Accident

Aircraft Type and Registration:	Cagatay CGT-50	
No & Type of Engines:	1 two-stroke DA100 piston engine 4 electric motors	
Year of Manufacture:	(Serial no: 569)	
Date & Time (UTC):	5 October 2023 at 1115 hrs	
Location:	Radnor Range, Powys	
Type of Flight:	Demonstration flight	
Persons on Board:	Crew - None	Passengers - None
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	Destroyed	
Commander's Licence:	Other	
Commander's Age:	29 years	
Commander's Flying Experience:	83 hours (of which 2 were on type) Last 90 days - 7 hours Last 28 days - 4 hours	
Information Source:	AAIB Field Investigation	

Synopsis

While conducting a demonstration flight at Radnor Range the right wing separated from the unmanned aircraft. The remainder of the aircraft descended rapidly, out of control and struck the ground close to personnel who were standing under the flight path.

The investigation found that the wing assembly on the accident aircraft did not have sufficient structural strength to carry the wing bending loads encountered in 1 g straight and level flight. Structural components known as wing joiners, which attached the wings to the fuselage, were shorter than the design specification. Together with a wing design that allowed movement of the joiner position and an absence of procedures to ensure the wing joiners were installed symmetrically during aircraft assembly, this created a condition where there was an uneven bending load distribution on the forward wing joiner.

The investigation determined that it was likely that old stock wing joiners from an earlier aircraft development model were inadvertently fitted to the aircraft at the production facility.

The UAS was operating in the specific category under a CAA operational authorisation (OA). The CGT-50 was not designed, built or tested to any recognised standards, nor was it required to be for operation in the specific category.

The manufacturer took several safety actions to improve quality and component control in its production facility. These included introducing dimensional tolerances on design

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drawings, introducing quality checks on supplied components, introducing serial numbers for wing joiners, modifying the design and production process and introducing wing joiner assembly procedures.

The range reviewed its safety plan and indicated its intention to make several improvements to operational communication and hazard management.

History of the flight

The aircraft was being flown during a week-long event, demonstrating unmanned technologies at Radnor Range[1] (the range). Its planned flight the day before the accident was cancelled for weather reasons.

The aircraft's technicians performed its assembly and pre-flight checklists normally. Loaded to its MTOW of 55 kg, the aircraft was started at 1114 hrs, facing into a reported headwind for the route of 12-13 kt. It took off vertically then transitioned to a forward climb. Around twelve seconds later the right wing detached. The aircraft descended rapidly, striking the ground near some pyrotechnic operatives who were standing under the flight path (Figure 1).

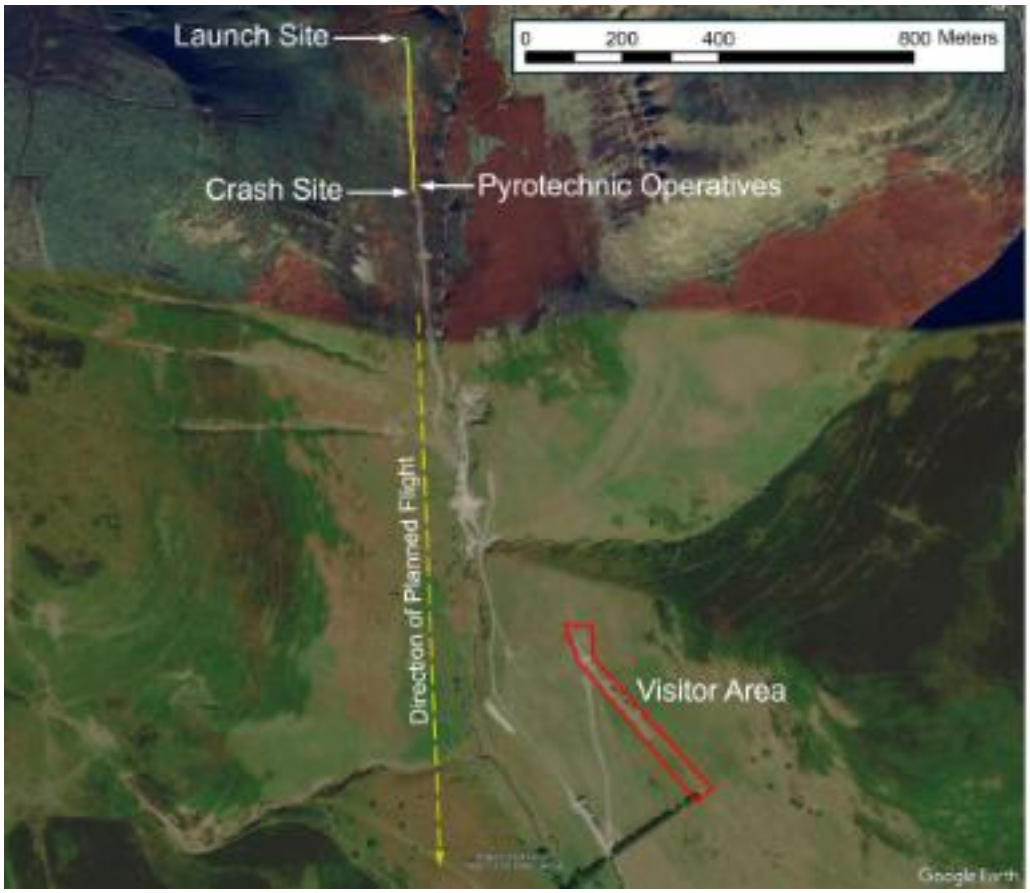

Figure 1

Overview of flight path and location of pyrotechnic operatives and visitor area

Footnote

[1] A civilian small arms range.

