Statens haverikommission
Swedish Accident Investigation Authority

Final report RL 2020:08e

Accident at Storsandskär, Västerbotten County, on 14 July 2019 involving the aeroplane SE-MES of the model GA8-TC 320, in conjunction with parachuting activities at Umeå Parachute Club.

File no. L-96/19

9 September 2020

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available on SHK´s web site: www.havkom.se

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This document is a translation of the original Swedish report. In case of discrepancies between this translation and the Swedish original text, the Swedish text shall prevail in the interpretation of the report.

Cover photo no. 3 – © Anders Sjödén/Swedish Armed Forces.

Content

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

Investigations of aviation incidents are governed mainly by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and by the Accident Investigation Act (1990:712). The investigation is carried out in accordance with Annex 13 of the Chicago Convention.

The investigation

SHK was informed on 14 July 2019 that an accident involving an aeroplane with the registration SE-MES had occurred at Storsandskär, close to Umeå Airport, Västerbotten County, the same day at 14:08 hrs.

The accident has been investigated by SHK represented by Hans Ytterberg, Chairperson until 5 August 2019, subsequently, Mikael Karanikas, Ola Olsson, Investigator in Charge, Sakari Havbrandt, Technical Operations Investigator, Johan Nikolaou, Peter Swaffer and Gideon Singer, Operations Investigators and Tomas Ojala, Rescue Services Investigator.

SHK has been assisted by Magnic AB, expert in audio and visual analysis, Ulf Ringertz, expert in aeronautical engineering, Liselotte Yregård, aeromedical expert and Element Materials Technology AB, expert in metals and material engineering.

Max Marton from the Australian Transport Safety Bureau (ATSB) has participated as an accredited representative on behalf of Australia. He has been assisted by David Punshon who is an adviser from the Civil Aviation Safety Authority (CASA) and by advisers from GippsAero Pty Ltd.

Joshi Deepak from the National Transportation Safety Board (NTSB) has participated as an accredited representative on behalf of the USA.

Jerry Köhlström, Bernt Kolm and Magnus Axelsson have participated as advisers for the Swedish Transport Agency.

David Waller has participated as an adviser for the European Union Aviation Safety Agency (EASA).

The following organisations have been notified: European Commission, EASA, ATSB, NTSB and the Swedish Transport Agency.

Investigation material

Interviews have been conducted with the jump leader, the person responsible for flight operations at Umeå Parachute Club, the examiner who conducted the pilot’s most recent proficiency check, the pilot’s parents, parachutists from Umeå Parachute Club, the air traffic controller on duty, the rescue swimmer from the Swedish Maritime Administration, the pilot who was first to fly over the area and identified the site, the chairperson of the Swedish Parachute Association (*Svenska Fallskärmsförbundet,* SFF) and several witnesses to the accident.

The accident site and the aeroplane have been examined. Technical examinations have been conducted of, among other things, aeroplane parts and material that was on board. Data from sensors have been obtained and analysed. A reference flight has been performed.

Meetings have been held with relatives on 18 September 2019 and 18 March 2020 in order to keep them informed.

A meeting with the concerned parties was held on 19 March 2020. At the meeting SHK presented the facts which were available at that time.

Final report RL 2020:08

Aircraft:	
Registration, type	SE-MES, GA8-Series
Model	GA8-TC 320
Class, airworthiness	Normal, Certificate of Airworthiness and valid Airworthiness Review Certificate (ARC)[1]
Serial number	GA8-TC320-12-178
Owner	Skydive Umeå AB
Time of occurrence	14 July 2019, 14:08 hrs during daylight Note: All times are given in Swedish daylight saving time (UTC[2] + 2 hours)
Location	Storsandskär, Västerbotten County, (position 63°46N, 020°19E, 1 metre above mean sea level)
Type of flight	Private/lift of parachutists
Weather	According to SMHI's analysis: At flight level 130: wind 340/20 knots, temperature -10°C, clouds with base at flight level 80 and top at flight level 110 to flight level 140 At the crash site: South to south-easterly wind, 5 knots, visibility >10 km, clouds 5–7/8 with ceiling at over 5,000 feet, temperature +15°C, dew point +8°C, QNH[3] 1014 hPa
Persons on board:	9
Crew members including cabin crew	1
Passengers	8
Personal injuries	9 fatalities
Damage to the aircraft	Destroyed
Other damage	None
Pilot in command:	
Age, licence	27 years, CPL[4]
Total flying hours	217 hours, of which 12 hours on type
Flying hours previous 90 days	12 hours, all on type
Number of landings previous 90 days	25, all on type

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[1] ARC – Airworthiness Review Certificate.

[2] UTC – Coordinated Universal Time.

[3] QNH – Barometric pressure at mean sea level.

[4] CPL – Commercial Pilot Licence.

SUMMARY

The purpose of the flight was to drop eight parachutists from flight level 130 (an altitude of 13,000 feet, approximately 4,000 metres). The load sheet that the pilot received did not contain any information about the individual weights of the parachutists or the total mass of the load. The pilot could thus not, with any help from the load sheet, check or make his own calculation of mass and balance before the flight.

The aeroplane was approaching the airport and, at 14:05 hrs, the pilot requested permission to drop the parachutists slightly higher because of clouds. The airspeed was decreasing in conjunction with the aeroplane's approach to the airport. Just over a kilometre from the airport where the jump point was located, the aeroplane suddenly changed direction to the left and began descending rapidly in almost the opposite direction. The aeroplane then travelled just under one kilometre at the same time as it descended 1,500 metres, which is a dive angle of over 45 degrees.

The aeroplane broke up in the air as both the airspeed and the g-forces exceeded the permitted values for the aeroplane. From an altitude of 2,000 metres, the aeroplane fell almost vertically with a descent velocity of around 60 m/s.

The fact that no one was able to get out and save themselves using their parachute was probably due to the g-forces and the rotations that occurred.

All those on board remained in the aeroplane and died immediately upon impact.

The pilot had limited experience of both normal flight and parachute operations. The aeroplane was tail heavy and the centre of gravity moved in such a way that the aeroplane became unstable. The task of navigating to a precise point at high altitude at the same time as a number of actions were to be performed in accordance with a checklist resulted in a heavy workload. The large amount of clouds made safe flying more difficult or even impossible. The high altitude could also have reduced the pilot's abilities as a result of hypoxia.

It is SHK's understanding that the lack of formal training, absence of a system for determining the centre of gravity and lack of support for flight operations have been decisive factors in terms of how the flight developed into an accident.

Causes/contributing factors

The control of the aeroplane was probably lost due to low airspeed and that the aeroplane was unstable as a result of a tail-heavy aeroplane in combination with the weather conditions, and a heavy workload in relation to the knowledge and experience of the pilot.

Limited experience and knowledge of flying without visual references and changes to the centre of gravity in the aeroplane have probably led to it being impossible to regain control of the aeroplane.

The following factors are deemed to be probable causes of the accident:

- The lack of a safe system for risk analyses and operational support, including data for making decisions concerning flights, termination or replanning of commenced flights.
- The lack of a standardised practical and theoretical training programme with approval of a qualified instructor.
- The lack of a safe system for determining centre of gravity prior to and in conjunction with the parachuting jumps.

Safety recommendations

EASA is recommended to:

- Consider introducing a formal training programme for pilots in parachute operations. (See section 2.7). *(RL 2020:08 R1)*
- Review the approval procedures of mass and balance documentation when certifying aircraft approved for parachute operations. (See section 2.6.3). *(RL 2020:08 R2)*

The Swedish Transport Agency is recommended to:

- As part of its oversight activities, ensure that there are appropriate loading instructions or equivalent in place and adhered to for parachute operations. (See section 2.8). *(RL 2020:08 R3)*
- With support of SFF, take measures to ensure that licensed parachutists have sufficient knowledge of aircraft mass and balance and flight operational consequences when moving around in the aircraft and that the Pilot/Commander receives the support necessary to maintain the rules that apply to the flight. (See section 2.9). *(RL 2020:08 R4)*

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 *Circumstances*

The purpose of the flight was to drop eight parachutists from flight level 130 (an altitude of 13,000 feet, approximately 4,000 metres). Earlier that day, the pilot had performed two other parachute lifts using the same aeroplane. The person responsible for flight operations at Umeå Parachute Club was on board and in the right pilot's seat during the first flight. He was also on board as a parachutist during the second flight. However, he was not on board during the flight in question, which was the third of the day.

Before each flight, the pilot received a load sheet, which contained information about the number of parachutists, the altitude they intended to jump from and the number of parachutes. However, the load sheets did not contain any information about the individual weights of the parachutists or the total mass of the load. The procedure was in accordance with the routine that applies for mass and balance calculation within the parachute club (see section 1.17.2).

1.1.2 The flight and the accident

The pilot took off from Umeå Airport at 13:33 hrs and headed south, towards the sea in order to climb. At 13:49 hrs, the aeroplane had climbed to 10,000 feet and reached the planned altitude of 13,000 feet ten minutes later.

The aeroplane flew towards the jump point, which was located at the airport. A holding patter to the south of the airport was entered due to other traffic. The pilot was then given clearance from the air traffic control to make the final approach towards the jump site. The aeroplane approached the airport and, at 14:05 hrs, the pilot requested permission to drop the parachutists slightly higher because of clouds, which was approved by the air traffic control but without any specific altitude being stated. Shortly afterwards, the pilot received clearance from air traffic control to drop the parachutists, which he confirmed. There was no subsequent radio communication with the aeroplane.

Figure 1. Image with radar data from LFV that shows the entire flight. UTC time. Map image: Google Earth: © Lantmäteriet Dnr R61749_190001.

Radar data combined with wind information show that the airspeed was decreasing in conjunction with the aeroplane's approach to the airport at flight level 136 (4,145 metres). At 14:07:02 hrs and with around 30 seconds left until the airport, and where the jump point was located, the aeroplane suddenly changed direction to the left and began descending rapidly in the almost opposite direction. The aeroplane then travelled just under one kilometre at the same time as it fell 1,500 metres, which is a dive angle of over 45 degrees. From an altitude of 2,000 metres, the aeroplane fell almost vertically with a descent velocity of around 60 m/s. The final response from the aeroplane's transponder was at 14:08:01 hrs, at an altitude of 1,475 feet.

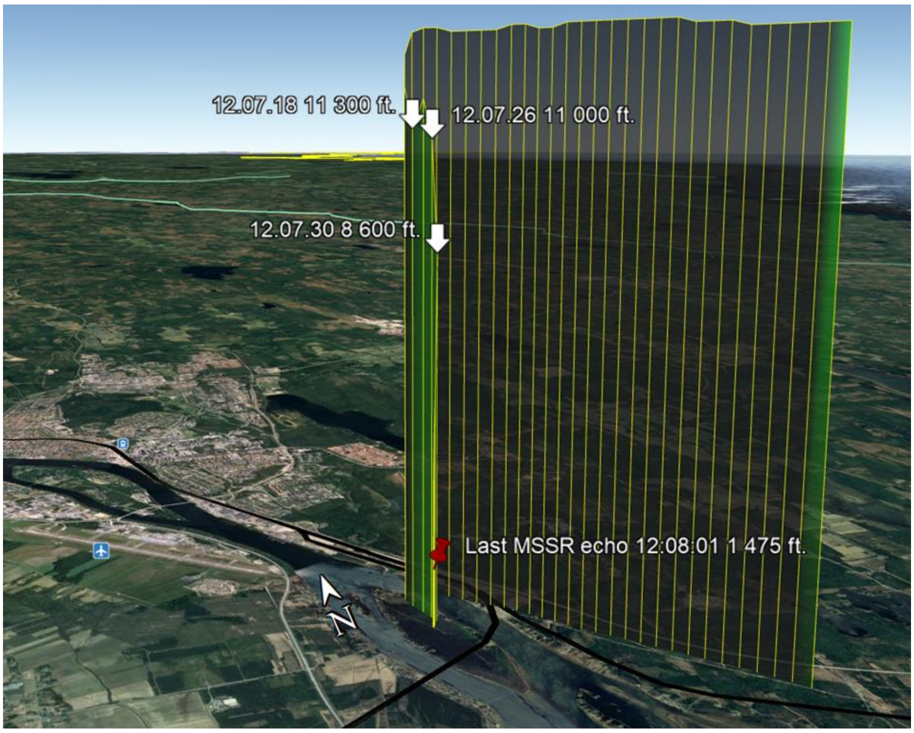

Figure 2. Image with radar data that shows the final stage. UTC time. Map image: Google Earth: © Lantmäteriet Dnr R61749_190001.

Several films of the final stage of the sequence of events, taken from the ground, show that the aeroplane, without fin and stabiliser, rotated clockwise in the horizontal plane (seen from above), with the left wing pointing upwards, while the right wing was missing (see Figure 3).

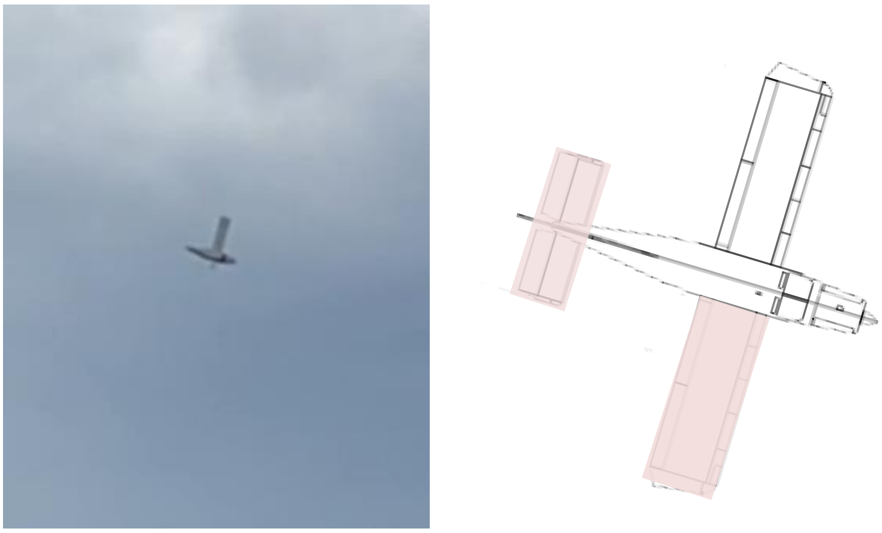

Figure 3. Left picture: Aeroplane in the final stage. The right wing, the stabiliser and the fin are missing. Photo: Private. Right picture: Image for clarification purposes that shows the missing parts marked in red. Picture: GippsAero Pty Ltd POH, red markings by SHK.

The aeroplane crashed in a forested area on the island of Storsandskär in the Ume River, 2 km from the drop zone at the airport.

A witness to the accident who went to the site of the accident saw, upon arrival, that the rear cabin door was open, but did not find any signs of life among those on board.

1.2 Personal injuries

	Crew members	Passengers	Total on board	Others
Deceased	1	8	9	-
Serious injuries	-	-	0	-
Minor injuries	-	-	0	Not applicable
No injuries	-	-	0	Not applicable
Total	1	8	9	-

1.3 Damage to the aircraft

Destroyed.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 *Qualifications and duty time of the pilot*

Pilot in command

Pilot in command was 27 years old and had a valid CPL with flight operational and medical eligibility.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	2	2	12	217
On type	2	2	12	12

Number of landings, on type – last 90 days: 25.
Familiarisation training[5] on type conducted on 20 April 2019.
Latest PC[6] conducted on 14 December 2018 on Piper PA-28.

The pilot's flight training

The pilot began his flight training at the aviation upper-secondary school in Arvidsjaur in the autumn semester of 2009. His first flight was performed on 6 August 2009 and concluded with an approved skill test on 13 December 2011, when he obtained a CPL with the rating SEP(land)[7] and a night rating. At the time of the skill test, the pilot had 165 flying hours, of which 10 hours were instrument flight training.

During his training in Arvidsjaur, the pilot flew various models of the Cessna 172 type.

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[5] Self-directed training on a variant of the same type of aeroplane or on specific equipment in the aeroplane.
[6] PC – Proficiency Check.
[7] SEP(land) – single-engine piston land.

In 2012, the pilot was an exchange student in New Zealand, where he flew 13 hours in a Cessna 172S with instructor.

From the end of 2012 to 15 August 2014, the pilot flew 22 hours at Umeå flying club. These flying hours consisted of flights with a Piper PA-28 and two hours in a Cessna 182 with an instructor.

After that, the pilot did not fly for four years due to problems with his sinuses.

In autumn 2018, the pilot regained his SEP(land) rating through 2 hours of flying with an instructor in a Diamond DA40 with an approved proficiency check (PC) in Umeå on a Piper PA-28.

