wheel brake lever handgrip can be set to hold the lever in a given position so that the appropriate brake operates when a rudder pedal is moved forward. Both brakes are inoperative when the rudder pedals are centralised again. The various lever positions are defined by the teeth of a ratchet device. A combination of lever movement and rudder pedal displacement is used to modulate the differential braking force applied and augment directional control on the ground. The number of notches required to provide differential braking can be counted during the operation described. If differential braking is required for a crosswind landing, the correct amount of brake can be set in the air.

Discussion on the use of the brakes in crosswinds

Advice on the use of brakes in the Chipmunk community is varied and, to a degree, divided. The point of debate is the benefit of pre-setting the system for differential braking to be available for use immediately on landing, compared with relying primarily on rudder authority for directional control followed by the gentle use of the brake lever to augment control if required. The Pilot’s Manual refers to the use of differential braking for crosswind landings and ground taxiing but offers no further advice. Although the pilot was unable to explain why this accident happened, he commented that he would seek further advice from a qualified Chipmunk instructor on suitable techniques to control the landing roll in various wind conditions.

ACCIDENT

Aircraft Type and Registration:	Pelican PL, G-MPAC
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2001 (Serial no: PFA 165-12944)
Date & Time (UTC):	30 August 2020 at 1205 hrs
Location:	Stoke Golding Airfield, Warwickshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Serious) Passengers - None
Nature of Damage:	Damage to propeller, landing gear, wings and fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	630 hours (of which 114 were on type) Last 90 days - 13 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft had flown from Oxenhope Airfield in Yorkshire and, with a northerly breeze, its pilot positioned to land on Runway 08 at Stoke Golding Airfield. He reported being slightly fast on the approach which resulted in a protracted flare and deep landing approximately halfway along the runway. Despite applying maximum braking, the pilot could not stop the aircraft, which overran the runway at an estimated 15 kt. It entered the boundary hedge and tipped nose-first into a deep ditch where it came to an abrupt halt. The pilot attributed the accident to accepting an excessively deep landing rather than going around.

The passenger was uninjured, but the pilot sustained severe injuries having struck his head on a metal bar running across the top of the cockpit. He put the severity of his injuries down to only having a 3-point harness and not bracing for impact. A post-accident field trial by the Light Aircraft Association showed that a slack shoulder strap would allow enough body movement for a seat occupant's head to strike the metal bar during a rapid deceleration.

History of the flight

The aircraft had flown from Oxenhope Airfield in Yorkshire. On arrival at Stoke Golding Airfield the weather conditions were good with a 10 kt northerly breeze and the pilot positioned to land on Runway 08. The aircraft was slightly fast on the approach, 58 kt rather than 50 kt, which resulted in a protracted flare and deep landing. The pilot estimated that he touched down approximately halfway along the runway. Despite the deepness of the landing, the view forward at touchdown looked longer than he was used to seeing at his home airfield. Satisfied that enough runway remained ahead, he elected to stop rather than initiate a go-around. Despite the pilot applying maximum braking, the aircraft did not slow down as quickly as he expected. He attributed the low rate of deceleration to short grass on a slightly downhill runway, little or no headwind and the additional weight of the passenger. He reported also having misread the airfield details, believing the runway to be 585 m rather than 525 m long.

Approaching the end of the runway it became evident that the aircraft would overrun into the boundary hedge beyond. The pilot was not aware that the hedge line contained a ditch and assumed the safest course of action was to go through it. The pilot stated that if he had known of the ditch he would have tried to turn away before impact. G-MPAC left the runway at approximately 15 kt and penetrated the hedge before tipping forward and coming to an abrupt halt (Figure 1 and Figure 2).

Figure 1

G-MPAC in the airfield's boundary ditch
(image © Leicestershire Police)

Figure 2

View looking down Runway 26
(image © Leicestershire Police)

The sudden deceleration caused the pilot to be thrown forwards and he struck his head on the front spar carry-through tube just behind the windscreen (Figure 3). He suffered severe injuries as a result. The passenger's straps were tight and, having braced for impact, he was uninjured.

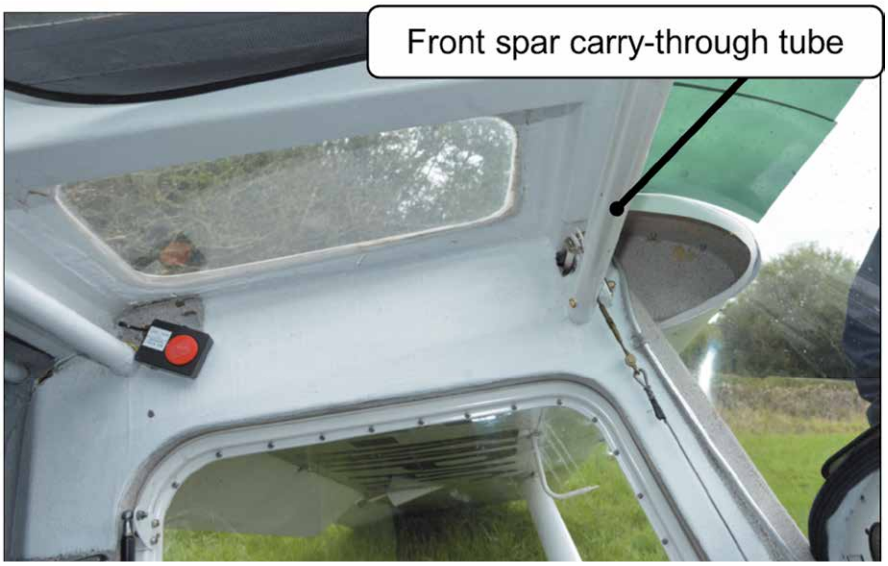


Figure 3

Front spar carry-through tube crossing behind G-MPAC's windscreen
(image © Leicestershire Police)

The occupants were able to exit the aircraft using the door on the right side of the aircraft, although progress was hindered by the hedge's thorny branches. Bystanders were quickly on scene to assist.