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Background to the operation

The CGT-50 UA was designed, manufactured, operated and distributed by a single organisation, based in Ireland, which for simplicity, will be referred to in this report as the operator. Much of the composite airframe manufacturing and component integration was carried out under sub-contract at a separate, but closely linked, production facility in Turkey. This was done using build-to-design documentation and instructions, as well as avionic systems and software provided by the operator.

Civil Aviation Publication (CAP) 722[2] *'Unmanned aircraft system operations in UK airspace – Policy and Guidance'* outlines policy and guidance in relation to the operation of UAS. It describes that UAS operations are regulated in a manner that is proportionate to the level of risk that the individual operation presents, with UAS operations falling into one of three categories, open, specific and certified.

The CGT-50 operation was being conducted under the specific category, a key element of which is that the UAS operator is required to hold an OA, issued by the CAA. CAP 722[3][4] *'Unmanned Aircraft System Operations in UK Airspace – Operating Safety Cases'* outlined the process that an applicant should follow to complete a safety assessment as part of the application process for an OA. This required submitting an operational safety case (OSC) for the proposed operation. The CAA would evaluate the OSC to determine if the operator's risk assessment was valid, and if satisfied, issue an OA. The OA document sets out the conditions and limitations of the operation.

The OA for this operation was issued by the CAA on 7 September 2023. The operator submitted an OSC, structured over three volumes[5], as part of the application process. The operator's OSC was prepared for the sole purpose of the demonstration flight at Radnor Range in October 2023, and the OA was valid only for this operation.

Operational authorisation documentation

Introduction

The operator's OSC for this operation was aligned with the range's safety plan and related documentation. The OA specified that *'Flights **must not** be carried out within **50 m**[6] of uninvolved persons...* [or] *assemblies of people.'*

Footnote

[2] Ninth edition amendment 1 dated December 2022 was extant at the time of the accident and at the time of the operator's application for an OA.
[3] Second edition dated December 2022 was extant at the time of the operator's application for an OA.
[4] From 23 April 2025, CAP 722A was withdrawn and UK SORA (Specific Operations Risk Assessment) replaced the CAP 722A OSC risk assessment method.
[5] Volume1: Operations manual; Volume 2: Systems; Volume 3: Safety risk assessment.
[6] Reduced to 30 m during takeoff and landing.

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Information from the OSC

The flight team

The OSC Volume 1 explained that a flight team is led by a *'Flight supervisor'*, who is responsible for operational communications during the flight. They decide from the operator's perspective *'…whether or not a flight can… proceed'*. They maintain *'live oversight of actual flight operations'*.

The *'Remote pilot'* (RP) is responsible *'for the overall safe conduct of the flight'*, ensuring any *'previously unidentified risks… are assessed and that appropriate actions are implemented'*. The RP is supported by a *'Visual observer/technician'* and *'Deployed airspace observers'*, who maintain situation awareness of the UA and alert hazards to the RP.

Operating guidance

The OSC Volume 1 included the following operating information:

> *'Remote pilots and accountable manager[7] will attend the flight briefings[8] from Range Control… The UAS is equipped with an FPV[9] camera which may be used to provide additional situational awareness during flight… For BVLOS VM[10] operations, 2 UHF radios and 2 cell phones[11] will be available to flight crew at all times… the first coordination will be made through Range Control for flight... Due to the nature of the site and demonstration, all personnel on-site are deemed as involved persons and will attend a safety briefing in advance of the planned flights at Radnor Range. All personnel outwith the flight crew and deployed airspace observers will be located within the designated "Visitor Area"...*
>
> *On completion of the pre-flight preparation the Supervisor[12] will contact range control to confirm permission to fly and ascertain an update on any planned movements. The Supervisor will then evaluate whether the operation can proceed and communicate the decision and any requirements or restrictions to the flight team. Supervisor will also liaise with ATC confirming the launch of the UAS…'*

Safety risk assessment

The OSC Volume 3 stated the *'Risk of harming uninvolved persons and third party aircraft is minimised and controlled'* and *'Ground crew informed about take-off and landing timing'*. The *'operation is taking place over a controlled ground area and within a NOTAM… and safety distances are maintained with ground personnel… with visual observers… to keep the UA within line of sight at all times'.*

Footnote

7 Operator's CEO.
8 Refers to 'Safety briefing' in Radnor safety plan section.
9 First person view.
10 Beyond visual line of sight with visual mitigation.
11 The flight crew and deployed airspace observers use these to communicate.
12 Flight supervisor.

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Radnor range safety plan

The *'Radnor range safety plan'* explained the event would be overseen by the Radnor safety officer (RSO). The RSO would *'Ensure that all personnel are made aware of the control measures identified in the Activity Risk Assessments*[13] *and that they are applied… Deliver a safety brief… to all personnel at the start of the activity… Ensure the whereabouts of all personnel is always known… Intervene if a breach of safety is about to occur'.*

Information from the range

The range operations director (ROD) explained the pyrotechnic operatives were scheduled to be present in the operating area until 1300 hrs (Figure 1), when the accident flight was due to commence. However, the flight was brought forward because of an earlier weather window, meaning they were still near the planned flight path when the flight occurred. Although the flight team made a radio call before taking off, both the ROD and the operator's RP commented that radio communication between them was somewhat unclear. The pyrotechnic operatives were visible on the aircraft's FPV camera (Figure 2). They had radio contact with the range, but not with the flight team.