The pilot had over 200 flying hours when he began flying parachutists in April 2019. Because the pilot had previous experience of aircraft with a constant speed propeller and EFIS (electronic flight instrument system), there were no specific training requirements aside from that the pilot had to familiarise himself with the aircraft type. Familiarisation training may be performed by the pilot himself.

There is no documented evidence of there being any training under the management of Umeå Parachute Club when it comes to dropping parachutists, but verbal information indicates that this was performed.

The flights with SE-MES were not documented in the pilot’s logbook, but were found on a note written by the pilot. It was possible to confirm the details using the aeroplane’s logbook and it amounted to a total of 12 hours and 25 parachute flights on five occasions (two in April, two in May and on the day of the accident). There was an additional pilot in the right pilot’s seat during 18 of these flights.

1.6 Aircraft information

The aircraft was an aeroplane of the model GA8-TC 320 (see Figure 4).

Figure 4. The aeroplane SE-MES. Photo: Krister Karlsmoen.

The aeroplane has a turbocharged Lycoming piston TIO-540 engine, with 320 horsepower and a constant speed propeller.

The aeroplane is mainly constructed in aluminium and is of a high wing type, with wing struts. It is 9 metres long, has a wingspan of just over 12 metres and is 4 metres high.

The aeroplane was modified for parachuting, which means that there were no seats other than the two pilot seats and that a wind deflector was installed at the cabin door in order to be able to fly with the door open.

The aeroplane was equipped for IFR[8]. However, the aeroplane was only maintained for VFR[9].

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[8] IFR – Instrument Flight Rules.

[9] VFR – Visual Flight Rules.

1.6.1 *Aeroplane*

TC-holder	GA8 Airvan Pty Ltd.
Model	GA8-TC 320
Serial number	GA8-TC320-12-178
Year of manufacture	2012
Gross mass (kg)	Max. take-off mass 1,814[10], actual [11] 1,958
Centre of gravity	Outside of the mass and balance diagram. Further information in chapter 1.16.2.
Total operating time (hours)	1,212
Operating time since latest inspection (hours)	25
Number of cycles	N/A
Type of fuel uplifted before the occurrence	AVGAS 100LL

Engine	Lycoming
TC-holder	Lycoming Engines
Type	TIO-540-AH1A
Number of engines	1
Serial number	L-13692-61A
Total operating time (hours)	1,212
Operating time since latest inspection (hours)	25

Propeller	MT-Propeller
TC-holder	MT-Propeller Entwicklung GmbH
Type	MTV-9-B/200-58
Serial number	130879
Total operating time (hours)	1,022
Operating time since inspection, hours	25
Limitations, hours	2,400/6 years

Deferred defects
None

The aircraft had a Certificate of Airworthiness and a valid ARC.

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[10] See 1.6.2.

[11] Actual take-off mass 1,958 kg at take-off from the ground, 1,905 kg when the accident scenario commenced.

1.6.2 *The aeroplane’s maximum take-off mass*

According to the aeroplane’s airworthiness documentation and the Swedish Transport Agency’s register, the maximum take-off mass was 1,814 kg.

A modification to increase the maximum take-off mass to 1,905 kg was performed on 3 April 2013 when the aeroplane was still registered in Australia. However, this modification had not been noted when the aeroplane was later transferred to the Swedish register.

1.6.3 *Construction and certification*

The GA8-TC 320 has been certified by EASA since 7 October 2009 in the normal category under the certification specifications for light aeroplanes, CS-23 Amendment 1.

According to the certification specifications, the limit load (g-force) is +3.8 g and -1.5 g. According to the specifications, the ultimate load shall be at least 1.5 times the limit load. This means that the aeroplane shall cope with a load of at least +5.7 g or -2.25 g before structural damage occurs on the aeroplane.

In accordance with CS-23.1589 (b) the aircraft flight manual shall contain loading instructions for each possible loading condition. The AMC[12] for this section refers to GAMA[13] specification 6.7, which in turn describes how there shall be procedures for calculating mass and balance for various phases of flight and for ensuring that the centre of gravity is within approved limits.

Specific conditions in accordance with EASA document SC-O23-div-01 apply when using aeroplanes for parachuting activities. This document states that, in addition to the basic requirements in CS-23, the following requirements, among others, shall be fulfilled on an aeroplane being used for parachuting activities:

- Specification of the maximum number of parachutists to drop.
- Seating/accommodation and restraints approved for use during take-off and landing.
- An investigation of mass and centre of gravity change during and after the departure of parachutists.
- A specific supplement to the aircraft flight manual must be produced that contains, among other things, information about the airspeed when dropping parachutists that should preferably be at least 1.2 times the stall speed.
- A placard with all speed limitations must be installed in clear view of the pilot.

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[12] AMC – Acceptable Means of Compliance.

[13] GAMA – General Aviation Manufacturers Association.

The aeroplane's EASA type certificate also states that a supplement to the aircraft flight manual for parachute operations and for in-flight rear door open operations is required. Furthermore, a modification is required, with a "wind deflector" mounted by the rear door.

SHK has read the content of the type certificate holder's documents C99-52-01 and C16-99-42 which were used to demonstrate compliance with the requirements of EASA document SC-O23-div-01. With regard to the requirements for an investigation of mass and centre of gravity change during and after departure of parachutists, these are met according to the type certificate holder's documentation by video demonstration of a flight test and operational experience of the aircraft. During the flight test, five parachutists, with a total weight of 500 kg, congregated by the door and carried out a coordinated exit at 8,000 feet. At the time, there were two pilots on board with a total weight of 186 kg. The speed at the exit was 80 knots. It was noted that the aircraft was controllable and that there were no aircraft handling issues. However, any balance calculations have not been declared.

1.6.4 *Operational limitations*

Operational limitations

The aeroplane is approved for flying under visual flight rules (VFR) day and night and under instrument flight rules (IFR) when the necessary equipment is installed and operational.

Speed limitations

Design maneuvering speed (V_a) is 121 knots. Full and abrupt rudder deflections may not be performed in excess of this speed.

Never exceed speed (Vne) is 190 knots. This speed may never be exceeded during any part of the flight.

Maximum structural cruising speed (Vno) is 147 knots and may only be exceeded in calm air and with caution.

Stall speed (Vs) with the flaps retracted at maximum take-off mass, centre of gravity at the forward limit and the engine at idle is 66 knots.

With the centre of gravity at the aft limit, the stall speed will be lower.

Mass limitations

Maximum take-off and landing mass are 1,905 and 1,814 kg, respectively.

Maximum mass on the floor in the cabin is 680 kg (marked in blue in Figure 5). The zones were not marked in the cabin of SE-MES.

The maximum mass on the baggage shelf (marked in red in the figure) is 113 kg and 22 kg in the rear luggage bin (marked in yellow and not accessible on SE-MES). According to information from the type certificate holder, the baggage shelf may not be used during parachuting activities because the supplement to the aircraft flight manual states that the parachutists have to be spread out over the floor area (1A–1C) (see section 1.6.5). The aeroplane did not contain any placard or other markings to indicate that the baggage shelf may not be used.

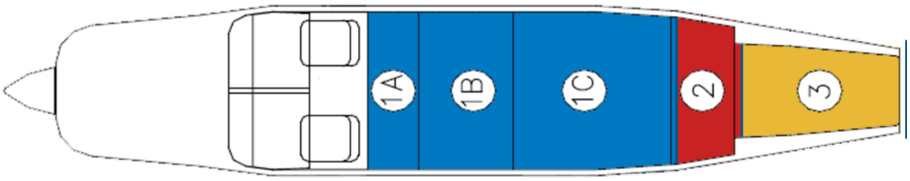

Figure 5. The aeroplane's cargo compartment. Picture: GippsAero Pty Ltd POH, colour markings by SHK.

1.6.5 *Supplement to the aircraft flight manual for parachuting*

In accordance with the type certificate, there is a supplement to the aircraft flight manual for parachute operations (C01-01-01). The purpose of the supplement is to provide the pilot with information about additional limitations and specific conditions, and also normal procedures and emergency procedures for parachuting.

The supplement states that there are no limitations in respect of the number of parachutists as long as the mass and balance are in accordance with the limitations in the aircraft flight manual.

Under the section *normal procedures* it is stated, among other things, that it is necessary for the jump master[14] to be given an adequately briefing about certain matters that are specified in more detail and that they convey the appropriate information to the parachutists. This information includes how the cabin door is to be opened during flight, that the parachutists should sit evenly spaced in the cabin area during take-off and while climbing, that the parachutists should not gather by the exit for too long before jumping and that the target speed for jumping is 80 knots.

The supplement's section on mass and balance includes the following.

The maximum number of parachutists that may be carried is determined by the available payload mass for any given flight. The combined mass of the equipped parachutists must not exceed this amount. The simplest method to maintain the aeroplane within the centre of gravity limitations is to distribute the total number of parachutists evenly on the main cabin floor.

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[14] The person who is responsible, in cooperation with the aircraft's commander, for ensuring that wind measurement and jumping out of the aircraft take place at the correct time and position, in accordance with applicable instructions for parachuting.

When conducting coordinated exits, a maximum of five (5) parachutists may congregate aft of the forward edge of the cabin door exit, with no more than three (3) outside of the aeroplane. The time spent in setting up this arrangement should be minimized. Parachutists inside the cabin should remain as far forward as practically possible.

Apart from these descriptions, there are no clear instructions on how the centre of gravity is to be calculated during the different phases of a flight with parachutists.

The type certificate holder has stated that a pilot cannot be expected to calculate the balance each time a parachutist moves around. Nor can the type certificate holder be expected to provide such specific information that covers all conditions.

1.6.6 *Description of parts or systems related to the occurrence*

Pilot's doors

Cockpit doors that open forwards are mounted on either side of the aeroplane. The door lock is a simple lock that is operated with a handle on both the inside and outside. The doors also function as emergency exits. However, there is no function that allows the emergency release of the doors during flight.

Figure 6. The aeroplane's pilot's door. Picture taken of another aeroplane of the same type. Photo: Håkan Carlberg.

The cabin door

A cabin door is located on the left rear side of the aeroplane. The door is opened by moving it slightly outwards and then sliding it forward on rails along the fuselage. The door lock is located at the back of the door and has a two-part release function. From the inside, the handle is pulled inwards before being rotated forward after which the door slides freely. From the outside, a button is pushed down above the handle with one hand and then the handle is turned with the other hand, whereupon the door slides forward freely. To close the door, it should be pushed rearwards and the handle then rotated either inside or outside the aeroplane until it is located in the lock catch.

Parachutists interviewed by SHK have stated that the rear door was hard to open, even at low speed.

Figure 7. The cabin door. Picture taken of another aeroplane of the same type.

Cabin layout

The aeroplane SE-MES was modified for parachuting, which means that it did not have any passenger seats. Nor were there any safety belts or restraint devices. There was only one handle in the cabin to hold on to, mounted above the door.

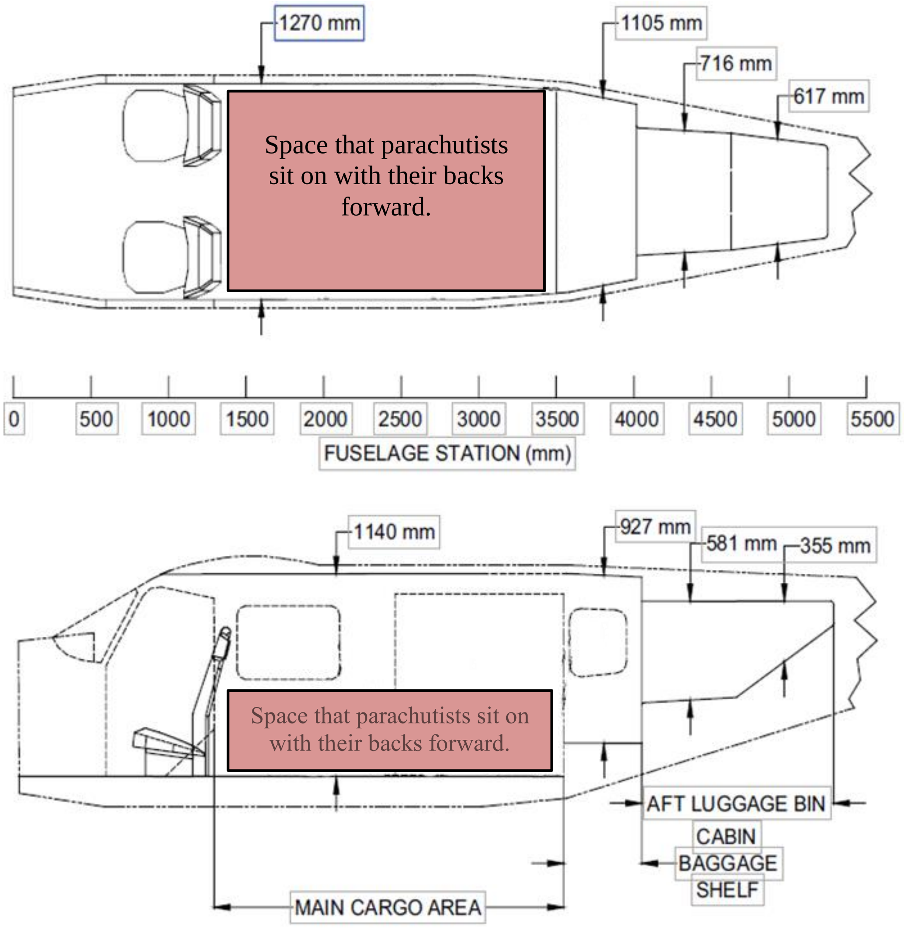

Figure 8. The floor space where parachutists sit, marked with *"main cargo area"*. Image: GippsAero Pty Ltd POH, textboxes by SHK.

Figure 9. Picture of the cabin taken from the aft bulkhead on another aeroplane of the same type.

Figure 10. Picture of the cabin taken from the cockpit of another aeroplane of the same type. SE-MES was not equipped in the same way as the aeroplane in the picture, there were no safety belts or ropes on the ceiling to hold on to. According to the type certificate holder, the raised section of the floor *(the baggage shelf)* furthest back may not be used when parachute operations are conducted.

Flight Control systems

The aeroplane has a conventional flight control system with aileron, elevator and rudder. The aileron and elevator are controlled via cables from the control columns. The rudder is controlled via cables from the rudder pedals.

The aeroplane has a movable stabiliser for pitch trim. The system consists of a jackscrew mounted on the forward beam of the horizontal stabiliser. Attachments mounted at the aft portion of the stabiliser act as the pivot points. The jackscrew and thus the position of the stabiliser is controlled via cables from a trim wheel located on the left part of the centre console in the cockpit.

There is no trim system for the aileron or rudder, i.e. for roll or yaw.

Electrical system

The GA8-TC 320 has a 12/14-volt electrical system consisting of a 12-volt battery and an alternator that supplies a nominal voltage of 14 volts.

The electrical system is constructed as a dual bus system, Bus 1 and Bus 2, which supply power to the aeroplane’s electrical services. The buses are connected to the battery and the alternator via master switches located on the overhead panel in the cockpit.

The aeroplane’s avionics are supplied through avionics buses that are connected to the buses with switches located on the overhead panel. Avionics Bus 1 is connected to Bus 1 by avionics switch 1 and Avionics Bus 2 is connected to Bus 2 by avionics switch 2.

Avionics Bus 1 supplies, among other things, radio communication system no. 1 and the engine monitoring system.

Avionics Bus 2 supplies, among other things, the aeroplane's transponder.