Figure 4

Photograph showing exit route through the right cockpit door
(image © Leicestershire Police)

Weight and balance

The aircraft's basic weight was declared as 380 kg and it had a maximum certified landing weight of 635 kg. The pilot calculated that, with his passenger weighing 95 kg, the landing weight at Stoke Golding was 585 kg.

Given the relatively light basic weight of the aircraft, with the passenger on board it was approximately 20% heavier than if the pilot had been solo. Approaching the field at 58 kt the aircraft's kinetic energy was 34% greater than it would have been at the target speed of 50 kt. Compared with a solo approach at target speed, G-MPAC had 60% more kinetic energy as it arrived in the flare.

Airfield information

Stoke Golding is an unlicensed grass airstrip with a single runway which is 525 m long. From the midpoint of the runway there is a slight downslope towards each threshold. The Pooley's Flight Guide shows 4 ft hedges at both ends of the runway but does not indicate the presence of a boundary ditch.

The accident pilot had been based at Oxenhope in West Yorkshire, where the shortest runway is 325 m long and the longest 460 m, for 13 years. Oxenhope is described in the Pooleys Flight Guide as a '*challenging airfield*.' The pilot reported that, due to waterlogging in the threshold area, the available safe landing run on Runway 24 at Oxenhope was only 225 m long. He also stated that a normal landing run for G-MPAC was 190 m. Video evidence recovered from a camera carried in the aircraft showed landing runs at Oxenhope, by necessity, often terminating quite close to the end of Runway 24.

Survivability

The pilot sustained severe head injuries resulting from impact with a metal bar running across the front of the cockpit. The aircraft was equipped with 3-point harnesses. The pilot reported that his lap strap had been tight and the diagonal shoulder strap was "comfortable". He surmised that tipping forwards into the ditch resulted in a greater upward vector within the cabin making contact with the bar more likely. The passenger attributed his lack of injuries to a tight shoulder strap and bracing for impact.

The Light Aircraft Association (LAA) conducted a field trial on the salvaged aircraft to assess the effectiveness of the harness in G-MPAC. They reported that the harness attachment points were secure and that the seat belt latch was in good working order. They considered it unlikely that the latch would have been inadvertently released during flight. The LAA also found that it was necessary to '*slacken off*' the single shoulder strap to reach forward and make '*essential adjustments*' on the instrument panel. It was apparent that unless the strap was tight it had a natural tendency to fall sideways off the shoulder. With a slack shoulder harness, the seat occupant's upper torso could pivot forward during a sudden deceleration allowing their head to strike the front spar carry-through tube crossing the top of the cockpit (Figure 5). The LAA used this accident as a case study highlighting to its members the importance of ensuring that all '*Hatches and Harnesses*' are secure and tight during pre-landing checks. The LAA also informed the only other owner of a G-registered

Pelican aircraft of their findings concerning harness security and the potential for injury from the spar carry-through tube.

G-MPAC – Pelican PL – Shoulder Harness Field Trial – 22.10.20

LAA Light Aircraft Association

Picture 1. Pilot seated upright, shoulder harness and lap strap tight.

In this configuration forward restraint exists; in the event of a sudden stoppage, from a relatively low speed impact, the upper body would be held firm.

Picture 2. Shoulder harness relaxed.

To reach the instrument panel to make essential adjustments, the shoulder harness must be slackened off.

Picture 3. Simulated impact 1 - initial phase.

With the shoulder harness in the relaxed state, the pilot will be thrown forward in any sudden stoppage. Note that the shoulder harness naturally falls sideways off the shoulder.

Picture 4. Simulated impact 2 - No upper body restraint.

In this simulation, the pilot's head will first impact the tubular front spar carry through (top of cockpit) and then the instrument panel.

Figure 5

LAA field trials report (courtesy of the LAA)

Additional information

Deep landings, those achieved beyond the normal touchdown zone, can quickly lead to situations where the braking distance required exceeds the remaining runway available ahead. As a precaution against runway overruns, in their Safety Sense Leaflet 1[1], entitled '*Good Airmanship*', the CAA recommends that pilots should go around if not '*solidly 'on' in the first third of the runway*'.

Analysis

For very light aircraft, relatively small increases in all-up-weight weight and excess speed can have a disproportionate effect on performance. While G-MPAC was below its maximum landing weight, it had 60% more kinetic energy as it arrived in the flare than had it been flown solo and on-speed. This additional energy contributed to the protracted flare and deep landing which was further challenged by a downhill slope and the lack of headwind.

It is likely that his acclimatisation to landing on a 225 m strip at Oxenhope contributed to the pilot's confidence that the 250+ m of runway remaining on touchdown at Stoke Golding would be sufficient. The pilot reflected that, having not controlled the approach speed accurately or landed in the first third of runway, he should have gone around. Establishing a touchdown cut-off point before starting an approach makes the subsequent, land or go-around, decision making process easier. When determining a safe cut-off point, exacerbating factors such as adverse weather conditions, landing weight and runway characteristics should be taken into consideration.