Figure 2

View from fin-mounted FPV camera showing location of pyrotechnic operatives

As a result of this accident, the range reviewed its safety plan and intends to make the following improvements: ensure robust radio communications between all parties on the range; ensure that a range employee accounts for the location of every person on the range before takeoff is permitted; introduce standard phraseology for takeoff permission and a

Footnote

[13] Contained in OSC Volume 3.

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"stop stop stop" call for use by anyone on the range who identifies a hazard; and advise range employees to "stop and think" about the ramifications of a schedule change before continuing to operate.

Additional information from the operator

The RP reported that, with the visitor area on the valley's east side, the UA's flight was planned to hug the valley's west side, parallel to the road. The flight team were aware of people on the road, but not that they would be under the flight path.

The RP reported believing the operator had learned from the event, for example, being mindful of the extent to which external pressures might affect an operation.

Recorded information

Data from the aircraft was recorded by the ground control station (GCS) at 1 Hz and a subset of this data in cloud storage at 5 Hz. The data included GPS position, inertial speed and acceleration, attitude, engine, battery, aircraft status and warning. A forward-looking camera mounted on the fin of the aircraft streamed video to the GCS (where it was recorded).

Accident flight

Figure 3 shows the flight path of the aircraft. The duration of the flight was about 40 seconds covering a distance of 340 m. Over the first 16 seconds, the aircraft climbed 60 ft vertically, before transitioning into forward climbing flight. As the aircraft accelerated through 53 KTAS (42 kt groundspeed), the video recording showed the right wing bending upwards at the root. At this point the aircraft was at 235 ft agl, having climbed a total of about 174 ft. It then began to tumble and descend to the ground at about 60 kt during which the right wing detached.

Video footage taken by one of the pyrotechnic operatives shows the aircraft overhead just as the wing failed.

The video images are consistent with the aircraft nominally in 1 g flight conditions ie wings level and no indication of buffet when the wing failed. Acceleration data from the aircraft's attitude and heading reference system (*AHRS*) was only recorded at the GCS (at 1 Hz) and not in the cloud storage. These 1 Hz samples were unlikely to have recorded any spikes in the acceleration data given such spikes happen over a fraction of a second with an instantaneous peak.

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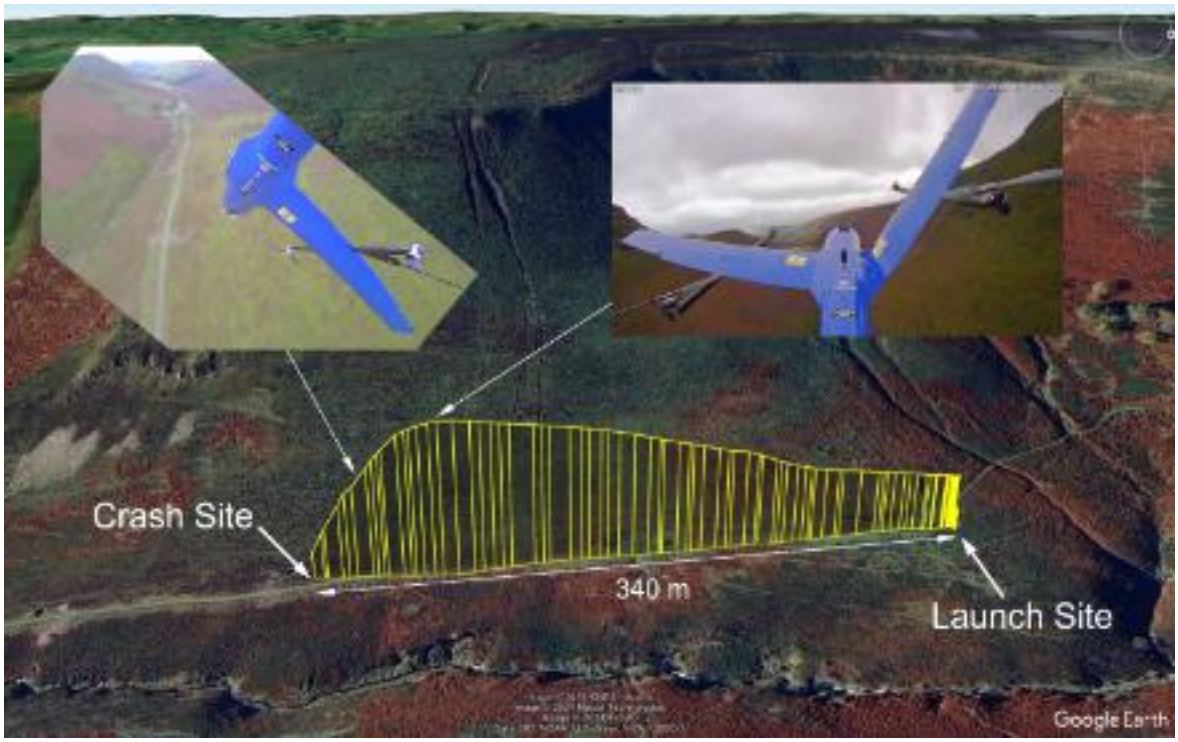

Figure 3

Flight path of the aircraft showing the view from the fin-mounted FPV camera when the wing failed and two seconds later as the aircraft tumbled towards the ground

The aircraft came to rest over 100 m further down the valley from the pyrotechnic operatives, close to the track.