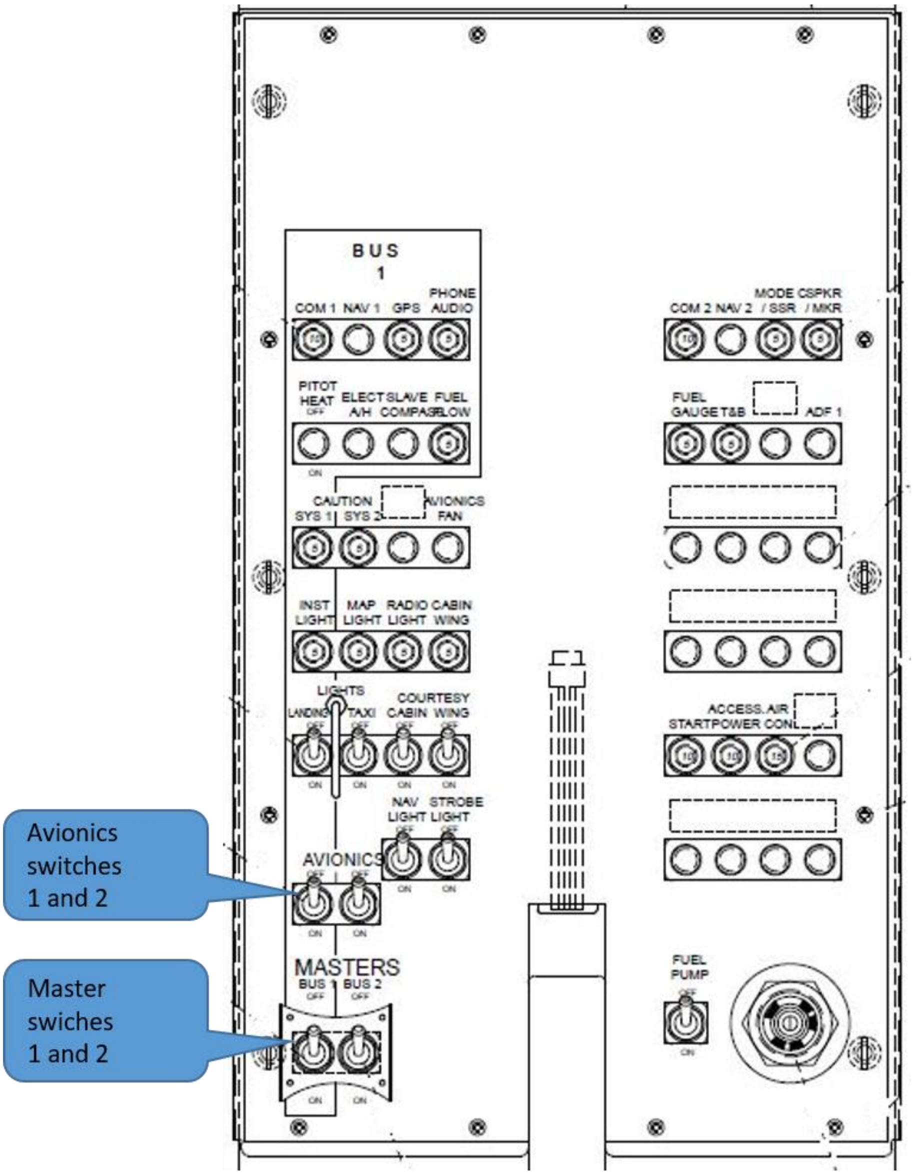

Figure 11. The overhead panel in the cockpit with switches for master power and avionics. Image: GippsAero Pty Ltd GA8/GA8-TC 320 IPC. Page 21-16. Figure 24-7A, textboxes by SHK.

Flight instruments

The aeroplane was equipped with an electronic primary flight display (PFD) of the type Aspen EFD 1000 Pro. This instrument displays information including the aeroplane's altitude, speed, attitude and horizontal heading information.

In the event that the power supply is interrupted, the instrument will automatically switch to its own internal battery.

There were also conventional flight instruments for speed, altitude, attitude and rate of climb and descent.

Figure 12. The flight instruments in SE-MES, with the Aspen PFD screen (marked with red ring by SHK) and the conventional flight instruments. Photo: Klas Sjöberg.

The Aspen EFD 1000 has a built-in warning systems. If the instrument's horizontal indicator displays extreme pitch angles, red arrows, known as chevrons, will show the direction in which to return the flight to a controlled state.

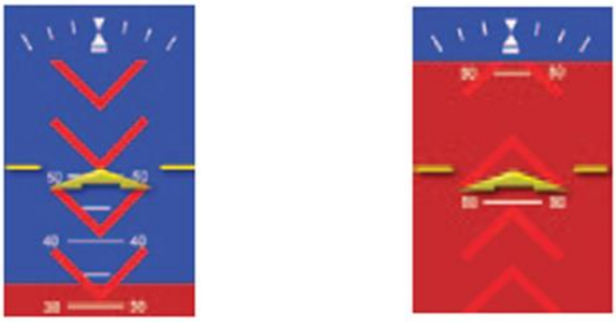

Figure 13. Chevrons (red arrows) indicating high and low pitch angle. Image: Aspen Avionics Inc.

A blocked pitot or static system[15], which could be caused by icing, is indicated with a red cross (X) and error messages in the primary flight information display. This results in the speed, altitude and attitude information disappearing.

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[15] Systems for measuring the aeroplane's speed and altitude.

Figure 14. Indication on the primary flight information display in the event of a blocked pitot or static system. Image: Aspen Avionics Inc.

Pitot-static system

The aeroplane's pitot-static system consist of, among other things, a pitot-static tube mounted close to the tip of the left wing that senses total and static air pressure. This is used by the aeroplane's instruments to calculate and display speed and altitude. The total pressure is measured through an outlet in the open end of the tube that points in the direction of flight. The static pressure is measured through ports located on the sides of the tube. This means that a sideslip, which may be due to an uncontrolled flight situation or other rapid movements, may give rise to misleading values for speed and altitude. The altitude information transmitted to surveillance radar by the aeroplane's transponder is derived from this system. The pitot-static tube is equipped with a heating element that is controlled using a switch mounted in the cockpit.

Stall warning system

The aeroplane is equipped with an electrical stall warning system. A metal vane is located on the leading edge of the right wing (see Figure 15). When the aeroplane is approaching a stall, the airflow raises the metal vane, which activates the sensor for an audible warning horn in the cockpit. The system is set to warn of an imminent stall when the speed falls to between 5 and 7 knots above stall speed. The system requires power but is independent of the master switch.

Figure 15. Stall warning vane on the wing.

Icing

The aeroplane is not equipped or approved for flight in icing conditions. However, there is a checklist that deals with unintentional flight in icing conditions. This checklist states that the altitude shall be changed or that the pilot is to turn back in order to get out of the icing conditions. Hot air to the front windscreen is to be turned on and the pitot-static tube heater activated.

1.7 Meteorological information

According to SMHI's analysis:

Flight level 130: wind 340 degrees, 20 knots, temperature -10°C, Flight level 140: wind 340 degrees, 25 knots, temperature -12°C. Cloud base flight level 80 and top at flight level 110 to flight level 140.

At the crash site: South to south-easterly wind, 5 knots, visibility >10 km, clouds 5–7/8 with ceiling at over 5,000 feet, temperature +15°C, dew point +8°C, QNH 1014 hPa.

Zero degree isotherm FL 060–080. Risk of icing over FL 080. No turbulence.

The accident occurred in daylight.

Forecast for the area around Umeå:

Light rain showers with visibility over 8 km and a cloud base at over 2 000 feet. Isolated embedded cumulonimbus clouds.

The following forecasts were issued for Umeå Airport:

TAF ESNU 140830Z 1409/1418 16006KT CAVOK PROB40 1411/1417 BKN045TCU=

TAF ESNU 141130Z 1412/1421 16006KT CAVOK PROB40 1412/1417 SCT045CB=

These forecasts indicate a high probability of towering clouds in the period after 13:00 hrs local time and cumulonimbus activity after 14:00 hrs.

The airport's observations:

At 13:50 hrs: calm, visibility more than 10 km, cloud a few towering cumulus 4,000 feet, broken 7,200 feet, temperature 15°C dew point 9°C, QNH 1013 hPa, recent drizzle.

At 14:20 hrs: calm, visibility more than 10 km, clouds few 5,300 feet, broken 8,200 feet, full cover 9,800 feet, temperature 15°C dew point 8°C, QNH 1014 hPa.

Wind information from another commercial flight:

The following information has been obtained from flight data of a commercial aeroplane that was approaching from the south and landed at Umeå Airport just before the accident.

Flight level 130 – wind, 351 degrees, 27 knots, temperature -9°C.
Flight level 136 – wind, 352 degrees, 30 knots, temperature -10°C.
Flight level 140 – wind, 351 degrees, 31 knots, temperature -11°C.

Cloud information

Figure 16 shows the aeroplane under the clouds at the time of the accident.

Further pictures of cloud formation during a previous jump using the aeroplane approximately 90 minutes prior to the accident are shown in section 1.18.6.

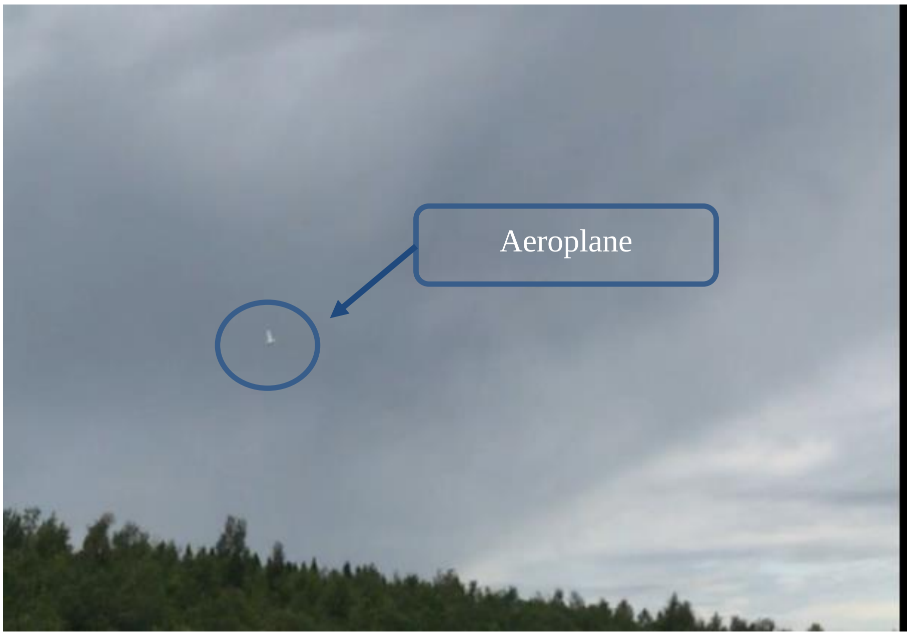


Figure 16. Cloud formation with the aeroplane falling in the final stage. Markings and text by SHK. Photo: Eva Johansson.

1.8 Aids to navigation

The aeroplane was equipped with several different GPS navigation systems including a Garmin GTN 650 and a Garmin GTN 750.

It was also equipped with a Garmin GTX 33 Mode S transponder, which transmits information about the aeroplane's identity and altitude to secondary surveillance radar systems (MSSR). The antenna for the transponder is mounted on the underside of the fuselage.

1.9 Radio communications

The pilot was in contact with air traffic control in Umeå during the flight. The radio communication was normal until the point at which the accident began. There was no radio traffic from the pilot after this. No distress call has been registered in the radio communications.

Time (UTC)		
11:51:24	TWR	Well exactly, they are a little early.
11:51:29	MES	Yes, but that's right, excellent, so I'm entering a holding pattern south of the runway approximately.
11:51:35	TWR	Echo Sierra.
11:58:17	MES	Umeå tower, Sierra Echo Mike Echo Sierra, want to drop the parachutists in five minutes, is that reasonable?
11:58:27	TWR	No Echo Sierra, that will be a bit too early but sure, you can head towards the field for now.
11:58:37	MES	Yes, but that's right, I'll head towards the field and maybe aim for eight minutes?
11:58:45	TWR	Yes, something like that yes.
12:02:17	TWR	Yes Echo Sierra, you have approximately four minutes left before the drop.
12:02:21	MES	Roger, Sierra Echo Sierra
12:04:28	TWR	Yes Echo Sierra, you are clear for final approach.
12:04:33	MES	Clear for final approach, and it's about two and a half minutes until the drop.
12:04:37	TWR	Echo Sierra, yes.
12:04:58	MES	… and (request) and drop a little higher due to clouds, Sierra Echo Sierra.
12:05:05	TWR	Echo Sierra, yes, that's fine.
12:05:07	MES	Thanks.
12:05:50	TWR	And Sierra Echo Mike Echo Sierra, you are clear to drop and descend north.
12:05:56	MES	Clear drop and descend south, Sierra Echo Mike Echo Sierra.
12:06:02	TWR	Yes Echo Sierra, confirm descend north.
12:06:06	MES	Oh sorry, eh descend north after the drop, Sierra Echo Sierra.

Table 1. Transcript of radio communications between the pilot (MES) and the air traffic control at Umeå Airport (TWR).

1.10 Aerodrome information

Not pertinent.

1.11 Flight recorders

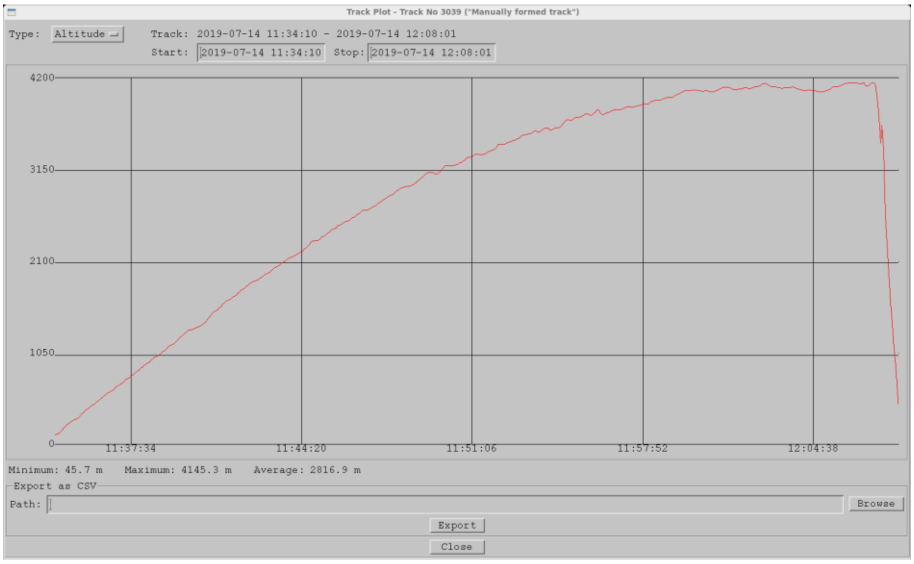
The aeroplane was not equipped with a flight data recorder or a cockpit voice recorder nor was there any requirement for such equipment to be installed on this type of aircraft.

However, SHK has obtained, or attempted to obtain, information from other sources or units, which are presented in this section.

1.11.1 *Radar and sensor recordings from LFV*

SHK has studied radar recordings in the form of monopulse secondary surveillance radar (MSSR) data from LFV. MSSR is a radar surveillance system that, in this case, communicates with the aeroplane's Mode S transponder. This system enables data with information about the aeroplane's identity, position and altitude to be recorded.

Figure 17 shows the full vertical profile of the flight as taken from MSSR data read out by Swedish Armed Forces. The Y-axis shows the aeroplane's height, whilst time is displayed on the X-axis. The data show a very rapid loss of altitude towards the end.



Track Plot - Track No 3039 ("Manually formed track")

Type: Altitude

Track: 2019-07-14 11:34:10 - 2019-07-14 12:08:01

Start: 2019-07-14 11:34:10 Stop: 2019-07-14 12:08:01

Minimum: 45.7 m Maximum: 4145.3 m Average: 2816.9 m

Figure 17. Altitude information from secondary radar (MSSR). Image: Swedish Armed Forces.

MSSR data is also presented in section 1.1.2 where it visually depicts the aeroplane's trajectory in Google Earth.

MSSR data is primarily intended as an aid to air traffic services and it is therefore adapted to this purpose. This means that the data is not entirely precise under certain circumstances. For example, if an expected signal response from the aeroplane's transponder does not arrive, the same altitude will be registered as that of the most recent registration received.

Wide area multilateration (WAM) is a fixed system with monitoring sensors that can be used to determine the position of an aircraft to a high degree of precision via triangulation.

SHK has studied WAM recordings from LFV's facility in Timrå. The data recorded contain information about the aeroplane's position, identity, altitude and ground speed. Because of the distance between Timrå and the aeroplane's position, only data registered at high altitude is accurate. With the aid of the WAM data SHK has calculated the aeroplane's airspeed, which is presented in section 1.16.6.

1.11.2 *Radar recordings from the Swedish Armed Forces*

Radar data and information from the Swedish Armed Forces is shown in Figure 18.

The blue radar track is from the secondary radar data (MSSR) and contains information about the aeroplane's position, time, altitude and horizontal ground speed.

The data show that when the aeroplane was on its final heading towards the airport and the jump point at flight level 136 (4,145 metres), the aeroplane's ground speed decreased during the final data points.

The data then show a change of heading to the left together with a loss of altitude and that the aeroplane then descended on an opposite heading with a variable rate of descent. The aeroplane fell almost vertically to the ground from an altitude of 1,654 metres. The last recorded altitude is 450 metres at 12:08:01 UTC, i.e. 14:08:01 hrs local time.

The red track is from the primary radar. This type of radar does not have information from the aeroplane's transponder and have larger margins of error for positions, which means that the track is different from that of the MSSR.

The data also show separate radar echoes from primary radar, which potentially are parts of the aeroplane, but may also be radar clutter caused by something else such as birds. These echoes are recorded after the change in heading and when the aeroplane was at an altitude of 3,000 metres. The positions of these echoes are uncertain and not consistent with the positions of the aeroplane parts upon impact.

