ACCIDENT

Aircraft Type and Registration:	Guimbal Cabri G2, G-PERH	
No & Type of Engines:	1 Lycoming O-360-J2A piston engine	
Year of Manufacture:	2016 (Serial no: 1164)	
Date & Time (UTC):	8 June 2018 at 1433 hrs	
Location:	Goodwood Aerodrome, Sussex	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - 2 (Serious)	Passengers - N/A
Nature of Damage:	Damaged beyond economic repair	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	59 years	
Commander's Flying Experience:	8,920[1] hours (of which 69 were on type) Last 90 days - 30 hours Last 28 days - 7 hours	
Information Source:	AAIB Field Investigation	

Synopsis

While conducting a Simulated Engine Failure from the Hover (SEFH) the helicopter yawed rapidly to the left. Despite the actions of the pilots the helicopter continued to yaw rapidly, and control was not recovered. The helicopter was seen to climb while spinning before descending rapidly and contacting the ground, sustaining severe damage. Both occupants suffered serious injuries.

The manufacturer has subsequently issued service letter SL 19-001, *Throttle management during simulated engine failure*, and SL 19-002, *Controllability in yaw at low rotor speed*.

History of the flight

On the day of the accident the commander and a student pilot were conducting a PPL(H) skills test; they were in the helicopter's left and right seats respectively.

The helicopter departed Goodwood Aerodrome at about 1300 hrs for a navigation exercise and then returned to the aerodrome to complete the remaining exercises, which included an SEFH. The SEFH was completed to a satisfactory standard, but

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Footnote

[1] The commander's total flying hours are a combination of fixed and rotary wing hours, with 4,420 rotary wing hours.

the commander noted that the helicopter yawed slightly to the right[2]. At the time the weather was fine with the wind from about 050° at 5 kt.

Once all the required exercises had been completed the commander asked the student whether there was anything else he would like to do. He asked if he could attempt another SEFH, as he felt he was able to fly the manoeuvre to a better standard; the commander agreed.

The student commented that during the subsequent SEFH, he recognised the helicopter starting to yaw to the right and applied left pedal to counteract this, after which the aircraft began to descend gently. His intention was to raise the collective to cushion the landing at about 1.5 ft agl. However, the helicopter started to rapidly yaw left. He applied full right pedal before handing control to the commander, who was already on the controls with full right pedal applied. The commander believes she moved the cyclic forward slightly to try to keep the helicopter level, but she could not remember what collective inputs she may have made. Witnesses in the control tower saw the helicopter spin and climb to about 40 ft agl, before descending and contacting the ground.

Once the helicopter had come to rest the commander secured it. The airfield's emergency response vehicles quickly arrived on the scene. They were followed shortly thereafter by local authority ambulances. Both pilots were seriously injured and, after being extracted from the helicopter, were taken to hospital by road.

Pilots' comments

Student pilot

The student pilot stated that the first SEFH landing felt "a bit firm" to him and he felt he could do better, so he took the opportunity to repeat the manoeuvre.

On the accident SEFH, after the helicopter start to yaw rapidly to the left, he also felt it climb. He felt that the application of the right pedal did cause the rate of left yaw to slow down. He tried to keep the helicopter steady with the cyclic but did not recall handing control to the commander. He reported that the forces involved were so violent that he was forced sideways to his right.

He added that he is "reactive" to the yaw during engine-off exercises and waits for the yaw to commence before applying the appropriate pedal to counteract it.

Footnote

[2] The Cabri G2's main rotor blades rotate in a clockwise direction when viewed from above. The torque effect is a tendency of the main rotor to yaw the fuselage in the opposite direction from the rotor. The tail rotor provides thrust to counteract this. After an engine failure the torque effect is reduced, resulting in a tendency for the helicopter to yaw in the direction of the main rotor blades, to the right in a Cabri G2. Hence some left pedal is required after the failure.

Commander

The commander stated that for a SEFH, once the student had established the helicopter in a stable hover, at approximately 7 feet agl, she announces "engine failure in 3, 2, 1, GO". On "GO" she closes the throttle ensuring it goes through the detent[3].

The commander stated the student had been a bit slow in applying the left pedal on the first SEFH. She believes that on the accident SEFH, she had not fully closed the throttle before the helicopter started to yaw to the left and thinks the student may have anticipated the left pedal and applied it before she said "GO" and the throttle was closed.