Description of aircraft

General

The CGT-50 (Figure 4) is a fixed-wing, vertical takeoff and landing (VTOL) UA, with a T-tail configuration and landing skids located at the front. It is equipped with a primary two-stroke gasoline engine which provides power for forward flight and four electric motors for VTOL. The electric motors, powered by four lithium polymer batteries, are mounted on carbon fibre booms, fixed to the wing during aircraft assembly.

The CGT-50 has a maximum all-up weight of 55 kg, including provision for 5 kg payload. It has a maximum endurance of six hours and can operate to a maximum altitude of 18,000 ft.

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Figure 4
CGT-50

Pre-flight wing assembly

The aircraft is stored and transported in a dedicated transportation box and is assembled on its launch table prior to flight.

A forward and an aft wing joiner are inserted through fixed joiner guides in the centre fuselage (Figure 5) and each wing, in turn, is fed on to the wing joiners, which slot into fixed joiner guides (hollow tubes) within the wing. Each wing joiner guide is fitted with an end cap at its outboard end. Mechanical connection of the wing is achieved via two fixed bolts at the fuselage-wing joint, with access to secure the nuts gained via the battery compartment in each wing. The VTOL booms are then attached to the underside of each wing and various services are connected.

Section 1.7 of the CGT-50 user manual[14] describes the steps required to assemble the aircraft accompanied by photographs. These are also described in the CGT-50 assembly checklist. At the time of the accident, neither the user manual nor assembly checklist included any instructions to require the wing joiners to be centralised on the fuselage, so that an equal joiner length was inserted in each wing.

Footnote

[14] Revision B, dated October 2022.

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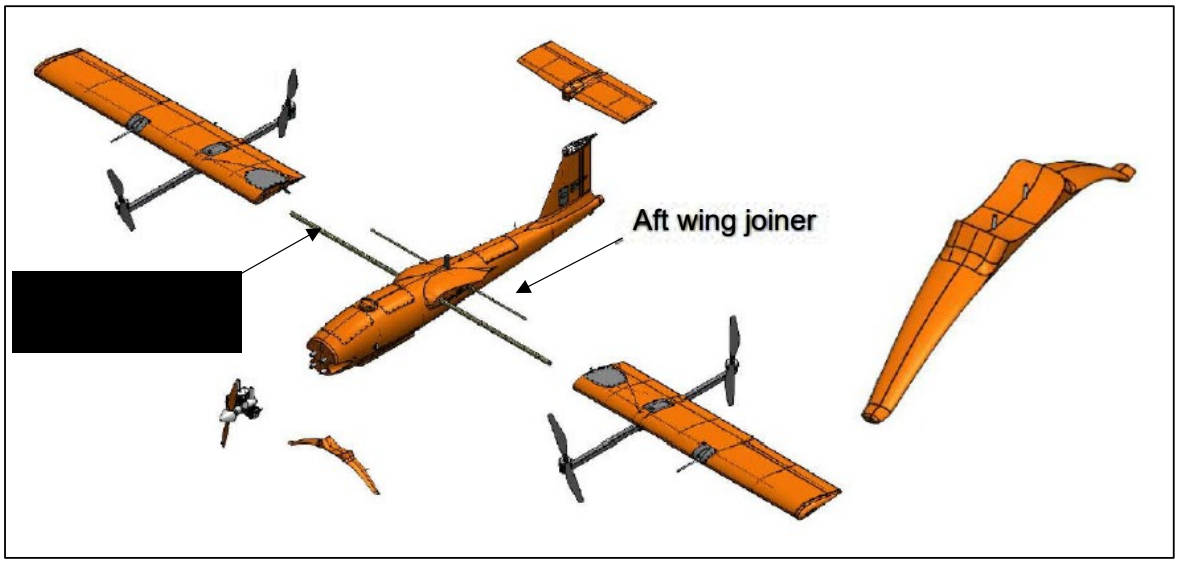

Figure 5
CGT-50 general arrangement

Wing structure

The CGT-50 wing and fuselage structure are constructed primarily from carbon fibre reinforced polymer composite (CFRP), with glass fibre polymer composite (GFRP) used in selected locations, including the wing root ribs and wing attachment point on the centre fuselage.

Two thin-walled, cylindrical, CFRP tubes, known as wing joiners, act as wing spars, reacting wing bending loads and transferring these into the fuselage.

Aircraft manufacturing

The CGT-50 software, electronics and airframe are designed by the operator. Manufacture of electronic components and composites materials are outsourced to suppliers.

The CGT-50 fuselage and wings are fabricated at the operator's production facility using a multi-step composite manufacturing process, which relies predominantly on manual lay-up and closed-moulding processes.

Aircraft history

Aircraft 569 arrived at the operator's facility in Ireland in August 2023, from its production facility in Turkey, prior to which it had completed a single flight of 16 minutes duration in January 2023. Three short hover-test flights and three training flights were performed by the operator's RPs between 4 and 21 September 2023, with no anomalies noted. At the time of the accident, the aircraft had accumulated a total flight time of 1 hour and 40 minutes.