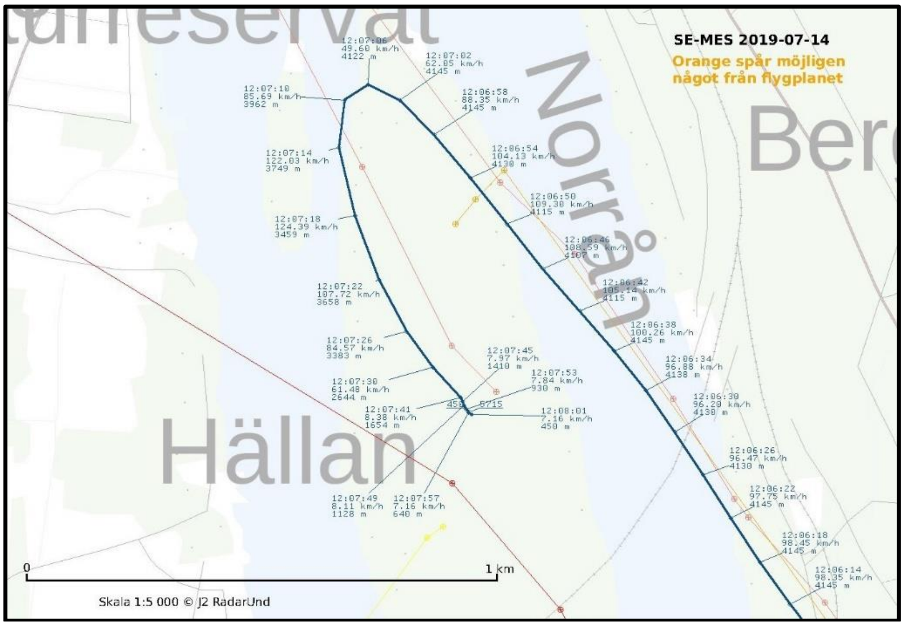


Figure 18. Radar data from the Swedish Armed Forces.

1.11.3 *Sound recording from a CCTV camera*

A private CCTV camera, which was on a property seven kilometres from the crash site, has recorded, among other things, engine sounds from the aeroplane. A spectrogram has been produced from the CCTV's video (see Figure 19).

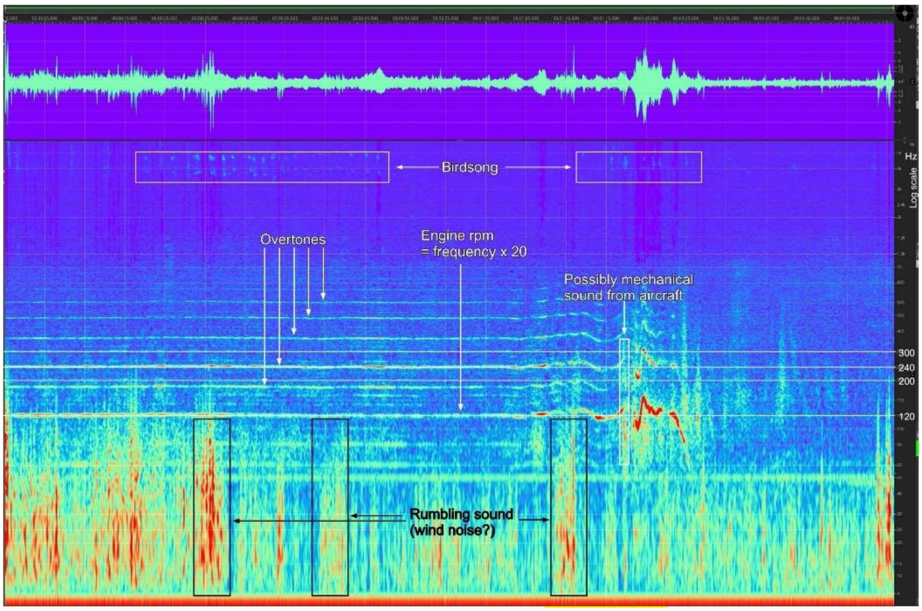


Figure 19. 1 minute and 45 seconds of the spectrogram from the CCTV camera; the recording ends 20 seconds before the crash. The scale on the y-axis is logarithmic.

The propeller rpm can be deduced from the spectrogram in the following way. The aeroplane was equipped with a three-bladed propeller. If, for example, the engine is rotating at 2,400 rpm, this is 40 revolutions per second. Because there are three propeller blades that make a sound upon each rotation, the resulting frequency will be 3 x 40 = 120 Hz.

The last thirty seconds of the sound from the CCTV recording shows changes in the engine rpm. The first overtone has been chosen for measurement.

From 2,400 rpm, there are rapid changes between 2,050 and 3,100 rpm. The sound of the engine then drops below 1,000 rpm.

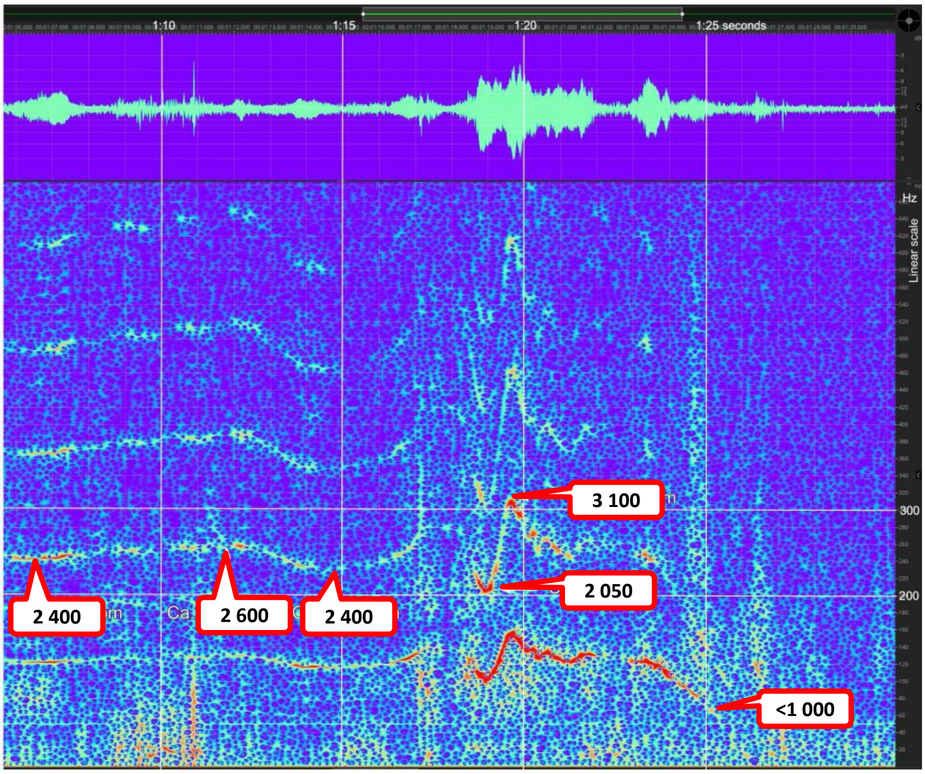


Figure 20. Enlarged spectrogram for the final part of the CCTV sound recording of the engine sound.

The CCTV recorded the actual time.

The horizontal distance from the CCTV camera to the aeroplane's position, at the area where the changes in course and altitude occurred, was 6,500 metres. Including the flying altitude, this gives a total distance of 7,600 metres.

Calculations including air density, wind data and the speed of sound resulted in the sound from the aircraft being delayed by about 23 seconds, to the position of the CCTV camera, at the time of the rapid change in course and altitude.

This means that the increase in engine rpm from 2,400 rpm approximately started at 14:07:02 hrs and that the peak of 3,100 rpm occurred at 14:07:16.

It should be emphasized that the above calculations of engine rpm from the surveillance camera's audio recordings have not been corrected for frequency changes due to the Doppler effect. The differences in engine rpm that can be observed between the sound recordings and the engine monitoring instrument EDM 800 (see section 1.11.7) before the rapid rpm changes can probably be attributed to the Doppler effect. As the aircraft approaches the surveillance camera, the recorded sound frequency increases.

1.11.4 *Recordings from ProTrack*

SHK has obtained data from two of the parachutists' electronic devices (ProTrack), the purpose of which is to provide audio signals about altitude and rate of descent. These devices have recorded altitude and rate of descent. The data were almost identical and one is presented in Figure 21. The device records four data point per second.

A filtered vertical rate of descent has been calculated by calculating the difference in altitude every six seconds.

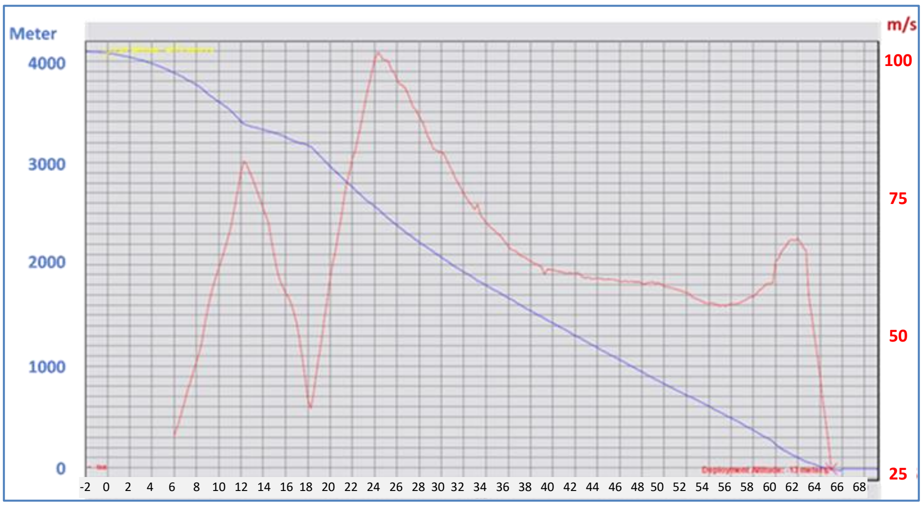


Figure 21. The blue curve shows the altitude in metres and the red curve shows the rate of descent in metres per second.

The recordings are based on pressure readings and the graphs are therefore converted to altitude. This means that it is not entirely certain that the altitude is accurate because any pressure changes inside the aeroplane will show up as changes in altitude.

1.11.5 *Recordings from GoPro cameras on board the aeroplane*

There were two GoPro cameras on board the aeroplane. The police in Umeå have obtained data from these cameras. There were however no recordings from the occurrence.

1.11.6 *Recordings from automatic activation devices*

All of the parachutists' parachutes were equipped with an automatic activation device, the purpose of which is to deploy the reserve parachute automatically at a predetermined altitude if the rate of descent is too high. All these devices had deployed.

Figure 22 shows the readout from one of the units. All the units showed the same data from 2,200 metres down to the ground and a rate of descent of around 60 m/s.

The devices deployed as they were supposed to do, depending on the chosen altitude setting, at an altitude of 250–350 metres.

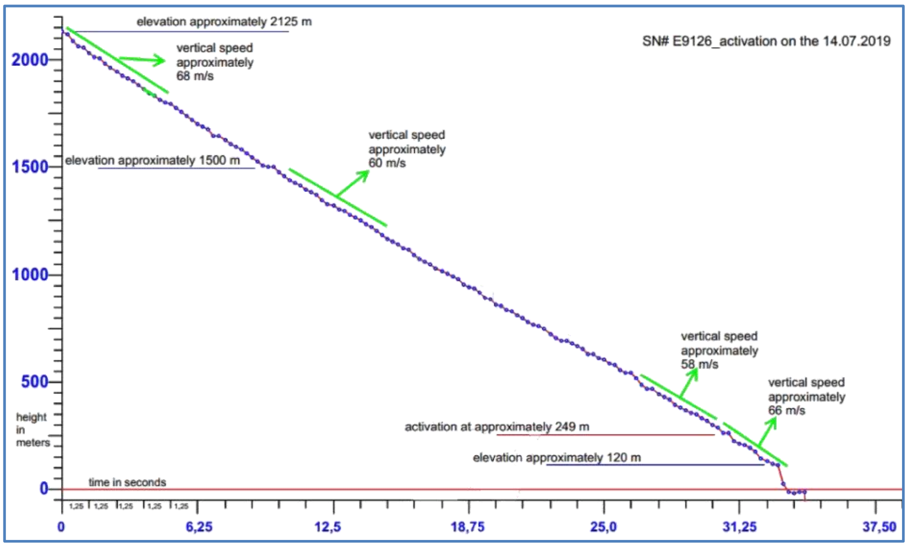


Figure 22. Readout from one of the automatic activation devices.

1.11.7 *Recording from the engine monitoring instrument*

The aeroplane was equipped with an engine monitoring system of the type J.P. Instruments EDM 800.

The instrument manages various engine parameters that are recorded every six seconds. With the help of J.P. Instruments, SHK has retrieved the data recorded during the occurrence.

However, the engine monitoring instrument had an internal clock that had an incorrect timestamp. Consequently, the time of the recorded throttle increase for take-off has been calibrated with the take-off time for the aeroplane according to sound recordings from the control tower at Umeå Airport, which has provided a corrected time for the recorded data.

Figure 23 shows selected parameters. The blue graph is the engine rpm and the red graph is manifold pressure[16] in inches of mercury (InHg), the time is in UTC.

The throttle increase for take-off occurs at 11:33 hrs, after which the engine rpm remains constant at 2,500 rpm during the climb and was reduced to 2,300 rpm when the planned flying altitude was achieved.

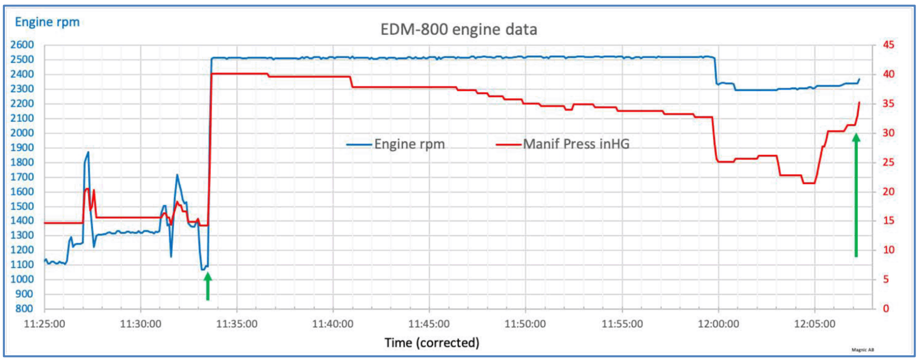


Figure 23. Readout from the engine instrument EDM 800.

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[16] Manifold pressure – vacuum pressure in the engine's intake system, and is a measure of throttle setting.

According to the aircraft's type certificate holder, the manifold pressure should be constant at 40 InHg up to 5,000 feet and then at 38 InHg up to 12,000 feet, after which it gradually begin to decrease as the air pressure decreases with altitude.

The registration shows, however, that the manifold pressure decreased below 38 InHg above 9,000 feet during the climb. Umeå Parachute Club has explained that the circumstances with the reduced manifold pressure at altitude has taken place over a period of time and has been explained by the maintenance personnel that this was due to the engine's increased operational time. SHK has not further investigated this deviation as the manifold pressure was 33 InHg at the maximum altitude, which is considered sufficient for safe flight.

Figure 24 shows the final stage of the recorded data. It is possible to observe that the manifold pressure increases at 12:05:00, which indicates an increase in throttle in conjunction with the pilot receiving clearance to climb higher because of clouds.

At 12:07:04, a further increase in manifold pressure and an increase in engine rpm was recorded.

The recordings suddenly stop at 12:07:16.

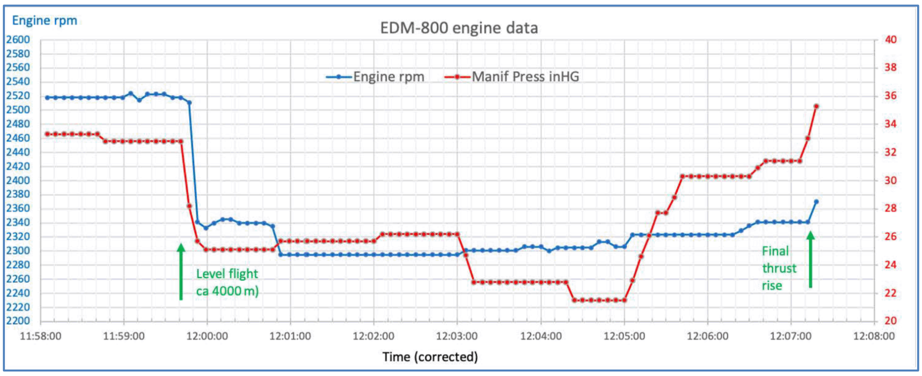

Figure 24. Final stage of the recorded data.

