ACCIDENT

Aircraft Type and Registration:	AS350 B3e Ecureuil, G-MATH
No & Type of Engines:	1 Turbomeca Arriel 2D turboshaft engine
Year of Manufacture:	2016 (Serial no: 8274)
Date & Time (UTC):	5 May 2017 at 0830 hrs
Location:	Wycombe Air Park, Buckinghamshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - 1 (Fatal) 1 (Serious) Passengers - 1 (Serious)
Nature of Damage:	Extensive
Commander's Licence:	Commercial Pilot's Licence (Helicopters)
Commander's Age:	45 years
Commander's Flying Experience:	5,747 hours (of which 579 were on type) Last 90 days - 53 hours Last 28 days - 17 hours
Information Source:	AAIB Field Investigation

Synopsis

The accident occurred whilst the helicopter was engaged in hydraulic failure training. An instructor was in the left seat of the helicopter, a pilot under training in the right seat and another pilot under training, who was a passenger on this flight, was seated in the rear.

The right-seat pilot was performing a hydraulics-off approach, to finish in a run-on landing. The instructor became dissatisfied with the approach parameters and took control in the latter stages, performing a hydraulics-off go-around into a left-hand circuit, before lining up the helicopter on final approach for the pilot to make a second attempt. Once again, the instructor took control late in the approach and performed another go-around. On this occasion, the left turn onto the downwind was flown with a higher angle of bank (AOB). The instructor was unable to control the roll attitude and the helicopter rolled left, beyond 90° AOB, descended rapidly and struck the ground, coming to rest on its left side.

All three occupants were seriously injured. The right-seat pilot died some weeks later from injuries sustained in the accident.

No technical issues were identified and a definitive reason why the instructor was unable to roll the helicopter back to a level attitude could not be determined.

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The investigation concluded that clearer instructions in the AS350 flight manual for hydraulics-off flight would help prevent similar accidents in future. In response to this accident, the helicopter manufacturer has taken safety actions including: amending the AS350 flight manual to limit the AOB to 30° during hydraulics-off flight and the inclusion of warnings not to conduct low speed manoeuvres with hydraulics off due to the danger of loss of control. It has also prepared a safety video describing how to perform hydraulics-off training.

History of the flight

Background

The purpose of the flight was type conversion training for two pilots who were converting onto the helicopter type. The training was being conducted by an instructor under the auspices of an Approved Training Organisation (ATO) based at Wycombe Air Park. The accident occurred during a revision flight in preparation for the pilots' Licence Skills Tests (LST).

G-MATH was equipped with a factory-installed 'Appareo Vision 1000' cockpit video and flight data recording system.

Accident flight

G-MATH departed Wycombe Air Park at 0805 hrs with the instructor in the left seat, one pilot in the right seat and the second pilot as a passenger in the centre left rear seat. This part of the training detail included autorotative exercises, practice engine failures, hover exercises and low-level circuit practice. It was completed uneventfully, after which the helicopter returned to Wycombe.

On arrival back at the airfield, the helicopter was routed south-west to position for a base leg approach to the grass area north of Runway 06 to commence hydraulic failure training. The instructor selected the ACCU TST switch ON and then OFF, in accordance with the AS350 flight manual procedure, to simulate a hydraulic failure. The flight manual procedure called for a '*flat approach into wind*', with a '*no-hover slow running landing at approximately 10 kt*'. The pilot in the right seat was at the controls and, in accordance with the procedure, he selected the HYD CUT OFF switch on the right collective lever to OFF to depressurise the hydraulics. He continued the approach and reduced speed for a planned run-on landing at low speed.

During the latter stages of the approach, the instructor felt that the right-seat pilot was allowing the aircraft to yaw and reduce speed too much, so the instructor took control and initiated a go-around. Recorded data show that this was followed by a left-hand circuit, flown with up to 32° AOB, to reposition the helicopter for a second attempt. The hydraulic system remained unpressurised. During the go-around the right-seat pilot kept his hand on the cyclic, although the instructor stated that he had briefed him not to do so.

Once re-established on final approach, the instructor handed over control to the right-seat pilot for a second attempt. Once again, the instructor was not content with the pilot's control of yaw and speed in the latter stages, so he took control and initiated another hydraulics-off go-around, quickly followed by a left turn downwind. The right-seat pilot kept his hands and feet on the controls. The roll rate in the turn was initially similar to that of the first go-around, but on this occasion the AOB increased. As the AOB reached 48°, the recorded image data showed the instructor changing his grip on the cyclic stick and leaning his body to the right, as if attempting to increase the amount of right control force input. The AOB stabilised briefly, after which the helicopter rolled further to the left, descended and struck the ground on its left side.

All three occupants were seriously injured. The instructor and the passenger in the rear seat survived, but the pilot in the right seat died some weeks after the accident as a result of his injuries.

When interviewed, the instructor stated that he had been unable to move the cyclic control to the right to arrest the roll to the left.

Accident site

The accident site was located within the airfield boundary, about 200 m north of the centre of Runway 06/24. The helicopter had struck the ground on its left side with little forward speed (Figure 1). The ground impact marks showed that the main rotor blades had struck the ground first when the helicopter was in a near 90° left bank, and the damage to the blades was consistent with them being powered. The tail boom had failed as a result of the inertia loads of the impact but there was no damage to the tail rotor. The fuselage came to rest on a heading of 019°(M).

Figure 1

G-MATH accident site
(Image on the left is a view to the east, taken a few hours after the accident.
The image on the right was taken the day after the accident,
after the lower fuselage panels had been removed)

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Aircraft information

G-MATH was an Airbus Helicopters AS350 B3e; a variant of the AS350 B3 with an uprated Arriel 2D engine. The AS350 B3 was certified in 1997 and was a significantly upgraded version of the original AS350 B, first certified in 1977. G-MATH was equipped with six seats; two pilot seats with dual controls in the front, and four passenger seats in the rear.

The helicopter had a single hydraulic system operated by a belt-driven hydraulic pump. In the event of a pump failure or hydraulic leak, the flight controls can be operated mechanically, but the control forces are higher. In the event of a loss of hydraulic pressure, or low hydraulic pressure (below 30 bar), a steady red 'HYDR' caption illuminates on the Warning-Caution-Panel (CWP) and a warning gong sounds.

The cyclic pitch control stick and collective pitch control lever operate three main servo actuators via a series of push-pull rods, bellcranks and a mixer unit (Figure 2). Moving the cyclic fore and aft actuates the forward servo actuator; this actuator controls pitch attitude by tilting the main rotor swash plate fore and aft. Moving the cyclic left and right actuates the left and right servo actuators; these actuators control roll attitude by tilting the swash plate left and right. The collective lever actuates all three servo actuators together to increase blade pitch, and it also increases engine power, with a resulting increase in rotor thrust.

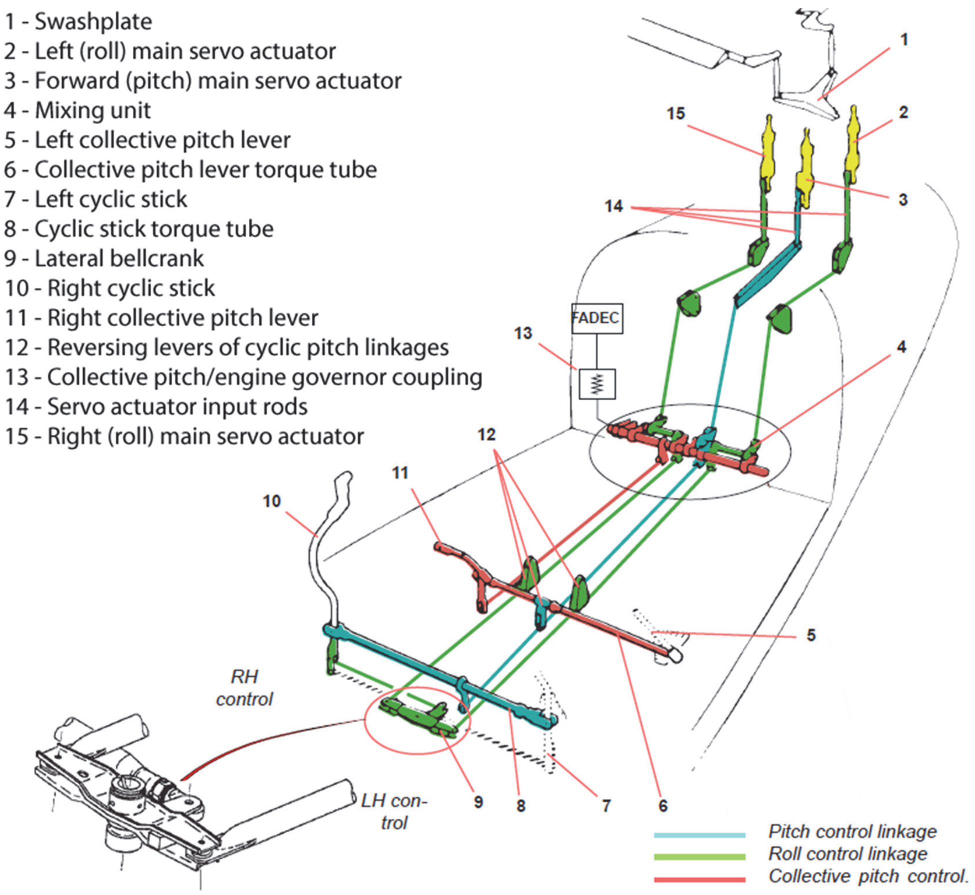

Figure 2

Diagram of the AS350 B3e main rotor flight controls
(Image courtesy Airbus Helicopters)