It is likely that the pilot's injuries resulted from his shoulder strap being "comfortable" rather than tight. The slackness in the shoulder strap was likely a result of the pilot adjusting it so that he could reach the instrument panel during the flight and not pulling it tight for landing. While the collision dynamics of this accident were due to a landing overrun, they could equally have resulted from a rejected takeoff.

Discussion

The accident pilot reflected in hindsight that a decision to go around would have been a more appropriate course of action than to continue with a compromised approach and landing. Pilot decision making is a key contributor to flight safety. Incorrect approach speeds, steep approaches, deep landings, challenging airfields and unhelpful weather conditions are known hazards in aviation. Anticipating and mitigating these and other hazards, including planning contingency strategies in advance, can help pilot decision making when unexpected, but not unanticipated, situations develop.

That the aircraft occupants were sat side-by-side and one suffered serious injuries while the other was uninjured highlights the importance of ensuring harness security during takeoff and landing.

Footnote

1 Available at http://publicapps.caa.co.uk/modalapplication.aspx?catid=1&pagetype=65&appid=11&mode=detail&id=1156 [accessed October 2020].

Safety action

The Light Aircraft Association took the following safety action:

- It alerted the only other owner of a G-registered Pelican aircraft to the potential for head injury in an accident if the harness shoulder strap is not tight.
- It used this accident as a case study to emphasise to its members the importance of the '*Hatches and Harnesses*' pre-landing check.

SERIOUS INCIDENT

Aircraft Type and Registration:	Piper PA-28-151, G-CKIO
No & Type of Engines:	1 Lycoming O-320-D3G piston engine
Year of Manufacture:	1976 (Serial no: 28-7615340)
Date & Time (UTC):	5 September 2020 at 1040 hrs
Location:	Woodside Farm, Hockerton, Nottinghamshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Minor damage to wing tip and strobe light
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	514 hours (of which 228 were on type) Last 90 days - 6 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was climbing away from a practice forced landing when its right wing collided with a tree. The instructor stated he had not realised how close the aircraft had become to the tree and that the student delayed applying power to climb away when instructed to do so.

History of the flight

The aircraft was on a training flight from Nottingham Airport with an instructor and a student onboard. The student, who held a lapsed PPL, was at the controls and was practising a forced landing over farmland. The instructor stated that he had not realised how close the aircraft had become to trees during the procedure and that the student delayed applying power to climb away when instructed. As a result, the aircraft's right wing tip struck the top of a tree when climbing away. This dented a section of the wing's leading edge and damaged the wing tip. The instructor took control and was able to fly the aircraft back to Nottingham Airport without further incident.

The instructor commented after the accident that he should have considered earlier in the descent whether the student would be able to land in the selected field. He also stated that he should have intervened more quickly when the student failed to act on his instructions to apply full power and climb away.

Discussion

Aircraft may practise forced landings away from an aerodrome if flown no closer than 150 m (500 ft) to any person, vessel, vehicle or structure. There is an increased risk of collision with objects the lower an aircraft flies, even while observing legal limits.

Although the damage in this case was such that the aircraft was able to fly away, a similar collision with a tree investigated by the AAIB in June 2018[1] resulted in fatal injury to both occupants. That accident involved a motor glider conducting practice forced landings although the cause of the collision could not be firmly established. The accident involving G-CKIO emphasises the need to discontinue practice forced landings at a safe altitude.

Footnote

1 Registration G-KHEH, investigation reference EW/C2018/06/01.

SERIOUS INCIDENT

Aircraft Type and Registration:	DJI Matrice 210 (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2019 (Serial no: 17TDG350020016)
Date & Time (UTC):	6 October 2019 at 1150 hrs
Location:	Danbury, Essex
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:	None
Commander's Licence:	Other
Commander's Age:	38 years
Commander's Flying Experience:	262 hours (of which 5 were on type) Last 90 days - 28 hours Last 28 days - 16 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional AAIB enquiries

Synopsis

The DJI Matrice 210 unmanned aircraft system was being operated in a manual flight mode over a nature reserve in support of emergency service operations. Whilst the aircraft was hovering at a height of about 54 m, the ballistic recovery parachute system fitted to the aircraft activated unexpectedly. The aircraft descended under the parachute and became lodged in a tree.

Testing of the parachute system did not identify any evidence of a system malfunction which could have triggered an erroneous parachute deployment, but a false-positive activation of the parachute system could not be ruled out.

Analysis of the aircraft recorded on-board data did not provide any insight into why the flight was abruptly terminated, although several possibilities were identified. It was not established whether the parachute system activated first, cutting power to the aircraft motors or whether the aircraft experienced an inflight failure which triggered the parachute deployment.

History of the flight

The DJI Matrice 210 is a quadcopter Unmanned Aircraft System (UAS) with a maximum takeoff mass of 6.14 kg. It is controlled on the ground using a handheld flight controller via radio frequency and a software application running on a tablet device attached to the controller. For the accident flight the takeoff mass was calculated to be approximately

5.5 kg, which included an underslung camera, two TB55 batteries and a ballistic recovery parachute system.