1.11.8 *Recordings from the aeroplane's navigation equipment*

The aeroplane was equipped with navigation equipment of the types Garmin GTN 650 and Garmin GTN 750, as well as an electronic flight instrument of the type Aspen EFD 1000 PFD.

SHK has examined the navigation equipment with the assistance of the French safety investigation authority (BEA). It emerged during the examination that none of the units were able to record flight data.

The Aspen instrument did not store any usable data.

1.11.9 *Recordings from mobile phones on board the aeroplane*

There were a number of mobile phones on board the aeroplane.

With the assistance of BEA and a company that specialises in retrieving data from digital devices, SHK has attempted to retrieve data from some of these phones. However, it was not possible to find any usable information.

1.12 Accident site and aircraft wreckage

1.12.1 *Accident site*

The aeroplane crashed into a forested area on the island of Storsandskär in the Ume River.

The crash site is located approximately 2,300 metres south-east of the location at Umeå Airport where the parachutists had planned to land.

The aeroplane crashed next to a spruce tree. The top and branches of the tree were missing, which indicates that the aeroplane hit the tree during the crash.

Figure 25. Picture taken directly above the crash site. Photo: Drone image from the Police.

1.12.2 *Aircraft wreckage*

The main part of the wreckage consisted of the fuselage, left wing, including wing strut, right wing strut and the engine and propeller.

The tail section, which was missing the stabiliser and fin (vertical stabiliser), had been cut off from the fuselage by the fire and rescue service in conjunction with the rescue operation and was lying a few metres away.

Figure 26. Picture of the wreckage on the day after the accident.

Figure 27. The tail section cut off by the fire and rescue service.

The right wing, the horizontal stabiliser and the fin had separated from the aeroplane in the air before the crash.

The right wing was broken into two pieces, as was the stabiliser. The outer section of the right wing and the right section of the stabiliser were found in the Ume River, to the west of Storsandskär. The inner section of the right wing was found 125 metres to the west of the wreckage. The tail fin was found 225 metres away in a westerly direction and the left section of the stabiliser was found 250 metres south-west of the fuselage.

Figure 28. The broken off fin of the aeroplane.

Figure 29. The inner section of the right wing.

Figure 30. The broken part of the left side of the stabiliser.

Figure 31. The outer part of the right wing was salvaged from the Ume River.

Figure 32. The right section of the stabiliser was salvaged from the Ume River.

The locations of the parts from the wreckage have been marked on Figure 33. The right outer wing and the right part of the stabilizer fell into the Ume River and were salvaged before SHK arrived at the site. The positions of these are according to information from The Swedish Maritime Administration and private individuals.

In May 2020 the balance horn for the right elevator was found on Storsandskär by a private person.

Figure 33. The accident site with the location of the parts of the wreckage. Photo: Google Earth: © Lantmäteriet Ref. no. R61749_190001.

The aeroplane wreckage was removed from the accident site using a helicopter and taken to SHK for more detailed examinations.

1.12.3 *Initial technical examinations of the aeroplane wreckage*

An initial technical examination was conducted together with representatives from the aeroplane's type certificate holder and advisers from the aviation authorities in Australia and Sweden. Further examinations have been conducted subsequently. Further information can be found in section 1.16.

1.13 Medical and pathological information

There is nothing to indicate that the mental or physical condition of the pilot was impaired.

There are comments concerning problems with sinuses in all of the pilot's aeromedical examinations since 2011. However, these have been deemed by the aeromedical examiner to be temporary and have not constituted an obstacle to flight duty.

1.13.1 *Hypoxia*

Spending time in air with a low air pressure can lead to hypoxia, i.e. the body's tissues are exposed to a lack of oxygen. This is because the oxygen diffusion rate decreases as the air pressure falls, which leads to reduced oxygenation of the blood. In the event of hypoxia, blood flows in the brain change, which can have an impact on cognitive functions, thus impaired memory function, lack of decision-making, attention and judgment.

Hypoxia occurs gradually at low oxygen levels. The body's oxygen reserves are gradually depleted, so the decline in oxygenation occurs slower in the beginning and faster the longer the exposure remains.

There are several factors aside from altitude that influence the risk for and severity of hypoxia. These include rate of climb, time spent at altitude, physical activity at altitude, fatigue, stress, extreme ambient temperature and individual physiological condition.

Requirements concerning supplemental oxygen use under the applicable regulations

Under NCO.SPEC.110(f) in Commission Regulation (EU) No 965/2012, the pilot-in-command should ensure that all flight crew members and task specialists use supplemental oxygen whenever he or she establishes that hypoxia at the altitude of the intended flight may impair the abilities of crew members or be injurious to task specialists.

If the pilot-in-command is not able to determine how hypoxia may affect those on board, he or she should ensure that task specialist and flight crew members continually use supplemental oxygen whenever the cabin pressure altitude exceeds 10,000 feet for more than 30 minutes and whenever cabin pressure altitude exceeds 13,000 feet.

However, NCO.SPEC.PAR.115 states that the requirement to use supplemental oxygen is not applied to either flight crew members other than the pilot-in-command or to task specialists who are performing duties that are essential to the specialised operation when the cabin pressure altitude exceeds 13,000 feet for a period of a maximum of 6 minutes, or exceeds 15,000 feet for a period of a maximum of 3 minutes.

SE-MES was above 10,000 feet for 18 minutes and above 13,000 feet for 8 minutes. There was no oxygen equipment on board the aircraft.

1.14 Fire

No fire broke out.

1.15 Survival aspects

1.15.1 *Rescue operation*

Provisions on rescue services are found primarily in the Civil Protection Act (2003:778) and the Civil Protection Ordinance (2003:789), in the following referred to by use of their acronyms in Swedish, LSO and FSO respectively. In addition, the Swedish Transport Agency's regulations and general guidelines (TSFS 2015:51) on alarm services and air rescue services apply to air rescue services.

According to Chapter 1, Section 2, first paragraph of LSO, the term "rescue services" denotes the rescue operations for which central government or municipalities shall be responsible in the event of accidents or imminent danger of accidents, in order to prevent and limit injury to persons and damage to property and the environment. Central government is responsible for mountain rescue services, air rescue services, sea rescue services, environmental rescue services at sea and rescue services in case of the emission of radioactive substances, as well as for searching for missing persons in certain cases (Chapter 4, Sections 2–3 of LSO). In other cases, the authorities of the municipality concerned are responsible for the rescue services (Chapter 3, Section 7, LSO).

The Swedish Maritime Administration is responsible for air rescue services in the event of air crashes. This remit includes search and location of aircraft in the event of a crash or suspected crash and operations when an aircraft is in distress or when there is a threat to air traffic.

Search and rescue services are directed from the Swedish Maritime Administration's Joint Rescue Coordination Centre (JRCC), where the rescue coordinator for an operation of this nature is located.

The fire and rescue service in the municipality concerned is responsible for the rescue operation when an aircraft is located within the boundaries of the municipality, in this case the Umeå regional fire defence service in Umeå Municipality.

The municipal rescue operation is led by a rescue coordinator who usually arrives at the site of an accident together with other rescue service resources.

The first call to SOS Alarm was received at 14:09 hrs from a person on Storsandskär who saw an aeroplane crash. A large number of further calls about the occurrence were received after this. The people calling had seen an aeroplane crash but were not able to give an exact position where it had crashed. Initially, the information was that the crash could be either on the island of Storsandskär or at Bergsboda on the mainland to the east of the island.

A call was also received from air traffic control in the tower at Umeå Airport, stating that a parachute plane had crashed with nine people on board, but the caller only had an approximate location for the crash site. Air traffic control also stated that a private plane was on the way to the area in order to search for the aeroplane.

From 14:12, SOS Alarm dispatched a large number of rescue resources from the Umeå regional fire defence service, ambulances and air ambulances, and also informed the police about the occurrence. By this time, the JRCC, which SOS Alarm connected to when the alarm calls started coming in, had already called in the SAR helicopter[17] from Umeå. The JRCC also called in a pilot boat and a boat from the Swedish Sea Rescue Society (SSRS) to the area where the aeroplane had crashed. The Coast Guard was also called in but their nearest resources were in Luleå and were therefore not able to provide assistance immediately. The rescue operation was initially focused on locating the crash site.

After even more people who had seen the aeroplane fall to the ground called SOS Alarm, it became clear that the aeroplane had crashed somewhere on the island of Storsandskär. The private plane that had been asked to fly over the area was able to locate the crash site on the island at 14:19 hrs. The position was also confirmed at the same time by an individual who arrived at the crashed aeroplane and called 112. The caller was able to see four people in the aeroplane, but was unable to detect any signs of life.

The crew of the SAR helicopter that had taken off from the base in Umeå at 14:20 hrs had heard when the private plane called the tower and announced the location of the crash site. The helicopter arrived at the site a few minutes later and winched a rescue swimmer down to the crash site. The individual who had called 112 from the site met up. The SAR helicopter flew to Umeå Airport in order to enable medical personnel to be transported to the crash site.

The rescue swimmer initially found five lifeless people in the aeroplane and was able to establish, following an examination, that there was no possibility of resuscitating them. The rescue swimmer remained at the site and took care of the witness while waiting for the rescue and medical personnel to arrive.

The first rescue services resource arrived at 14:26 hrs at the harbour in Bergsboda on the eastern side of Storsandskär. A large number of members of the public with boats had gathered there to help with the transport of rescue services personnel. Once on the island, it was only possible to go by foot to the crash site because the terrain was hard to cross, with dense vegetation.

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[17] SAR (Search And Rescue) – the Swedish Maritime Administration’s search and rescue helicopter.

Rescue services personnel reached he crash site at 14:33 hrs where they were met by the rescue swimmer. After they had searched in and under the severely damaged aeroplane, the nine people who had been on board were found, all showing no signs of life. Medical personnel arrived just after the rescue services and were able to establish that all those who had been on board the aeroplane had died. At which, all the medical resources that were still on their way to the accident site were recalled.

After the aeroplane was located, the JRCC terminated the air rescue operation at 14:49 hrs. The SAR helicopter, which had been parked at Umeå Airport, collected the rescue swimmer and was back at base at 15:10 hrs. The Umeå fire defence service terminated the municipal rescue operation at 15:00 hrs but had left some personnel on site in order to assist the police with recovery of the bodies. They also provided assistance with boat transport to and from the island.

POSOM[18] groups were activated in order to provide emergency support to people affected by the accident. An assembly point for relatives was arranged at the airport in Umeå and another assembly point for witnesses and others who were affected was organised in a church. Debriefings were also conducted with the rescue personnel who had participated in the operation.

The emergency locator transmitter (ELT[19]) of the type Kannad 406 AF-Compact was activated during the occurrence. However, the JRCC was not able to receive any signal from the ELT; probably because its antenna and associated wiring was broken during the crash.

1.15.2 *Survival aspects*

All those on board had parachutes on. Nevertheless, none of them were able to save themselves using their parachute.

The pilot’s doors are mounted on hinges at the front of the door. SHK has calculated that the force required to open the door is around 50 daN (kP) at the lowest possible speed and 150 daN at 120 knots.

After the aircraft broke up and rotated with the left wing pointing straight up, the air pressure created a force corresponding to 150 daN on the right door.

The pilot was still strapped in to the left pilot seat at the time of the crash. All of the parachutists were found in the aeroplane.

The rear cabin door was at least partly open following the crash. It has not been possible to establish if this was open prior to the crash or if it was opened by the impact with the tree. However, it is probable that it was unlocked.

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[18] POSOM – Swedish acronym for psychosocial care.

[19] ELT – Emergency Locator Transmitter.

The cabin door is opened by the lock being opened and it being pushed out a little and then forwards outside of the fuselage. According to information from witnesses, it is hard to open even under a normal opening speed of 70–80 knots.

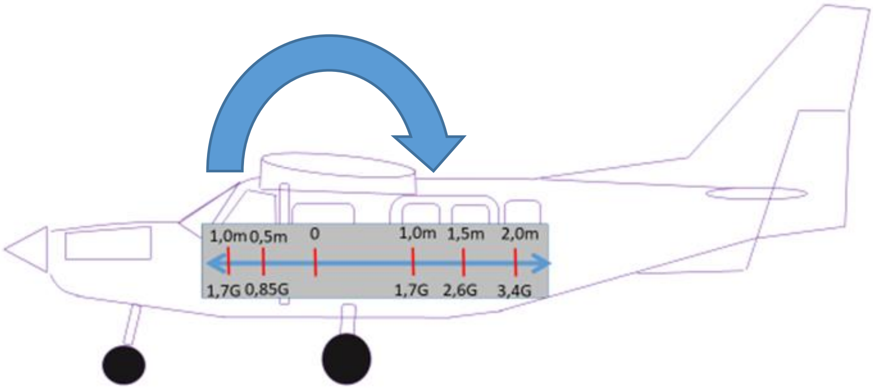

Figure 34. G-forces along the length of the aeroplane after the wing broke during that part of the sequence of events that is recorded on film.

After the aeroplane broke up, it rotated at 0.6 revolutions/second with the left wing up, which, according to SHK's calculations, resulted in g-forces of up to 3.5 along the length of the aeroplane (see Figure 34).

1.15.3 *Position of and injuries to crew and passengers, and the use of seat belts*

The pilot wore a safety belt with shoulder straps.

The parachutists had no safety belts or other safety devices as no such devices were installed in the aeroplane. There was a handle mounted on the ceiling of the cabin next to the rear door. Otherwise there was nothing in the cabin for the parachutists to hold on to.

The impact occurred with the fuselage relatively horizontal and on its right side. Towards the end of the sequence of events, the rate of descent was around 60 m/s and the crash was not survivable.

1.16 Tests and research

1.16.1 *Examination of the right wing and wing strut*

A visual inspection of the broken outer part of the right wing showed remaining deformations on the lower surface of the wing, probably caused by negative g-forces. The right wing strut was broken at its attachment. A detailed examination of the broken surfaces of the wing showed overload fractures. Damage indicates that the right outer wing was broken off upwards by positive g-forces.

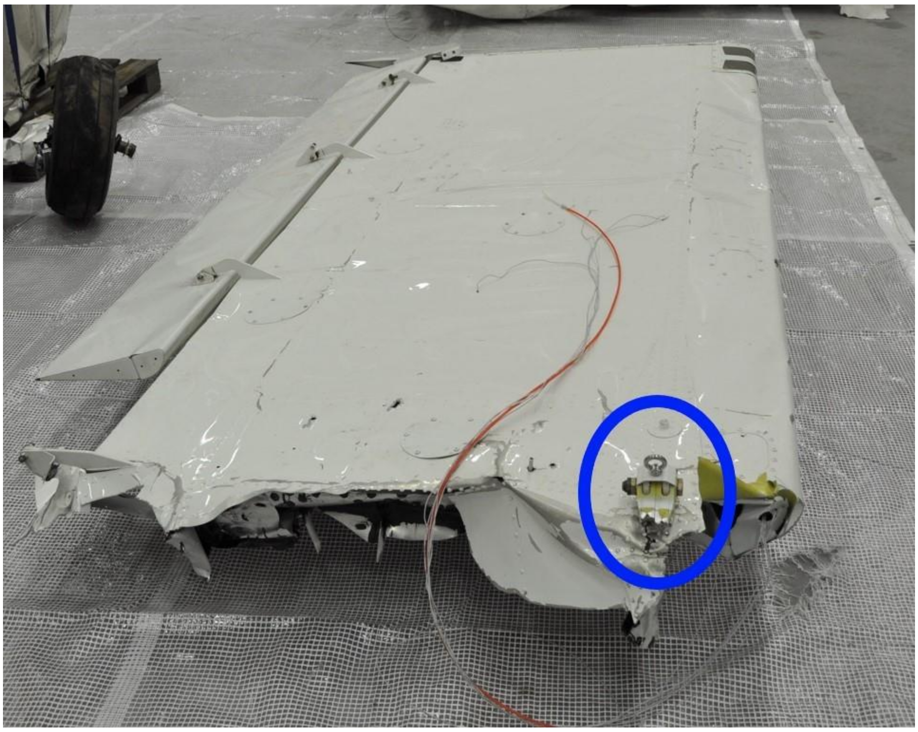

Figure 35. Lower surface of the broken outer section of the right wing. The broken attachment to the wing strut is marked.

Figure 36. Upper surface of the outer section of the right wing.

The attachment of the right wing strut and the sequence in which the wing broke

The broken attachment to the right wing strut was pushed into the underside of the wing and was not in its normal position (see Figure 37).

The result of a fractographic examination of the fracture surfaces showed an overload fracture in tension and bending. No signs of corrosion, fatigue cracking or other material defects were found. The examination shows that the fracture of the wing preceded the fracture of the attachment to the wing strut.

Figure 37. The broken attachment to the right wing strut.

Figure 38 shows the probable sequence in which the outer section of the right wing broke. Please note that the attachment is pushed in towards the lower surface of the wing and that the attachment is rotated.