In normal flight with the hydraulics on, the main servo actuators are hydraulically powered. Each actuator has an accumulator which provides a short period of hydraulic pressure reserve to reach the safety speed in the event of a hydraulic failure.

A guarded hydraulic cut-off (HYD CUT OFF) switch is located on the right collective lever. When this is selected OFF the HYDR caption illuminates, the hydraulic system is depressurised and the main servo accumulators are depressurised simultaneously. This loss of pressure causes a locking pin inside each servo to drop into place, enabling the control input rods to be locked and move the servo actuators mechanically. The cyclic control forces required to move the servos are higher with the hydraulics off.

The tail rotor pitch is controlled by foot pedals which mechanically actuate a hydraulic servo actuator in the tail boom. A yaw load compensator is connected in parallel with the servo to reduce control loads in the event of hydraulic pressure loss. The yaw load compensator retains its pressure when the HYD CUT OFF switch is selected OFF. Keeping this pressurised is important to assist with yaw control when practising hydraulics-off flight.

When the accumulator test (ACCU TST) button is pressed the red HYDR caption flashes on the CWP and the hydraulic system and yaw load compensator are depressurised, but the main servo accumulators remain pressurised for a limited time, allowing the pilot to reach the safety speed. To simulate a hydraulic system failure, during the first part of a hydraulics-off training procedure this button is selected on and then off once safety speed is reached.

The manufacturer's recommended safe airspeed range (safety speed) for manoeuvring with the hydraulics off is 40 to 60 kt. In this speed range, to maintain level flight the pilot needs to hold a cyclic force of about 4 to 6 kgf to the left and 5 kgf forward. These forces increase at higher airspeeds and also at low speeds near the hover.

The collective lever has a neutral force position at about 40% torque and any movement up or down from that position requires increasing amounts of force.

There is an adjustable cyclic friction ring at the base of the right cyclic which allows the pilot to adjust the force required to deflect the cyclic (when the hydraulics are on, there are no feedback control forces).

The helicopter was fitted with an aftermarket 2-axis HeliSAS autopilot and stability augmentation system using a Supplemental Type Certificate. This system consists of a pitch and a roll servo which are connected to the cyclic's pitch and roll control rods beneath the cabin floor. When the HeliSAS system is turned off by the pilot, electromagnetic clutches disconnect the servo motors from the cyclic control system. When engaged, the servo motors apply loads of about 1.4 kgf at the cyclic grip.

The aircraft was fitted with a Vehicle and Engine Management Display (VEMD). The amount of engine torque, N1 or T4 was depicted on a 'First Limitation Indicator' (FLI) gauge, on a scale of 0 to 12, where 10 was the maximum allowable.

There is a dual hydraulic system option that can be fitted to the AS350 B3 and B3e. When this is fitted there is no requirement to carry out 'hydraulics-off' training.

Recorded information

G-MATH was equipped with an 'Appareo Vision 1000' system, which recorded cockpit video, audio and flight data parameters. It was fitted by the helicopter manufacturer to allow the operator to review previous flights and to aid accident investigators. Unlike an FDR or CVR, the Vision 1000 system is not a certified, crash-protected recording system.

The unit was mounted centrally in the cabin roof, behind the pilots' seats, and provided a camera view of the instruments, flight controls and windows. Recorded information included video at four frames per second (fps), ambient cockpit audio from an onboard microphone, GPS position and GPS altitude information. Attitude and acceleration data were also measured and recorded. Recording commenced when electrical power was applied on the helicopter. In addition to cockpit audio, it can also record from external audio sources such as the helicopter's intercom and/or radios. In G-MATH, this option had not been fitted, so only cockpit audio was recorded.

The device was found at the accident site, detached from its cockpit mount and hanging from a cable. This meant that switch positions and the normal view of the occupants could no longer be seen on the video once the helicopter had struck the ground.

The device was successfully downloaded and contained just over two hours of audio and video, along with flight data from several flights, including the accident flight. These recordings were used in preparing the History of the flight (see above). In addition to the data recorded from the Vision 1000's attitude and acceleration sensors, information was read from the cockpit airspeed indicator (ASI) and FLI gauges. ASI data was not discernible below 20 kt due to the scaling of the gauge.

The ambient cockpit audio recording levels were low, meaning only loud sounds from the helicopter's engines/transmission were recorded and no flight crew speech was audible on the recordings.

Hydraulics-off approach and go-around

The Vision 1000 recorded image and flight data were analysed to compare the two go-arounds. Throughout both manoeuvres, no unexpected warnings or cautions were present and the main rotor rpm was as expected. The white 'SAS'[1] light was ON, (signifying the HeliSAS system was powered, but on standby (as it had been since takeoff)) and there was approximately 218 kg[2] of fuel on board. Prior to the first approach, the recorded video shows the instructor correctly performing the flight manual 'ACCU TST' procedure. At 0829:50 hrs, the right-seat pilot selected the 'HYD CUT OFF' switch to OFF and the red HYDR caption was illuminated on the CWP.

First go-around

The instructor took control for the go-around with the helicopter approximately 5 ft agl and groundspeed of approximately 13 kt (airspeed was not registered on the ASI). The

Footnote

1 Stability Augmentation System.
2 Fuel quantity was estimated from the quantity indication bar on the VEMD.

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helicopter pitched down to 12° nose-down, FLI increased to a maximum of 6.3 and the aircraft rolled left, reaching 29° AOB at approximately 27 ft agl. As the speed increased, pitch attitude returned to approximately level and the GPS groundspeed stabilised at 43 kt. The indicated airspeed read from the cockpit gauge remained at or below 20 kt for most of this manoeuvre. The helicopter then rolled to the right to arrest the turn on the downwind leg, continuing to climb to a maximum GPS-recorded height[3] of 74 ft agl.

The recorded images showed that as the instructor took control, the right-seat pilot initially relaxed his grip on the controls and then removed them briefly from the cyclic and completely from the collective until taking control for the second approach.

The base leg turn was a continuous manoeuvre with the helicopter rolling left to 32° AOB and commencing the approach descent as it turned onto the final approach heading. The airspeed only began to increase once the instructor had lined the helicopter up on the approach heading.

Comparison of first and second go-arounds

When the instructor took control for the second go-around, the helicopter was at approximately 35 KIAS and approximately 20 ft agl. This occurred with the helicopter positioned slightly to the north-east of the first circuit. (Figure 3).