Instructor's comments

The student's instructor, who had flown the six instructional flights with him prior to the accident, commented that the student was very conscientious and always well prepared. He added that he could, at times, "over-analyse" some of his performances and be excessively critical on himself despite the skills demonstrated being generally of an acceptable standard.

Helicopter's Flight Manual

Section 4 of the Cabri G2's Flight Manual, *Normal Procedures,* states:

> *'**Training***
>
> *…*
>
> ***Power failure in hover in ground effect practice***
>
> 1. *Roll-off throttle frankly[4] until on its stop,*
> 2. *Counteract yaw motion by applying left pedal,*
> 3. *Increase collective as ground approaches, to smooth landing,*
> 4. *Push collective down once landed.*
>
> ***Note 1**: If the helicopter is light, it may bounce after a first touchdown.*
>
> ***Note 2**: The Cabri G2 has no natural tendency to depart in roll or pitch after failure. No systematic corrective cyclic action is needed.*
> *A slight forward motion at impact is recommended for better control.*
>
> ***Note 3**: For a forgiving practice, respect a maximum of 5 feet height.*
>
> *…'*

Footnote

[3] See *Helicopter information* for a description of the Cabri G2's throttle.

[4] The manufacturer commented that 'frankly' means that the throttle should be closed in one motion and without hesitation.

Accident site

The accident site occurred in the Helicopter Training Area at Goodwood Aerodrome. The helicopter came to rest upright with the right side of the fuselage in contact with the ground and pointing in a north-east direction. The landing gear had penetrated the fuselage on the left side and the right passenger door had broken and become detached. The fenestron tail rotor had detached from the tail boom and there was evidence that two of the main rotor blades had struck the ground (Figure 1). Both landing skids had dug into the ground with no evidence of movement after contact.

Figure 1

G-PERH at the accident site

Helicopter information

The Guimbal Cabri G2 is a light two-seat helicopter primarily used to train private pilots and for aerial photography and observation. It is the first helicopter to be primarily certified to EASA CS27 and then to achieve FAA FAR-27 certification for helicopters with a maximum takeoff weight of less than 3,175 kg (7,000 lbs).

The airframe is composed of three sections; main fuselage, engine section, and tail boom. The main fuselage is a carbon-fibre reinforced monocoque, constructed in five parts. In the cabin there are two side-by-side seats, with the pilot occupying the right position. The main fuselage also includes a central structure, baggage compartment and fuel tank. The engine section is isolated from the cabin by a firewall with the engine supported on a tubular steel frame. The composite tail boom incorporates a Fenestron tail rotor, vertical fin and a horizontal stabilizer.

The landing gear is composed of two tubular bows with skids. It is attached to the fuselage by soft elastomeric mounts, to avoid potential ground resonance problems. The landing gear is designed to withstand vertical landing loads combined with smaller longitudinal and lateral loads.

Seats

The seats have been designed to reduce the forces on the passengers in the event of an impact and are capable of absorbing loads up to 19 g forward and up to 30 g vertical, which corresponds to a free fall rate of about 10 m/sec (2,000 ft/min). The seats comprise a composite shell with minimal cushioning added for comfort. The seat shell is attached to the bulkhead by two seat rails, which allow it to move vertically and is restrained by an energy absorbing strut (Figure 2).