The UAS was being flown manually in support of police operations at Backwarden Nature Reserve, Danbury, Essex. A pre-flight risk assessment noted that the forecast wind speed was 16 mph with 26 mph gusts, but the actual wind speed on the ground was measured as 7 mph. The pilot conducted function checks after takeoff and checked the aircraft's stability in the wind conditions. The UAS controller indicated a high wind warning and a FLY WITH CAUTION message was displayed, but the pilot assessed that the aircraft's flight was stable.

The aircraft was flown at a height of approximately 50 m to the area of interest. While in the hover, the ballistic recovery parachute system deployed without warning. The aircraft's motors stopped and it descended under the parachute, coming to rest in some trees. No other warnings were displayed on the controller. From the ground, the pilot assessed that no damage occurred when the aircraft landed in the trees but it was subsequently damaged during recovery from the trees.

The aircraft was sent to a UK repair organisation, which forwarded it to the UAS manufacturer for repair and analysis of the recorded onboard data. The parachute system was sent to the parachute manufacturer for examination and analysis of the recorded on-board data from both the parachute system and the aircraft's flight log.

Parachute system information

The operator had fitted a ParaZero SafeAir M200 ballistic recovery parachute system to the aircraft. The SafeAir is an optional after-market safety device that aims to reduce the risk of operating unmanned aircraft over populated areas, by reducing impact energy in the event of an in-flight failure. The M200 model is specifically tailored for use with the DJI Matrice 200 series of unmanned aircraft, including the Matrice 210.

The parachute and the system's internal electronics are mounted on a plate which is fitted on top of the aircraft (Figure 1). It is attached to two parachute mounting legs, which are connected to the aircraft's landing leg joints. A flight termination device, known as TerminateAir, is mounted above the aircraft's battery compartment. A cable connects it to the rest of the parachute system.

The SafeAir system uses independent sensors to monitor the flight parameters of the aircraft. If it detects a critical aircraft failure, the first step of the activation sequence is that the TerminateAir device disconnects the aircraft's batteries, cutting power to the motors. This prevents the motors becoming entangled in the parachute chords or causing laceration injuries. A lever on the TerminateAir is placed across the door of the aircraft's battery compartment, to prevent the batteries being physically ejected.

Having cut power to the motors, the parachute is then activated by a pyrotechnic charge, allowing the aircraft to descend in a controlled manner. An audio alarm alerts bystanders to the potential threat of the descending aircraft.

Figure 1

Parazero SafeAir M200 installed on a DJI Matrice 210 RTK unmanned aircraft
(*Source: Parazero*)

The SafeAir system will trigger a parachute deployment if it detects an aircraft freefall event. For such an event to be detected, the overall acceleration of the aircraft must drop below 3 m/sec^2, and remain below this threshold for a period of 300 milliseconds (ms). (Note that the aircraft is always subject to the earth's gravity of 1g which would be detected as 9.81 m/sec^2 during hovering flight.) The 300 ms delay was designed to mitigate the differences between the accelerations measured by the SafeAir and those measured by the aircraft. The overall acceleration is resolved from the X, Y and Z accelerations that are measured within the SafeAir unit itself, and no adjustments are made to take account of the SafeAir and aircraft accelerations being measured at different locations. Vibration levels may also be different at the two measurement locations.

As part of its risk mitigation, the operator's procedures required the SafeAir parachute system to always be fitted when operating the Matrice 210.

Review of recorded information by parachute manufacturer

The parachute manufacturer analysed the log files from both the aircraft and the parachute system and stated that they were '*similar until the moment of deployment*'. Thereafter the aircraft's flight log ended at cruise altitude, while the parachute system log continued to record the parachute deployment, characterised by erratic acceleration readings, and a descent at a constant rate (Figure 2 - note that the altitude data recorded by the SafeAir is barometric).

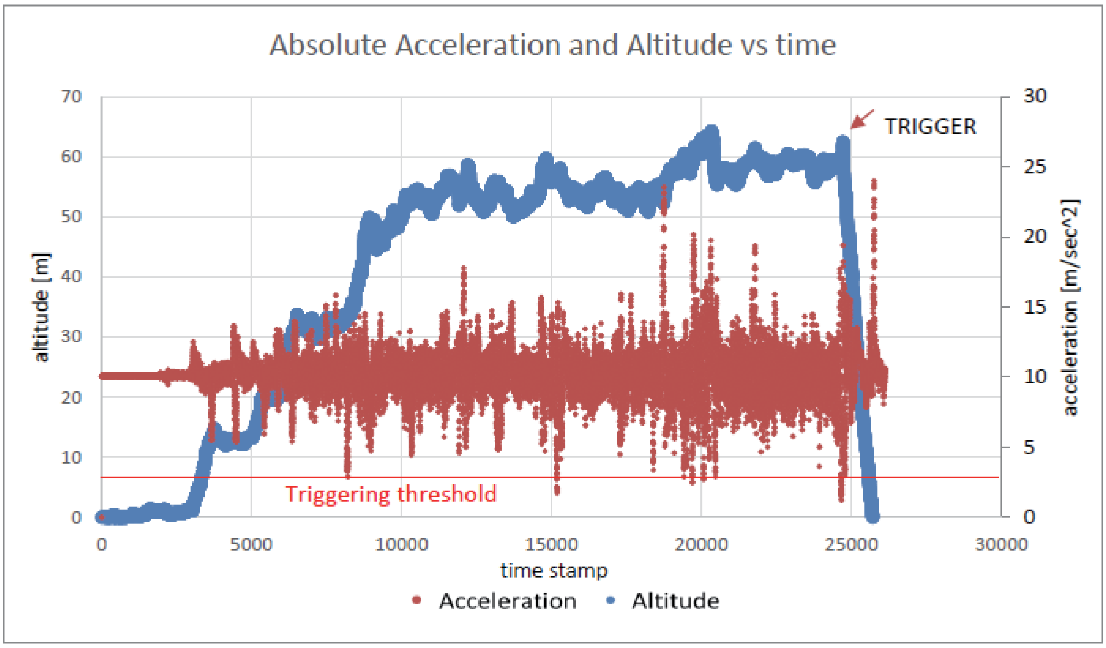


Figure 2

SafeAir recorded data for the accident flight
(Source ParaZero)