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Aircraft examination

Following the accident, the aircraft wreckage was photographed in situ by the operator's personnel before being loaded into the aircraft's transportation box and transported to its facility in Ireland. The wreckage was examined by the AAIB at the operator's facility several days after the accident.

The wings and empennage were relatively intact; the fuselage was heavily fragmented.

Examination of the right wing and wing-to-fuselage connection revealed that the reinforced root rib had been pulled out of the wing structure and had experienced an intra-ply failure. The forward third of the root rib remained loosely attached to the right wing, while the remaining portion of the root rib, along with the inboard wing root skin, remained attached to the fuselage by the wing attachment bolts (Figure 6).

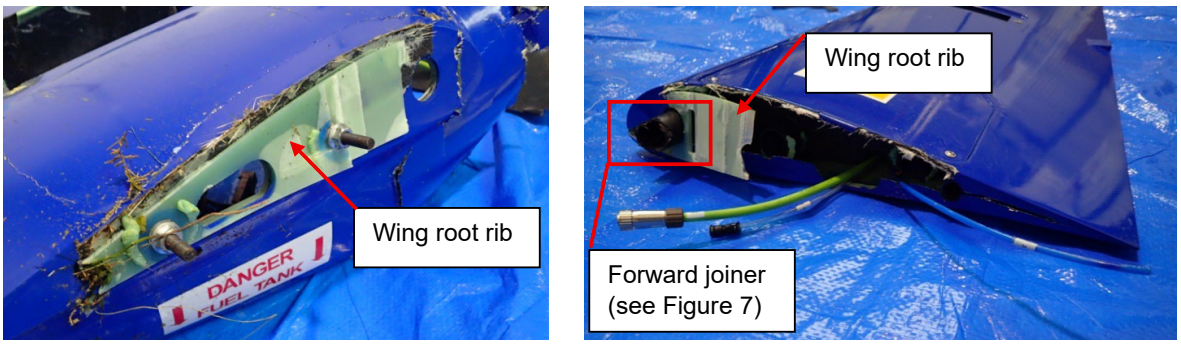

Figure 6

Right wing-to fuselage attachment interface and large portion of wing root rib (left image) and right wing root with remaining small portion of wing root rib attached (right image)

The forward and rear single-piece wing joiners had each broken into three parts, with a segment remaining installed in each wing and a central portion remaining within the fuselage. The fracture face of the forward joiner portion remaining in the right wing, which can be seen in Figure 6, is shown in more detail in Figure 7.

Figure 7

Fracture face of right wing forward wing joiner

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Each joiner segment was removed and measured, as was the internal length of the joiner guide tube in each wing. The intact wing joiners from sister aircraft 570 were also measured for comparison. The results are summarised in Table 1.

Joiner	Left wing portion (cm)	Fuselage portion (cm)	Right wing portion (cm)	Total length (cm)
569 Forward joiner	82	36	108	226
569 Rear joiner	59	38.5	55	152.5
569 Forward joiner guide tube	116	39	107	262
569 Rear joiner guide tube	58.5	38.5	58.5	155.5
570 Forward joiner	N/A			224
570 Rear joiner	N/A			141

Table 1

Wing joiner measurements from Aircraft 569 and Aircraft 570

It was evident from these measurements that when aircraft 569 had been assembled prior to the accident flight, the forward and rear joiners had not been centralised on the fuselage to allow for symmetrical joiner insertion in each wing.

The forward joiner on aircraft 569 was 2.0 cm longer than that from the sister aircraft 570, and the rear joiner was 14.5 cm longer.

Internal measurement of the forward joiner guides on the accident aircraft identified that a wing joiner could be inserted 116 cm into the left wing, but only 107 cm into the right wing. It was noted that the end cap was missing from the outboard end of the forward joiner guide in the left wing. The absence of the end cap meant that it would be possible for the forward joiner to be installed further into the left wing than intended, such that it could protrude beyond the end of the joiner guide, until it reached the next internal rib. Despite this possibility, the as-found installation of the forward wing joiner was more biased towards the right wing.

The operator stated that the total length of the joiner guides was designed to be slightly longer than the joiners and that the exact positioning of the joiners within the guides was not critical. It did not consider joiner end caps to be essential items.

The operator reported that it had found the end cap dislodged from the forward joiner after the aircraft had arrived at its facility. The loose end cap was removed from the wing prior to the accident flight but subsequently could not be located by the operator following the accident and was therefore not available for examination.

Visual examination of the outboard end of the left wing forward joiner guide, where the end cap should have been fitted, showed that adhesive was present on only half of the circumference and the surface condition was not conducive to achieving a strong bond.

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Detailed component examination

The fracture faces from the left and right wing segments of the failed joiners and the wing-to-fuselage attachment points, were subject to detailed examination at a materials failure laboratory to determine the failure modes.

Optical microscopy

Cross-sections of the two wing joiners were examined in an optical microscope. It was noted that sections from the rear joiner were more resin-rich with a relatively low fibre content and exhibited increased porosity compared to those from the forward joiner. The forward joiners had an approximate average wall thickness of 2.5 mm, while that of the rear joiners was approximately 1.0 mm but there was some variation along their length.

Fractography

The fracture faces of the failed joiners were examined using a scanning electron microscope (SEM). The architecture of the fibres was primarily woven and unidirectional plies were observed with the lay-up. The fractured fibres showed evidence of overload failure in tension and compression; some fibre ends displayed radial markings consistent with static tensile fracture, while other fibres exhibited microbuckling caused by static compression fracture. In general, the tensile fractures were present on the lower surface and compressive fractures on the upper surface. This was consistent with flexural failure of the joiners due to upwards wing bending.