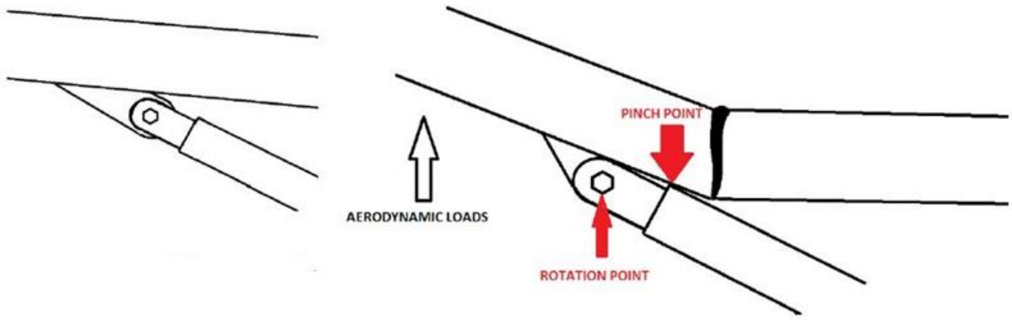

Figure 38. Sequence of failure of the right wing and attachment to the wing strut. Image: CASA.

The inner section of the right wing

The inner section of the right wing, which was unsupported after the wing strut fractured, had subsequently broken off from the fuselage (see Figure 39).

Figure 39. The inner section of the right wing.

1.16.2 *Examination of the empennage*

The broken parts of the empennage have been examined. This has included the stabiliser and its attachments, parts of the elevator system and the fin (vertical stabiliser).

Attachments to the stabiliser

The stabiliser has three attachment points (see Figure 40 and 41). It is mounted to a forward bracket that is riveted to the stabiliser's front spar. This bracket is also attached at the jackscrew for stabiliser trim. The rear part of the stabiliser is attached to two brackets; right and left. These brackets are the stabiliser's pivot points.

All rivets to the front attachment were sheared.

Bolts and nuts to the attachment of the rear brackets were broken under overloading or they were missing as a result of the occurrence.

Figure 40. The stabiliser’s attachments.

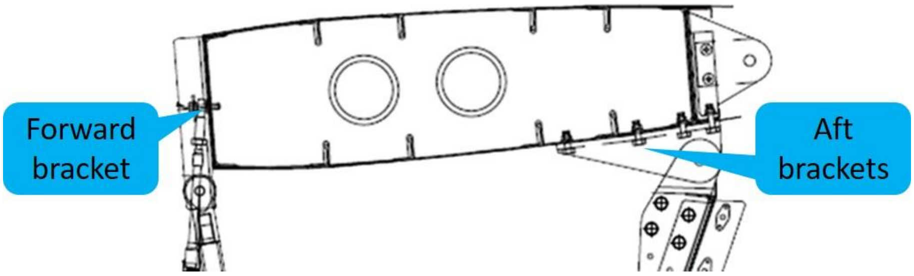

Figure 41. Cross-section of the stabiliser showing its attachments. Image: GibbsAero.Pty Ltd Service Manual. Amendment 54. Page 27-19. Figure 27-15, textboxes by SHK.

The two rear brackets for attachment of the stabiliser were mounted to the lower surface of the stabiliser using four screws (see Figure 42). The lower right image shows the lower surface of the stabiliser where one of the brackets has been mounted. There was damage to the skin panel and the screw holes in the stabiliser. The other attachment on the stabiliser showed similar damage.

This damage indicates that all the screws were mounted in place at the time of the failure.

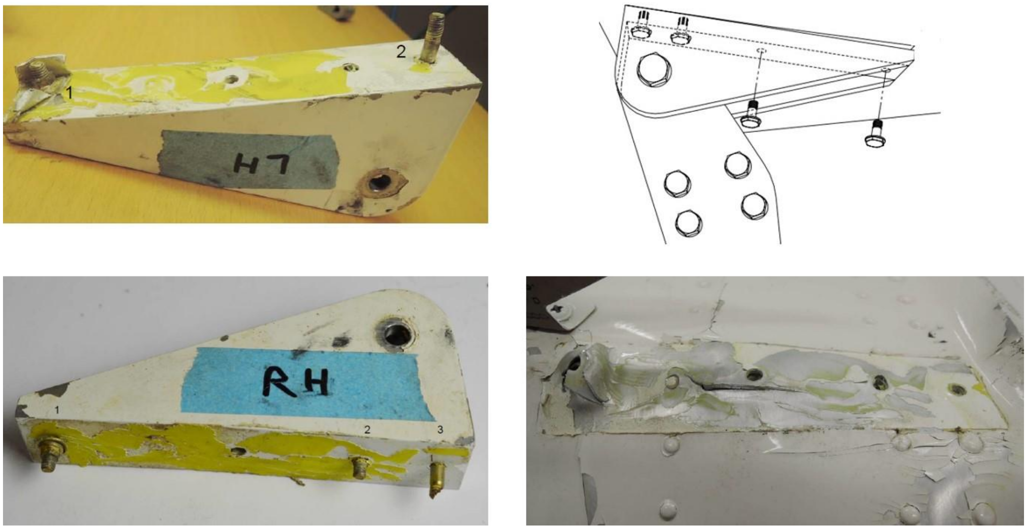

Figure 42. The brackets and attachment to the stabiliser. Upper right image: GippsAero Pty Ltd SB-GA8-2002-02 Figure 2.

All ten rivets on the bracket for attachment to the front spar of the stabiliser were sheared. The arrows indicate the direction of fracture (see Figure 43).

Figure 43. Bracket for front attachment of the stabiliser.

Jackscrew for pitch trim control

A visual inspection of the jack screw showed no damage or anything abnormal. The threads of the screw are undamaged and can easily be rotated in the nut. The ball joint at the top of the screw is bent, but this can be explained by the fact that it was mounted to the bracket that was broken off from the stabiliser.

The position of the screw was 90 % towards the end position for trimming the leading edge of the stabilizer upwards, ie. for trimming the aircraft's nose down. According to the type certificate holder, this position on the screw corresponds to a position on the stabiliser of 1.3 degrees leading edge up.

The elevator's balance horn

The elevator balance horn on the right elevator was missing. An examination of the holes for the rivets that attach the balance horn to the elevator showed that the rivets had been pulled through the rivet holes by overloading, which has caused the balance horn to detach (see Figure 44).

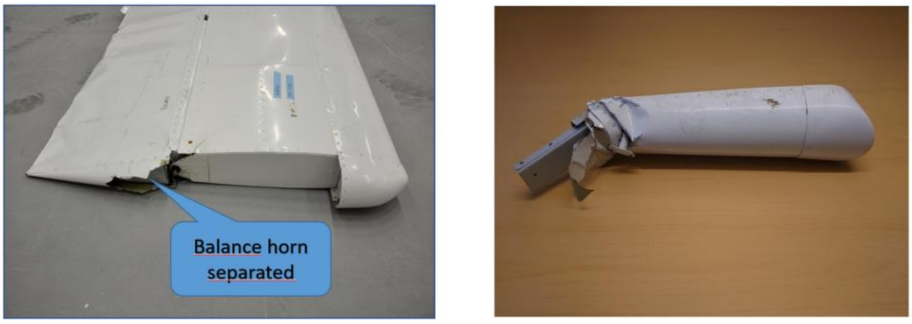

Figure 44. Left picture: Stabiliser and elevator with the balance horn separated. Right picture: The separated balance horn.

Elevator control arm

Figure 45 shows a picture of the broken control arm to the right elevator and an illustration of the stabiliser and elevator, with the position of the control arm marked in blue.

The control arm had an overload fracture. Upon examination welding defects were discovered. The overload fracture had been initiated in a 10 mm long weld defect, which is marked with a white arrow in Figure 45. There were also welding defects on the left control arm, but this was not broken off.

However, calculations show that the welding defect did not cause the control arm to break.

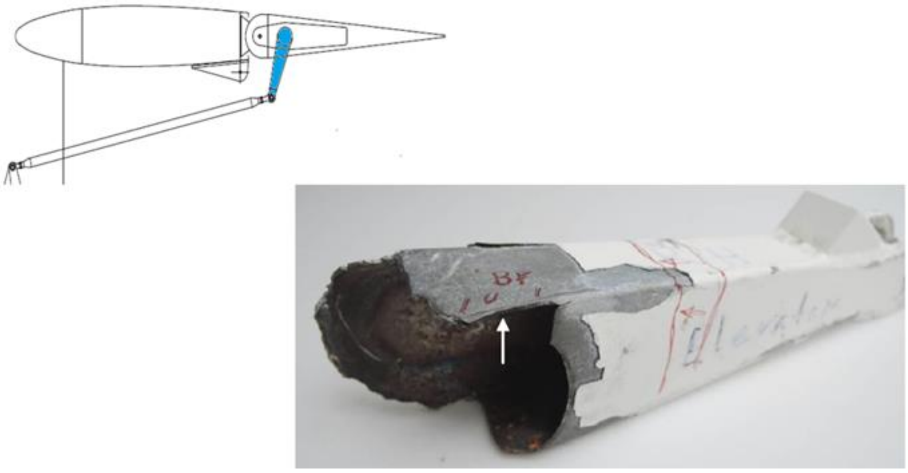

Figure 45. Right control arm to the elevator. Left upper image: GippsAero Pty Ltd GA8-TC 320 Service Manual. Amendment 54. Page 27-15. Figure 27-11, blue marking by SHK.

Sequence of failure of the parts of the empennage

Figure 46, which shows the empennage looking backwards from the direction of travel, illustrates the likely sequence in which the various parts of the empennage, the stabiliser and the fin, have broken up in the air.

Damage and broken skin panels on the right side of the fin indicate that the fin has been pushed and broken to the left seen in the direction of flight. The red dashed line shows the area where the tail fin has initially failed.

The damage to the stabiliser’s attachments, structure and skin panels indicates that the right part of the stabiliser has been broken off upwards and to the left. Damage to the top side also indicates that it has been pushed towards the right side of the fin.

Damage to attachments and structures of the left part of the stabiliser indicates that it has been broken off downwards.

All the fracture surfaces that have been examined show signs of rapid overload fractures. There were no signs of fatigue, corrosion or other material defects.

Figure 46. Sequence of failure of the stabiliser and the fin.

1.16.3 *Examination of the engine and propeller*

One of the blades on the three-bladed propeller was relatively undamaged, one was damaged at its tip and one was broken off at its root. The fact that one of the blades was undamaged indicates that the engine was not supplying power at the time of impact with the ground.

The engine can be rotated by hand, which indicates that it has not seized.

A visual examination of the engine did not reveal any damage or remarks that may have contributed to the sequence of events.

The engine with the propeller attached were separated from the aeroplane wreckage at the accident site for technical reasons.

Figure 47. Engine with propeller.

1.16.4 *Other technical observations*

- The control handle for the flaps was in a retracted position.
- All engine controls were in a fully forward position.
- The aeroplane's flight control system and surfaces with control cables have been examined to the extent that is possible, without remarks. All the damages were of the type that occurs during a crash.
- The aeroplane's pitot-static tube system has been examined visually without remark.
- The switch for pitot heat was in the off position.
- The electrical master 1 and 2 switches were in the "ON" position.
- It has not been possible to establish the position of the switches for the avionics due to damage caused to these during the crash.

1.16.5 *Examination of the parachutes*

All the parachutes on board have been examined and weighed.

The eight parachutists' parachute equipment were all complete, with both main and reserve parachutes.

The pilot was equipped with an emergency parachute, which was complete and consisted of a main parachute.

As the parachutist's automatic activation devices had been activated, a number of pilot chutes[20] were found in the wreckage.

1.16.6 *Calculation of the aeroplane's speed*

Recorded WAM data (see section 1.11.1), which includes information about position and time, has been used to calculate the aeroplane's ground speed (GS[21]) during the final moments at 13,600 feet (4,145 metres), which is just before the aeroplane lost altitude and changed heading to the left.

Using wind data from SMHI's analysis and from the commercial flight that landed at Umeå Airport just before the accident (see section 1.7) it has also been possible to calculate the aeroplane's true airspeed (TAS[22]).

The aeroplane's calibrated airspeed (CAS) has been calculated by correcting for the density of the air at 13,600 feet in relation to the standard atmosphere.

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[20] Pilot chute – smaller chute that is activated by the emergency deployment device, the task of which is to pull out the reserve chute.

[21] GS (Ground Speed) – horizontal speed relative to the ground.

[22] TAS (True Airspeed) – actual speed relative to the air.

According to the aircraft flight manual, the position error of the airspeed indicator is small at speeds of around 70 knots. This means that the indicated airspeed (IAS) that the pilot sees on the airspeed indicator is about the same as the calibrated speed.

GS → correction for wind = TAS → correction for standard atmosphere = CAS → correction for position error = IAS.

The calculations show that, in the final moments before the aeroplane lost altitude from 13,600 feet, the speed was below 70 knots and decreasing.

1.16.7 *Determination of centre of gravity*

SHK has weighed another aeroplane of the same type in order to determine the position of the centre of gravity with parachutists in the various stages of the flight.

By weighing and calculating changes in centre of gravity, it was possible to calculate the parachutists centre of gravity position along the length of the aeroplane for both take-off and for a normal position in conjunction with opening the door prior to a jump.

The mass of those on board and their location in the aeroplane at the time of the accident are assumed on the basis of information from the parachute club, post-mortem examinations and by weighing the equipment.

With the aid of this information, SHK has calculated that the aeroplane's mass was 1,905 at the time of the accident. The centre of gravity has been calculated at 1,659 mm aft of datum prior to door opening and 1,694 mm during normal positions for door opening.

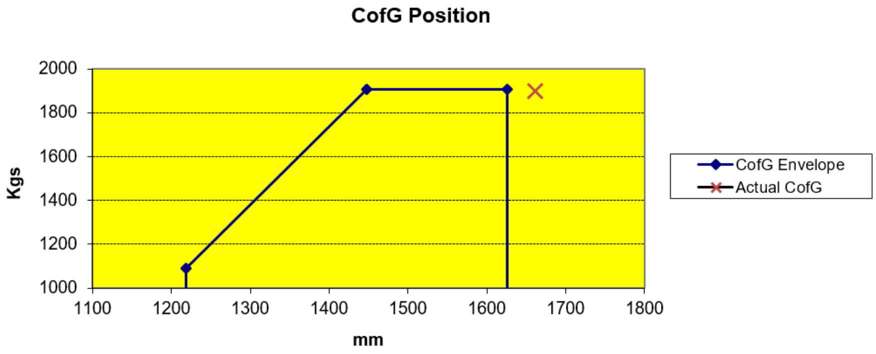

Figure 48. The centre of gravity prior to door opening, 1,659 mm.

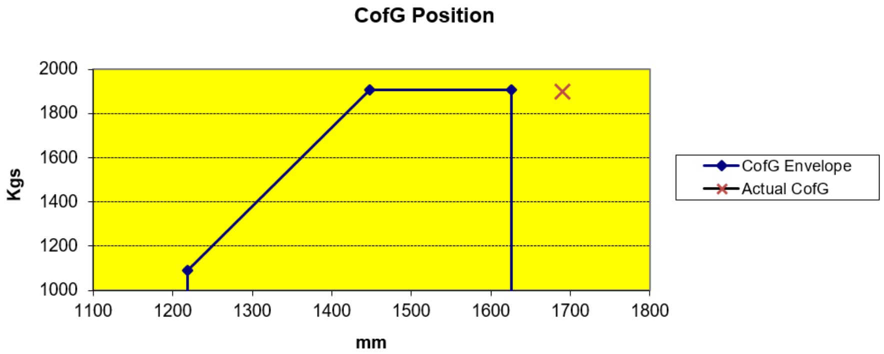

Figure 49. The centre of gravity during door opening, 1,694 mm.

The permitted area at maximum mass is 1,448–1,626 mm. According to this calculation, mass and balance were outside of the mass and balance diagram.

At the same time, it should be said that it is not possible to retrospectively determine the mass and balance of the aeroplane with great accuracy.

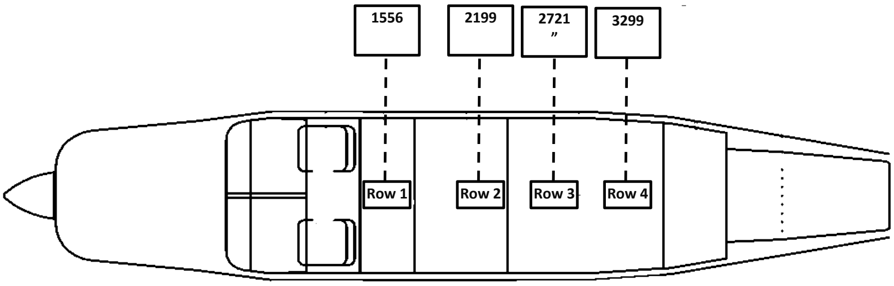

Figure 50. The calculated moment arms for the parachutists prior to door opening expressed in millimetres. Image: GippsAero POH. The rows marked by SHK.