Testing of the parachute system by parachute manufacturer

The parachute manufacturer tested the electronic and mechanical aspects of the SafeAir parachute system including the TerminateAir device and no anomalies were noted. In order to determine whether a TerminateAir malfunction could have disconnected the aircraft's batteries, leading to a loss of power in flight and subsequent parachute deployment, tests were conducted with the parachute system installed on a DJI Matrice 200 aircraft. The SafeAir system was armed and the entire assembly was subjected to 24 hours of continuous vibration testing. A higher vibration rate than that observed during the accident flight was used. At the conclusion of the vibration testing, the system was still armed, no parachute trigger had been detected and the batteries were still connected.

The Matrice 200 with the SafeAir unit fitted was then flight tested to assess the behaviour of the parachute system during flight. A flight profile similar to that of the accident flight was used and additional, more extreme, manoeuvres were flown. No abnormal events were recorded during the flight test. The parachute system did not trigger, nor did the acceleration cross the triggering threshold (Figure 3).

The parachute manufacturer considered that the sudden end of the aircraft's flight log during the accident flight, could be explained by a total power failure of the Matrice 210. However, it stated that a false-positive parachute deployment could not be ruled out, although such a phenomenon could not be recreated during flight testing.

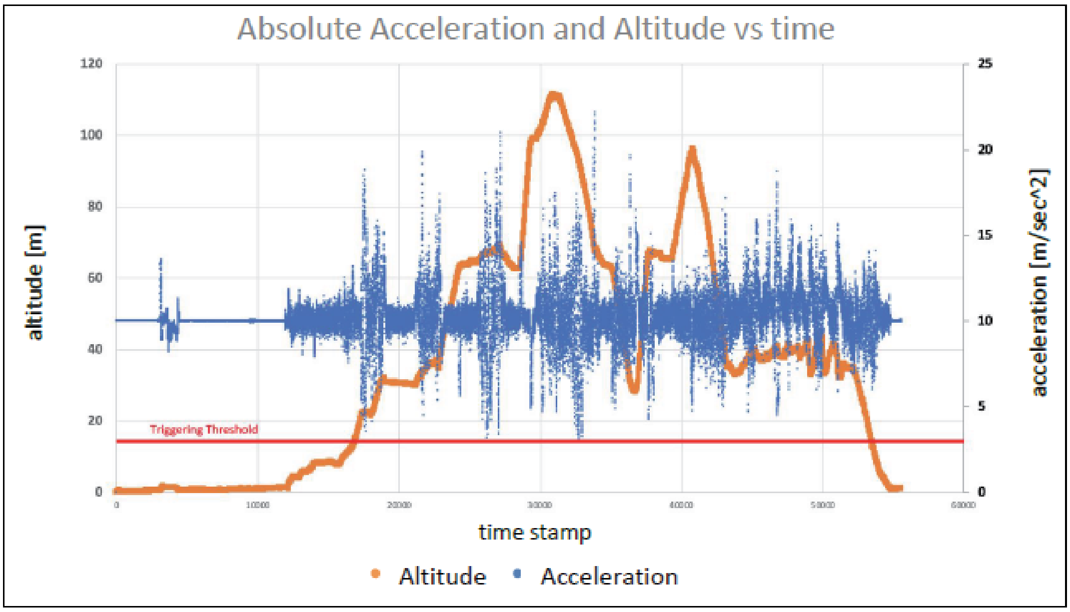


Figure 3

SafeAir recorded data for the test flight
(Source ParaZero)

Review of recorded information by AAIB

A review of the aircraft's on-board recorded data by the AAIB confirmed that the recording ended abruptly after 220 seconds, when the aircraft was hovering at a height of 53.5 m (recorded resolution is 0.5 m), having travelled 390 m from the takeoff point. The energy level (state of charge) of the aircraft's two batteries was 87% (Figure 4). The figure also compares the aircraft's altitude and acceleration data with the equivalent data from the SafeAir log file and shows that as the flight progressed, the acceleration recorded by the SafeAir system grew in amplitude compared to that recorded by the aircraft.

Figure 5 is a close-up of the last one second of the flight before power was lost to the aircraft. During this second the aircraft's inertial measurement unit (IMU) sensed slight changes in vertical speed that equated to about 2.6 cm height gain, with the aircraft's acceleration decreasing from just over 1g to below the SafeAir's trigger threshold over the last 25 ms. During these last 25 ms, the aircraft's nose-up pitch reduced by 0.77° (so about 30°/sec) and the thrust (probably in response) increased the power of the front motors and decreased the power of the rear motors. There were 23 more points in the aircraft's log file, covering a 109 ms period, that were corrupted (the last 12 of which appeared to be from an earlier flight two months earlier). The aircraft's log did not contain any warnings or provide an insight into the reason for the parachute activation, or if the batteries had been disconnected.