SEM examination of the resin matrix regions within the wing joiners showed features consistent with static overload failure. There was no evidence of fatigue crack propagation within the fracture surfaces of the wing joiners.

Right wing root rib

Examination of the GFRP root rib reinforcement showed that there was an absence of surface preparation or bonding along the bottom half of the bond line, on the surface that bonded to the wing root skin. This would have compromised the strength of the structure in this area and promoted peeling fracture under the wing bending loads (Figure 8).

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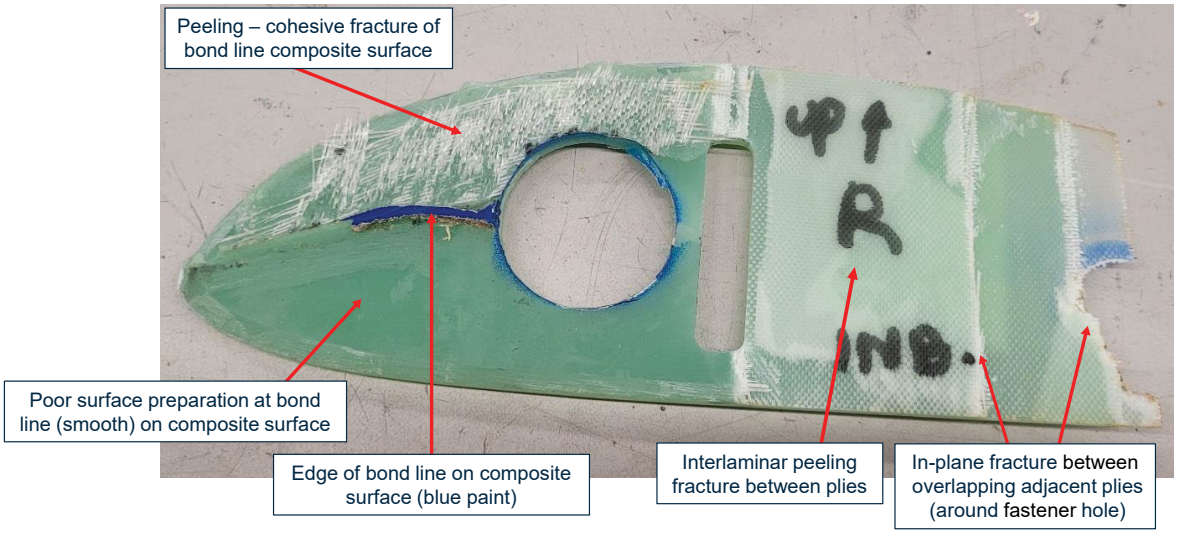

Figure 8

Inboard face, forward portion of right wing GFRP root rib

On the opposite (outboard) surface to that shown in Figure 7, the forward CFRP root rib reinforcement also exhibited poor surface preparation, poor adhesive bond and dis-bonding regions, where the joiner guides and wing bolt covers attached to the root rib.

Operator's internal investigation

Findings

The operator carried out a review at its production facility and identified that at the time of the accident, no acceptance test procedures or specific quality checks were in place for wing joiners upon receipt from the supplier. No tracking procedures were in place for individual components and wing joiners were not individually serialised.

The wing joiners are supplied as standard off-the-shelf components, with the forward joiner measuring 2.5 m and the aft joiner 2.0 m. During production assembly of the CGT-50, the joiners are shortened to the required length (2.48 m and 1.5 m) when the wings are offered up to the fuselage. As the wings are built using manual lay-up, the production facility expected some variation in final joiner length.

The wing joiners from aircraft 570, the sister ship to aircraft 569 and produced in the same batch, also did not meet specification on length. At the time of this discovery, aircraft 570 had been shipped to a customer. The operator requested the wing joiners to be returned and they were replaced with another set that met the correct specification.

Shorter forward wing joiners of 2.25 m were used on a previous product, the CGT-45, the last example of which was produced in 2019.

The operator identified that there were two possible scenarios to explain the incorrect joiner lengths on aircraft 569 and 570. Either the forward and rear wing joiners were cut to different incorrect lengths during aircraft assembly; or the joiners used for 569 and 570 were from old stock, which remained in stores at the production facility from the CGT-45 production, which it considered more likely.

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A review of wing joiner stock at the production facility following the accident revealed that all existing joiners in stock were the expected length, and so the operator did not consider there was an issue with the supply of the joiners.

Resulting actions

In response to the findings of both the AAIB's and its own investigation, the operator implemented the following measures to improve quality and component control in its production facility.

- Introduced quality control procedures to perform a dimensional check, weigh and test bending deflection of wing joiners upon receipt at production facility.
- Added dimensional tolerance values for wing joiners to design drawings and quality control procedures.
- Allocated individual serial numbers to wing joiners.
- Modified the wing design and simplified the production process to allow wing joiners to be used in standard supplied lengths, without the need for shortening during assembly. This included aft joiners being ordered in 1.5 m length rather than 2.0 m.
- Modified the design of the joiner guide end caps to increase the adhesive surface area and bond strength.

