ACCIDENT

Aircraft Type and Registration:	Silent 2 Electro, G-CIRK
No & Type of Engines:	1 FES electric motor
Year of Manufacture:	2013 (Serial no: 2054)
Date & Time (UTC):	23 April 2021 at 1305 hrs
Location:	Wormingford Airfield, Colchester, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Light Aircraft Pilot's Licence (Sailplanes)
Commander's Age:	71 years
Commander's Flying Experience:	295 hours (of which 55 were on type) Last 90 days - 13 hours Last 28 days - 13 hours
Information Source:	AAIB Field Investigation

Synopsis

During the ground roll for a self-launched takeoff, the motor glider suffered a propeller strike shortly before it got airborne. The eyewitness evidence and recorded data showed that the glider climbed steeply to about 100 ft before stalling and entering an incipient spin to the left. The glider struck the ground nose-first and the pilot suffered serious injuries, in part due to the lack of energy absorbing structure ahead of the pilot's seat. The pilot had no recollection of the accident flight. No mechanical fault or defect was found that would explain the aircraft pitching up excessively after takeoff. The steep climb was most likely the result of an excessive aft stick input that was not corrected.

While the investigation could not positively identify the cause of the aft stick input, it is likely that distraction, pilot workload or stress were factors in the accident. Additional contributory factors were the aircraft's characteristics of low stick forces with low sensory feedback, and poor stall warning indications.

As a result of the investigation findings the BGA has published and sent a *'Safety Briefing'* to Silent 2 Electro owners in the UK which provides guidance on operating the motor gilder. This has also been provided to the European Gliding Union for onward dissemination to other European gliding associations.

History of the flight

G-CIRK was a self-launching motor glider[1] (SLMG[2]) equipped with a nose-mounted Front Electric Self-launch motor (FES[3]). The accident flight was the pilot's second self-launched flight of the day. Other than experiencing a left wing drop during the ground roll, the pilot's previous launch, two hours earlier, had appeared to go without incident.

On the accident flight, with the assistance of a wing runner, the pilot prepared to take off on Runway 09 (RW09) at Wormingford Airfield (Wormingford). After giving the all-out signal the pilot started G-CIRK's motor and began his takeoff roll. When he could no longer keep up with the aircraft, the wing runner released the right wing, whereupon the glider's left wing dropped to the ground. After the wingtip wheel touched the ground, the aircraft yawed left but the pilot managed to correct this and was then able to level the wings after approximately 10 m of ground contact. Shortly after the glider's wings had been levelled, its tail lifted off the ground and a witness saw a puff of dirt near the nose of the glider, which they assumed had resulted from a propeller strike. Witnesses reported that, after liftoff, G-CIRK initially began a shallow climb before its nose pitched up and it climbed more steeply than during its previous launch.

At a witness-estimated height of between 50 ft and 200 ft agl, the glider rapidly rolled left and appeared to enter a spin. After rotating between 90° and 180° around the vertical, G-CIRK struck the ground nose first before coming to rest upright, in a field bordering the runway.

Several gliding club members were quickly on scene and administered first aid to the pilot until air ambulance medics arrived, approximately 10 to 15 minutes after the accident. Once medically stabilised, the pilot was evacuated by air to hospital with injuries reported to be life-threatening.

Accident site

The accident site revealed that the aircraft had struck the ground in a steep nose-down attitude, after which the aircraft had yawed to the left and ended up pointing in the opposite direction of its final travel before coming to rest (Figure 1). The aircraft was about 230 m north-east of where it lifted off from the runway. The front of the cockpit was destroyed (Figure 2), the left wing had suffered significant damage and the tail had snapped in half. Both propeller blades had detached at their root and were close to the wreckage.

A series of 11 propeller slash marks were found on the runway surface near the liftoff point (Figure 4) with an initial spacing of about 10 cm.

Footnote

1 In this report the terms glider and sailplane are used as interchangeably for the same class of aircraft.

2 An SLMG is an aircraft with the characteristics of a non-power-driven glider, which is fitted with one or more power units and which is designed or intended to take off under its own power.

3 FES stands for Front Electric Self-launch / Self-sustainer. FES motors are used as both self-sustainer propulsion systems on gliders and also for self-launch on some light gliders.

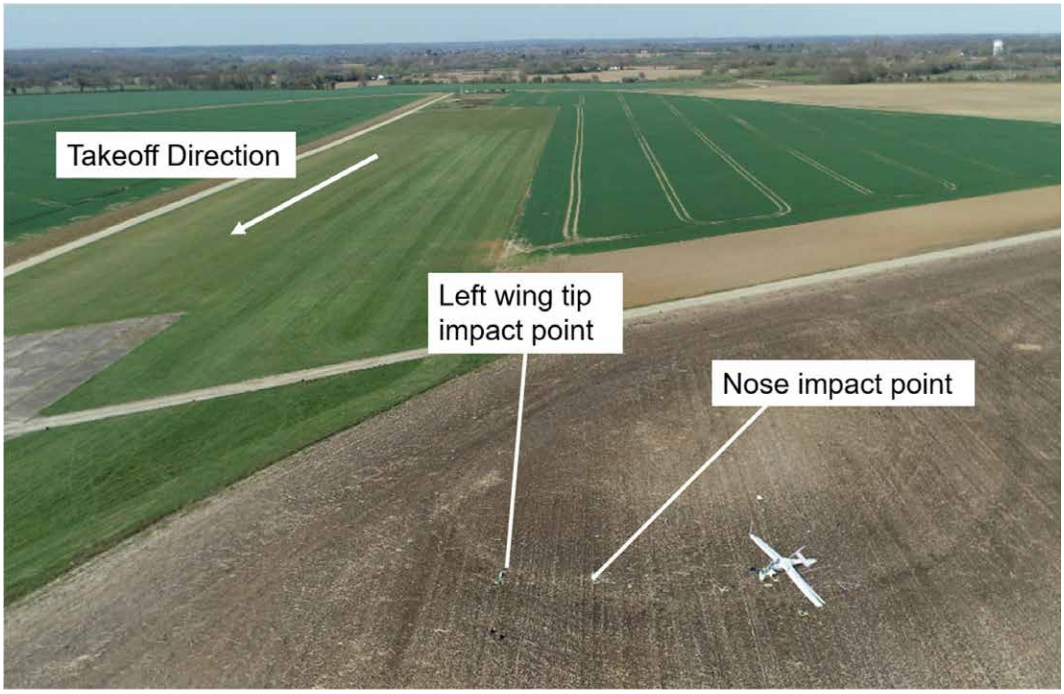

Figure 1
Accident site

Figure 2
Damage to the aircraft

Recorded information

Sources of recorded information

Recorded information was recovered from three flight loggers[4] fitted to the glider and a ground recording of its FLARM[5] transmission data[6]. This provided a GPS derived track and altitude of the glider during its takeoff run, climb and subsequent descent, with the data ending shortly before the glider struck the ground.

A GPS derived track and altitude recording was also available for the previous self-launch of G-CIRK, with it taking off at 1129 hrs and landing at 1158 hrs. A video recording of this takeoff was also captured by a witness using a mobile phone.

Recorded data

Figure 3 provides the GPS derived data for the accident flight and previous self-launch takeoff, with the recordings aligned when the glider had started to climb. The altitude of both recordings has been adjusted to indicate height agl and the derived KTAS is based on a wind from 130° at 11 kt[7]. Figure 4 provides the GPS data points for the accident flight overlaid on a terrain image. Figure 3 and Figure 4 also provide the relative timing and position on the runway respectively for the propeller strike[8].

The recorded data, in conjunction with witness marks on the runway, showed that approximately 12 seconds after the pilot had started the takeoff run, G-CIRK's propeller struck the surface of the runway (Figure 3 and Figure 4 Point A). However, this did not appear to adversely affect its acceleration and two seconds later, the data indicates that it may have then lifted off but remained close to the runway surface for several seconds whilst it continued to accelerate (Figure 3 and Figure 4 Point B).

About six seconds after the propeller strike, G-CIRK was recorded at a height of about 15 ft agl and its estimated airspeed was 42 KTAS (Figure 3 and Figure 4 Point C). It then climbed for the next six seconds at an average rate of 900 ft/min, while also deviating to the left of runway track by about 12° (Figure 4). As the aircraft climbed, its airspeed also gradually reduced. The trajectory of the aircraft, based on the maximum recorded height of 88 ft agl (Figure 3 and Figure 4 Point D), indicates that it climbed to about 100 ft agl, at which point its airspeed was about 30 KTAS (Figure 3 and Figure 4 Point E). The glider then descended. The last data point was recorded when the glider was at about 40 ft agl and its rate of descent was 500 ft/min (Figure 3 Point F). The glider subsequently struck the ground, 36 m laterally from the last data point.

Footnote

4 LX Navigation manufactured Eos 57, Zeus 4.3 and FLARM Red Box.
5 FLARM is a flight alarm system that transmits the position and altitude of an aircraft over a low-powered, short-range radio as part of an electronic conspicuity system that can alert pilots to the proximity to other suitably equipped aircraft.
6 Data recorded by the Open Glider Network (OGN) http://wiki.glidernet.org/ [accessed March 2022].
7 Based on information provided by the Met Office.
8 Analysis of the recorded GPS track during the previous takeoff and the accident flight, in combination with the position where the takeoff runs had commenced and the propeller marks occurred, showed that the horizontal position of the aircraft was accurate to within 4 m.

Comparison of the accident takeoff and the previous self-launch takeoff showed that the aircraft's acceleration during the takeoff roll, and its airspeed during the first few seconds of the climb, were similar. However, the climb profiles then diverged. During the previous takeoff, the initial rate of climb was maintained at about 200 ft/min (Figure 3 Point G) until the glider's airspeed had reached 50 KTAS, after which, the climb rate increased to about 430 ft/min.

During the previous flight, it was estimated[9] that the FES motor had been in operation for a total of about nine minutes.

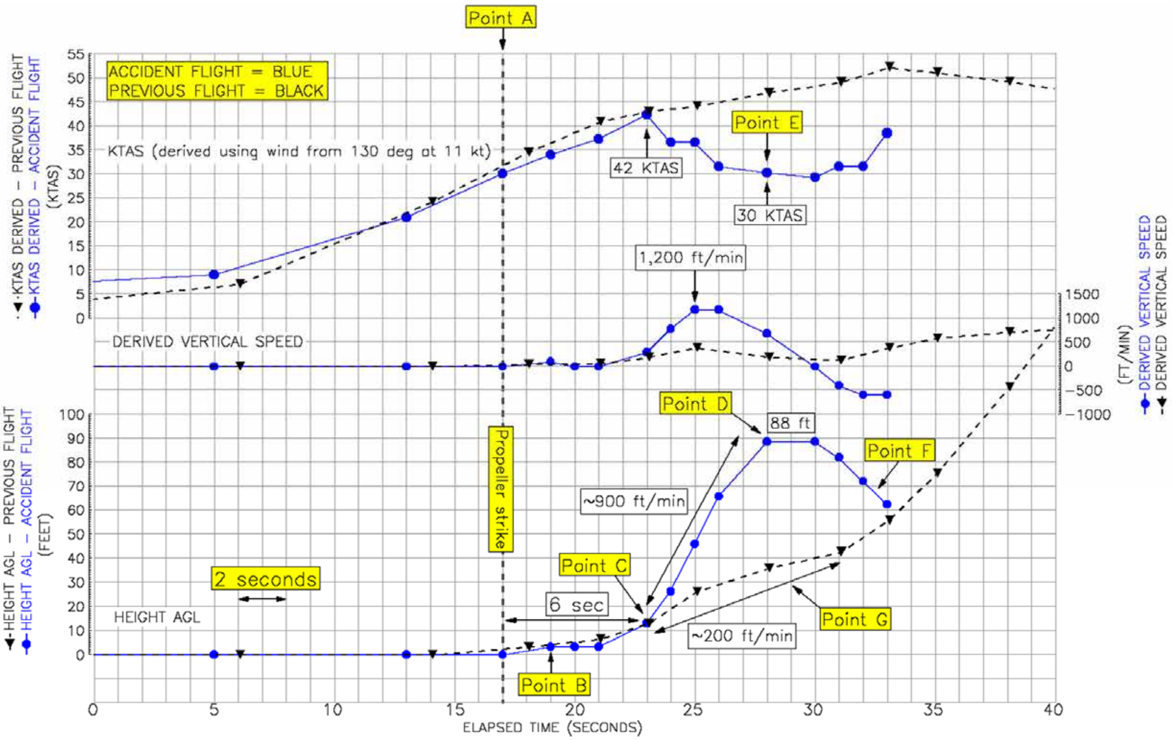

Figure 3

GPS derived data for accident and previous self-launch takeoff

Footnote

9 Based on the recording from the Eos 57 that included an environmental noise level intended to identify if an engine or FES was in use during flight.