Figure 5 also shows the acceleration recorded by the SafeAir system, when it detected 300 ms of freefall. This triggered the TerminateAir within 2 ms and the parachute deployed 50 ms later. However, the drop in acceleration to below the SafeAir trigger threshold occurred about 700 ms before a drop in acceleration was measured by the aircraft.

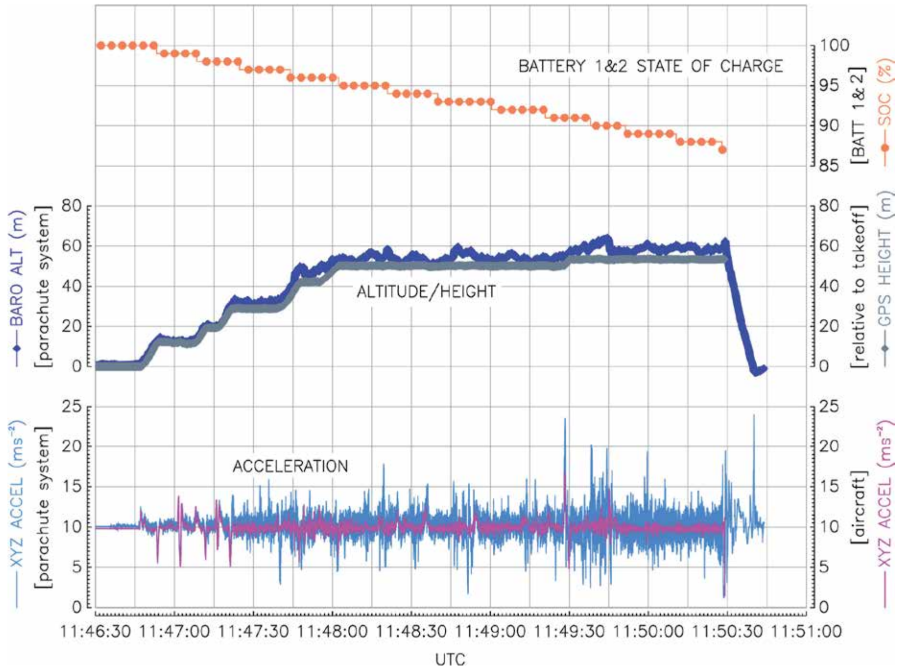


Figure 4

Flight log data from the aircraft and SafeAir system for the accident flight

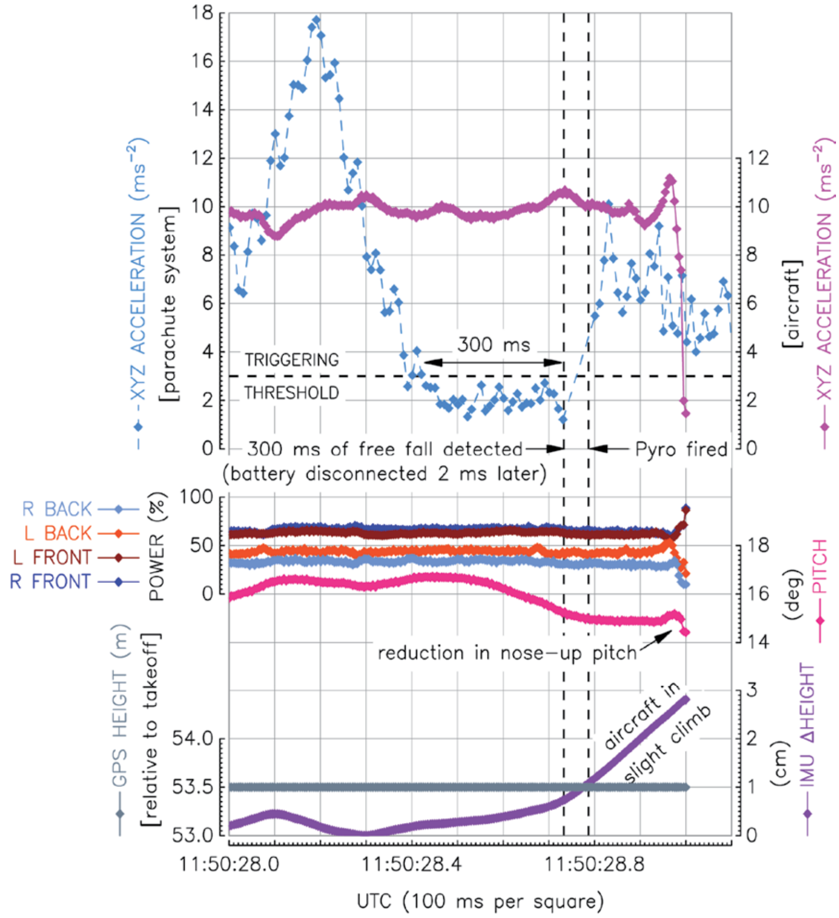


Figure 5

Comparison of acceleration prior to parachute deployment

Comparison of accelerations

The two acceleration data sets in Figure 5 appear misaligned; however, given that the aircraft logged data at about 200 Hz and timestamped each line of data in the log file with a UTC time, these should be accurate to within 5 ms. Similarly, the parachute system logged data at about 100 Hz so should be accurate to within 10 ms. It is also time stamped data but relative to the start of logging. The alignment of these data sets, therefore, relies on matching accelerations during a couple of portions of the flight, ideally at the start and then as near to the end as possible where a match in acceleration can be found to confirm the alignment. Figure 6 does this by comparing accelerations shortly after takeoff and then 150 seconds later (about 60 seconds before parachute deployment). Note that each square on the x-axis is 500 ms so any misalignment more than say 50 ms would be noticeable.