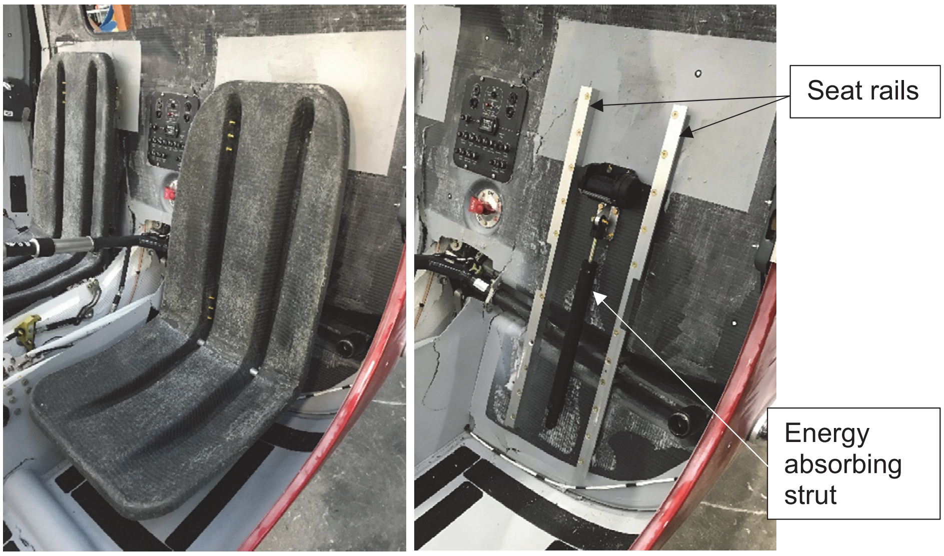

Figure 2

Left seat composite shell and seat rails with energy absorbing strut

Engine and controllers

The helicopter is powered by a four-cylinder, air-cooled Lycoming O-360-J2A engine. It is installed aft of the main gearbox, with its crankshaft facing forward and is supported on elastomeric vibration mounts.

To reduce pilot workload the helicopter is equipped with an electronic engine governor to maintain the engine at the nominal speed regardless of power demand. The governor regulates the engine speed to 2,650 rpm using data from an engine speed pickup, rotor speed pickup and the throttle position. If the engine speed is commanded to below 2,000 rpm (such as for shutdown) the engine governor disengages but will re-engage and accelerate the engine to the nominal running speed once the speed is above 2,000 rpm.

The engine throttle control is on the collective lever and is operated by a conventional twist-grip (Figure 3). The twist grip rotates a shaft which, through a system of cams and levers, operates the engine throttle cable. At the extreme clockwise rotation of the twist grip, a detent gives the pilot a physical indication that the throttle has fully closed. A motor, controlled by the governor, is connected to the twist grip shaft and there is a friction coupling which allows the pilot to overcome the governor if required. A switch on the end of the collective activates or deactivates the engine governor.

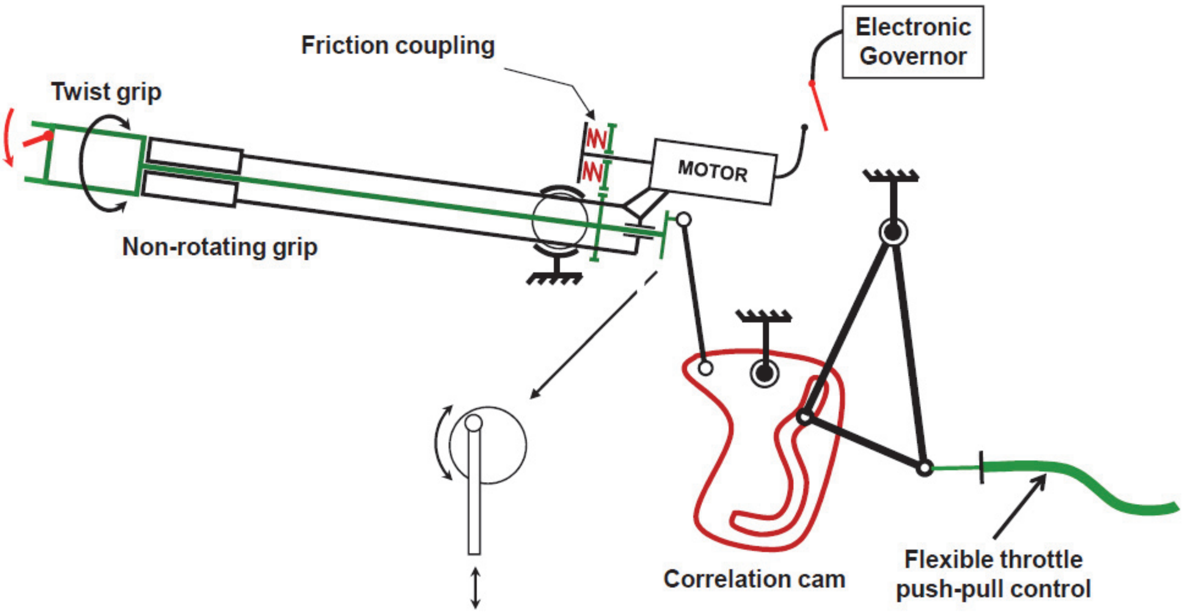

Figure 3

Engine throttle control system

Correlation cam

The output of the throttle shaft from the collective lever is connected by a linkage to a correlation cam so that when the collective is raised the throttle will increase the engine power. The cam profile is designed to aid the function of the engine governor and to minimise the pilot work should the governor fail. When the collective lever is raised with the throttle twist grip fully closed, the cam profile is designed to have no effect on the engine throttle.