1.16.8 *Reference flight*

SHK has conducted a reference flight with an aeroplane of the same type that was equipped in the same way as SE-MES but it did not have an extra conventional artificial horizon and only had one GPS navigation screen, unlike SE-MES, which had two.

The flight was conducted with nine people on board, a pilot who was an instructor for the parachute club, SHK's representative in the right seat, who was also qualified to fly this class of aeroplane, and seven parachutists.

A mass and balance report was presented, which showed how many people and parachutes were on board and the mass of each person. However, the internal placement of the parachutists was not known before it was time to load the aeroplane. SHK asked who would be sitting in each position and then measured the lever arm for each jump row and then calculated a centre of gravity.

At the time there were light south-westerly winds and a temperature of 28 degrees and 2/8 cumulus clouds with tops over the maximum jump altitude.

SHK's observer was given the opportunity to maneuver the aeroplane throughout the entire flight during one of the two flights that were conducted, which provided insight of the operation of this kind.

Following the take-off, rpm was reduced to 2,500 and the manifold pressure to 38 inches. An indicated airspeed of 80 knots was maintained to the jump altitude. At the jump altitude, rpm was reduced to 2,300 and speed was adjusted to between 70 and 80 knots.

The fuel mixture was kept at rich up to the jump altitude, when it was reduced to 80 litres/hour. The cylinder temperature was also checked regularly.

One thing that was clearly observed was that it was necessary to maintain quite a firm pressure on the right pedal in order to maintain coordinated flight during the entire climb and the jump phase. It was not possible to release this pressure as there was no rudder trim.

When the parachutists began to move backwards in order to open the door and jump, a pronounced trim change towards the back was noted. The trim wheel needed a large number of rotations in order to correct a small change in trim, which resulted in the control column having to be pushed forward a fair amount in order to maintain speed while finding the time to perform the trim so that the speed would not fall below 70 knots.

The final approach track had been programmed into the installed GPS unit. Some workload was also required in order to maintain the final approach heading.

The aeroplane was allowed to descend slightly in order to maintain the speed above 70 knots.

When all the parachutists had left the aeroplane, descent began at a speed that was not permitted to exceed 120 knots, which is the speed limit with the cabin door open.

The aeroplane became much easier to maneuver with lower mass and with a centre of gravity that had been moved forward.

The workload on the pilot during the jump was considered to be high and required rapid compensation with the control column, giving right rudder in order to fly coordinated, and continually trimming forward in order to maintain speed. In addition to this, it was necessary to monitor several engine instruments and adjust rpm and mixture. The pilot was also required to take on a large mental workload in order to hold the final approach with the help of a line on the GPS screen and navigate with precision to the jump point.

1.16.9 *Strength calculations*

SHK has performed rough calculations of the strength of the wings and stabiliser.

The calculations for the wing have been performed by distributing lift evenly over the wing area, which results in a bending moment at the span station for the fracture. The surface inertia moment for the wing section has been estimated by simplifying the construction to a box between the two spar webs, then adding the longitudinal cross reinforcements. This method does not provide an accurate result but shows that the ultimate load for the wing, at the wing strut, is higher than the 5.7 g that is stipulated for the aeroplane.

A calculation of the screws for the stabiliser attachment shows that an asymmetrical load of close to 700 daN on one half of the stabiliser is required in order for a failure to occur. An airspeed of over 120 knots and a very fast roll is required in order to achieve this asymmetrical load. This is deemed to be well within the construction requirements.

1.16.10 *Longitudinal stability*

Test flights

The type certificate holder has conducted test flights with the centre of gravity at 1,703 mm, i.e close to the calculated centre of gravity during door opening on the accident flight (1,694 mm). These tests show that the control force required to increase speed from a trimmed state at 80 knots to 100 knots is only 0.2 daN. The stability is divergent at over 100 knots, which means that the speed increases without any forward pressure on the control column being required. No test involving reducing speed was conducted.

Stability calculation

SHK has performed stability calculations with the assistance of Ringertz Aerospace. Because there is no complete set of aerodynamic data, the calculations are rough but do show that the aeroplane is unstable but controllable at the calculated centre of gravity during door opening on the accident flight.

1.16.11 *Trajectories*

On the basis of the radar data and the ProTrack equipment, SHK has calculated the aeroplane’s airspeed and g-forces.

Radar data has been used to calculate horizontal speed.

Altitude readings from the ProTracks have been used to calculate vertical speed and vertical acceleration. Because altitude is recorded every quarter of a second, even small measurement errors cause large indents in the curve. For this reason, SHK has chosen to perform the calculation using two-second averages, which gives a reasonably smooth curve.

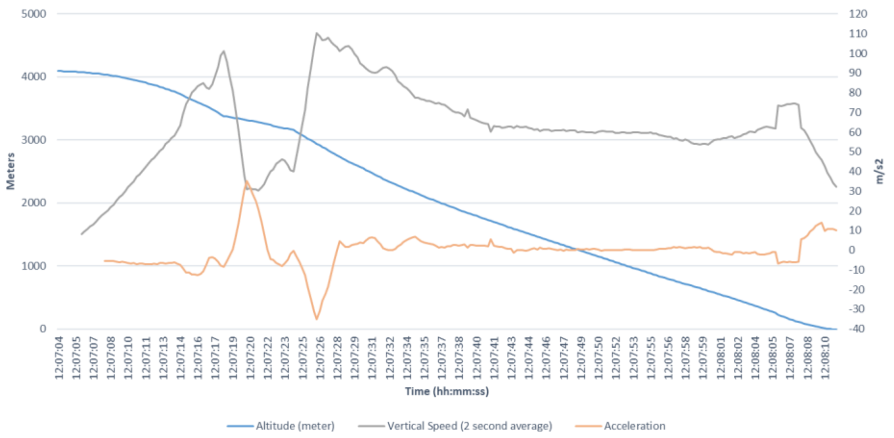

Figure 51. The blue curve shows the altitude in metres, the grey curve shows the rate of descent in metres per second and the yellow curve shows vertical acceleration in metres per second squared.

The calculations show that there have been vertical accelerations of up to 35 m/s^2, which entails a vertical g-force of 3.5 g.

At an altitude of just over 3,000 metres, the rate of descent was 100 m/s and the horizontal speed, calculated from radar data, was 45 m/s. This means that the dive angle was just over 60 degrees. This can be used to calculate the airspeed at 109 m/s (218 knots).

The wing’s lift, which caused g-force on the aeroplane, is perpendicular to the flight path. Vertical acceleration is a component of lift, which, because of the dive angle, must have been significantly higher (see Figure 52).

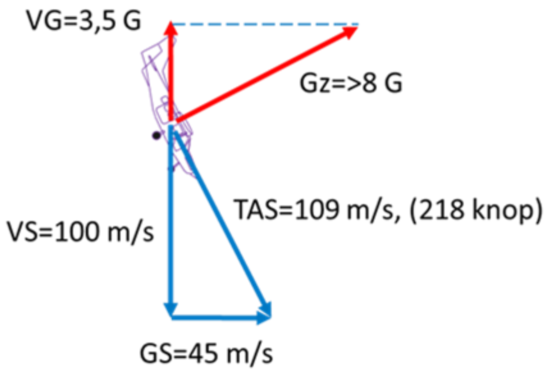

Figure 52. Calculation principle

The calculations cannot be regarded as precise because the basic data have been derived from various sources that all have some margin of error. Nevertheless, it is highly likely that the airspeed exceeded 200 knots and g-forces of over 6 g have occurred. In the calculations, it has been assumed that the aeroplane has flown between the radar points on a straight heading and with the wings level.

However, the aeroplane has probably both banked and moved in some form of spiral or arc, which means that the speed and g-forces may have been much higher.

1.16.12 *Examination of the aeroplane's doors*

There are indications that the rear cabin door was in the open position at the time of the impact with the ground. There are also signs that the left pilot door was closed and locked.

There is clear impact and paint marks from the red door handle on the outside of the fuselage and on the inside of the rear door. The position of these marks indicates that the rear door was open and that the door handle was in an unlocked position (see Figures 53 and 54).

Figure 53. The picture shows an impact mark from the internal door handle on the outside of the fuselage.

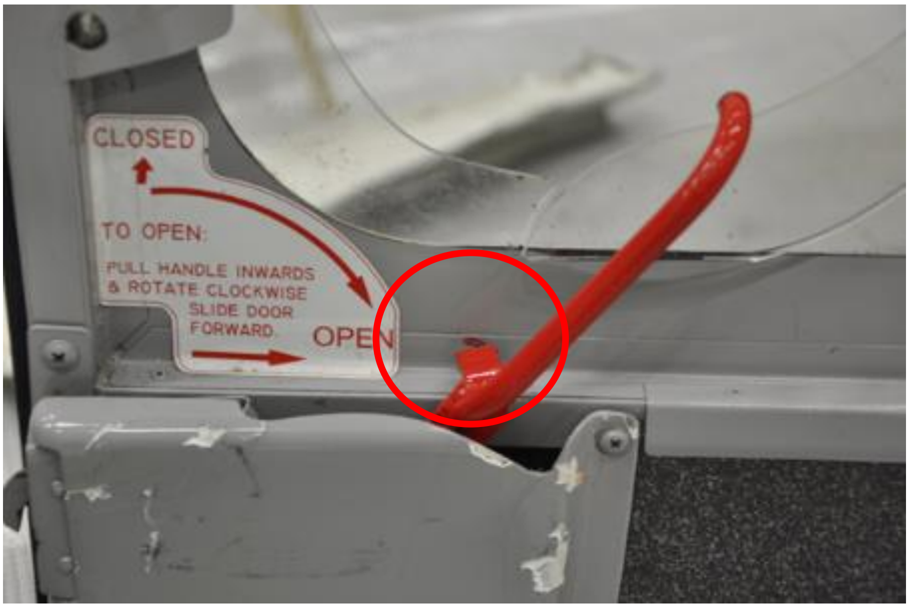

Figure 54. The picture shows a mark from the handle on the inside of the door.

There are also marks and deformation on the centre door slide rail’s end position to indicate an open door (see Figure 55).

Figure 55. Left picture: Shows damage to the fuselage at the forward position of the door when it is open. Right picture: Marking by SHK that shows the position of the damage on the fuselage. Photo: Krister Karlsmoen.

There was no damage to the rear cabin door’s lock mechanism (see Figures 56 and 57).

Figure 56. The cabin door’s lock hasp.

Figure 57. The cabin door's locking pin on the fuselage.

An examination of the left pilot door showed that the locking catch that keeps the door locked was ripped out from its attachment to the fuselage (see Figure 58).

Figure 58. The picture shows that the pilot's door's locking catch was ripped out of its attachment.

1.17 Organisational and management information

1.17.1 *Swedish Parachute Association (SFF)*

The Swedish Transport Agency, by virtue of Chapter 12, Sections 1 and 8 of the Aviation Act (2010:500) and Chapter 12, Sections 1 and 4 of the Aviation Ordinance (2010:770), has delegated to SFF the authority to issue certificates of competency, students' certificates and to conduct inspections and supervision of recreational parachute jumping in Sweden. The Transport Agency has also tasked SFF with ensuring that these activities otherwise comply with aviation safety requirements. The decision to delegate and the agreement signed between the Transport Agency and SFF indicates that SFF's activities are to be governed by a handbook system that, among other things, describes procedures and instructions for its activities.

SFF has produced a handbook system of this type. Chapter 402:03 contains provisions concerning aircraft and pilots. According to 3.3.1, pilots of aircraft from which parachuting is conducted shall be approved for the task and trained by a head of operations at an air organisation and/or by a person responsible for flight operations at a parachute club, and that the flying hours requirements shall be complied with. The chief instructor (CI) at the parachute club notifies SFF of approved pilots, which gives them eligibility to perform jump flights throughout Sweden. Jump leaders shall ensure that pilots are informed of any local regulations and of the provisions compiled in the instructions for pilots.

The training mentioned in section 3.3.1 of the handbook is described in more detail in sections 3.3.4–3.3.7. It states there that the training plan for pilots of jump planes includes a general part and a specific part. The specific part is in turn divided into a theoretical section and a practical section. The specific, theoretical section shall contain a review of limitations and operation of the aeroplane in question. The specific, practical section shall contain flying and landing with a fully loaded aeroplane, jump flight profiles, climbing and descending, as well as jump flights with experienced parachutists. The general part shall contain elements including a review of jump flight profiles, including spotting[23], and a briefing on emergency procedures, including bailing out by the pilot.

The requirements regarding flying hours are specified in 3.3.2. This specifies, as far as is of interest here, that pilots of aeroplanes from which parachuting is performed shall hold at least an A-licence[24] or equivalent and have at least 200 total flying hours in single-engine aeroplanes.

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[23] Spotting – calculation of the jump point.

[24] A-license – Former Swedish national licence equivalent to PPL.

Chapter 402:01 contains basic provisions. Section 1.1.9 states that it is not permitted to jump without visual ground contact and intentionally passing through clouds is not permitted.

1.17.2 *Umeå Parachute Club*

Generally

Umeå Parachute Club is a non-profit association that was formed in 1967 and whose task is to conduct sports parachuting. Everyone on board the plane was a member of the parachute club.

Procedures for flying

The parachute club has documented procedures for flying with the GA8, which, among other things, describe pre-flight procedures, engine start, handling of navigation and engine instruments, taxiing, the various phases of flight, including the final approach to a jump. The section on final approach to a jump states that extensive management of engine values is necessary. It also describes how the airspeed must not exceed 80 knots on the final approach because it is not possible to open the cabin door at higher speeds and that the altitude is to be maintained by increasing power.

Procedures for calculating mass and balance

SkyWin is an administrative program for parachute clubs that Umeå Parachute Club used. The program can administer members, aircraft, jumps and finances. It also has a function as a manifest program where the weight of each parachutist and the total weight of the parachutists are presented and where it can be checked that the load before a flight stays within the limit of the aircraft’s maximum take-off mass. If the limit is exceeded, a warning message may be displayed. The print load message, “Load sheet”, which the program produces can (depending on the setting) show both the total weight for all parachutists and the weight of each individual parachutist.

Umeå Parachute Club had the parachutists’ weights registered in SkyWin. According to information, however, not all functions of the program were used. As previously mentioned, there were no weights presented on the load sheet that the pilot received before the flight. SkyWin has no function for balance calculation before flight.

There were no described routines within the club regarding mass and balance calculation. According to information, no such calculations are made for each flight, as it is done based on experience, and you feel on the ground if the aircraft is too tail heavy and the parachutists can then be asked to move forward.

Procedures prior to a drop according to interviews

During take-off and climbing, 78 knots, full throttle, maximum propeller rpm and rich mixture are to be maintained. The parachutists sit on the floor facing backwards (see Figure 59).

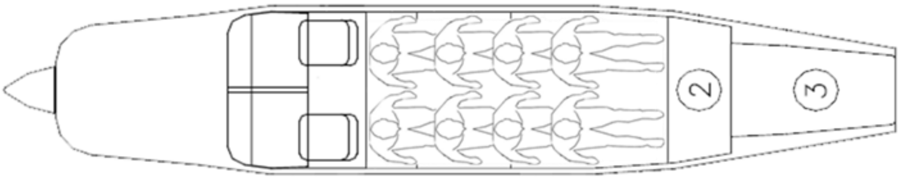


Figure 59. The parachutists during take-off and climb. Image of the aircraft: GippsAero Pty Ltd POH, objects of parachutists by SHK.

At an altitude of 3,500 metres, the parachutists turn around, get on their knees and check their equipment (see Figure 60), still at a speed of 78 knots.

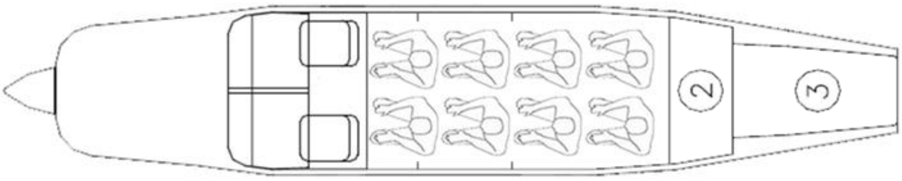


Figure 60. The parachutists check their equipment. Image of the aircraft: GippsAero Pty Ltd POH, objects of parachutists by SHK.

At 4,000 metres and when clearance to drop is received from the air traffic control, the dome light is lit by the pilot. The parachutists turn around and move towards the door in groups (see Figure 61).