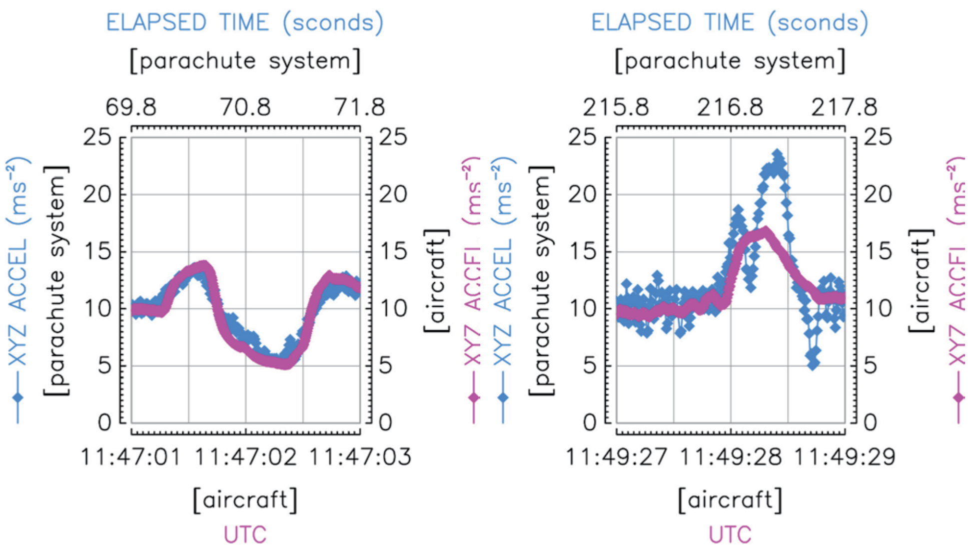


Figure 6

Comparison of accelerations to time align aircraft and parachute system datasets

Information from the aircraft manufacturer

The UAS manufacturer also analysed the aircraft's onboard recorded data. Preliminary information provided by the manufacturer stated: '*Primary conclusion: Hardware or structure issue. Secondary conclusion: Internal power-off in the air ([electronic speed controller] ESC voltage jump)'.* It also stated that *'there is a very high possibility that the parachute cut off the batteries of the M210, as the ESC and Fly control and battery* [parameters] *stops at the same time',* despite the batteries still having charge remaining. However, the UAS manufacturer did not provide any additional information to support its conclusions, despite several requests. The UK repair organisation confirmed that the UAS manufacturer repaired the aircraft under warranty and in addition to replacing items damaged during recovery of the aircraft, replaced the battery compartment module, batteries and a power board.

Previous accidents

The AAIB has investigated several accidents involving DJI Matrice 210s which have crashed due to a sudden loss of power. In those cases, the aircraft batteries indicated an erroneously high State of Charge (SOC), the cause of which is discussed in report EW/G2018/09/04, of AAIB Bulletin 11/2019. There was no indication from analysis of the flight log for this event that it was related to the same battery issue.

Analysis

During a routine manually operated flight of an unmanned aircraft, the ballistic recovery parachute system deployed and the aircraft descended towards the ground, becoming stuck in trees. There were no warnings generated on the UAS controller, other than an advisory FLY WITH CAUTION message due to the wind conditions. Review of the aircraft's flight log did not reveal the reason for the sudden termination of the flight and the batteries had 87% SOC remaining when the flight ended.

The parachute manufacturer conducted electronic, mechanical, vibration and flight testing of the SafeAir parachute system and its TerminateAir device and did not identify any evidence of a system malfunction which could have caused an unintentional parachute deployment. It concluded that the parachute deployment could have been a valid activation of the system in response to a sudden loss of power to the aircraft but could not rule out a false-positive activation of the system. However, it was unable to replicate a false-positive activation during post-accident testing of the parachute system.

The AAIB independently reviewed both the aircraft's flight log and the data recorded by the parachute system. The aircraft's flight log recorded a drop in the acceleration from 9.81 m/s (1g) to below the SafeAir trigger threshold over the last 25 ms of recording during which the aircraft's nose-up pitch started to decrease at 30 /sec with a corresponding change in thrust distribution fore and aft to counter this. However, this was about 700 ms after the SafeAir measured a drop in its acceleration below the threshold level. The differences in the recorded acceleration between the two systems makes it difficult to correlate the two. The changes in motor thrust and slight climb indicate that the motors were operating and generating positive thrust up to the point that the recording stopped. This could have been a result of the parachute system falsely detecting a freefall condition; however, the aircraft's flight log event file did not contain entries to say that the batteries had been disconnected. The investigation was unable to explain the erroneous data at the end of the fight log.

Conversely, if the loss of power was a result of an aircraft power failure, causing the aircraft to go into freefall thus triggering a parachute deployment, the alignment in time of the accelerations between the two systems would have to be shifted by about 700 ms. However, this would be contrary to the evidence of aligned data at point earlier in the flight.