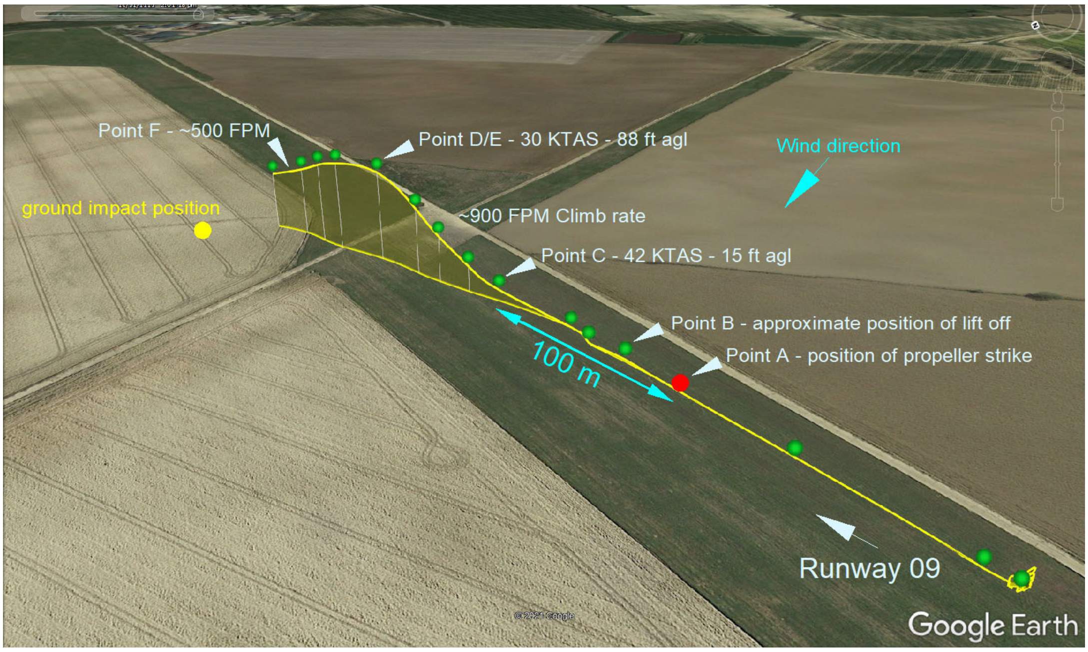

Figure 4

GPS derived data for accident takeoff

Video of the takeoff prior to the accident takeoff

The video of the pilot's previous takeoff showed that approximately three seconds after the glider started to move, the pilot transferred his left hand from the instrument panel mounted FES control unit onto the flap lever (Figure 5). The flap lever appeared to be in the flap +1 position but the angle from which the footage was taken meant that this could not be positively confirmed. After a further five seconds, the wing tip runner released the right wing and the glider immediately started rolling left over a period of one second, until the left wing touched the ground. G-CIRK's tail wheel lifted off the ground three seconds later, just before the glider rolled right into a wings level attitude. During the following six seconds, some minor oscillations were noted in all axes but the pilot appeared to correct these. The glider then lifted off and climbed in a nose up attitude to a height of about 30 ft agl, before the nose was lowered slightly, to what appeared to be an almost level pitch attitude, and a shallower climb was established. The video ended when the glider was at a height of about 45 ft agl.

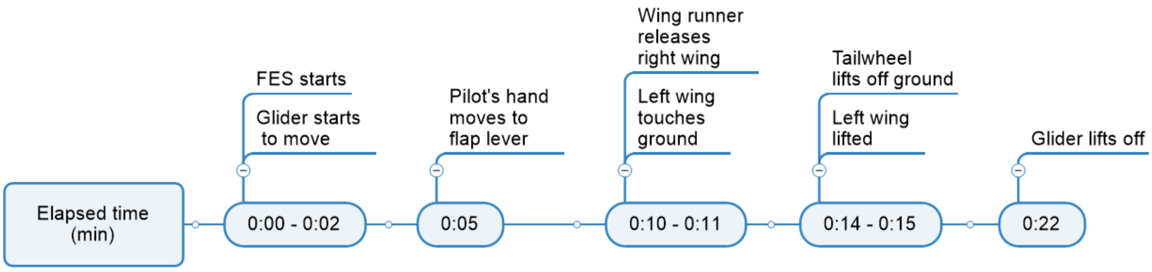

Figure 5

Timeline of the pilot's previous self-launch takeoff

Aircraft information

General

The Silent 2 Electro is a single-seat electric-powered SLMG. It has a maximum takeoff weight of 300 kg, or 315 kg if a Ballistic Parachute Recovery System (BPRS) is fitted, and it can be operated in the UK as a Single-Seat De-regulated Microlight (SSDR). This means that it is not required to have a Certificate of Airworthiness or a Permit to Fly; there is no requirement for its design or construction to be checked and anyone can perform maintenance on it.

The aircraft is factory-built and constructed from carbon and glass fibre re-enforced plastic. It has a 13.5 m wingspan with a small wheel under each wing tip, and a retractable monowheel (Figure 6). The flying controls, which consist of a speed brake, flaperons, rudder, elevator, and a moving tailplane, are operated by a system of pulleys, cables and push rods. The tailplane angle is coupled by a cable to the position of the flap control rod. The flap positions are: S, -1, 0, +1 and L (Land). As the flap is moved down the tailplane moves leading-edge down to compensate for the trim change due to flap deflection. There is no separate pitch trim lever so the pilot cannot trim for a specific speed.

Figure 6

Silent 2 Electro (image used with permission)

The accident aircraft, G-CIRK, had a fixed tailwheel and was fitted with the optional Magnum 300 BPRS. The standard aero tow hook had been removed and replaced with a belly hook mounted further aft to assist with winch launches.

Using another Silent 2 Electro aircraft, held in a level attitude with a pilot in the seat, the minimum distance between the propeller tip and the ground was measured to be 13 cm. The propeller tip touched the ground when the aircraft was pitched 5° nose-down.

Propulsion system

The aircraft is powered by a nose-mounted FES 22 kw brushless electric motor and a folding propeller with a maximum rpm of 4,500. The motor is powered by two 58 V lithium polymer batteries connected in series, providing a total voltage of 116 V. Power to the motor is controlled by a FES Control Unit (FCU) instrument mounted on the instrument panel (Figure 7). The FCU instrument displays propeller speed and battery charge levels, and it has a rotary throttle knob for controlling the motor speed. The knob does not have any stops and can be rotated continuously in either direction. Clockwise rotation increases rpm and anti-clockwise rotation decreases rpm. The motor is stopped by rotating the knob anti-clockwise with a few twists.

The two batteries are fitted in a compartment behind the cockpit. When fully charged the batteries have a combined capacity of 4.3 kWh and can supply sufficient energy for about 12 minutes at full power or operate at a cruise power setting of 4 KW for about an hour.

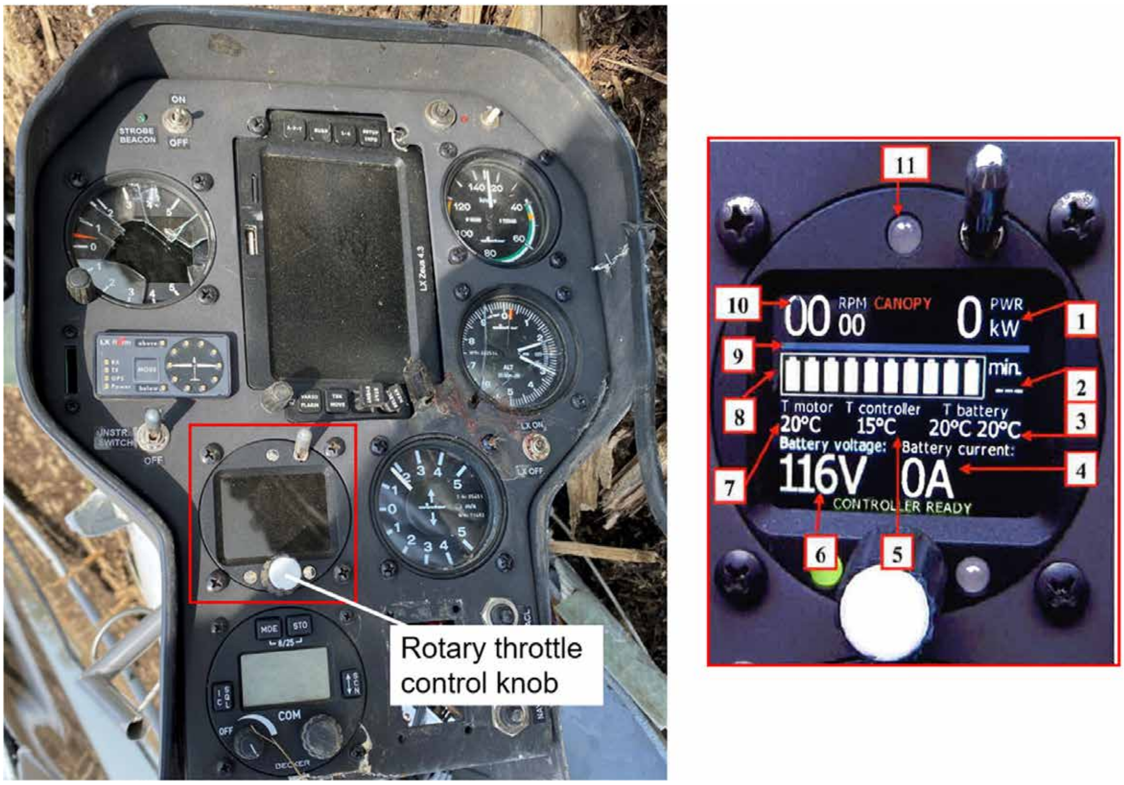

Figure 7

FCU instrument in the cockpit instrument panel (left) and enlarged detail (right)

Pitot tube

A pitot tube is used for measuring airspeed and G-CIRK was fitted with an angled version attached to the leading edge of the vertical tail (Figure 8, left). This same type of pitot tube was fitted to the Silent 2 Electro that was used for a flight evaluation as discussed later in the report. Later model Silent 2 Electro’s have a straight pitot tube (Figure 8, right). It was reportedly changed to reduce aerodynamic drag.

Figure 8

Angled pitot tube fitted to G-CIRK and the flight evaluation aircraft (left) and straight pitot tube fitted to later model Silent 2 Electro's (right)

Flight and Maintenance Manual

Typically, a flight manual, often referred to as a pilot's operating handbook, is an aircraft-specific reference document supplied by manufacturers of regulated aircraft and targeted at pilots flying that aircraft type. It is normally a comprehensive manual containing important information for pilots about their aircraft and its systems. Flight manuals would typically include details of limitations to be observed, operating performance data, procedures for normal and emergency situations and other pilot-relevant information.