The operator also indicated its intention to amend the pre-flight assembly for installation of wing joiners onto the aircraft

Airworthiness considerations

CAP 722 indicates that while certified UA and/or certified equipment may be used for specific category operations as a means of risk reduction, or as a mitigating measure in the risk assessment, there is no requirement for UA's operating in the specific category to be designed, certified, built or tested to any recognised standards.

The OA process relies on operational and procedural mitigations to separate the hazards associated with the particular UA operation from uninvolved persons that could be harmed. At the time of the operator's application, the process did not include any independent design, technical or airworthiness assurance.

During the CAA's assessment of the operator's application, the aircraft was not inspected. The CAA advised the investigation that, based on the relative complexity of operation, the disclosed operational mitigations and the fact that the operation was due to be conducted in a sterile area, this was not considered a necessary part of the application process.

Failure modes

Section 1.18 of the operator's OSC Volume 2 outlined the known failure modes that the operator considered could occur on a CGT-50 UA during flight. Information was presented

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in tabular form listing the failure mode, the immediate technical consequence, its impact on the control of the UA, recommended pilot actions in response to the failure, resulting outcomes and whether such outcomes lead to operation outside the pre-defined operational volumes.

It included the failure mode *'Structural failure of primary aircraft structure (fuselage, wing, horizontal or vertical stabiliser),'* which it described as an improbable single point failure. This failure mode would result in immediate loss of control of the UA, with uncontrolled flight into terrain (UFIT). The only documented pilot action was to initiate the emergency response plan. The operator stated that the operational volume was defined such that any UFIT would occur in the ground buffer area[15].

Safety risk assessment

The operator's OSC Volume 3 described the operator's hazard identification and the classification of likelihood and severity for each hazard. In Section 2.8, the operator defined 61 risk mitigations (numbered M1 to M61) based on its experience of CGT-50 operations. The mitigations largely related to pilot competence, training, operational procedures and separation of any potential aircraft hazard from uninvolved persons on the ground.

Mitigation M45 stated *'CGT-50 UAS manufactured according to standards defined in OSC Volume 1 Attachment 2'.*

M45 was listed as a mitigation against several hazards relating to UA system or component failures. It was also listed as a mitigation against hazard No 1: *'Airframe failure: including wings, main frame and total tail surfaces'*. This hazard was described as having outcomes including mid-air collision with another aircraft or collision with an uninvolved person.

Section 4 of Volume 3 presented each of the identified hazards in the format of Claim, Argument, Evidence. For hazard No 1, the OSC claimed that risk was 'Tolerable and ALARP'[16] and presented the following argument:

> *'CGT-50 manufactured to quality standards. CGT-50 is maintained according to defined procedures. Risk of harming uninvolved persons and third party aircraft due to airframe failure is minimised and controlled within the operation. The operation is taking place over a controlled ground area and within a NOTAM to minimise the risk to uninvolved persons and third party aircraft. Operation is taking place below 400 ft and safety distances are maintained with ground personnel. The operation is taking place with visual observers to observe third party aircraft approaching the operation area and to keep the UA within line of sight at all times. If an uncontrolled flight occurs due to a critical system failure, the flight simulation shows the system will remain within a horizontal distance of %45 [sic] of flight altitude and at least 1:1 ground risk buffer is used for this operation.'*

Footnote

[15] A minimum 150 m buffer from the aircraft's flight path is defined in the OSC to mitigate against ground risk. The OSC states that the aircraft will remain withing the ground buffer, even in uncontrolled conditions.

[16] As Low As Reasonably Practical.

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Analysis

Proximity of the aircraft to ground personnel

The planned operation

The OA was granted upon a comprehensive OSC produced by the operator, in consideration of the range's safety plan. Multiple flights by different operators were scheduled to occur inside a controlled area.

Clear controls were established to minimise risk to *'uninvolved'* spectators. They were confined to a visitors area which was well over the required distance from the planned flight path. Everyone else in the operating area was considered *'involved'* and would attend safety briefings. The RSO would monitor personnel movement on the range and give takeoff permission for each flight. Methods of communicating, maintaining situation awareness, and announcing hazards were specified.

The accident flight

Weather issues meant the accident flight was brought forward, inadvertently overlapping with the pyrotechnics operatives being under the flight path. The RSO might have been unaware of their presence, and/or it was not identified as a hazard. Although the pyrotechnics operatives' vehicles were visible on the aircraft's FPV camera, the intended flight path was perhaps closer to the road underneath than the flight team realised.

The flight team called for takeoff permission. However, unclear radio communications with the range – and absent radio contact with pyrotechnics operatives – probably reduced situation awareness and impeded the intended takeoff decision making process. The aircraft subsequently struck the ground just over 100 m from the pyrotechnics operatives.

The OA process puts onus on protecting uninvolved persons. Although the event underwent substantial planning, and occurred in a controlled operating area, the resulting proximity of the falling aircraft to the pyrotechnics operatives alludes to practical challenges related to protecting involved persons, robust communications, and the pressures of schedule changes. Consequently, the range has reviewed its safety plan and made several improvements to methods of operational communication and hazard management.

Failure of the right wing

Detailed examination of the wing joiner fracture faces identified the presence of both tensile and compressive static overload failures within the fractured fibres. This was consistent with flexural failure of the joiners due to upwards wing bending.