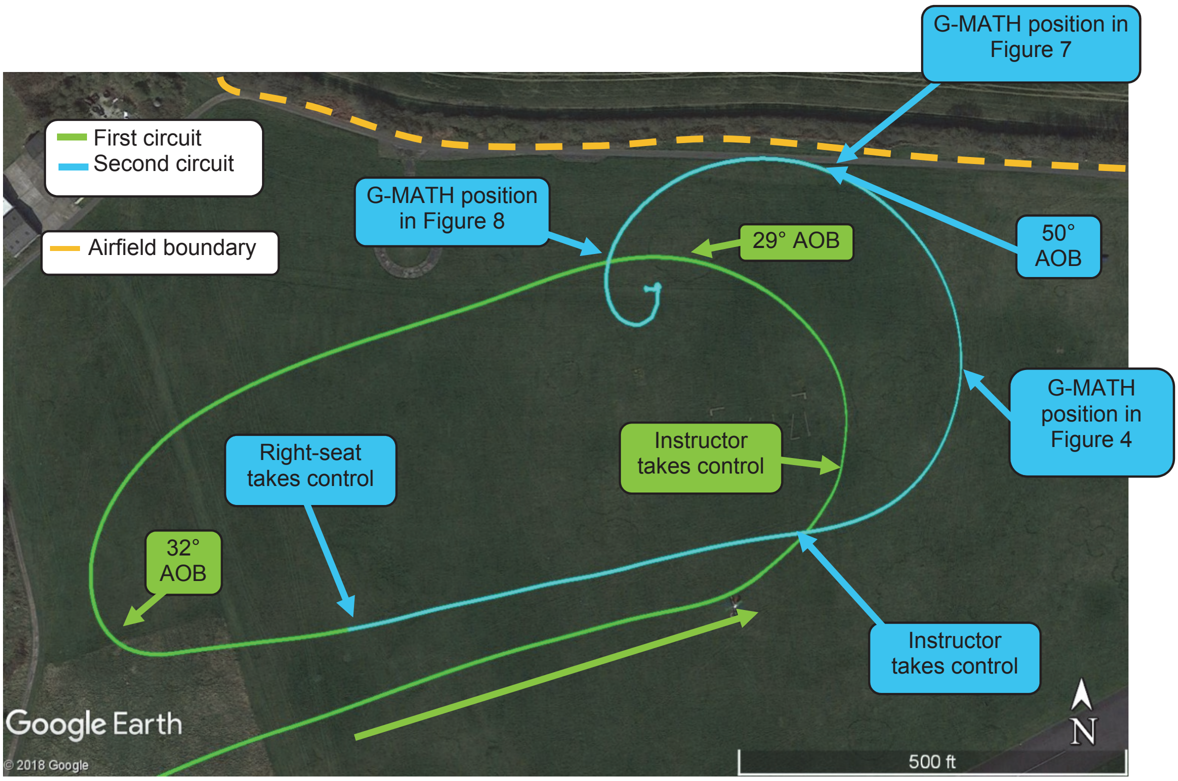

Figure 3

Final 90 seconds of G-MATH flight data

Footnote

3 GPS height was calculated from current GPS altitude minus the GPS altitude at impact.

The instructor applied left and forward cyclic, left pedal and raised the collective, producing a corresponding increase in FLI. Indicated airspeed and altitude began to increase as the helicopter pitched nose-down and rolled left. The left roll was initiated at a height of approximately 20 ft agl and reached 30° at approximately 47 ft agl. Throughout the initial stages of the second go-around, the right-seat pilot's hands and feet were still on the controls but his grip on the cyclic was seen to loosen (Figure 4).

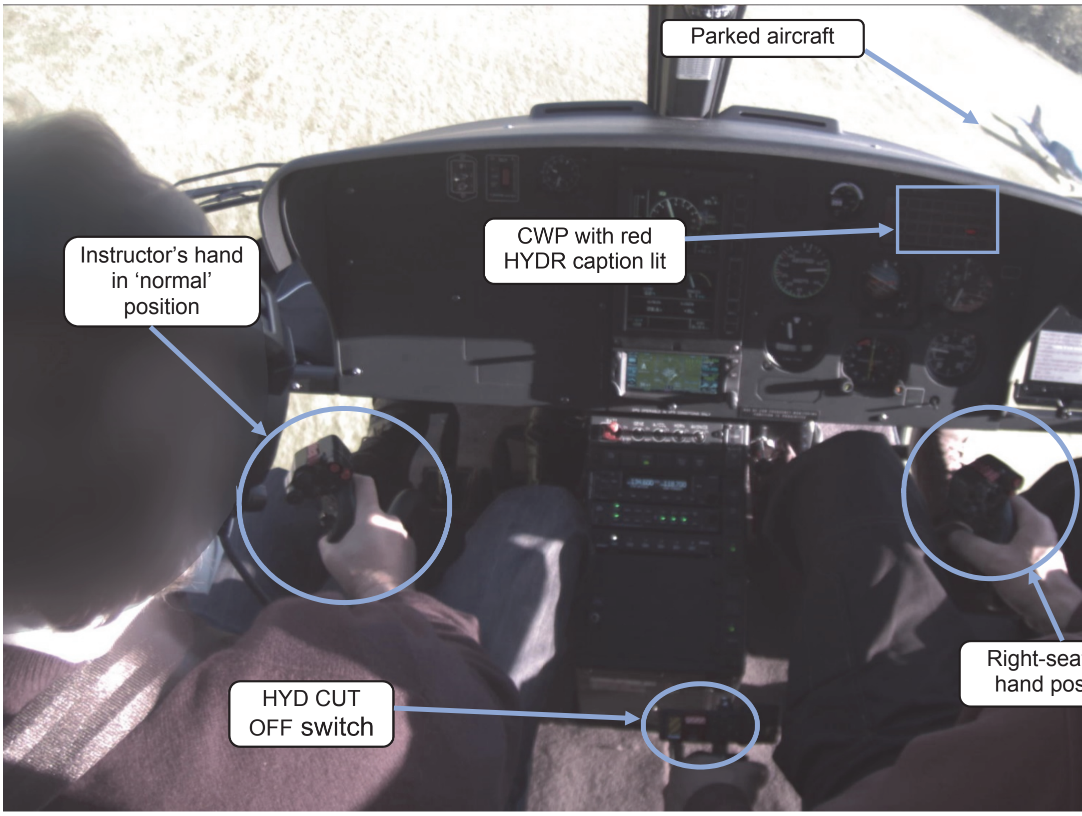

Figure 4

Second go-around showing right-seat pilot with hands and feet on the controls (instructor's head has been blurred).

Figure 5 presents data from both go-arounds, aligned at the point when the helicopter began to pitch nose-down. This figure shows that the helicopter attitude during the initiation of the go-around was similar on both occasions. The helicopter pitched down and rolled to the left to approximately the same attitudes and at similar rates in the first 7.5 seconds of the turn. The rates of turn were -11.9°/sec and -10.6°/sec respectively.

The recorded data shows a divergence in parameters between the two go-arounds after the first 7.5 seconds. In the first go-around, the pitch and roll attitudes began to return to zero as the helicopter rolled out of the turn onto the downwind leg. In the second go-around, the roll and nose-down pitch continued to increase; this commenced at 0832:50 hrs.

The main differences between the two manoeuvres at the point of divergence was the airspeed, which was below 20 KIAS for the first go-around but 47 KIAS for the second, and height, with the helicopter approximately 25 ft higher on the second go-around. The Vision 1000 data also showed the instructor applying more left pedal in the second go-around.

The ground track and turn radius of the first 180° turn of each circuit were similar despite the difference in the AOB; this was due to the higher airspeed on the second go-around. The second go-around was commenced when on the final approach heading.