Unlike for regulated aircraft, there is no requirement for SSDR aircraft to have a flight manual, although the manufacturer of G-CIRK did publish one. Rather than issuing a standalone flight manual and a separate routine maintenance manual, the glider's manufacturer published a combined Flight and Maintenance Manual (FMM). In addition to the usual contents of a flight manual, it contained details of routine maintenance tasks to be carried out on the aircraft.

While exceeding the UK regulatory requirement, the FMM was not as comprehensive as might be expected for a regulated aircraft. The investigation made the following observations on the content of the FMM:

- Neither target liftoff nor recommended climb speeds were specified.
- FMM guidance is to maintain a '*tail down attitude* [during the takeoff roll] *to avoid a prop*[eller] *strike*' but does not specify whether the tail wheel should be held on the ground or to what degree it can, or should, be raised as airspeed increases.

- The '*Aborted Take-Off and Engine Failure Drill*' does not include actions in the event of an engine failure or aborted takeoff before liftoff.
- While the Normal Procedures section of the FMM highlights the risk of a propeller strike on takeoff, the emergencies section does not include actions to take if one occurs.
- The flap position table in the Performance Data section appears to contradict the Normal Procedures section. The former states that the '*best usage*' flap settings for takeoff are L and +1 but the latter says to '*set the flaps at position +1*.'
- While the FMM recommends pilots familiarise themselves with the stalling characteristics of the glider it does not specifically direct them to explore how those characteristics differ during powered flight.
- In a section called 'Electric Powerplant Use and Maintenance' the FMM states '*Always self-launch with freshly charged batteries*', but this does not appear in the 'Operating Limitations' section of the FMM.

Stall speeds

The FMM provides the following indicated (IAS) and calibrated (CAS) stall speeds[10] for the aircraft with landing flap (Table 1). Stall speeds with other flap configurations are not published.

Gross Weight	Stall Speed (IAS)	Stall Speed (CAS)
245 kg	32 kt	29 kt
275 kg	34 kt	31 kt
300 kg	35 kt	32 kt
315 kg	35 kt	32 kt

Table 1

Silent 2 Electro stall speeds (with landing flap)

Aircraft manufacturer

The aircraft was originally manufactured by a company called Alisport SRL in Italy which produced a total of 49 Silent 2 Electro's between 2011 and 2018, including G-CIRK. In 2018 this company was bought by Porto Aviation which produced an additional two Silent 2 Electro's before selling the design and assembly jigs to a new company called Alisport

Footnote

[10] The indicated airspeed (IAS), expressed in kt is KIAS and is the speed indicated on the airspeed indicator, which has some instrument and position error. The calibrated airspeed (CAS), expressed in kt as KCAS, is the airspeed that would be indicated with no instrument or position error, and reflects aircraft performance. The true airspeed (TAS), expressed in kt as KTAS, is the CAS corrected for air density and is the actual speed of the aircraft relative to the air mass. At sea-level on a standard day TAS and CAS are the same.

Swiss in October 2019[11]. Alisport Swiss completed the final assembly on two Silent 2 Electro's before ceasing production in 2021. It is not yet known if production will resume. In this report the term 'aircraft manufacturer' will be used for Alisport Swiss and the term 'original aircraft manufacturer' will be used for Alisport SRL.

While under construction at the original aircraft manufacturer the type received an approval from the Deutscher Aero Club (DAeC). This meant that the aircraft met the German ultralight requirements LT-ULF, and the type received is what is called a 'Geraetekennblatt' which is a form of approval but is not an internationally recognised type certificate.

Aircraft examination

The aircraft wreckage was recovered to the AAIB facility near Farnborough for a detailed examination. All the damage to the flying controls was consistent with impact damage. The tailplane actuation system operated normally but the broken tail boom had resulted in the actuating cable going slack, so it was not possible to determine the tailplane angle at impact. It was also not possible to determine the flap angle at impact due to damage to the flap control system. No mechanical fault was found that would cause an un-commanded pitch-up. There were no blockages in the pitot tube. The landing gear was in the DOWN position and the BPRS had not been operated. 4.5 kg of nose ballast was fitted.

The electric motor was too severely damaged to test, but the separated propeller blades indicated that the motor was rotating at impact. As well as the root damage, the propeller blades had leading edge nicks and one blade had tip damage (Figure 9).

Figure 9
Propeller blade damage

Both batteries were removed and connected to test equipment. Their state is detailed in Table 2.

Footnote

[11] An additional 91 non-electric versions of the Silent 2 were also built.

	Battery 1	Battery 2
State of Charge	64.5%	64.7%
Stage of Health	99.1%	99.1%
Voltage	53.0 V	53.0 V

Table 2

Battery state after the accident

The maximum voltage of each battery is 58 V. The motor manufacturer estimated that an unloaded total voltage of 106 V would result in a maximum rpm of 4,200 instead of the normal maximum of 4,500 rpm.

The 10 cm initial spacing of the propeller slash marks in the runway surface indicated an approximate groundspeed of 27 kt at a propeller rpm of 4,200, and 29 kt at 4,500 rpm.

Survivability

The pilot suffered serious injuries in the accident and spent more than three months in hospital. He had been secured by a four-point harness, but the aircraft type does not have significant energy absorbing structure ahead of the pilot's seat to protect the occupant in a nose-first impact. As an SSDR the aircraft type was not required to meet the crash load test requirements of CS 22.561[12].

Weight and balance

Each Silent 2 Electro is provided with a weight and balance report which provides a table of seat load and nose ballast resulting in a recommended CG. The moment arms of the seat and the nose ballast are not provided.

G-CIRK's weight and balance table indicated that, for the pilot's declared boarding weight of 72.5 kg, the recommended amount of nose ballast was 3.0 kg for a CG of 404 mm. The forward and aft CG limits were 357 mm and 448 mm respectively. The takeoff weight was 294 kg. The pilot found that 3.0 kg of ballast left the glider feeling "tail-heavy" so he chose to fly with 4.5 kg of nose ballast. This changed the trim point to make the glider more nose heavy, requiring a reportedly, "more-comfortable," aft stick input to hold desired attitudes. He also reported that using flap S at speed above 70 kt gave a "more balanced" feel to the controls than using flap -1 or 0.

Measurements on another Silent 2 Electro revealed a discrepancy between the measured moment arm of the nose ballast and the moment arm used in its weight and balance table. The moment arm measured between the centre of the nose ballast and the wing leading edge datum was 137 cm, but the figure used in the table was 147.1 cm. The moment arm could not be accurately measured on G-CIRK due to the structural damage, but the moment arm used in its table was 151.0 cm.

Footnote

[12] CS 22 refers to Certification Specification 22 which contain the EASA certification requirements for sailplanes.

Meteorology

At the time of the accident, good weather prevailed. While wind velocity was not recorded at Wormingford Airfield, Stansted Airport and RAF Wattisham, 20 nm west and 13 nm northeast of Wormingford respectively, both recorded south-easterly winds between 9 and 13 kt around the time of the accident. These observations and those of eyewitnesses indicated that when the pilot began his takeoff, the wind at Wormingford was south-easterly at 10 to 15 kt. The crosswind would have been approximately 10 kt from the right. The glider's crosswind limit for takeoff was 19 kt (35 km/h). The recorded data analysis[13] was based on the Stansted Airport wind recorded at 1320 hrs which was 130°/11 kt. The air temperature at Stansted at that time was 14°C.

Airfield information

Wormingford is a grass airfield with a single runway designated RW09/27, approximately 1,600 m long and orientated 080°/260° M (Figure 10). The runway is bounded by a track to the south and arable land to the north.

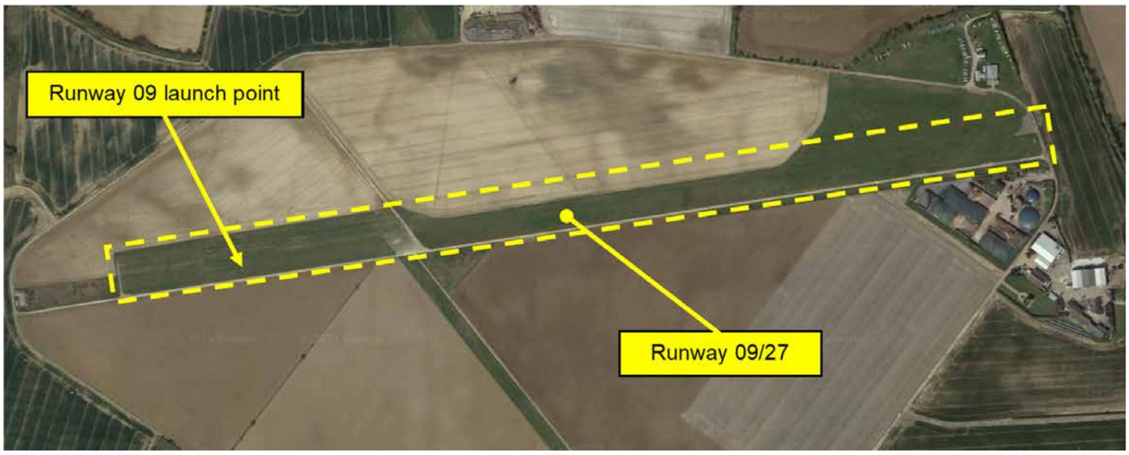

Figure 10

Wormingford Airfield
(image ©2021 Bluesky, CNES/Airbus Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, Map data ©2021)

The gliding club stated that the runway was proactively maintained, with any ruts being filled by hand and the surface routinely rolled to ensure it stayed "relatively flat and smooth." The accident pilot described RW09 as being in "good condition."

Accident pilot and training

The accident pilot started gliding in 2014 and undertook most of his flying with the club at Wormingford. He held a Light Aircraft Pilot's Licence for sailplanes (LAPL(S)) as well as a British Gliding Association (BGA) glider pilot's certificate. The pilot achieved the BGA's Silver gliding endorsement in 2017 and qualified as a BGA Basic Instructor in 2019. His

Footnote

13 See *Summary of recorded data.*

LAPL(S) licence was valid for life and he held a current flying medical certificate at the time of the accident.

The pilot bought G-CIRK second-hand in late-2019. The glider was supplied with a Flight and Maintenance Manual (FMM)[14] and, in addition to this, the pilot obtained a set of flight notes developed by a UK representative of the manufacturer. These flight notes were informally developed to supplement the FMM, providing amplifying guidance beyond that contained within it. The notes were described as '*a summary of the general characteristics of the Silent 2 Electro compiled by a selection of pilots based on their own personal experience of flying the aircraft*' and explicitly stated that it was '*not intended as an alternative to reading the Flight Manual.*' In relation to getting airborne, the notes stated that '*the glider will typically lift off when the indicated airspeed of 90~100 kph (48~53 kt) is reached*' and recommended that pilots '*maintain air-speed 90~100 kph (48~53 kt) for the duration of the climb-out*'. The accident pilot used the combined advice from both these sources to inform his approach to flying the Silent 2 Electro. He reported using flap +1 for self-launched takeoffs and 50 kt as his target climb speed.