The reinforced GFRP structure at the root rib also experienced delamination, intra-ply failure and bonding failure. Because the wing joiners and root rib were effectively independent from each other (ie the joiner guides were not mechanically fastened, nor effectively bonded to root rib), there was insufficient evidence to determine with certainty the failure sequence. So, it was not determined whether the root rib or wing joiners failed first. Together though,

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the observed failures indicated that the wing assembly did not have sufficient structural strength to carry the wing bending loads encountered during the accident flight.

The wing separated when the aircraft was in 1 g straight and level flight. From the in-flight video and flight log, there appeared to be nothing unusual about the wing loading or the accelerations experienced by the aircraft during the accident flight. Although it is acknowledged that sampling rate limitations meant the recorded acceleration data would have been unlikely to capture any instantaneous peak accelerations.

Production quality of wing components

The wing joiners supplied by the production facility and fitted to the accident aircraft were shorter than the design specification. This would have compromised their ability to transfer wing bending loads to the fuselage. The operator determined the most likely scenario was that old stock wing joiners from the CGT-45, last produced in 2019, were inadvertently fitted to aircraft 569 and sister aircraft 570 at the production facility.

No tracking procedures were in place for individual components in the production facility and wing joiners were not individually serialised. There was also an absence of quality control procedures for externally supplied components. As a result of this investigation, the operator has undertaken steps to serialise wing joiners and introduce quality checks on receipt of components at the production facility.

The manufactured quality of the wing joiners, particularly the rear joiner which exhibited resin-rich areas, was found to be of a lower quality in comparison with that of typical aerospace grade materials and structures.

The reinforced GFRP root rib and wing-fuselage attachment exhibited areas of poor/absent surface preparation and variable uniformity of adhesive application between the GFRP and the wing structure. This created a bond quality that was poor in comparison to normal aerospace standards of construction. Combined with variable bonding of the joiner guides to the wing structure, this would have resulted in a lack of strength in the wing root structure which could have contributed to the wing failure.

Operational experience

While the operator conducted quality checks upon receipt of a new aircraft from the production facility, at the time of the accident these checks did not specifically include the wing joiners. Having conducted several hover tests and training flights on the accident aircraft without issue in the weeks prior to the accident, the operator considered it to be a proven airframe with validated flight time. No problems were encountered on the previous flights which could have alerted the operator to issues with the wing joiners or the structural integrity of the wing attachment. As such, the reduced-length wing joiners supplied with aircraft 569 were not identified until the investigation.

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Design considerations

The CGT-50 was not designed, built or tested to any recognised standards, nor was it required to be, in order to be operated in the specific category, or for the operator to hold an operational authorisation. There were no defined load cases for the flight envelope of the aircraft and structural load-carrying components were not designed to any pre-determined limit or ultimate loads. The design, development and testing process involved a large degree of trial and error. The manufacturer considered the CGT-50 to be a proven aircraft, based on a substantial number of 'successful' test flights and operational flights.

The CGT-50 wing design was such that the wing joiner guides were intentionally slightly longer than the joiners, to accommodate a degree of variability in the installed joiner position. In addition, the absence of the end cap on the left wing forward joiner guide on the accident aircraft, would have created the possibility for the forward wing joiner to be inserted further than intended into the left wing. Despite this, aircraft examination showed that the installation of the forward wing joiner was more biased towards the right wing, a situation which was exacerbated by the installation of joiners that were shorter than required. This would have resulted in an uneven load distribution on the forward joiner.

At the time of the accident, neither the aircraft assembly instructions in the CGT-50 user manual nor the aircraft assembly checklist, included instructions to centralise the joiners on the fuselage, to ensure that an equal joiner length was inserted in each wing. The operator has since introduced assembly instructions which specify this requirement. It also stated its intention to modify the aircraft design to mitigate this condition.

Risk mitigation considerations in the OSC

The hazard of a failure of primary aircraft structure, and the associated consequences, were recognised and documented in the operator's OSC. While the OSC risk assessment for this hazard relied predominantly upon mitigations related to pilot competence, training, operational procedures and separation of any potential aircraft hazard from uninvolved persons on the ground, it also relied on the technical mitigation that the aircraft was manufactured and maintained to quality standards. The investigation found that this mitigation was ineffective in preventing the hazard from being realised, due to the design and production quality issues described in this report.

Conclusion

The right wing separated from the aircraft during flight because the wing assembly on the accident aircraft did not have sufficient structural strength to carry the wing bending loads encountered in 1 g straight and level flight. The combination of wing joiners that were shorter than the design specification, a wing design that accommodated a degree of movement of the joiner position and the absence of procedures to ensure the wing joiners were installed symmetrically during aircraft assembly, created a condition where there was an uneven bending load distribution on the forward wing joiner.

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Although the flight occurred in a controlled area, away from protected uninvolved spectators, the aircraft fell next to personnel involved in the range operation. The range has taken safety action to improve communication and hazard management during operations.

Safety actions

The range reviewed its safety plan and stated its intention to ensure robust radio communications between parties on the range; ensure the location of every person on the range is known before takeoff is permitted; introduce standard phraseology for takeoff permission; introduce a “stop stop stop” call; and advise range employees to “stop and think” about the ramifications of a schedule change before continuing to operate.

To improve quality control measures at its production facility, the operator introduced serial numbers and conformance checks for wing joiners and simplified the production process. It modified the wing design in relation to wing joiner length, including the addition of dimensional tolerances and to increase the adhesive surface area for joiner guide end caps.

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GLOSSARY OF ABBREVIATIONS

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