As the flight progressed, the parachute system was measuring increasingly greater amplitudes in acceleration compared to those measured by the aircraft. These were perhaps a result of the accelerations being measured from different locations and with different levels in vibration. The 300 ms trigger delay was designed to mitigate against false-positive detections due to transient differences in accelerations between the two systems, but any delay will always be a compromise between false positive detections and late detections of true aircraft failures.

The aircraft was not examined by the AAIB. Without additional information from the UAS manufacturer it was not possible to establish whether the aircraft experienced a sudden power loss or other failure, which triggered activation of the parachute system, or whether the parachute system detected an erroneous trigger and activated in response, cutting power to the aircraft motors. However, the fact that the batteries, battery compartment module and a power board were replaced during the repair, could indicate a power problem with the aircraft, even though it is difficult to reconcile this with the alignment of data between the two systems.

The AAIB is currently investigating two other events involving unexpected activation of a ballistic recovery parachute on DJI Matrice aircraft and will collate any common factors emerging from those investigations.

Conclusion

A routine flight of an unmanned aircraft terminated prematurely when the ballistic recovery parachute system activated unexpectedly. It was not established whether the parachute system activated erroneously, cutting power to the UAS motors or whether the UAS experienced an inflight failure which triggered the parachute deployment.

Safety action

The parachute system manufacturer is aware of the log alignment issues between its system and the DJI Matrice 200 series of aircraft. As such, the latest parachute system that is being designed for the DJI Matrice 300 series aircraft will communicate directly with the aircraft to cut power to the motors, leaving power on the aircraft to continue logging data, and enable more accurate syncing of the aircraft and parachute system log files.

AAIB Record-Only Investigations

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

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

The accuracy of the information provided cannot be assured.

Record-only investigations reviewed November - December 2020

24-Jul-20 **Skyranger 912S(1)** **G-CDUS** Greenhills Farm, Wheatley Hill, County Durham

During the landing roll the aircraft started to drift left and departed the grass strip before came to rest in a drainage ditch. The left main gear drag strut had failed, likely to be associated with the impact with the ditch.

08-Aug-20 **Maule MX-7-180** **N280SA** Lofshaw Hill, Keswick, Cumbria

While flying a circuit, the pilot reported that he misjudged the landing and the aircraft nosed-over and came to rest on its back.

09-Aug-20 **Vans RV-7** **G-CGJN** Bassett's Farm Airfield, Essex

The aircraft landed long at a farm strip and the pilot turned the aircraft to avoid a hedge at the end of the landing area. The left wing tip came into contact with the hedge during the turn. The pilot assessed that he had not factored for the tailwind component and the high ambient temperature of 32°C for his approach.

11-Sep-20 **Robinson R44** **G-CDUE** Peterborough Business Airport, Cambridgeshire

The helicopter was caught by a gust of wind as the pilot lifted into a low hover, which resulted in a rapid yaw to the right. As the pilot attempted to control the yaw, the tail rotor struck the ground. The tail rotor and boom detached.

11-Oct-20 **ISA 180 Seeker** **G-SEKR** Leeds East Airport, North Yorkshire

During the second test flight of a new aircraft prototype the pilot was unable to extend the landing gear and conducted a wheels-up landing. The force required to extend the manually-operated landing gear system was higher than that anticipated during the design process. The flight test programme and any resulting design amendments are being monitored by the LAA.

19-Oct-20 **Flight Design CT2K** **G-CCNG** Athey's Moor Airfield, Longframlington, Northumberland

After landing normally the aircraft began a skid to the left, which the pilot was unable to correct. As the aircraft came to a halt off the left the side of the runway, the propeller and wingtip made contact with ground. The landing gear, wing and propeller were damaged.

Record-only investigations reviewed November - December 2020 cont

03-Nov-20 **Cessna 152** **G-TALA** Tatenhill Airfield, Staffordshire

The pilot planned to fly two or three circuits and calculated that the fuel on board was sufficient for the flight. After encountering improving weather when airborne the pilot left the circuit for a short local flight. On returning to the circuit the engine spluttered and stopped. Whilst gliding to land the nosewheel caught a sapling in the hedge at the end of the runway and the aircraft was flipped onto its roof. The pilot sustained minor injuries.

04-Nov-20 **Rans S6-ESD XL (Modified)** **G-MYYV** Near Northrepps Airfield, Norfolk

A perceived low climb rate on takeoff led to the pilot reducing power in an attempt to clear any fuel flow issues. Upon re-applying full throttle, the engine stopped and, during the subsequent forced landing in a field, the nose gear and propeller were damaged.

26-Nov-20 **Vans RV-8** **G-RVAR** Vale of Neath Gliding Club, Rhigos, Mid Glamorgan

The aircraft landed long on a grass runway. The right main wheel dug into the turf pulling the aircraft to the right onto softer ground, tipping it onto its nose and right wing tip. The pilot stated that he would seek the advice of an instructor qualified on type for guidance on approach techniques.

20-Dec-20 **Rotorsport UK MTO Sport** **G-PALT** Beccles Airfield, Suffolk

Due to insufficient speed, the aircraft suffered a retreating blade stall during the takeoff climb, causing the rotor blades to move downwards and contact the propeller blades. Although the rotor and propeller blades incurred some damage, the aircraft landed safely.

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

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.

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

Published March 2020.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

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

AAIB Bulletin 2/2021

Air Accidents Investigation Branch