The accident pilot first flew G-CIRK during his self-launch training, which he completed with a third-party training organisation in January 2020. This training, which was not conducted at Wormingford, comprised dual instruction with a flying instructor (FI) in a Super Dimona (Figure 11) followed by five solo self-launches in G-CIRK, all from a paved runway and supervised by the same FI. The dual elements of the training included five self-launched takeoffs and practise aborted takeoffs on the ground in the Super Dimona. The Super Dimona differed significantly from the Silent 2 Electro in that it was a Touring Motor Glider (TMG)[15] rather than an SLMG. It had side-by-side seating, tricycle undercarriage and a piston engine operated by a conventional throttle lever which moved forward and aft. The AAIB is not aware of any two-seat tandem self-launch FES-equipped sailplanes in production and the FI had not flown the Silent 2 Electro type.

During his first flights from Wormingford in G-CIRK, the pilot had undertaken a series of self-familiarisation exercises, including exploring the power-off stalling characteristics of the glider. He had not carried out any power-on stalls. He was aware that the LX navigation flight computer could be configured to provide an aural low speed warning but he did not use it as it provided nuisance warnings in the turbulence of thermalling.

The pilot reported that, compared with other gliders he had flown, G-CIRK required a higher level of active pilot input to hold a steady gliding attitude. This he ascribed to the glider not having any pilot-operable manual pitch trim control.

Footnote

[14] See section *Flight and Maintenance Manual.*

[15] A Touring Motor Glider (TMG) is an aircraft with the characteristics of a non-power-driven glider which has one or more integrally mounted, non-retractable power units, one or more non-retractable propellers and is designed or intended to take off under its own power.

Figure 11

Super Dimona (image used with permission)

While the glider was self-launch capable, the pilot generally preferred to winch launch to conserve battery power in case he ran out of natural lift while cross-country flying. Prior to 23 April 2021 (the day of the accident), the pilot's previous self-launch was 8 months earlier, and that had been his first self-launch since completing his initial training in January 2020 (Figure 12).

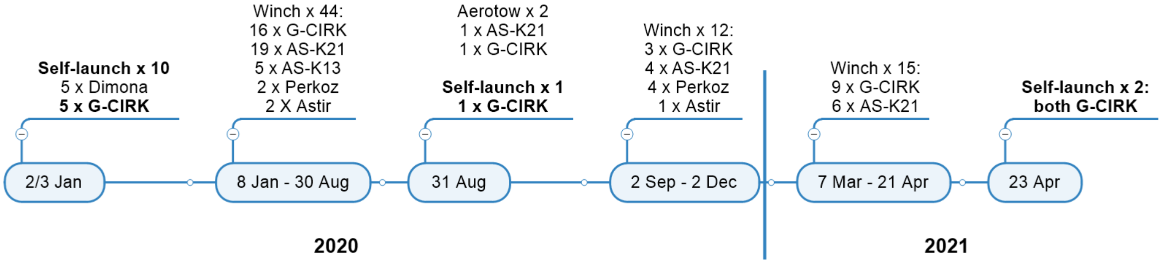

Figure 12

Summary of accident pilot's flying from start of self-launch training

While the pilot had no recollection of events on the day of the accident, he speculated that he elected to self-launch for the purpose of adding qualifying takeoffs toward the regulatory currency requirement of five self-launches in a rolling 24-month period. The pilot reported that, because the glider had a wingtip wheel and unlike for a more-dynamic winch launch, he would not have been overly concerned by a wing drop during the early stages of a self-launch, although he had not experienced a wing drop before the day of the accident.

The pilot had not charged the FES batteries between launches on the day of the accident and reported being unaware the FMM stated that self-launches should be carried out with fully charged batteries.

The pilot explained that for a self-launch, after the tailplane became effective during the ground roll, he would raise the glider's tail thereby lowering the wing angle of attack to avoid lifting off prematurely. He reported being aware of the propeller strike risk and that he would have aimed for a neutral pitch attitude when raising the tail.

The pilot was more familiar with winch, rather than self, launching in G-CIRK. He described the glider as having good winch-launch characteristics and said it was a "very natural" action to select and hold the climb attitude after liftoff. Once established in the climb the stick would be in a "neutral" position and, generally, only small pitch inputs were needed to maintain the target climb speed of 50 kt. The pilot reported preferring flap 0 for winch launches because it helped to prevent the glider lifting off prematurely and had "better control" characteristics than with flap +1.

The pilot observed that for an aborted takeoff, when compared with a standard cable release mechanism, the ergonomics of the FES control system were less intuitive. In an emergency requiring immediate motor shutdown, diverting attention away from flying the aircraft to locating and operating the FES throttle knob would be highly distracting at a critical stage of flight. Unlike pulling a cable release toggle, shutting down the FES was neither an instantaneous nor instinctive action. He considered that it would be safer if future designs for FES gliders incorporated a more intuitive and ergonomic means of cutting engine power.

Silent 2 Electro Flight Evaluation

The AAIB organised a series of evaluation flights on a Silent 2 Electro to explore the glider's handling characteristics, with specific focus on those flight regimes most pertinent to the accident flight. The evaluation pilot was a current military test pilot with extensive gliding experience[16]. The flight evaluations were conducted from a tarmac runway with a glider ballasted to give a representative CG position close to that of the accident glider. A portable sensor was used to record pitch angle, barometric pressure and GPS data. A camera was used to record the instruments and cockpit control positions, and a digital force sensor was used to record control stick forces. The significant findings from the flight evaluation were as follows:

Stick control forces

On the ground the stick could be placed in all positions and would not return to neutral when released. A force of 0.4 dAN[17] was required to pull the stick full aft, 0.6 dAN to push the stick full forward, and 1.6 dAN to apply full left or right stick. These forces were similar to the forces experienced in flight at low airspeeds. In the 40 to 50 kt airspeed range the stick could be displaced at least 2.5 cm forward or aft without returning to neutral when released.

The stick force versus airspeed relationship was measured at low airspeed and full power (the takeoff scenario) and is shown in Figure 13. The slope was very flat at 0.1 dAN per

Footnote

16 Graduate of the Empire Test Pilots School, 6,700 hrs total time, BGA Full Category Instructor, 3 Diamonds and 1,100 hrs on gliders.

17 1 daN is a unit of force equal to 10 Newtons which is 2.2 lb or 1.02 kgf.

10 kt in the nose-down direction, and 0.06 dAN per 10 kt in the nose-up direction. And the break-out friction force[18] of 0.1 dAN was high in comparison to the additional force required to change airspeed.

The test pilot reported that the flat stick force gradient and high break-out friction has two effects: it means that the pilot receives minimal feedback through the stick about how the aircraft is manoeuvring or its attitude, and it is difficult for the pilot to feel where the stick needs to be positioned to adopt a specific aircraft attitude or fly the aircraft smoothly and predictably.

The glider had weak positive longitudinal static stability at a CG that was 40 mm forward of the aft CG limit, so the stability would have been even less at the aft limit.

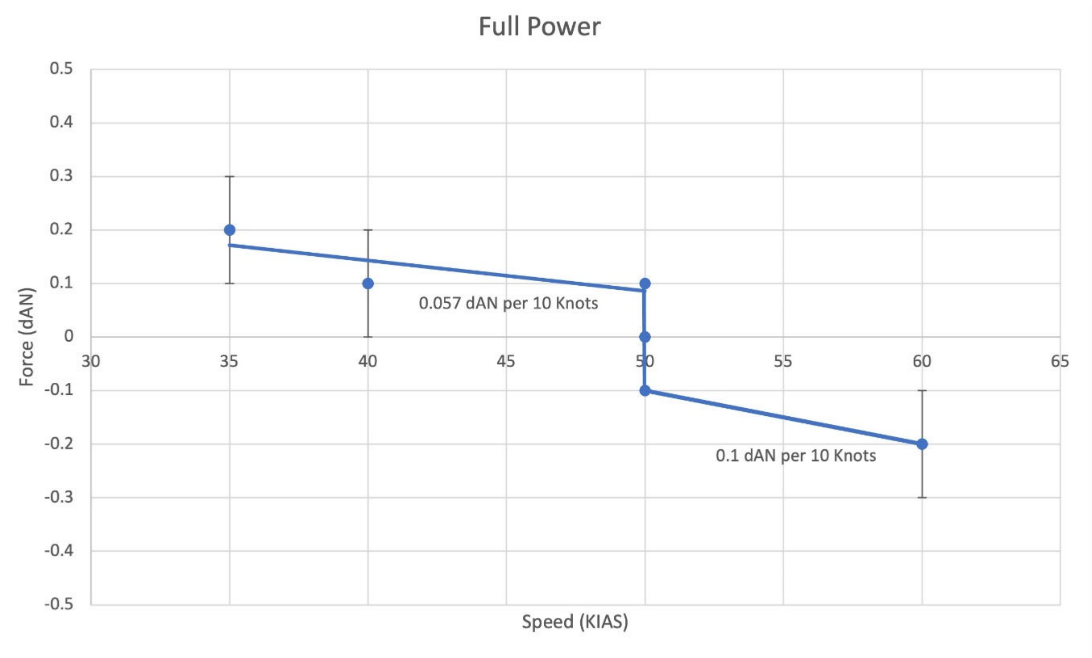

Figure 13

Stick force versus airspeed measurements

Stall characteristics and stall warning

During power off stalls from level flight, at flaps +1, decelerating at 1 kt/sec, there was light buffet at 38 KIAS and then the glider stalled at 37 KIAS in a nose-up attitude, with the nose dropping 2 seconds later. The stick force and displacement were not an obvious indicator of an impending stall. Beyond the point of stall, the glider typically yawed 10-15° and then rolled in the same direction before pitching down. Centralised forward movement of the stick led to a rapid recovery with a typical height loss of 150 to 200 ft. Significantly, there was only minimal pre-stall buffet and the test pilot found that buffet was not a good indicator to pilots that they were approaching the stall.

Footnote

18 The break-out friction force is the force that must be applied to the stick before the stick starts to move.

During full power stalls the airspeed indicator would sometimes fluctuate and indicate an erroneously high airspeed, sometimes jumping from 37 KIAS to 60 KIAS at the stall and displaying up to 80 KIAS after wing drop, so only the initial stall speed was reliable.

The full power stalls occurred in three main phases. During the first phase the glider decelerated to approximately 35 to 38 KIAS at flap 0 and flap + 1, while the attitude rose to 20 to 25° nose-up. The horizon was not visible from the cockpit, making it difficult to visually assess the attitude. Airframe pre-stall buffet was subtle, typically occurring only 1 kt and 1 second before the stall. This buffet was easily masked by the noise and vibration from the propeller and motor. Approaching the stall stick forces were light even when the stick was fully aft. If the stick remained fully aft the second phase of the stall occurred, the glider's nose dropped 10° below the horizon and the airspeed indicator jumped up to an erroneous 60 KIAS. This occurred over a 2 to 3 second period and at a rate that did not trigger a sensation of falling as a tactile cue for the pilot. Buffet levels increased during this phase. If the stick remained fully aft the aircraft entered the third phase, where the airspeed indicator erroneously showed 80 KIAS and the glider rolled rapidly to approximately 50° angle of bank.

According to the test pilot the pre-stall buffet during the full power stalls was '*minimal, subtle, inconsistent and not a reliable indicator of an impending stall*'. The typical height loss was 220 to 270 ft.

The test pilot concluded that, '*under the conditions tested, a startled, task-saturated and inexperienced pilot or one with a lack of stalling currency, could easily miss the natural pre-stall warning cues inherent in the Silent 2 Electro.*'

Rapid climbs

Rapid climbs were performed from entry speeds between 40 and 50 KIAS, with full power and flap +1 to see what pitch angle would produce the height gain observed in the accident takeoff, while allowing the airspeed to decelerate to a stall.

An interpolation of the data revealed that a gentle pull from about 41-44 KIAS would result in a 100 ft height gain prior to stalling at a pitch angle between 30° and 35°. The stick pull force to achieve this was only about 0.3 daN.