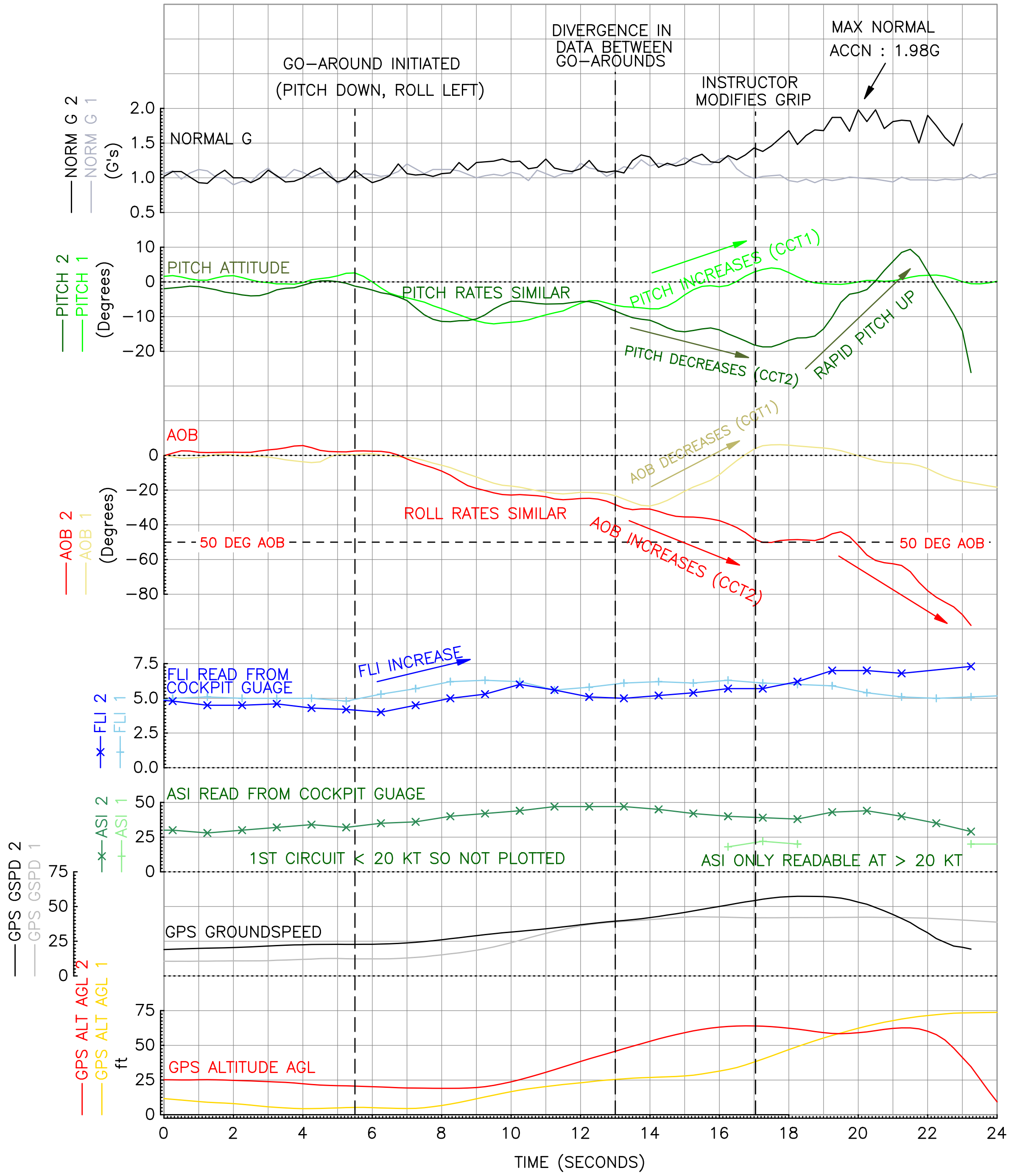

Figure 5

G-MATH comparison of two go-around manoeuvres.
Lighter coloured lines and '1' denote first circuit; darker lines and '2' denote second circuit.
(Data ends at impact)

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Last 10 seconds of recorded data

In the final stages of the second go-around (Figure 6) the AOB increased to 50° left and the helicopter pitched down to -19° over four seconds. (The view from the cockpit video and recorded position at this point showed the helicopter was just inside the airfield boundary hedge). The recorded height was 64 ft agl.

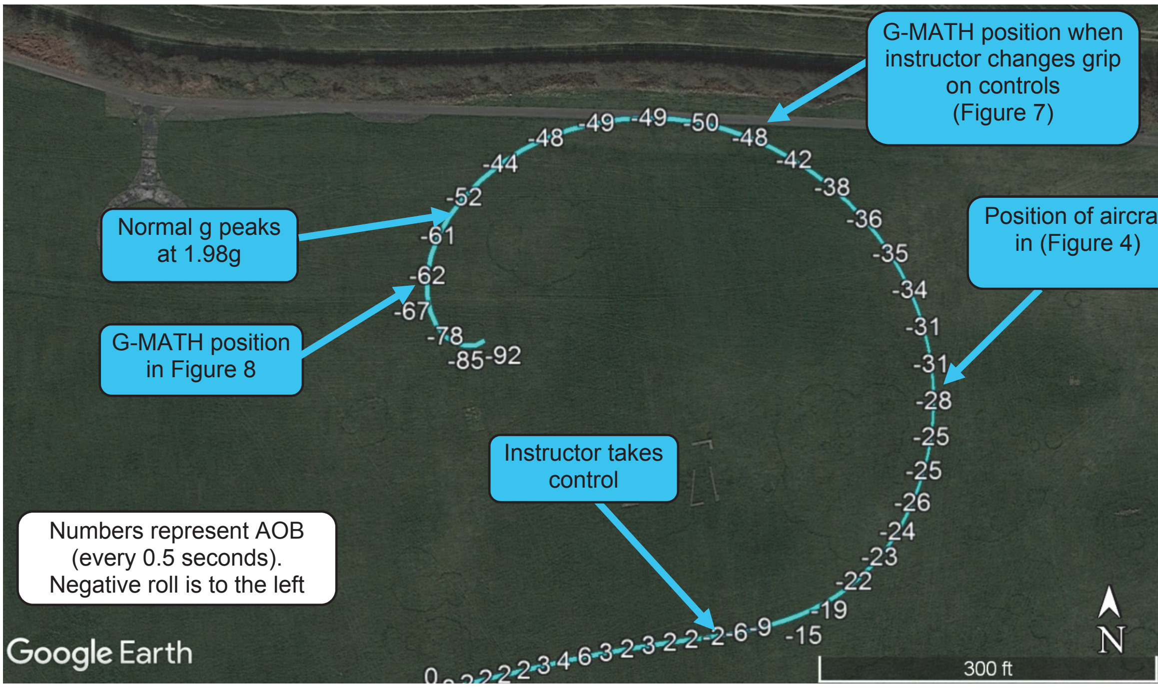

Figure 6

G-MATH final go-around manoeuvre showing AOB

At 0832:54 hrs the video showed the instructor changing his grip on the cyclic (Figure 7). The AOB then briefly stabilised at approximately 49° left as the helicopter began to pitch up. The AOB then briefly recovered to 44° (Figure 6).

From this point, the cyclic is seen to move to the right and aft but the AOB continued to increase as the helicopter pitched up and the recorded normal acceleration increased, reaching a maximum of 1.98 g at 52° left AOB. One second later, the right-seat pilot tightened his grip on the cyclic and maintained his grip until the helicopter struck the ground 3.5 seconds later.

After the instructor's grip on the cyclic had changed, his body also leant to the right (Figure 8) and for the final 3 seconds prior to the accident, obscured the Vision 1000's view of the right collective lever and the position of the hydraulic cut-off switch on the end of the right collective. The view of the CWP was not obscured and the red HYDR light remained illuminated until the end of the recording.

The helicopter struck the ground at 0833:01.5 hrs at a recorded vertical speed of -1,900 ft/min and 97° left AOB. Impact acceleration was not captured, possibly due to the recording sample rate of only 4 Hz, or the camera becoming detached from its mount.

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Figure 7

G-MATH at 0832:54 hrs during second go-around showing changed grip for instructor (compare with Figure 4). (Instructor's head has been blurred)

Figure 8

G-MATH at 0832:58 hrs during second go-around showing instructor's right lean (62° AOB). (instructor's head has been blurred)

Control inputs

Position data of the control inputs (cyclic and collective) were not recorded by the Vision 1000 but the controls are visible in the video. Given that the instructor reported not being able to recover the helicopter to a level attitude, the position of the cyclic throughout this manoeuvre was of interest. Ordinarily, a comparison could be made between cyclic position during a 'full and free' control check prior to takeoff; however, on this helicopter type this check is not required to be performed, nor can it be due to the nature of the control system. It was also not possible to perform this on G-MATH after the accident due to the damage to the helicopter.

An AS350 B3e was selected which the manufacturer advised had controls representative of those fitted to G-MATH, but a different cockpit avionics fit. The flight controls were disconnected to allow them to be moved to the limits of travel and the Vision 1000 alignment was checked to be as close to G-MATH as possible. This was verified using a live link to the camera. This was not a precise setup and so an exact match could not be achieved, but the setup was nevertheless considered to be representative. Video recordings of full cyclic and control movements were then made.

During the final stages of the flight, only the right-seat pilot's cyclic was visible as the instructor had changed his hand position, obscuring the Vision 1000 view of his controls. The video imagery showed that at 0832:58 hrs and a left AOB of 62° (3.5 seconds prior to impact), the right-seat pilot's cyclic was positioned in the furthest right position which is shown in Figure 9. This figure also shows how his grip had tightened on the cyclic. While the exact cyclic position could not be established, when comparing to the 'full and free' check performed on the test helicopter, it shows that the cyclic had not reached its right limit (Figure 10).

Pilot interviews

The instructor and surviving pilot were interviewed by the AAIB. Initial interviews were conducted in hospital in the hours immediately following the accident. More detailed interviews were conducted subsequently after they had left hospital and were recovering from their injuries. Their recollection of the sequence of events was similar, though both differed from the events recorded by the Vision 1000 system.