Tail rotor effectiveness

The manufacturer commented that the main rotor can produce lift in a hover at rotor speeds well below its authorised speed range of 515 to 540 rpm and even below 450 rpm[5]. However, in such a situation, the Fenestron thrust will not be sufficient to maintain effective yaw control and even with full right pedal, the helicopter will start spinning uncontrollably to the left. In addition, if such a loss of control in yaw occurs, raising the collective will lower the rotor speed even more and will aggravate the situation by increasing the spin rate to the left.

Footnote

[5] 450 rpm is the minimum authorised rotor speed in autorotation.

Helicopter examination

Airframe

The airframe was subjected to a visual examination at the AAIB facilities to assess the damage sustained during the impact. The monocoque structure was largely intact with evidence of crushing on the aft right underside. All access panels were in place except for the luggage door and right passenger door, which was broken in two pieces. There was evidence on the underside of penetration from the landing gear bows at both mounting locations. The front landing gear bow had caused minor damage to the central console in the cabin and the aft bow had penetrated the luggage bay and the fuel tank volume. The flexible fuel tank liner had deformed around the bow without perforation and no fuel had leaked. The Fenestron had detached from the tail boom and there was impact damage to the tips of two main rotor blades.

Following the visual examination, the helicopter was digitised using a '3D' structured light scanning system to quantify the structural deformation. All exterior surfaces were scanned, as well as the landing skids, engine bay and cabin interior. The results of the scan were then compared with the original design data obtained from the helicopter manufacturer (Figure 4).

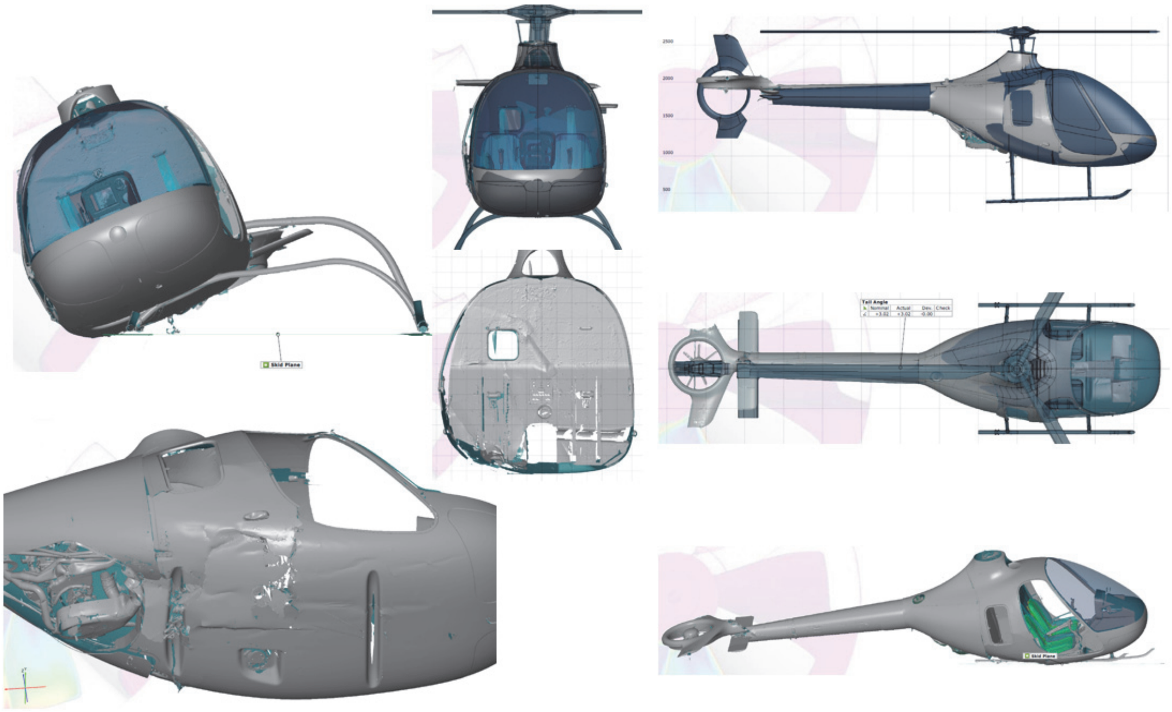

Figure 4

Digital analysis of G-PERH

The results of the scanning showed that the tail boom of the helicopter was misaligned by approximately 3° to the left of nominal and bent slightly upwards. The cabin bulkhead showed evidence of multiple damage locations of crushing, cracking and delamination.