The climbs demonstrated that a 100 ft height gain from a speed of 41 to 44 KIAS would not have been achievable without power.

Entry Airspeed (KIAS)	Peak Pitch Attitude (degrees)	Height Gain (ft)
40	35	49 ft
40	38	75 ft
40	30	79 ft
40	35	82 ft
45	30	110 ft
47	25	133 ft
50	30	156 ft

Table 3

Height gain and peak pitch attitude during rapid climbs

Self-launch assessment

The test pilot's first flight on type was a self-launch at flap +1 which the test pilot found to involve a high workload due to unfamiliarity with the FES operation and trying to maintain the wings level in an 8 to 10 kt crosswind. The left wing tip wheel briefly touched the runway prior to liftoff. The test pilot found that raising the tail during the self-launch resulted in pitch and directional oscillations while the pilot was attempting to select the desired attitude and maintain runway heading. It was easy to overcontrol in pitch, resulting in the tail being raised more than planned. The climb after liftoff was flown at about 48 to 50 KIAS which resulted in a pitch angle of 10° and a climb rate of about 470 ft/min.

Aborted takeoff assessment

Four simulated takeoff aborts were performed. The abort speeds for the first three were 20, 30 and 35 KIAS, and these were undertaken before the test pilot had gained any experience on type. The tailwheel was kept on the ground and the pilot kept his hand on the FCU throttle knob during the acceleration phase. The pilot found that when aborting it took him time to select 0 rpm and found that managing the FES while maintaining directional control led to a high pilot workload but was safely achievable.

The fourth aborted takeoff was performed later in the day after the test pilot had gained experience operating the FES in flight. This time the pilot placed his left hand on his left thigh after setting power and initiated the abort at 35 KIAS. He found that locating the throttle knob and executing the abort was simple, as he had performed this physical action many times while airborne that day.

The test pilot assessed that, for an inexperienced pilot or one not current on type, the workload during an aborted takeoff on the ground was high. Once experience was gained on the glider and the operation of its FES, ground aborts during takeoff were more straightforward. Airborne aborts were not attempted.

Winch launch assessment

A winch launch was flown with flap 0[19] and was described by the test pilot as '*uneventful*.' The initial peak pitch attitude was 34° nose-up.

Airworthiness requirements

Certification Specifications for sailplanes

The EASA certification requirements for sailplanes are in Certification Specification (CS) 22. The Silent 2 Electro was not certified to CS 22 and nor was it required to be; however, CS-22 regulations are designed to ensure a certain level of safety so they are useful to compare an uncertified aircraft to.

CS 22.173[20] on 'Static Longitudinal Stability' states that the slope of the stick force versus speed curve must be positive and '*have a value such that any significant speed change will cause a variation in stick force plainly perceptible to the pilot.*' The 'Acceptable Means of Compliance' (AMC) to this requirement state that: '*Compliance with this requirement can be assumed, if the slope of the curve, stick force versus speed, is at least 1 N per 10 km/h at all speeds up to V_{NE}.*' V_{NE} is the 'never-exceed speed' and 1 N per 10 km/h equates to 0.19 daN per 10 kt or 0.19 kgf per 10 kt.

CS 22.207 on 'Stall warning' states that there '*must be a clear and distinctive stall warning'* through the *'inherent aerodynamic qualities of the sailplane (e.g. buffeting) or by a device that will give clearly distinguishable indications'*. The stall warning must begin between a speed of 5% above and 10% above the stall speed, or between 2 and 5 seconds before the stall occurs when the speed is reduced at 2 km/h per second. Compliance with this requirement is not required if, when the stall occurs, '*no appreciable wing-dropping occurs when both ailerons and rudder are held*' neutral. EASA were asked what a 'appreciable wing drop' consists of and they said 30° angle of bank. They also stated that a noticeable nose drop would be a trigger point for recovery, and if pushing the stick forwards at that point prevented more than 30° of bank then the requirement would be met.

CS 22.779 specifies the motion and effect of cockpit controls for sailplanes and powered sailplanes. It states: '*Cockpit controls must be designed so that they operate as follows: Throttle control – Forward to increase power*.'

Footnote

19 Flap 0 was used for the winch launch as recommended by the aircraft owner.

20 European Union Aviation Safety Agency (2021). *Certification Specifications, Acceptable Means of Compliance and Guidance Material for Sailplanes and Powered Sailplanes (CS-22)*. Amendment 3 https://www.easa.europa.eu/document-library/certification-specifications/cs-22-amendment-3 [accessed March 2022]

DAeC ultralight airworthiness requirements

The DAeC approved the Silent 2 Electro to LTF-UL[21] which contain airworthiness requirements for three-axis controlled ultralight aircraft. The DAeC provided the AAIB with an English translation of the 2003 version of these requirements, which were used to assess the Silent 2 Electro. The stall warning requirements in it are similar to CS 22 in that no stall warning is required if there is no 'appreciable wing-dropping'. However, the static longitudinal stability requirements are different in that LTF-UL 173 states that the slope of the curve, stick force versus speed, *'must be positive and have a value such that any significant speed change will cause a variation in stick force plainly perceptible to the pilot'*, without providing a specific minimum figure of stick force versus speed.

LTF-UL 779 on *'Motion and effect of cockpit controls'* is similar to CS 22.779 and states that cockpit controls must be designed such that *'Power lever: forward to increase forward thrust'*. However, the DAeC stated that their interpretation of the rule is that it only applies to a power lever and that the rotary knob on the Silent 2 Electro is not a power lever.

Aircraft manufacturer comments

The aircraft manufacturer assisted the AAIB with the investigation but as they had only recently acquired the aircraft type, they could not answer questions about its development and DAeC approval. They stated that they were not responsible for aircraft such as G-CIRK which were manufactured by the original aircraft manufacturer, but that the design had not changed since they started manufacturing the type.

The aircraft manufacturer acknowledged that the stick forces were very light, like some other ultralight aircraft, and that not having much stick centring force can be "difficult for the average pilot", but that most of their customers want the light forces for comfort reasons, especially for long soaring flights. However, if the manufacturer resumes production of the aircraft type, they will consider adding a spring to the pitch control system to increase stick forces.

The manufacturer also acknowledged that there is little buffet prior to stall to warn a pilot. Most powered light aircraft have a stall warning vane or suction port on the leading edge of the wing which provides an aural warning when an angle of attack close to stall is reached. This is not fitted to most gliders as it adversely affects the drag and therefore the glide performance of the wing.

Pilots typically practice power-off stalls when learning to fly a new aircraft type, and the manufacturer considered that there could be a safety benefit for Silent 2 Electro pilots to practice full power stalls to help them recognise the onset of stall in the takeoff scenario.

The manufacturer was unaware of an erroneous airspeed issue during power-on stalls and considered that it might be related to an older type of pitot tube that was fitted to the aircraft

Footnote

[21] LTF-UL is a German acronym for Lufttüchtigkeitsforderungen für aerodynamisch gesteuerte Ultraleichtflugzeuge, meaning 'Airworthiness requirements for three axes standard control ultralight aircraft'

the AAIB used for the flight evaluation and to G-CIRK. The manufacturer said they would investigate this issue if they resumed production.

Although not specified in the flight manual, the manufacturer considered that pilots new to the type should fly the aircraft with a more forward CG to increase longitudinal stability and increase the stick forces.

The manufacturer's test pilot stated that he almost always does a self-launch takeoff with flap 0. This is not one of the takeoff flap settings in the flight manual, but he stated that it provides a higher trim speed with negligible increase in stall speed compared to flap +1, so it provides a higher speed and stick force margin to stall. If the best climb angle was needed to clear an obstacle, then he recommended using flap +1.

The flight manual does not provide a lift-off or initial climb speed. The manufacturer stated that lift-off and initial climb is 90 km/h which is 49 kt. But they also stated that the takeoff should be conducted at the speed indicated by a yellow triangle on the air speed indicator which is 46 kt and is the glider's approach speed.

Regarding the takeoff technique the flight manual states a tail down attitude should be used to avoid a propeller strike. The manufacturer's test pilot said that some Silent 2 Electro's are fitted with a steerable tailwheel which can result in steering issues if the tailwheel is held on the ground during the takeoff roll so lifting the tail is preferable. He stated that all Silent 2 Electro's sold to the UK had a fixed tailwheel.

The manufacturer was aware of other propeller strike events during takeoff. They were aware of a few events where the propeller tips touched a concrete runway, and the aircraft took off without any issues. They did not consider that a light propeller touch on a grass runway would cause any significant issues. However, they considered that aborting the takeoff would normally be the safest option following a propeller strike.

The flight manual does not include an aborted takeoff on the ground procedure, but the manufacturer stated that the technique would be to cut the power by twisting the FCU throttle control knob, and then applying the wheel brake.

The manufacturer was asked to provide information on the nose ballast arm used to calculate the weight and balance tables to help explain the discrepancy found, but this information has not been provided yet.

If the manufacturer resumes production, they stated that they would update the flight manual with an aborted takeoff procedure, add a section on pilot training, add a takeoff and climb speed, add information about airspeed errors, and will consider adding flap 0 as a takeoff setting and recommending new pilots fly at a more forward CG.

Other accidents to Silent 2 Electro

On 19 October 2015 a Silent 2 Electro, registration G-CIYA, experienced a similar accident on takeoff from Husbands Bosworth Airfield in Leicestershire. During the initial climb following a self-launch, the aircraft entered an incipient spin. One wing struck the roof of a farm building, before the other wing and fuselage struck the ground. The pilot was seriously injured. The investigation did not reveal any malfunction or defect to account for the accident. Although the pilot was experienced and current in light aircraft, gliders and motor-gliders, he had not flown the aircraft type before. The full details are published in AAIB Bulletin 7/2016[22]. The report did not mention any indications of a propeller strike.

On 1 May 2017 a Silent 2 Electro suffered a stall and spin shortly after takeoff from Skövde Airport in Sweden. The pilot was seriously injured. The accident was not investigated by the Swedish Accident Investigation Authority but the AAIB obtained some information from the Swedish Soaring Federation that the takeoff was carried out with low batteries, and that the pilot may have reduced power in response to a low voltage warning, which resulted in the aircraft climbing poorly followed by a stall and spin.

On 22 July 2021 there was a fatal accident involving a Silent 2 Electro, registration D-MANS, near Conthey, Switzerland. The aircraft appeared to have stalled while ridge soaring. This accident is the subject of an ongoing investigation by the Swiss Transportation Safety Board.