Instructor

The instructor stated that he was conducting a Type Rating course for the two pilots. He had conducted two days of ground school interspersed with some flying with both pilots. He specifically recalled that hydraulics-off flight had been "an issue" for the right-seat pilot. For the day of the accident, the instructor recalled departing the circuit to the north to conduct some emergency handling exercises. He could not recall the exact content but felt that these exercises would have been suitable for the Skills Test which the pilot was due to take that afternoon. The instructor subsequently stated that he had briefed the students prior to the exercise that there was only one hydraulic cut-off switch, located on the right collective lever and that they should only turn the hydraulics back on if he requested them to do so.

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Figure 9

G-MATH Vision 1000 view showing right-seat pilot's cyclic position at its furthest right during the second go-around

Figure 10

View from exemplar helicopter Vision 1000 showing full right cyclic in mid fore-aft position

The helicopter then returned to the airfield and the instructor initiated the hydraulics-off training exercise. His recollection of the procedure was correct, as confirmed by the Vision 1000 data. He recalled that the exercise went well until the final stages, at which point he intervened as the right-seat pilot was allowing the helicopter to crab sideways and was not maintaining a level attitude. He then believed that he had landed the helicopter to debrief the pilot and to reset the hydraulic system; however, the Vision 1000 video showed that this did not occur.

For the second attempt, the instructor recalled performing a tight circuit to reposition on final approach to allow the pilot to repeat the approach and landing. He stated:

> "once again he allowed the speed to drop too far and allowed the approach to get crooked. The exercise requires quite a lot of forward cyclic since Hyd Off the aircraft tries to slow very quickly at slower speeds. I felt the approach was very marginal so I took control again."

He believed that he initiated an early left turn and explained that the right-seat pilot had been briefed not to restore hydraulics as he took control because of the low height and speed in a regime where significant forces are required on the controls. He stated that usually the helicopter is quite docile above 40 kt and that a hydraulics-off go-around is usually no problem.

In describing the final moments of the flight, the instructor stated:

> "Shortly after initiating a climb and then left turn, the aircraft rapidly and involuntarily banked to the left (possibly in excess of 70°) and I was unable to correct the attitude of the aircraft through any amount of physical force. The controls seemed to be completely jammed. As far as I recall the aircraft maintained this extreme angle of bank to the left until it impacted the ground as I was unable to influence any control upon the aircraft's flight trajectory."

Following review of the AAIB draft report, the instructor stated that:

> "by the time the aircraft had reached 30 degrees AOB, we had already lost control."

The instructor stated that the majority of the 580 hours he had accumulated on AS350 aircraft was on the B/B2 variant, although the majority of the training he had conducted was on the B3. He acknowledged that the hydraulics-off control loads could be "quite high".

Passenger

The other pilot under training, who was a passenger on the flight, was seated in a rear passenger seat. His recollection of the accident flight was that the helicopter initially went to the north of Wycombe Air Park to conduct confined area training and an autorotation. On returning to the airfield, he heard the instructor tell the right-seat pilot that they would do a hydraulics-off drill. His recollection was that this was done exactly as the flight manual states and that the speed was reduced to approximately 50 kt. He recalled that the speed should be around 10 to 15 kt in the latter stages and that the instructor emphasised speed control. The passenger thought the approach seemed good, but that in the later stages the speed was reducing excessively. He remembered the instructor telling the pilot to increase speed and then helping him with speed control. He also recalled that the aircraft landed after this exercise.

On the second go-around he recalled that the helicopter went forward and quickly left. Around 40° AOB he felt the bank was greater than usual and excessive. The helicopter continued to bank left and then struck the ground.

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Hydraulics-off procedures

Hydraulic failure training procedure

Supplement 7 to the AS350 B3e Flight Manual[4] contained the hydraulic failure training procedure:

STEP 1: FAILURE SIMULATION

- **In steady flight conditions:**

1. Instructor.. **[ACCU TST]**: ON position:
   - CHECK **HYDR** flashes + Gong
2. Trainee .... **Safety speed** to between 40 and 60 kt (74 and 111 km/h)

- **Once safety speed reached:**

3. Instructor.. **[ACCU TST]**: Reset to OFF position:
   - CHECK **HYDR**

STEP 2: HYDRAULIC FAILURE TRAINING PROCEDURE

4. Hydraulic cut-off switch.............................. OFF:
   - CHECK **HYDR** + Gong
   - Control loads are increased
5. Perform a flat approach into wind
6. Make a no-hover, slow running landing at around 10 kt (18.5 km/h)

Do not perform hover or taxi without hydraulic pressure.

- **After landing:**

7. Hydraulic cut-off switch.............................. Reset to ON to restore hydraulic assistance before subsequent takeoff or hovering flight
   - CHECK **HYDR** within 3 sec.

The training procedure stated that the limitations and emergency procedures in the basic flight manual and supplements remained applicable. At the time of this accident, the training procedure did not state whether the hydraulics should be reinstated during a go-around.

Footnote

[4] Flight manual revision status 31 January 2017.

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AS350 B3e Flight Manual Emergency Procedures

Chapter 3.6 of the Emergency Procedures section of the flight manual contained the emergency procedure for a hydraulic failure:

FLIGHT MANUAL

3 HYDRAULIC ALARMS

WARNING PANEL	CORRECTIVE ACTIONS
HYDR Loss of hydraulic pressure or pressure < 30 bar (435 psi)	**Keep aircraft at a more or less level attitude.** **Avoid abrupt maneuvers.** **CAUTION** **Do not use [ACCU TST] pushbutton as this will depressurize the yaw load compensator resulting in heavy pedal control loads.** **Do not attempt to carry out hover flight or any low speed maneuver.** **The intensity and direction of the control feedback force will change rapidly. This will result in poor aircraft control and possible loss of control.** **As control loads increase, be careful not to inadvertently move twist grip out of FLIGHT position (TWT GRIP light off).** **NOTE** **The accumulators contain sufficient pressure to secure flight and to reach the hydraulic failure safety speed.** • **<u>HIGE, Takeoff, Final</u>**: (if immediate landing is possible) 1. Land normally 2. Twist grip............................ Set to IDLE position 3. Collective pitch.................... LOCK 4. Engine starting selector ...... OFF • **<u>In flight</u>**: Smoothly, 1. IAS .... SET to between 40 and 60 kt (74 Km/h and 111 Km/h) (hydraulic failure safety speed) 2. Hydraulic cut-off switch (collective pitch).................. OFF Pilot has to exert forces: - on collective increase or decrease around no force feedback point, - on forward and left cyclic. **LAND AS SOON AS POSSIBLE** **NOTE** **Speed may be increased as necessary but control loads will increase with speed.** 3. <u>Approach and landing</u>: over a clear and flat area - Perform a flat approach into wind - Make a no-hover slow running landing at around 10 kt (18.5 km/h) **- Do not perform hover or taxi without hydraulic pressure** 4. <u>After landing</u>: - Collective pitch .... LOCK - Shutdown procedure .... Apply

APPROVED 350 B3e **3.6**

The emergency procedure stated that the helicopter should be kept at a '*more or less level attitude*' and to '*avoid abrupt manoeuvres*'. In contrast, the French language version of the flight manual procedure stated that the attitude should be maintained at approximately zero degrees[5].

There was no advice in the flight manual pertaining to a go-around from a hydraulics-off approach. The flight manual stated that hydraulic assistance could be recovered at any stage by selecting the HYD CUT OFF switch to ON.

AS350 B3e Flight Manual Limitations

The Limitations section of the flight manual did not specify any bank angle limits for flight with or without hydraulics. It did include a general limitation stating that aerobatic manoeuvres were forbidden.

EASA Operational Evaluation Board Report (OEBR)

The AS350 OEBR, produced by the EASA Certification Directorate, contained Teaching Areas of Special Emphasis (TASE). These identified training procedures which should receive special attention. One of those highlighted was simulated hydraulic failure training.

On this topic the OEBR included the information that, if necessary during the training exercise, hydraulic assistance could be recovered immediately by resetting the hydraulic cut-off switch to ON.

It also included the notes:

> ***'Left hand collective lever is not equipped with 'HYD' switch,***
>
> - To be *well prepared, brief your Trainee for setting the collective lever HYD switch to on, if necessary.*
> - *If the Instructor decides to take over the controls, he must plan to continue the flight up to the landing without hydraulic assistance.*
> - *CAUTION: when hydraulic pressure is restored in flight, the forces disappear which can lead to an abrupt left roll movement.'*

The OEBR contained, amongst others, the following caution in respect of hydraulics-off training:

> - *'The statistics show that failure to strictly comply with the procedure consequently increases the risk level. '*

The OEBR did not state whether a go-around should be performed with hydraulics off or on.