Seats and attachments

The position of the seats was recorded with the cushions removed to enable accurate measurements to be taken from the composite shell (Table 1). Once the seat shells were removed, the length of the energy absorbing struts was measured:

Strut	**Nominal Length**	**Measured Length**	**Extension**
Left	302 +/- 0.5 mm	351.6 mm	49.6 mm
Right		304.5 mm	2.5 mm

Table 1

Seat position and energy absorbing strut extension

The right seat shell was examined, and several damage locations were identified. The left seat was undamaged.

The lower end of the right seat, outboard track was bent inwards and forwards by approximately 20° and the lower end of the inboard track showed minor deformation. The bend was located at the lower attachment to the seat and a witness mark was evident on the seat shell from the track. The deformation of the right seat tracks was coincident with the crushing deformation of the lower section of the monocoque and cabin bulkhead.

Landing gear

The landing gear assembly was intact and removed from the helicopter at the accident site. There was evidence of bending of the tubes and local buckling at the joints. It was noted that the landing skids fitted to the accident helicopter were of a later modification standard which was introduced to prevent the bow tubes from failing, which had occurred in previous accidents. The geometry of the landing gear assembly was measured using the 3D structured light system and it was found that the right skid was straight, in accordance with the design, whereas the left skid was curved. The aft end of the left skid was bent upwards by approximately 5 mm and was forward of the right skid by more than 350 mm. The profile of the two bows between the skids showed evidence of the right skid being bent outwards whereas the left side showed no such deformation.

Engine bay

The engine bay was covered by three composite access panels and the Lycoming engine was supported by a steel tubular frame attached to the monocoque. The frame also supported some ancillary equipment and the Fenestron drive shaft. Visual examination and digital analysis of the frame identified several members were bent and the right lower monocoque attachment point was deformed in the impact. The friction lining of the Fenestron drive braking system was damaged due to misalignment of the drive shaft and it was noted that the main drive belt was not correctly aligned on the upper pulley.

Survivability

There are four requirements to survive a crash:

1. Maintain a liveable volume for the occupant throughout the crash sequence.
2. Restrain the occupant.
3. Keep the crash loads experienced by each occupant within human tolerance.
4. Provide time to escape. Primarily, this is time to escape a post-crash fire.

The manufacturer actively markets the safety features of the Cabri G2 helicopter and its compliance to survivability requirements of EASA CS-27 and FAA FAR-27. The carbon fibre monocoque provides a rigid structure for the protection of the occupants. In this accident the liveable cabin volume was not compromised, and the seat belts restrained the occupants. However, lateral movement of the right seat occupant during the impact sequence most probably resulted in the right passenger door being broken. It is not thought any injuries were sustained from this.

The lack of post-crash fire meant that there was no immediate urgency to evacuate the helicopter and the first responders were able to remove the occupants in a timely manner, limiting the potential for further injury.

The energy absorbing struts in the seat system are designed to reduce the loads on the occupants in the event of a vertical impact. The manufacturer states that in certification testing the '*occupants would survive a 2000 ft/min impact, equivalent to a 5 m free fall'.* In this accident the left seat strut extended to 116% whereas the right seat strut extended to 101%. However, the injuries sustained by both occupants were similar and so it is judged that the impact energy was absorbed by a different mechanism for the right seat occupant.

Analysis

Loss of control

The first simulated SEFH was completed to a satisfactory standard, but the helicopter yawed slightly right and, in the student's opinion, landed firmly. Given that the student tended to over-analyse some of his performances, could be highly self-critical and generally strived for excellence, it is likely he would aim for a gentler landing in any subsequent SEFH.