Pilot licensing

When the pilot bought the glider, he gained the understanding from various sources that he needed to qualify for solo self-launching before he could fly the glider without direct supervision using another launch method such as winch-launch or aero-tow. This was not the case. The investigation found evidence of other pilots also being confused over licensing requirements for self-launched SSDR gliders. A CAA Information Notice[23] (IN) covering licensing for SSDR powered sailplanes, published in 2014, and rescinded following the publication of ANO 2016 (due to the transfer of regulatory powers from the CAA to EASA), stated that:

> *'…the valid licences for aircraft that are within both the SLMG definition and the microlight aeroplane definition are:*
>
> > *… 3. any Part-FCL Light Aircraft Pilot Licence (Sailplanes) (LAPL(S)) or Sailplane Pilot Licence (SPL) that includes 'self' as a launching method.'*

The wording of the IN could be interpreted as meaning LAPL(S) and SPL holders wishing to fly SSDR gliders, including the Silent 2 Electro type, were required to hold and maintain self-launching privileges irrespective of launch method being used. This contrasts with the

Footnote

22 https://www.gov.uk/aaib-reports/aaib-investigation-to-silent-2-electro-g-ciya [accessed March 2022]
23 Civil Aviation Authority Information Notice Number: IN–2014/139 Pilot Licences for Flying Single-Seat Powered Sailplanes that are within the Microlight Mass Limit issued 19 August 2014.

wording of the superseding regulation, EASA.SFCL.155 (covering launch methods), which was not specific to SLMG and stated:

> *'…SPL holders shall exercise their privileges only by using those launching methods for which they have completed specific training either during [their] training course …or during additional training provided by an instructor after the issue of the SPL. This specific training shall consist of the following:*
>
> > *…(2) in the case of aerotow or self-launch, a minimum of five launches in dual flight instruction, and five solo launches under supervision. In the case of self-launch, dual flight instruction may be conducted in TMGs'*

BGA licensing experts reported that the rules surrounding self-launching had been in place since at least 2012 and that self-launching privileges were only required if the pilot wished to use that method of launch. At the time of the accident, the BGA website hosted a document containing a précis of various guidance sources related to self-launching, including an extract drawn from the *'Aircrew* [Commission] *Regulation Reg(EU) 1178/2011*[24] *FCL.130.S LAPL(S) – Launch Methods*.' This document[25] also included a template syllabus and record for self-launch endorsement training. The guidance document was replaced in August 2021 with a webpage, titled '*SFCL Compliant Pilot Training'*[26], containing links to source documents to avoid the risk of publishing a locally collated document that might not reflect contemporary amendments to the regulatory framework. The revised webpage included the following specific guidance on launch privileges for pilots of self-launching sailplanes:

> *'SFCL permits a sailplane to be flown by an SPL holder using winch or aerotow or bungee or self-launch, providing that the pilot holds the appropriate launch type privileges and recency. This means that a pilot new to self-launching may fly a self-launching sailplane using aerotow or winch, which can be a helpful way of becoming familiar with handling characteristics prior to the first self-launch on type.'*

Ballistic Parachute Recovery System (BPRS) Awareness

The Magnum 300 BPRS installation on G-CIRK consisted of a rocket and parachute located in compartments behind the pilot seat, and an activation handle on the right side of the cockpit which was connected by a cable to the rocket. The activation handle had a safety pin to prevent inadvertent operation and this was to be removed before flight. The BPRS is activated by pulling the activation handle.

The damage to the cockpit of G-CIRK had exposed the activation cable, and the pin was not inserted, so the rocket presented a hazard to the emergency services attending the

Footnote

[24] Commission Regulation (EU) No 1178/2011 dated 3 November 2011 which lays down technical requirements and administrative procedures related to civil aviation aircrew pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R1178&from=EN [accessed March 2022].

[25] Dated 12 October 2017.

[26] https://members.gliding.co.uk/flying-information-and-resources/pilot-licensing/declared-training-organisation-easa-compliant-training [accessed March 2022].

scene. Fortunately, gliding club members who were at the airfield at the time of the accident and were aware of the BPRS, arrived at the accident site first and were able to secure the activation handle[27] and subsequently warn the emergency services paramedics about the hazard.

Two placards were affixed to the fuselage aft of the cockpit to warn people about the hazards from the rocket and parachute (Figure 14). These placards conformed to the requirements in ASTM F2316-12[28]. They did not conform to the placard requirements in BCAR Section S[29], sub-section K on *'Microlight Parachute Recovery Systems'*, which require the 'DANGER' placard to be larger than that specified in ASTM F2316-12[30], and which also require a double offset black and yellow chequered line to surround the parachute and rocket exit area (Figure 15). As an SSDR the Silent 2 Electro is not required to meet BCAR Section S; however, the CAA published Skywise article SW2021/91[31] on 29 April 2021 which stated that: '*The CAA strongly recommends that owners of SSDRs fitted with a BPRS comply with the requirements of BCAR Section S, Sub-Section K, to clearly identify the presence of the BPRS to emergency services and first responders in the event of an accident.*'

Figure 14

BPRS placards on G-CIRK

Footnote

[27] The pin could not be inserted into the activation handle due to impact damage of a surrounding bracket, so the club members tied some string through the pin hole.

[28] ASTM F2316-12, Standard Specification for Airframe Emergency Parachutes.

[29] CAP 482 British Civil Airworthiness Requirements (BCAR) Section S – Small Light Aeroplanes, Issue 7 https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=5575 [accessed March 2022]

[30] BCAR Section S requires the dimensions of the triangular part of the placard to be a height 130 mm and width 150 mm, whereas ASTM F2316-12 requires the triangular placard to have a minimum size of 3 inches (76.2 mm).

[31] http://skywise.caa.co.uk/marking-and-placarding-of-ballistic-parachute-recovery-systems-on-single-seat-deregulated-ssdr-aircraft/ [accessed March 2022]

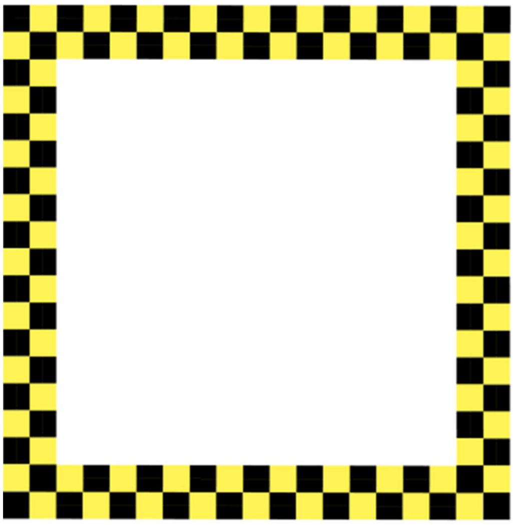

Figure 15

From BCAR Section S, sub-section K, sample of double offset black and yellow chequered line which should surround the parachute and rocket exit area

In some accidents the placards can be obscured as a result of structural damage, wreckage orientation or due to fire. Following an accident to a CZAW SportCruiser (G-EWZZ) which was equipped with a BPRS and suffered a post-impact fire, the AAIB published the following Safety Recommendation on 11 June 2015[32]:

Safety Recommendation 2015-011

It is recommended that the Civil Aviation Authority introduce an information system, for aircraft operating in the UK that allows first responders and accident investigators to identify if an aircraft is equipped with a Ballistic Parachute Recovery System. This information system should include details of the type of system fitted, the location of the major components, routing of the actuator cable and the actions required to make the system safe.

At the time there were technical difficulties to modify the UK's aircraft registration database 'G-INFO'[33] to include details about an aircraft's BPRS, and other reasons which resulted in this recommendation not being acted upon[34]. However, since the accident to G-CIRK the AAIB revisited this recommendation with the CAA, and the CAA have taken the following safety action:

Footnote

[32] Report in AAIB Bulletin 5/2015 https://www.gov.uk/aaib-reports/aaib-investigation-to-czaw-sportcruiser-g-ewzz [accessed March 2022]

[33] https://www.caa.co.uk/aircraft-register/g-info/ [accessed March 2022]

[34] CAA Factor F3/2015 contains the full CAA response on Safety Recommendation 2015-011 https://publicapps.caa.co.uk/docs/33/F3-2015%20G-EWZZ%20Issue%202.pdf [accessed March 2022]

Safety Action

On 24 January 2022 the CAA updated G-INFO to show when an aircraft is fitted with an Emergency Ballistic Device, such as a Ballistic Parachute Recovery System (BPRS), an active ejector seat or canopy miniature detonating cord. The CAA undertook the task of identifying UK-registered aircraft fitted with such devices to support this change. To capture newly-registered aircraft with an Emergency Ballistic Device in the future, the CAA is updating the aircraft registration process to specifically require owners to declare the aircraft status with respect to an Emergency Ballistic Device.

The AAIB also plans to update its guidance document to the emergency services to inform them of the availability of this new information on the G-INFO database.

As some owners of SSDR aircraft fitted with BPRS may not be aware of the recommended BPRS placard types and sizes that should be fitted, the CAA are planning the following:

Safety Action

The CAA are planning to contact the registered owners of SSDR aircraft, which are fitted with a BPRS device, to inform them about Sky Wise article SW2021/91 which strongly recommends that owners of these aircraft comply with the requirements of BCAR Section S, Sub-Section K, to clearly identify the presence of the BPRS.

Effects of high workload and stress on human performance

CAP 737 *Flight crew human factors handbook*[35] provides examples of processes that result in high workload such as '*doing an unfamiliar or novel task, doing a new or unlearned task, doing a challenging task*' and '*making a decision.*'

CAP 737 discusses the symptoms of increasing workload which include *'Attentional and task focusing.'* Attentional focusing is a cognitive strategy that has evolved to maximise concentration on a problem or threat but can have the negative consequence that '*other events and stimuli that would normally draw attention, fail to do so.*'

Another symptom is '*Task shedding and reprioritisation'* where some aspects of a task with concurrent elements are omitted, such as monitoring the airspeed indicator (ASI).

It also mentions that '*Very high workload (particularly fast onset) and feelings of not coping with the workload can cause high arousal or stress.*' Stress and high workload have similar effects on human performance including '*omission*', '*error*' and '*coning of attention.*' Additionally, CAP 737 mentions '*regression*' where, under stress, behaviour may regress to the earliest learnt.

Footnote

[35] Civil Aviation Authority (2014), *Flight-crew human factors handbook*, CAP 737. https://publicapps.caa.co.uk/docs/33/CAP%20737%20DEC16.pdf [accessed March 2022]

Analysis

Accident flight

The accident occurred following a self-launched takeoff. It was the pilot's third self-launch takeoff since completing training more than a year previously. During the takeoff roll the propeller struck the runway and then the aircraft climbed at an excessively steep angle for a self-launch. From comparing the recorded data of the accident flight with the flight evaluation data, the pitch angle was estimated to be between 30 and 35°, when a normal pitch angle after takeoff would be about 10°. The flight evaluation data showed that climbing at this angle from an initiating speed of 41 to 44 KIAS leads to a height gain of about 100 ft with power applied, followed by a stall and wing drop if recovery action is not taken in time.

The eyewitness evidence and recorded data showed that the aircraft climbed about 100 ft before stalling and entering an incipient spin to the left. The flight evaluation showed that 100 ft was insufficient height to recover from a power-on stall. The aircraft struck the ground nose-first and the pilot suffered serious injuries, in part due to the lack of energy absorbing structure ahead of the pilot's seat.

No mechanical fault or defect was found that would explain the aircraft pitching up excessively after takeoff. The 100 ft climb after takeoff indicates that power was applied and that the propeller had only suffered minor damage during the propeller strike. Although the batteries were not fully charged, the recorded data did not reveal a significant difference in the initial acceleration profile compared to the previous takeoff, so this did not appear to have been a factor in the accident.

The pilot had no recollection of the flight and there was no evidence from recorded data or eyewitness sources to explain the steep climb which led to the accident. Recorded data evidence showed that the pilot's previous self-launch, two hours earlier, followed a typical climb profile, as described by other Silent 2 Electro pilots.

The test pilot concluded from the flight evaluation that a self-launch takeoff in the Silent 2 Electro can be a high workload event for an inexperienced pilot or one not current on the launch type. They also found that the glider had a flat stick force gradient and high break-out friction which meant that the pilot receives minimal feedback through the stick about how the aircraft is manoeuvring, and it is difficult for the pilot to feel where the stick needs to be positioned to adopt a specific aircraft attitude. With little control feedback, any distraction diverting a pilot's attention away from the aircraft's attitude could lead to inadvertent stick inputs leading to undetected flight path deviations. The brief and subtle pre-stall indications seen during power on stalls would give a pilot only limited time to recognise and recover from a rapidly approaching stall in a steep nose-up attitude, or they could be missed entirely.

While the investigation could not determine the reason for the steep climb it considered that it most likely resulted from a single or combination of factors outlined in Figure 16 and explained below.