Footnote

5 It stated in French: '*Maintenir l'appareil à assiette ≈ 0.*'

Aircraft examination

The left side of the cabin floor was significantly deformed and crushed in the accident sequence.

The HYD CUT OFF switch on the right collective was found in the forward, hydraulics on, position, but it could have been switched back on during the last 3 seconds before impact or it could have been knocked during the impact or during evacuation[6]. The spring-guarded ACCU TST switch was off.

All the flight control linkages were connected. Some control rods were deformed due to ground impact loads and there were two overload failures (left pedal pitch link and tail rotor gearbox input lever) which were also the result of ground impact. There was resistance to moving the right cyclic stick, so the cyclic friction was removed to facilitate movement, but the number of turns of the ring was not recorded. The control resistance was due to deformation of the cabin floor and the control rods beneath it, rather than cyclic friction. An inspection for foreign objects that might have jammed the cyclic controls did not reveal anything. The HeliSAS control servos and control rods were properly connected; when they were disconnected the servos moved freely with no resistance. As the HeliSAS was off during the flight no further investigation of the system was carried out.

The main servo accumulators were in good condition and the nitrogen charge was correct at about 13 bar for each of them. The tail rotor accumulator pressure was measured at 19 bar. When the ACCU TST switch was pressed with electrical power on the aircraft, the pressure reduced to 12 bar which indicated that the tail rotor accumulator was pressurised at the time of the accident.

The hydraulic system was tested by using a drill and special adaptor to drive the hydraulic pump. The system pressurised to normal pressure and the HYDR warning caption in the cockpit extinguished. Turning the hydraulics off with the collective mounted cut-off switch depressurised the system and depleted the three main servo accumulators (as designed) and caused the HYDR warning caption to illuminate.

Due to the deformation in the flight control rods, the servo actuator input rods were disconnected from the main servos. Hydraulic pressure was applied and the servos were actuated by moving the input lever by hand. The input levers moved freely but the front servo actuator piston rod did not extend or retract due to a bend in the piston rod which was the result of ground impact loads. The right servo actuator also had a bent piston rod which meant that full extension was not possible, but full retraction was possible with the head disconnected. The left servo actuator and tail servo actuator piston rods moved freely full range.

When hydraulic pressure was removed the servo actuator locking pins operated normally on all servos, locking the input levers, which meant that that the servo actuator could be operated manually without hydraulic assistance.

Footnote

6 The HYD CUT OFF switch has a fixed guard around the switch to help prevent the hydraulics being inadvertently turned off, but the guard does not prevent the switch from being knocked ON.

No pre-impact faults were found that would have prevented normal operation of the flight controls with the hydraulics on or off.

The powerplant was not examined as there was clear evidence from the Vision 1000 video that the engine and main rotor were producing power at impact.

The hard plastic fuel tank had cracked open at its base and most of the fuel contents had drained away.

Survivability

The occupants did not wear helmets and there was no requirement for them to do so.

The left front seat harness had been cut to release the instructor, while the right front seat harness was undone. There were conflicting witness reports about whether the right front seat harness was fastened when the emergency services arrived. A review of the cockpit imagery revealed that the right front seat harness was highly likely to have been fastened at impact. When checked, the right front seat harness operated normally.

The aircraft was fitted with stroking crashworthy seats, but due to the sideways impact direction these had not provided any force attenuation. All seats had remained secure on their mountings. The left side of the cabin was extensively damaged due to the impact.

The airfield fire and rescue service responded quickly and were on scene within a few minutes. They were subsequently supported by the local authority fire brigade and ambulance service. Others at the airfield also came to assist.

When the emergency services reached the scene, the passenger in the rear seat was standing up through the right passenger door of the helicopter. He had suffered multiple injuries, including a fractured pelvis and serious facial injuries. He was assisted out by the fire service and then laid on the ground nearby, while the emergency services assisted the other occupants.

The instructor had suffered multiple serious lacerations, broken ribs and collarbone and was semi-conscious.

The pilot in the right seat was unconscious and not breathing when first responders arrived on scene. He was extracted from the aircraft and resuscitated before being transferred to hospital by air ambulance. He died as a result of his injuries some weeks later.

Medical information and pathology

The pathology for the pilot who was fatally injured indicated that he had sustained extensive thoracic injuries during the accident. These injuries may have contributed to the cardiac arrest which he suffered. The findings strongly suggested that the cause of death was a grave hypoxic injury resulting from a lengthy cardiac and respiratory arrest. The pathology report stated there was no evidence of previous cardiac disease and that no evidence was found to suggest that the pilot had suffered a heart attack prior to the accident.

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A quantity of a prescription drug was found at the accident site. In his statement to the AAIB, the instructor stated that he was taking the drug under the supervision of a doctor who was not an Aviation Medical Examiner (AME). The instructor stated that he was using the drug infrequently in a very low dose and had not taken it for four or five days before the accident. A CAA AME consulted by the AAIB stated that if taken with a dosage as reported by the instructor, the drug would not have been detrimental to the instructor's performance.

Personnel

The instructor and pilots under training held valid and current EASA CPL(H)s and current Class 1 medical certificates. The instructor, who held a Flight Instructor (Helicopters) rating, was not an employee of the ATO at Wycombe Air Park but was trained in and had signed up to the ATO's Operations Manual procedures.

Weight and balance

G-MATH's estimated weight and centre of gravity at the time of the accident were 1,836 kg and 3.31 m, respectively. The estimated weight included the weight of the occupants, baggage and 218 kg of fuel. The allowable CG range at this weight is 3.27 to 3.48 m. The maximum takeoff weight (MTOW) is 2,250 kg.

Meteorology

No METAR or TAF is published for Wycombe Air Park. When the ATC log was opened at 0800 hrs, the following weather was recorded: wind 050° at 12 kt, cloud FEW 050, QFE 1004 hPa, QNH 1023 hPa. When G-MATH lifted off at 0803, ATC passed the following weather information: QNH 1023 hPa and wind 060° at 8 kt. At 0832 hrs, ATC reported a wind of 060° at 12 kt to another aircraft on approach to Wycombe.

Airfield information

The Aerodrome Control Section of Manual of Air Traffic Services Part 2 sets out the procedures for helicopter operations at Wycombe Air Park. The helicopter training area in use on the day of the accident is defined as area 'NOVEMBER'. It is used when Runway 06/24 is active and is centred at a position 120 m west of the Runway 35 stop end markers (western edge). It extends from 30 m north of Runway 06/24 out to the boundary of the aerodrome. There is no restriction to crossing the boundary during circuits.

Additional information

Previous AS350 hydraulics-off training accident

The Transportation Safety Board of Canada (TSB Canada) published Aviation Investigation Report A13Q0021, concerning a hydraulics-off training accident which occurred on 3 February 2013, which bore some similarity to the G-MATH accident.

The helicopter involved was an AS350 BA helicopter, registration C-GPHN. A training flight was being conducted, with an instructor and two pilots under training on board. During the hydraulics-off training detail the instructor took control of the helicopter and flew a tight

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left-hand circuit at low altitude and low speed without hydraulic pressure assistance. There was no Vision 1000 camera fitted. The instructor reported that, in the moments following the start of the final approach, the cyclic stick moved sharply forward and to the left out of the palm of his hand. The instructor grabbed the cyclic stick to re-establish level flight, since the helicopter was quickly banking to the left in a nose-down attitude. The main rotor blades struck the runway and the helicopter came to rest on its left side. The instructor was seriously injured, whilst the other two pilots sustained minor injuries.

The TSB Canada report included the following observation:

> *'The investigation also revealed that some flight instructors were not fully aware of the risks associated with manoeuvres at low altitude and in hover without hydraulic pressure assistance.'*

The report findings included the following statement:

> *'The helicopter's flight profile deviated from the flight profile recommended by the aircraft manufacturer when the hydraulic system is depressurised. As a result, the flight instructor encountered heavy, unpredictable flight control feedback forces.'*

Another recorded finding was that the left collective lever does not have a HYD CUT OFF switch and so the instructor was unable to easily restore hydraulic pressure.

Established UK-based AS350 operator's hydraulics-off procedures

A large, long-established AS350 operator in the UK was consulted by the AAIB regarding their procedures for hydraulics-off training flight. While their operations manual reflected the helicopter manufacturer's, they advised anecdotally that it was their practice that go-arounds be flown straight ahead, and that the hydraulic system is re-selected on prior to manoeuvring. They also recommended the use of no greater than 20° AOB for hydraulics-off flight. Additionally, their helicopters had been fitted with a second HYD CUT OFF switch[7] on the left collective lever, so that the instructor can quickly re-select the hydraulics on if necessary.