Despite the student stating that he was reactive to the yaw in simulated engine failure exercises, it is probable that in this instance he anticipated it by applying left pedal and then started to raise the collective to cushion the landing before the throttle was closed. The forces experienced as the helicopter was yawing rapidly may also have caused him to unintentionally raise the collective. Lifting the collective before the throttle was fully closed would have resulted in the correlator cam increasing the engine speed until, at 2,000 rpm, the engine governor would have re-engaged. These actions would have caused an increase in engine speed resulting in the high rate of yaw and climb, which the student felt. Had the throttle been fully closed the correlator cam profile would have had no effect on the engine speed when the collective was raised.

The application of right pedal not stopping the yaw to the left indicates that the rotor speed had reduced, thus making the Fenestron less effective.

Impact Sequence

Immediately prior to ground impact, the helicopter was rotating with a high rate of left yaw, in a slightly nose-up attitude and rolled to the left. The first impact point was the aft end of the left landing skid and this deformed upwards. The aft bow penetrated the fuel tank volume, but the fuel quantity was such that the liner was able to deform without rupturing. It is likely that at this moment the left seat moved downward on the seat rails, absorbing the vertical energy for the occupant.

As the impact sequence progressed the helicopter pitched forward, and the left skid deformed further as it dug into the soft ground. Due to the yawing motion, the helicopter rolled to the right until the right skid contacted the ground and dug into the ground, deforming the right side of the bow. The helicopter fuselage still had inertia in yaw and consequently it slid around the profile of the landing gear bows until the right aft fuselage contacted the ground. As a result of this lateral motion, the lower part of the Fenestron struck the ground and applied a torsional load at the junction to the tail boom, resulting in failure of the composite structure. The fuselage was now inclined to the right and two of the main rotor blades hit the ground, the impact of the second causing the engine to stop.

As the aft right side of the fuselage contacted the ground, the remaining vertical energy was absorbed by the composite structure crushing and delaminating. This was clearly seen at the lower cabin bulkhead position and caused the right seat rails to deform. From the direction of the deformation it was possible to deduce that the loads were predominantly lateral. This was also demonstrated by the right seat occupants contact with the right door and the damage to the outside of the seat shell.

Survivability

The seats fitted to the Cabri G2 are designed to absorb only vertical energy and, along with seat belts, restrain the occupants in the longitudinal direction. From analysis of the impact sequence it has been shown that the left seat occupant was subjected to vertical loads during the initial impact and the seat stroke was enough to survive the impact. As the accident progressed, due to the high rate of yaw, the loads became lateral in direction and so the energy absorbing seat became less influential for survivability. Further, the deformation of the seat rails did not impede the motion of the right seat as the loading was predominantly lateral. The remaining energy was absorbed by the distortion of the composite structure which kept the loads experienced by the right seat occupant below survivable limits.

Conclusion

The accident was probably initiated by premature application of the left yaw pedal and raising the collective lever, before the throttle was fully closed during a simulated engine failure exercise. This was probably because the student anticipated the right yaw before the commander had said "GO" and the throttle was fully closed.

In this accident, the helicopter maintained a liveable volume for the occupants throughout the accident sequence and the first responders were able to extricate the occupants in a timely manner without risking further injury. The flexible fuel tank liner had not been compromised and there was no post-crash fire. The occupant retention system did not prevent the right seat occupant from contacting and breaking the access door, however he was retained within the cabin. A combination of the energy absorbing seat system and the destruction of the composite fuselage absorbed the vertical and lateral impact energy such that both occupants survived the crash with injuries which were serious but not life-threatening.

Safety actions

As a result of this, and other similar events, the manufacturer published in February 2019 two Service Letters to prevent reoccurrence. They are available on its customer support portal.

SL 19-001 - Throttle management during simulated engine failure.

This service letter provides an explanation of the engine governor / correlator system and the need to ensure the twist grip throttle is fully closed whilst practicing certain manoeuvres. It proves advice to flight instructors on how to position the hand on the throttle grip to enable the throttle to be closed in one movement and therefore ensuring the engine throttle does not open when the collective is raised.

SL 19-002 - Controllability in yaw at low rotor speed.

This service letter proves advice on yaw control when operating with low rotor speeds. It includes a list of scenarios where yaw control could be lost and mitigating actions to prevent loss of control. One scenario is Simulated Engine Failure from the Hover. When operating at low rotor speeds with full or almost full right pedal applied it is recommended not to raise the collective but keep it as low as possible and increase forward airspeed by cyclic input, and not to increase the rotor speed by turning the twist grip.

Published 19 September 2019.