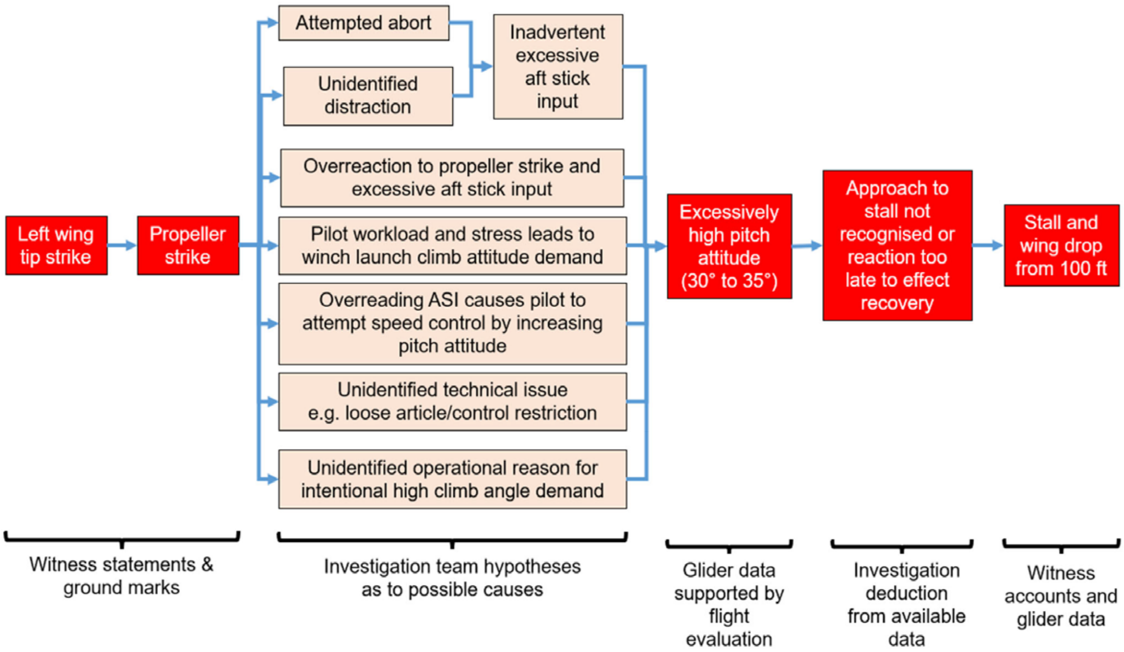

Figure 16

Sequence of events: actual (in red boxes) and possible (in pink boxes)

Inadvertent excessive aft stick input

It was possible that the pilot inadvertently applied an excessive aft stick input shortly after liftoff because a compelling stimulus diverted his attention away from the primary flying task and monitoring the glider's climb attitude. One possible scenario was considered to be the pilot focusing on the FCU following the propeller strike, either to check motor performance or to abort the launch. This would be an example of attentional focusing and task shedding or reprioritisation which are both likely to be experienced under high workload. The design of the FCU throttle knob was not ideally suited to the task of aborting a takeoff in an emergency. It required visual attention and a degree of manual precision to locate and control the rotary knob.

The investigation could not exclude the possibility of some other form of unidentified distraction.

Overreaction to propeller strike and excessive aft stick input

The investigation considered that if the pilot responded to the propeller strike more forcefully than required it might have resulted in an excessive aft stick input. The minimal control feedback in pitch could have masked an overcontrolling stick input. The imbalance in control forces between the control axes might also have contributed to any element of overcontrolling. The pilot would likely have been using heavier and more coarse control inputs to regain lateral and directional control during the takeoff roll but the required pitch input at liftoff would have been more subtle. However, the observed shallow climb established immediately after liftoff suggested that an initial overreaction to the propeller strike was less likely.

Pilot workload and stress

It was considered likely that the pilot experienced high workload during the takeoff run, because of his inexperience of self-launching this aircraft type and the crosswind. The video of the takeoff prior to the accident takeoff showed that the pilot needed to correct oscillations in all axes and lift the wing after a wing drop. During the accident takeoff, eyewitnesses reported a wing drop and a yaw which the pilot successfully corrected. However, workload likely further increased when the propeller struck the ground. This high workload might have led to him experiencing stress. Any resultant stress could have resulted in a regressive response by the pilot of selecting a more-familiar, winch-launch pitch attitude of 30 to 35° rather than the lower climb attitude required for a self-launch. CAP 737 describes *'regression'* as going back to the *'earliest learnt'*, and the pilot had learnt winch launches well before self-launches and he had conducted many more winch launches than self-launches in G-CIRK.

Overreading ASI

The flight evaluation revealed that the ASI can overread during power-on stalls. This is probably caused by the propeller slipstream hitting the pitot tube on the vertical tail. If the ASI had overread during the takeoff climb this might have caused the pilot to increase the pitch attitude to reduce the speed back to his target. However, the ASI was only seen to overread close to stall, so if it was a factor in the accident, it would probably have occurred late when the pilot had already reached an excessively high pitch attitude for a different reason.

Unidentified technical issue

The investigation did not find any evidence of a technical failure or control restriction but could not conclusively rule out an unidentified transient failure such as might be caused by a loose article affecting a control run.

Unidentified operational reason

One potential operational cause that could not be conclusively ruled out was distraction caused by the presence of birds after takeoff, although none of the eyewitness reports mentioned birds.

Light stick forces

Regardless of the reason for the excessive aft stick input, the aircraft's very light longitudinal stick forces make an excessive aft input more likely. The flight evaluation revealed that a force of 0.3 dAN, relative to a break-out force of 0.1 dAN, was sufficient to cause an excessively high pitch attitude that would lead to a stall from an entry speed of 41 to 44 KIAS. 0.3 dAN is a pull force that can be generated with a 300 g weight. The stick force gradient is also very flat at 0.1 dAN per 10 kt nose-down and 0.06 dAN per 10 kt nose-up (at low speeds). This is less than half of the CS-22 requirement of 0.19 dAN per 10 kt. The requirements in LTF-UL are more subjective and only require that the gradient be positive which might explain why it was approved.

The manufacturer stated that other ultralights have light stick forces and that their customers like it for comfort reasons, but this comes at a cost to safety. Light stick forces mean that excessive pitch deviations are more likely, which can lead to an inadvertent stall. The manufacturer stated that they will consider adding a spring to the pitch control system to increase the stick forces if they resume production. Adding a standard pitch trim system would also help to compensate for any increase in stick forces.

Pilots can also increase the stick forces by applying more nose ballast to move the CG forwards which increases longitudinal stability. The aircraft manufacturer suggested that low time pilots in particular should consider doing this.

As a result of this investigation, the BGA sent a *'Safety Briefing'*, based on the information from the flight evaluation and investigation findings, to Silent 2 Electro owners in the UK and published it on their website[36] on 28 January 2022. They also sent it to the European Gliding Union (EGU) on 2 February 2022, for onward dissemination to 20 other European gliding associations and to the EGU safety working group. The BGA does not regulate SSDR's but does provide guidance to all sailplane operators to help to maintain and improve safety. The *'Safety Briefing'* is at Appendix A, and it states the following regarding stick forces:

> *'Very light stick forces in pitch combined with high levels of friction in the controls. This means the pilot receives minimal feedback on how the aircraft is responding to control inputs. Flying with a more forward cg should increase stability and stick forces.'*

Stall characteristics and stall warning

The excessive pitch attitude after takeoff which reached a maximum of about 30° to 35° might have been avoided if the aircraft characteristics had provided the pilot with a strong indication that the aircraft was approaching the stall. There was no artificial stall warning device fitted and the aerodynamic buffet was very subtle and only occurred about 1 kt or 1 second above stall.

This accident is similar to the accident to G-CIYA where the pilot also adopted a high pitch attitude after takeoff and either did not recognise the approach to stall or reacted too late to it.

CS-22 states that there must be a clear and distinctive stall warning via natural buffet or an artificial device, and that the warning must begin 2 to 5 seconds before the stall occurs (or 5% to 10% above stall speed). The buffet during the flight evaluation was not distinctive and did not occur within the time or speed parameters. However, it appears that this may have

Footnote

[36] https://members.gliding.co.uk/bga-safety-management/managing-flying-risk-index/motorgliders-self-launching-and-self-sustainer-sailplanes/ [accessed March 2022]

still met the CS-22 requirements as no stall warning is required if there is no appreciable wing drop if recovery action is taken at the first indication of stall. But when you stall from a low height the lack of appreciable wing drop is not necessarily going to assure a safe outcome. A stall in the Silent 2 Electro cannot be recovered from 100 ft even without a wing drop. The only way to help prevent a low altitude stall is to provide a distinctive stall warning with a sufficient margin.

A stall warning vane or suction port could be added to the aircraft, or aerodynamics strips could be added to the wing to trigger more natural buffet near stall. However, these affect the glide performance, so the manufacturer was not considering them.

Pilots typically practice power-off stalls when learning to fly a new aircraft type, and the manufacturer considered that there could be a safety benefit for Silent 2 Electro pilots to practice full power stalls to help them recognise the onset of stall in the takeoff scenario.

The BGA's *'Safety Briefing'* about the Silent 2 Electro therefore includes the following:

> *'Very little physical or aural indication that a stall is approaching with full power. Practising power-on stalls at a safe height can teach the pilot how to recognise the subtle indications of an approach to a stall with full power (and with other power settings).'*

The aircraft manufacturer's test pilot stated that an additional measure that could be taken to reduce the risk of a stall on takeoff is to do a self-launch with flap 0. He stated that it provides a higher trim speed with negligible increase in stall speed compared to flap +1, so it provides a higher speed and stick force margin to stall. The manufacturer stated that they would consider adding flap 0 as a takeoff setting to the flight manual if they resume production.

As an interim measure the BGA's *'Safety Briefing'* about the Silent 2 Electro includes the following guidance for pilots to consider:

> *'Self-launching with Flap 0 instead of Flap +1 (Flap +1 is recommended in the flight manual) may be helpful. There is very little difference in stall speed between Flap 0 and Flap +1, but the trim speed is higher with Flap 0, which means that there is a higher trim margin to stall. The angle of climb will be shallower with Flap 0.'*

Taking off with sufficient airspeed can help reduce the risk of a stall. The flight manual does not provide a takeoff or climb speed and the aircraft manufacturer provided some conflicting advice on what this speed should be. They stated that they would add some speeds to the flight manual if they resumed production. The test pilot who carried out the flight evaluation recommended a 50 KIAS initial climb speed which was also what the accident pilot said he targeted.

The BGA's *'Safety Briefing'* about the Silent 2 Electro therefore includes the following:

> *'The flight manual does not provide a take-off or climb speed. A climb speed of 50 kts provides normal handling and should ensure a good margin to stall.'*

FCU throttle design

The test pilot found that during an aborted takeoff it took him time to select 0 rpm using the rotary throttle knob and that doing this while maintaining directional control involved a high pilot workload, but that practice and familiarity made it easier. The accident pilot also said that in an emergency requiring immediate motor shutdown, operating the throttle knob would be highly distracting and divert attention away from flying the aircraft. Both CS-22 and LTF-UL state that the throttle control must move forward to increase power, and by implication aft to reduce power. The FES throttle control was initially designed to be used as a 'sustainer' motor, meaning that it would be turned on in flight and turned off before landing. For a purely airborne operation a rotary throttle knob may be appropriate and it takes up less cockpit space, but for a throttle that is used for takeoff and where a takeoff may need to be suddenly aborted, its operation is not quick or as intuitive. However, rehearsing the physical actions of an aborted takeoff may help.