Estimate of right lateral cyclic force that could be applied

The G-MATH instructor stated that he had been unable to move the cyclic any further to the right during the second go-around. A test was set up to measure how much lateral force a person could apply to the cyclic with a normal grip position, and with a modified grip position with a right lean as applied by the instructor about 7 seconds before impact. Four male individuals took turns applying their maximum possible right cyclic force using the normal and modified grip positions. The maximum force they applied ranged between 6.6 to 10.1 kgf

Footnote

[7] The two HYD CUT OFF switches are connected in series so that if either switch is off, the hydraulics are depressurised. In a practice hydraulic failure, after the student selects their switch to OFF, the instructor selects his switch off and resets the student's switch to ON. This leaves the hydraulics depressurised, but the instructor is able to turn on the hydraulics as necessary with his switch.

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with the normal grip position and 8.9 to 17.6 kgf with the modified grip position. These measurements were taken without the individuals operating the collective or yaw pedals.

Certification requirements for control loads following loss of hydraulic pressure

When the AS350 B1 variant was being developed in 1985, the French Directorate General for Civil Aviation (DGAC) attached some special conditions to its certification concerning the control loads in the event of a loss of hydraulic pressure[8]. It stated that the cyclic control loads should not exceed 6.7 daN (6.8 kgf) in roll or 11.1 daN (11.3 kgf) in pitch during a 'protracted application', and should not exceed 13.3 daN (13.6 kgf) in roll or 26.7 daN (27.2 kgf) in pitch during a 'temporary application'. The former requirements for 'protracted application' were similar to the loads specified in the British Civil Airworthiness Requirements Section G2 of 1975. It stated that *'in the event of a failure in the power-control system it should be possible to continue steady flight and execute a normal landing without exceeding the following control forces:'* 70 N (7.1 kgf) for lateral controls and 111 N (11.3 kgf) for longitudinal controls.

The current certification requirements for small rotorcraft in EASA CS-27[9] do not specify control force limits related to handling requirements without hydraulic assistance. AC 27.695[10] states that for a rotorcraft with a single hydraulic system:

> *'A manually operated mechanical system may be used as the alternate system to a single hydraulic system if, after the loss of the single hydraulic system, the pilot can control the rotorcraft without exceptional piloting skill and strength in any normal maneuver for a period of time as long as that required to effect a safe landing.'*[11]

Flight test controls loads during certification of AS350 B1

To meet the DGAC's special conditions for control forces following loss of hydraulic pressure, the aircraft manufacturer conducted a flight test in an instrumented AS350 B1 in 1985. Cyclic forces were not measured directly but were calculated from the forces measured at the servo actuators. The data showed that the lateral cyclic control force required to maintain level flight at 45 kt was 5 kgf to the left which increased to 12.7 kgf to the left at 130 kt. The AOB was not recorded during any of the manoeuvres, nor were the control forces measured or calculated in a bank.

The aircraft manufacturer stated that, in the time between these flight trials and the accident to G-MATH, no measurements or calculations of the control loads in a bank without hydraulic assistance had been made.

Footnote

8 DGAC letter SFACT/TC No 53639 dated 25 June 1985.

9 Certification Specification 27, Amendment 4, 30 November 2016.

10 The Acceptable Means of Compliance (AMC) in CS-27 consist of Federal Aviation Administration (FAA) Advsiory Circular AC 27-1B Change 4 dated 1 May 2014 with some changes and additions. AC 27.695 refers to a sub-section of AC 27-1B.

11 The following sentence states that '*The control forces should not exceed those specified in § 27.397',* but these are very high loads (298 N lateral and 445 N longitudinal) which relate to strength requirements rather than handling requirements.

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Aircraft manufacturer's calculation of control loads after the accident to G-MATH

As a result of the accident to G-MATH, the aircraft manufacturer performed some calculations to try and estimate the cyclic control forces a pilot would experience at the increased 'g' levels in a bank flown at constant altitude. The manufacturer had obtained main servo actuator force data during flight trials in an EC130 which has the same rotor and servo actuators as the AS350 B3e. This data was obtained with the hydraulics on, but the measured forces on the servos could be used to calculate approximately what the cyclic force would be with the hydraulics off, using the geometry of the mechanical control system. From this data they determined that at an airspeed of about 40 kt, the left cyclic force that is normally required to maintain level flight will reverse direction to a right cyclic force at high 'g' levels. This would mean that in a left bank, the pilot would start by increasing the left cyclic force to roll left and would be maintaining a left cyclic force to stay in the bank. However, as the AOB and 'g' level increased the pilot would need to start applying right cyclic to maintain bank.

Based on their calculations a right cyclic force of 4.3 kgf would be needed to maintain bank in a left bank of about 60° at 2g (based on G-MATH's weight of 1,836 kg). However, the manufacturer stated that there are many assumptions and potential inaccuracies in the calculation method such that this value should only be taken as an indication of the possible force.

Aircraft manufacturer's informal flight test to evaluate hydraulics-off control loads in a steep bank

In September 2017, one of the aircraft manufacturer's test pilots carried out an informal flight test in an H125 helicopter ('H125' is the new name for the AS350 B3e). The flight was to qualitatively assess the hydraulics-off cyclic control forces in left turns up to 60° AOB[12]. There was no instrumentation and the data from the Vision 1000 was not provided to the AAIB. The test pilot reported that up to 45° AOB the cyclic control forces were similar to that in level flight; about 4 to 6 kgf needed to be applied in the forward and left direction. Beyond 45° AOB, these control forces started to reduce and reaching 60° AOB the forces were unstable in both the longitudinal and lateral directions, but they were assessed as quite light, at less than 2 kgf. He estimated that the reversal in control force direction occurred at 1.7 to 1.8 g[13] and the airspeed range was 45 to 70 kt. He stated that the helicopter remained fully controllable.

Human performance - startle effect

The possible effects of 'startle' on the instructor's performance were considered. Startle is defined in US Federal Aviation Authority Circular 120-111[14] as:

> *'an uncontrollable, automatic muscle reflex, raised heart rate, blood pressure, etc., elicited by exposure to a sudden, intense event that violates a pilot's expectations.'*

Footnote

[12] The aircraft's weight was 1,820 kg, pressure altitude 1,200 ft, QNH 1015 hPa, temperature 24°C.
[13] Estimated g force. The instruments do not display g.
[14] Federal Aviation Administration (2015). Advisory Circular 120-111 Upset Prevention and Recovery Training. https://skybrary.aero/bookshelf/books/3175.pdf (accessed September 2018)

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According to Martin, Murray, Bates and Lee (2016)[15] a physical startle response starts with an eye blink followed by an aversive movement away from the stimulus and orientation of attention towards the startling stimulus.

Startle can result in impaired human performance and if the startle is associated with a threat then the resulting fear can further increase the effects. This is called 'fear potentiated startle'. Research cited in Rivera et al (2014)[16] suggests that psychomotor and cognitive performance can be impaired for 30 to 60 seconds after a startling stimulus. Thackray and Touchstone (1969)[17] showed that startle resulted in a 65% increase in the error rate on a psychomotor tracking task, using a joystick, five seconds after a startling stimulus (psychomotor impairment).

Analysis

Pilot handling aspects

The accident occurred during a hydraulics-off training detail. The instructor was dissatisfied with the right-seat pilot's first approach and took control of the helicopter to perform a hydraulics-off go-around and a left-hand circuit to reposition for a second attempt. On the first circuit, a maximum AOB of 32° was recorded.

The instructor again took control in the latter stages of the second approach before commencing another left-hand circuit. As the turn developed, the instructor reported that he had been unable to move the cyclic to the right to reduce the bank angle. He stated later that control was lost by the time the helicopter reached 30° AOB. The roll rates up to 30° AOB were similar on both go-arounds and on the second go-around the roll rate remained approximately constant up to 40° AOB. It could not be determined from the cockpit imagery at what AOB the instructor started to apply right cyclic force to either arrest or reduce the left bank angle, but it showed the instructor changing his grip and leaning to the right in a possible attempt to apply greater right lateral force to the cyclic when the AOB reached 48°. The AOB stabilised at 50° then reduced briefly, before increasing again, despite the instructor's apparent continued efforts and the helicopter descended rapidly and struck the ground at 97° AOB. The low height at which the hydraulics-off left turns were performed meant that little height was available to attempt a recovery following a loss of control.