The BGA's *'Safety Briefing'* about the Silent 2 Electro therefore includes the following:

> *'Procedure for an aborted take-off. Cutting the power quickly using the FES rotary knob is not as easy or as intuitive as pulling back on a throttle lever (for example in a TMG). Pilots should on all occasions complete a comprehensive self-brief for the take-off and any eventualities. This should always contain a point on the take-off run where the acceleration of the aircraft can be checked. Pilots should mentally rehearse what they would do in the event of needing to abort a take-off so as to be able to quickly and correctly react to a problem.'*

The BGA have also published the following guidance on their website[37]:

> *'Note 2. Flight training for self-launching privileges is likely to take place in a TMG. It should be noted that the forward and aft moving throttle lever in a TMG operates differently from the rotary knob which is a feature in many electrically powered self-launching sailplanes. The difference should be carefully considered, including rehearsing how to abandon a takeoff, eg rotate the knob fully anti-clockwise, and how to manage a total or partial power failure on takeoff in a very light aircraft where the aircraft may take longer than expected to accelerate following recovery from the power failure.'*

Footnote

[37] https://members.gliding.co.uk/flying-information-and-resources/pilot-licensing/declared-training-organisation-easa-compliant-training [accessed March 2022]

Takeoff technique

The FMM guidance is to maintain a '*tail down attitude* [during the takeoff roll] *to avoid a prop*[eller] *strike*' but it does not specify whether the tail wheel should be held on the ground or to what degree it can, or should, be raised as airspeed increases. The pilot of G-CIRK reported that he aimed for a neutral pitch attitude when raising the tail, but this could increase the risk of a propeller strike.

The BGA's *'Safety Briefing'* about the Silent 2 Electro therefore includes the following:

> *Take-off technique. Keeping the tailwheel on the ground, or just above it, until lift-off reduces the chance of a propeller strike. Aggressive use of large forward stick inputs early in the ground run should be avoided, particularly on uneven surfaces, as this increases the likelihood of overcontrolling in pitch and a prop strike.*

Erroneous airspeed during a stall

The flight evaluation revealed that during power-on stalls the propeller slipstream impinged on the pitot tube and caused erroneous overreadings on the ASI. The aircraft manufacturer was not aware of this issue and stated that they would investigate it if they resumed production. They believed that the pitot tube had been changed by the original aircraft manufacturer from an angled pitot tube to a straight pitot tube to reduce aerodynamic drag, but it is possible the change was also to address ASI overreadings.

The BGA's *'Safety Briefing'* about the Silent 2 Electro therefore includes the following:

> *'Indicated airspeed can increase erroneously during and post stall when full power is set.'*

Weight and balance

Measurements on another Silent 2 Electro revealed a discrepancy between the measured moment arm of the nose ballast and the moment arm used in its weight and balance table. The moment arm measured between the centre of the nose ballast and the wing leading edge datum was 10 cm more forward than the figure used in the table. The manufacturer was asked to provide information to help explain the discrepancy, but this information has not been provided yet. It is possible that the datum being used in the tables is different to the datum shown in the flight manual. Silent 2 Electro owners should be made aware of this potential discrepancy.

The BGA's *'Safety Briefing'* about the Silent 2 Electro therefore includes the following:

> *Weight & balance. The weight and balance tables for one aircraft seem to be using a moment arm for the nose ballast that is 10 cm greater than the physical distance measured. This would mean that the W&B tables are indicating a more forward CG than reality.*

SSDR Pilot licensing

The pilot was correctly licenced and qualified for self-launch takeoffs in the Silent 2 Electro and held a current flight medical at the time of the accident. Although the pilot's understanding of the rules regarding flight without a current self-launching privilege was incorrect, this did not affect his approach to flying G-CIRK. The pilot reported that his intention had been to maintain his self-launch qualification to give increased flexibility in selecting the most appropriate launch method for a given day's flying. While the pilot had no recollection of the events on the day of the accident, he surmised that he was carrying out self-launches for the purpose of maintaining the launch-type privilege.

The investigation found that some confusion remained in the glider pilot community regarding the regulatory requirements for flying SSDR gliders. It was likely that this confusion had, in part, stemmed from the wording of CAA Information Note 2014/139 which was rescinded in 2016. Contrary to some pilots' understanding, the regulations in force at the time of the accident did not require them to gain a self-launch endorsement for their first flights on this type of glider. Launch type privileges earned on other gliders were transferable to SSDRs. If he had chosen to do so, the accident pilot could have undertaken his first flights in G-CIRK at his home club by winch launching, for which his licence was already suitably endorsed. There is no enduring requirement for SSDR glider pilots to maintain self-launch currency provided they do not use that launch method if the privilege has lapsed. The BGA have added additional guidance to their website to make this clear.

FMM guidance

While the FMM could have been more comprehensive, it exceeded UK regulatory requirements at the time of the accident. The flight notes developed by the manufacturer's UK agent were well-intentioned but were also an implicit acknowledgement that the FMM lacked detail in some areas. The aircraft manufacturer has stated that it will amend the FMM if it resumes production. In the meantime, the BGA's 'Safety Briefing' provides useful guidance.

BPRS awareness

Emergency services first responders attending the accident were initially unaware of the potential risk to life posed by the undeployed BPRS system fitted to G-CIRK. Had the accident occurred in a more remote location without BPRS-aware bystanders emergency services personnel would have only had the BPRS placards to alert them of the hazard. In some accidents the placards can be obscured as a result of structural damage, wreckage orientation or due to fire. An additional layer of safety would be to have an information system that can be used by the emergency services to identify aircraft fitted with a BPRS before the emergency services arrive at the scene. As a result the CAA have updated the aircraft register, G-INFO, to indicate if an aircraft is fitted with a BPRS or other ballistic recovery system such as an ejection seat. The CAA are also planning to contact the registered owners of SSDR aircraft, which are fitted with a BPRS device, to inform them of the BPRS placard types and sizes that should be fitted.

The AAIB also plans to update its guidance document to the emergency services to inform them of the availability of this new information on the G-INFO database.

Conclusion

The accident was the result of an excessively steep climb after takeoff which resulted in a stall that was not recognised or the reaction to it was too late to effect recovery. No mechanical fault or defect was found that would explain the aircraft pitching up excessively after takeoff. The steep climb was most likely the result of an excessive aft stick input that was not corrected.

While the investigation could not positively identify the cause of the aft stick input, it is likely that distraction, pilot workload or stress were factors in the accident. These factors coupled with the aircraft's characteristics of low stick forces with low sensory feedback, and poor stall warning indications made the accident more likely to occur.

Safety actions

The BGA has published and sent a *'Safety Briefing'* to Silent 2 Electro owners in the UK and to the EGU which provides guidance on operating the Silent 2 Electro (Appendix A). It covers ways to address the aircraft's stick force characteristics, its stall characteristics, recommendations on takeoff handling, takeoff flap and takeoff speeds, as well as recommendations on mentally rehearsing aborted takeoffs.

On 24 January 2022 the CAA updated G-INFO to show when an aircraft is fitted with an Emergency Ballistic Device, such as a Ballistic Parachute Recovery System (BPRS), an active ejector seat or canopy miniature detonating cord. The CAA undertook the task of identifying UK-registered aircraft fitted with such devices to support this change. To capture newly-registered aircraft with an Emergency Ballistic Device in the future, the CAA is updating the aircraft registration process to specifically require owners to declare the aircraft status with respect to an Emergency Ballistic Device.

The CAA are planning to contact the registered owners of SSDR aircraft, which are fitted with a BPRS device, to inform them about Sky Wise article SW2021/91 which strongly recommends that owners of these aircraft comply with the requirements of BCAR Section S, Sub-Section K, to clearly identify the presence of the BPRS.

Published: 7 April 2022.

Appendix A

Copy of BGA Safety Briefing sent to UK-based Silent 2 Electro owners and published on the BGA website on 28 January 2022[38]. A link to the briefing was also provided via BGA e-news[39]. This document was also sent to the European Gliding Union (EGU) on 2 February 2022 for onward dissemination to 20 other European gliding associations and to the EGU safety working group.

GUIDANCE FOR PILOTS OF SSDR SELF-LAUNCHING SAILPLANES

Single Seat De-Regulated (SSDR) aircraft

There are very few formal requirements surrounding SSDR's. They are freed from the burden of airworthiness regulation because they pose negligible risk to third parties. However, they are not required to be designed and built to the same standard or have the same level of crashworthiness as conventionally designed CS22 sailplanes and powered sailplanes. The fact that there is no legal requirement for design evaluation, maintenance or flight testing does not mean that these should not be done. It is entirely up to the owner to decide on his or her own approach to these activities; BGA inspectors can provide guidance to owners.

Licencing and medical requirements apply. Flight training for self-launching privileges is likely to take place in a TMG. Launch type training and conversion guidance applicable to pilots of all self-launching sailplanes including SSDR's is available from the BGA website[40] and is recommended to all new pilots of self-launching sailplanes including SSDR's. BGA instructors can provide guidance.

Guidance specific to the Silent 2 Electro

Test flying of a Silent 2 Electro in support of an accident investigation has identified several features associated with the type that pilots may not be aware of:

1. Very light stick forces in pitch combined with high levels of friction in the controls. This means the pilot receives minimal feedback on how the aircraft is responding to control inputs. Flying with a more forward cg should increase stability and stick forces.

Footnote

[38] https://members.gliding.co.uk/bga-safety-management/managing-flying-risk-index/motorgliders-self-launching-and-self-sustainer-sailplanes/ [accessed March 2022]

[39] https://members.gliding.co.uk/2022/01/28/guidance-for-pilots-and-owners-of-ssdr-aircraft/ [accessed March 2022]

[40] https://members.gliding.co.uk/flying-information-and-resources/pilot-licensing/declared-training-organisation-easa-compliant-training/?web=1&wdLOR=c3C4F391C-EFC3-47B7-B3CB-B459A073B23B [accessed March 2022]

2. Very little physical or aural indication that a stall is approaching with full power. Practising power-on stalls at a safe height can teach the pilot how to recognise the subtle indications of an approach to a stall with full power (and with other power settings).

3. Indicated airspeed can increase erroneously during and post stall when full power is set.

4. Self-launching with Flap 0 instead of Flap +1 (Flap +1 is recommended in the flight manual) may be helpful. There is very little difference in stall speed between Flap 0 and Flap +1, but the trim speed is higher with Flap 0, which means that there is a higher trim margin to stall. The angle of climb will be shallower with Flap 0.

5. The flight manual does not provide a take-off or climb speed. A climb speed of 50 kts provides normal handling and should ensure a good margin to stall.

6. Take-off technique. Keeping the tailwheel on the ground, or just above it, until lift-off reduces the chance of a propeller strike. Aggressive use of large forward stick inputs early in the ground run should be avoided, particularly on uneven surfaces, as this increases the likelihood of overcontrolling in pitch and a prop strike.

7. Procedure for an aborted take-off. Cutting the power quickly using the FES rotary knob is not as easy or as intuitive as pulling back on a throttle lever (for example in a TMG). Pilots should on all occasions complete a comprehensive self-brief for the take-off and any eventualities. This should always contain a point on the take-off run where the acceleration of the aircraft can be checked. Pilots should mentally rehearse what they would do in the event of needing to abort a take-off to be able to correctly react to a problem.

8. Weight and balance. The weight and balance tables for one aircraft seem to be using a moment arm for the nose ballast that is 10 cm greater than the physical distance measured. This would mean that the W&B tables are indicating a more forward CG than reality.

Risk management guidance for flying motor gliders, self-launching and self-sustainer sailplanes is available from the BGA website[41].

Footnote

[41] https://members.gliding.co.uk/bga-safety-management/managing-flying-risk-index/motorgliders-self-launching-and-self-sustainer-sailplanes/ [accessed March 2022]