The cockpit images showed that the right-seat pilot kept his hand on the cyclic during both go-arounds, contrary to the briefing, but he appeared to relax his grip when the instructor

Footnote

[15] Martin, Murray, Bates, Lee (2016). A flight simulator study of the impairment effects of startle on pilots during unexpected critical events. Aviation Psychology and Applied Human Factors, 6(1), 24-32. https://econtent.hogrefe.com/doi/pdf/10.1027/2192-0923/a000092 (accessed September 2018)

[16] Rivera, J., Talone, A.B., Boesser, C.T., Jentsch, F., Yeh, M. (2014). Startle and surprise on the flight deck: Similarities, differences and prevalence. Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting 2014, 1047 – 1051. https://www.skybrary.aero/bookshelf/books/3748.pdf (accessed September 2018)

[17] Thackray, R.I. and Touchstone, R.M. (1969). Recovery of motor performance following startle. Federal Aviation Administration, Office of Aviation Medicine https://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/1960s/media/AM69-21.pdf (accessed September 2018)

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took control. Whilst this did not appear to be significant for the first go-around according to the cockpit imagery, it was not possible to determine if his hand on the cyclic had been influential during the second go-around. It was only in the final 3.5 seconds before impact that the right-seat pilot appeared to tighten his grip on the cyclic.

Control forces

The evidence from the instructor and the Vision 1000 suggests that at 50° AOB and beyond, even while trying to apply full right cyclic, the instructor was unable to move it to the right and he could not roll the helicopter level.

A detailed examination of the helicopter did not reveal any technical faults that would explain the high control forces reported by the instructor, nor why the instructor was unable to move the cyclic further to the right during the final manoeuvre.

The control force measurements carried out during the investigation revealed that modifying the cyclic grip and leaning to the right, in the manner performed by the instructor, increased the amount of right cyclic force that could be applied. The maximum force the four tested individuals were able to apply ranged between 8.9 and 17.6 kgf.

The hydraulics-off certification requirements for the helicopter allowed a maximum lateral cyclic force of 6.8 kgf during protracted application and 13.6 kgf in a temporary application. However, there was no requirement to measure the control forces in a steep bank and therefore AOB was not recorded during the certification flight tests.

During the investigation, the manufacturer attempted to calculate the control loads as a function of 'g' using EC130 flight test data. This determined that a control force reversal occurred as the 'g' increased (to maintain height in a turn, the 'g' will increase with increasing AOB). This meant that in a left bank the pilot would need to apply and hold a left cyclic force to keep it in a left bank, but as the AOB increased the pilot would need to apply a right cyclic force to stop the AOB from increasing. The calculations determined that a right cyclic force of 4.3 kgf would be needed to maintain a left bank of 60° at 2g. This is below what the instructor should have been able to apply, especially with the right lean and modified grip position.

The manufacturer cautioned that there were many assumptions and potential inaccuracies in the calculation method, so they performed an informal flight test to investigate the control loads in a bank. The flight test involved left rolls up to 60° AOB in an airspeed range of 45 to 70 kt. The control loads were assessed as light; less than 2 kgf but varying between the left and right direction. It is not known if the specific airspeed, 'g' and bank angle combination of the accident manoeuvre was attained during this informal flight test.

It is possible that there are conditions in steep bank angles where the control forces are higher than those determined during the brief informal flight test. The manufacturer's test pilot was expecting some control force reversal during the manoeuvres which the instructor of G-MATH would not have been expecting.

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Human performance aspects

It is possible that an unexpected control force reversal, the sudden steep AOB, and the proximity of the ground caused the instructor to become startled. The instructor's right lean, away from the approaching ground, could be interpreted as an 'aversive movement', as would be expected in a startle response. It may have been theoretically possible for the instructor to exert sufficient control force to recover, but the possible startle may have resulted in a psychomotor impairment that prevented him from doing so. The amount of time available to the pilot to recover from the high AOB was less than five seconds and this is consistent with the period where impairment may be expected.

Previous accident to C-GPHN

The accident to C-GPHN, investigated by TSB Canada, bore similarities to the G-MATH accident in that both accidents involved the helicopter being manoeuvred close to the ground during hydraulics-off training. In both cases, control was lost, with insufficient height available to recover. The TSB Canada investigation report stated:

> *'Past experience and the interpretation of the RFM might lead pilots to believe they can control the aircraft at any stage of flight without hydraulic pressure assistance, without factoring in the unpredictable nature of flight control loads.'*

It is possible that the hazards of hydraulics-off operation are not as widely appreciated as they should be amongst AS350 instructors and pilots in general.

Flight Manual instructions

Hydraulics-off training

The hydraulic failure procedure contained in Chapter 3.6 of the Emergency Procedures section of the AS350 B3e flight manual stated that the aircraft should be kept at a more or less level attitude and abrupt manoeuvres should be avoided. It also cautioned against attempting any low speed manoeuvre and that the intensity and feedback of the control feedback force will change rapidly, resulting in poor aircraft control and possible loss of control.

A '*more or less level attitude'* is open to interpretation. It is not a clear limit, and therefore operators have had to establish practical limits. Maintaining a level attitude is not reasonable because it may be necessary to manoeuvre to land. The large well-established UK-based AS350 operator consulted by the AAIB stated that they restored the hydraulics for go-arounds from hydraulics-off training approaches and also limited the AOB to 20° for hydraulics-off flight.

The hydraulics failure training procedure contained in Supplement 7 stated that the limitations and emergency procedures in the basic flight manual and supplements remain applicable. However, the documents required pilots to cross-reference both to obtain all the relevant information pertaining to hydraulics-off flight.

An amendment to the Supplement 7 training procedure to include the instructions and cautions from the hydraulic failure emergency procedure would remove the need for any interpretation and serve to better highlight the actual risks associated with hydraulics-off training.

Go-arounds during hydraulics-off training

The Supplement 7 hydraulic failure training procedure instructions stated that the HYD CUT OFF switch should be reset to ON to restore hydraulic assistance before subsequent takeoff or hovering flight. At the time of this accident, there were no instructions on how to perform a go-around from an unsatisfactory hydraulics-off training approach.

The EASA A350 OEBR TASE included additional information not included in the Supplement 7 procedure. This included briefing the student to set the collective lever HYD switch to ON if necessary and provides a caution that:

> *'when hydraulic pressure is restored in flight, the forces disappear, which can lead to an abrupt left roll movement.'*

The TASE did not contain any instructions on how to perform a go-around from an unsatisfactory hydraulics-off training approach.

Amendments to the AS350 flight manual to introduce a clear AOB limit for hydraulics-off flight and to describe how to perform a go-around from a practise hydraulics-off approach would provide an increased level of safety during hydraulics-off operations.

Conclusion

No technical issues were identified with the helicopter. The investigation was unable to determine the reason why the instructor was unable to roll the helicopter back to a level attitude during the second hydraulics-off go-around, which was flown at a greater AOB than the first. However, it is possible the pilot suffered a startle effect from the unexpected control force reversal, the sudden steep AOB, and the proximity of the ground.

The C-GPHN and G-MATH accidents involved the helicopter being manoeuvred close to the ground during hydraulics-off training. In both cases, control was lost, with insufficient height available to recover. It is possible that AS350 pilots and instructors are not universally aware of the hazards of manoeuvring the helicopter at low height with hydraulics off. Clearer instructions in the AS350 flight manual on how to perform hydraulics-off flight would help to prevent similar accidents in the future.

Safety actions

The helicopter manufacturer stated that the analysis of the G-MATH accident has revealed that the flight conditions and safety requirements already contained in the AS350 hydraulic failure procedure and Flight Manual Supplement 7 hydraulic failure training procedure were not well enough highlighted, possibly leading to misinterpretation and hence flight outside the dedicated flight envelope for these procedures.

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All times are UTC

Consequently, Airbus Helicopters has taken the following safety actions intended to prevent reoccurrence:

The AS350 flight manual has been amended to:

- Include a clear angle of bank limitation of 30° for hydraulics-off flight;
- Include warnings to clearly emphasize the risk of loss of control of the helicopter if the hydraulic failure or hydraulics-off training procedures are not complied with;
- State: '*In case of a go-around during hydraulic failure training procedure, it is recommended to abort the training and to reset the hydraulic cut-off switch to 'ON'*
- Include the note: '*When resetting the hydraulic cut-off switch to ON, be prepared for a significant decrease of cyclic and collective control loads*'.

Airbus Helicopters has taken the further safety actions of publishing Safety Information Notice No. 3246-S-29 highlighting these flight manual changes and preparing a video[18] on how to conduct hydraulics-off training safely.

Footnote

[18] A link to this video is at: https://dai.ly/k35kJCQ5f47SQcrffPU (accessed September 2018)

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