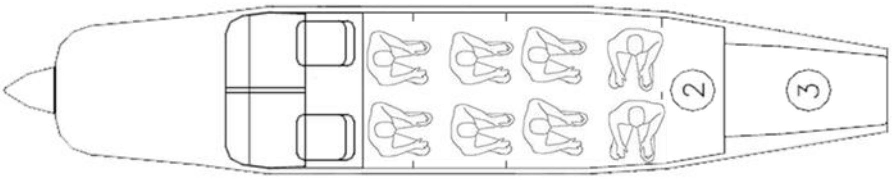
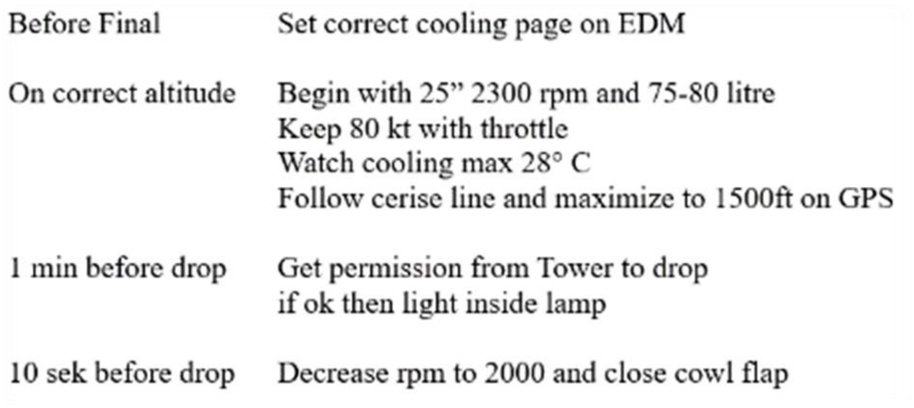


Figure 61. The parachutists’ position during door opening. Image of the aircraft: GippsAero Pty Ltd POH, objects of parachutists by SHK.

The parachute club had a checklist that describes what to do when dropping parachutists. This includes that the rpm is to be reduced to 2,000 in order to reduce the propeller blast around the aeroplane and make it easier to open the door.



Before Final	Set correct cooling page on EDM
On correct altitude	Begin with 25” 2300 rpm and 75-80 litre Keep 80 kt with throttle Watch cooling max 28° C Follow cerise line and maximize to 1500ft on GPS
1 min before drop	Get permission from Tower to drop if ok then light inside lamp
10 sek before drop	Decrease rpm to 2000 and close cowl flap

Figure 62. Picture of the checklist for final approach and jumping for SE-MES.

1.18 Additional information

1.18.1 *Regulations*

Commission Regulation (EU) No 965/2012

Parachuting with aircraft other than complex motorised aircraft may be conducted accordance with Annex VII (Part-NCO) of Commission Regulation (EU) No 965/2012 laying down technical requirements and administrative procedures related to air operations provided that a) it is conducted by an organisation created with the aim of promoting aerial sport or leisure aviation, b) that the aircraft is operated by the organisation on the basis of ownership or dry lease, c) that the flight does not generate profits distributed outside of the organisation, and d) that whenever non-members of the organisation are involved, such flights represent only a marginal activity of the organisation.

No specific permit or approval from Swedish authorities is required for activities conducted under Part-NCO.

NCO.SPEC.105 states that specialised operations, which parachuting is considered to be, shall be performed in accordance with a checklist. It is the pilot-in-command who, on the basis of a risk assessment, assessing the complexity of the activity to determine the hazards and associated risks inherent in the operation and establish mitigating measures, shall establish such a checklist. The checklist, which is relevant to the duties of the pilot-in-command, crew members and task specialists shall be readily accessible on each flight and shall be regularly reviewed and updated, as appropriate.

NCO.GEN.105 describes i.a. that the pilot-in-command shall be responsible for that the mass of the aircraft and the centre of gravity location are such that the flight can be conducted within limits prescribed in the airworthiness documentation.

NCO.POL.100 further describes that during any phase of operation, the loading, the mass and, the centre of gravity (CG) position of the aircraft shall comply with any limitation specified in the AFM or equivalent document.

Specific provisions concerning parachuting are found in Section 4 of Part-NCO. This states that the checklist for parachute operations (PAR) shall contain, among other things, normal, abnormal and emergency procedures, relevant performance data, required equipment and any limitations. (NCO.SPEC.PAR.100).

Commission Regulation (EU) No 1178/2011

Annex 1 (Part-FCL) to Commission Regulation (EU) No 1178/2011 laying down technical requirements and administrative procedures related to civil aviation aircrew sets out the requirements there are for flying as a pilot-in-command of an aeroplane. The minimum requirement to fly a GippsAero GA8 with eight parachutists within the scope of the rules in Part-NCO, is a private pilot licence with the rating SEP(land). Because the GippsAero GA8 has a constant speed propeller and EFIS, the pilot is also required to have completed differences training in these parts. Otherwise, only familiarisation training is required. Differences training involves both the acquisition of new knowledge and training under the supervision of an instructor. The instructor will then certify the differences training in the pilot’s logbook. Familiarisation training, i.e. the acquisition of knowledge about the aeroplane, is something that pilots can complete themselves, e.g. through independent study of the aircraft flight manual, and thus does not encompass any form of instructor-led training or exercises. (See Subpart H of Part-FCL and guidance issued by the EASA associated with the regulation).

When it comes to other specialised operations such as glider towing and banner towing (advertising), a specific rating is required (FCL.805).

Glider towing requires both at least 30 hours of flight time as pilot-in-command and 60 take-offs and landings in aeroplanes, completed after the issue of the licence, and a training course at an ATO[25] that includes theoretical knowledge instruction on towing operations and procedures, at least 10 instruction flights towing a glider, including at least 5 dual instruction flights, and familiarisation flights in a glider which is launched by an aircraft.

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[25] ATO – Approved Training Organisation.

Banner towing requires both at least 100 hours of flight time and 200 take-offs and landings as pilot-in-command on aeroplanes, after the issue of the licence, at least 30 of which shall be in aeroplanes, and a training course at an ATO that includes theoretical knowledge instruction on towing operations and procedures, at least 10 instruction flights towing a banner, including at least 5 dual flights.

Commission Regulation (EU) No 923/2012

Commission Implementing Regulation No 923/2012 laying down the common rules of the air and operational provisions regarding services and procedures in air navigation (SERA[26]) contains standardised European rules of the air. This regulation contains provisions on visibility and distance from clouds for flying under visual flight rules (VFR).

Under SERA.5001, at and above an altitude of 3,050 metres (10,000 feet), visibility of eight kilometres and 1,500 metres horizontal and 300 metres vertical (1,000 feet) distance from clouds are required.

National regulations

The Swedish Aviation Administration's regulations (LFS 2007:46) on parachuting contain certain provisions on flight duty on board aircraft when parachuting, aeronautical equipment and flight crew, as well as specific regulations concerning safety. These regulations, which are from the period prior to the European regulatory framework entering into force, contain some deviations in comparison to this. Because there is limited potential for separate national regulations, it is unclear whether some of the provisions – where there are European rules – are applicable. According to information from the Swedish Transport Agency, a process of reviewing the national regulations in this respect is ongoing.

1.18.2 *Previous occurrences*

A similar accident occurred in Finland in 2014[27]. During flight, with a pilot and ten parachutists on board, control of the aeroplane was lost and it then broke up. The pilot and two of the parachutists who were furthest forward in the aeroplane were able to get out through the pilot's door. The others did not manage to get out of the aeroplane and did not survive. The centre of gravity was aft of the permitted area and the pilot was relatively inexperienced.

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[26] SERA – Standardised European Rules of the Air.

[27] Aircraft accident resulting in the death of eight parachutists at Jämijärvi on 20 April 2014. Safety Investigation Authority, Finland L2014-02.

The Safety Investigation Authority in Finland issued recommendations including:

> *The European Aviation Safety Agency is recommended to prepare specified theoretical knowledge and flight training requirements for pilots-in-command in skydiving operations.*

The EASA's initial response was negative. Reference was made to applicable regulations that require the pilot to conduct a risk analysis and take action to compensate for risk found, for example theoretical training. In addition, the EASA did not believe that introducing training for parachute pilots was a proportional measure.

In a second response from 2016, the EASA maintained the same fundamental standpoint but stated that an analysis of parachute operations would be conducted in 2016. No results of this analysis have been reported. However, in unofficial contact with SHK, the EASA has stated that information about the risk involved in parachute operations will be presented on a website.

1.18.3 *Stall*

Lift on a wing is obtained through the reaction force of the air particles that the wing meets and forces downwards (see Figure 63). The greater the angle that the wing has in relation to the direction of airflow, the greater the lift. The angle between the wing and the airflow is called the angle of attack.

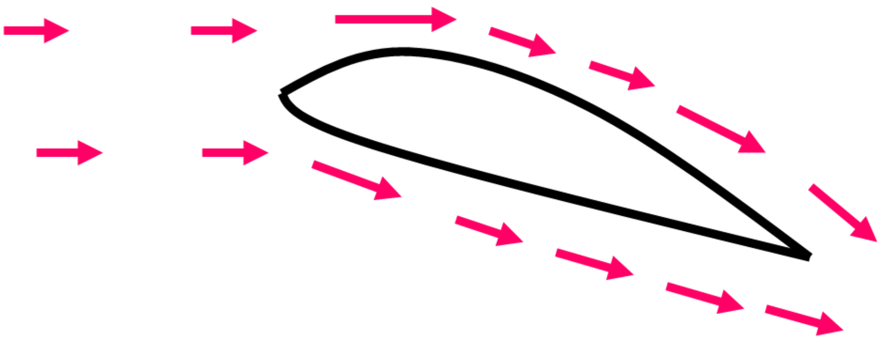

Figure 63. Sketch showing how lift is generated.

Five factors affect the amount of lift: airspeed, angle of attack, air density, the wing's cross-sectional shape and the wing area. During flight, the pilot is able to influence the speed and angle of attack. For example, the angle of attack must be increased if the speed is reduced in order to prevent lift decreasing.

However, there is a limit to how much the angle of attack can be increased (see Figure 64). When it becomes too high, the air is not able to flow and pass around the wing and lift decreases. This is called stall. When the wing stalls, aerodynamic drag also increases.

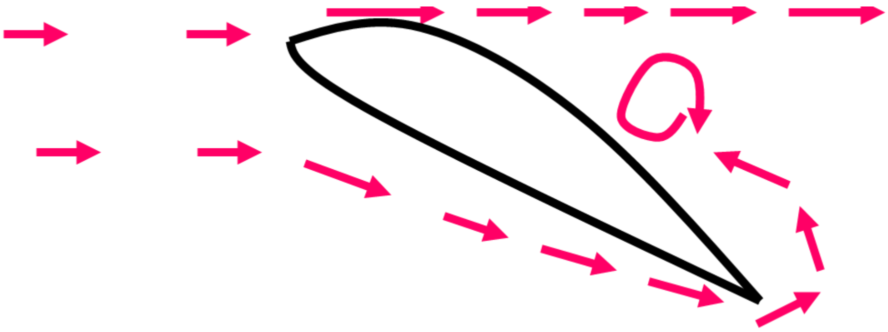

Figure 64. Sketch showing stall.

If the aeroplane is flying at an angle though the air, it may be the case that one wing stalls before the other (see Figure 65). The stalled wing has less lift and more drag than the other. This leads to a yaw and roll rotation, which may be the start of a spin.

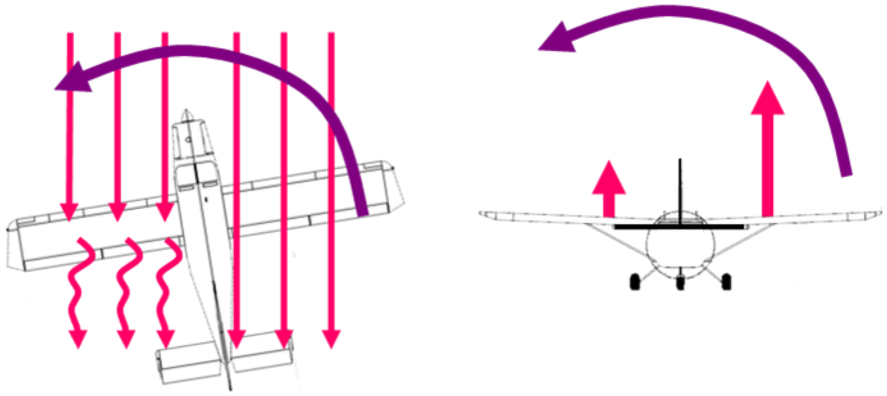

Figure 65. Sketch showing a sideslip stall.

1.18.4 *Stall warning during a previous flight*

Parachutists that were in the aeroplane during the previous flight reacted to the fact that the stall warning sounded several times during the flight, especially during the final approach to the jump. At that time, there were two parachutists located furthest back on the baggage shelf. After they were told off and had moved forward, the warning stopped.

SHK has examined video of previous flights and has found that the baggage shelf has been used by parachutists in conjunction with jumping. This has also been confirmed during interviews with parachutists from the club.

1.18.5 *Flying without visual references*

Spatial orientation is defined in a flight context as the ability to perceive the aeroplane’s position and movements in relation to the surface of the earth. Information about the position and movements of the head and body relative to the surroundings primarily involves three senses: vision, the somatosensory system and the sense of balance.

Under normal circumstances, vision provides an intuitive depiction of one's own movements relative to the surroundings and of the direction of gravity. As a rule, such visual information is reliable and thus has a major significance to a person's ability to orientate themselves spatially and balance. The somatosensory system, with receptors of pressure and tension in the skin, muscles, joints and internal organs, contributes to the perception of how the body is oriented relative to gravity. The balance organs of the inner ear encompass two receptor systems; the semi-circular canals, which react to turning of the head, and the vestibular sacs which perceive linear acceleration and the position of the head in the gravitational field.

It is impossible to perceive the position of the aeroplane by means of only vestibular sacs or the somatosensory system. Consequently, pilots are entirely dependent on their instruments when flying without external visual references. An important part of instrument flight training is learning to ignore disorientation.

1.18.6 *Other observations*

Trim drift

According to information, a phenomenon known as trim drift has occurred in the actual aeroplane in the past. At speeds of around 120 knots, the trim wheel has begun to rotate backwards by itself, which trims the leading edge of the stabiliser down, resulting in the nose of the aeroplane being raised.

During the technical examination, the jackscrew was in the opposite position, for the leading edge of the stabiliser up, i.e. in a trimmed position for the aeroplane's nose down.

Cloud observations

The accident occurred during the pilot's third flight of the day. SHK has studied films and photographs from the second flight, about one and a half hours before the accident. Footage from the films shows the cloud structure and formation during that flight (see Figure 66–69).

Figure 66. The parachutist with the camera leaves the aeroplane at approx. 12:41:53, the altimeter shows 4,000 m (needle at 0). The transponder altitude at 12:41:51 local time is 4,092 m. Picture: Umeå Parachute Club.

Figure 67. At 12:42:04 the parachutists approach the cloud tops. Picture: Umeå Parachute Club.

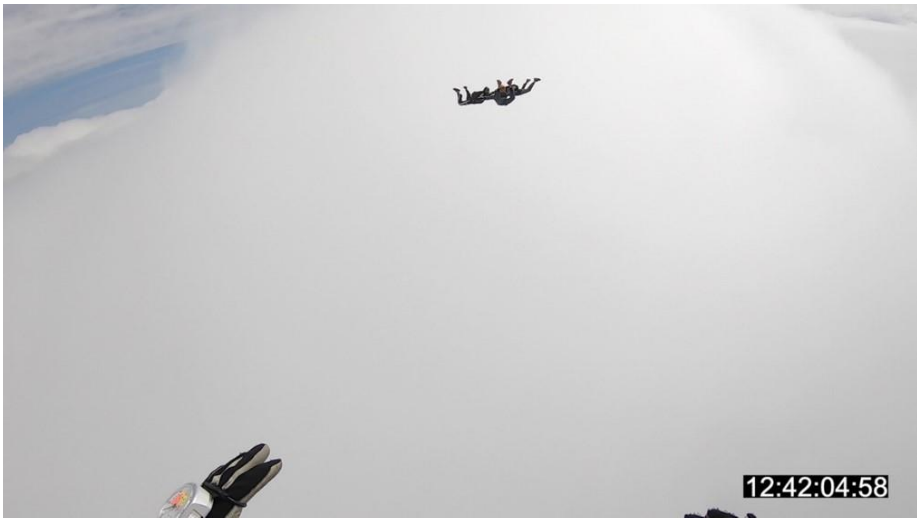

Figure 68. At 12:42:04 they approach the cloud tops when the altimeter shows 3,600–3,700 m. Picture: Umeå Parachute Club.

Figure 69. The cloud base is clear at 12:42:24 at approx. 2,700 m. Picture: Umeå Parachute Club, markings by SHK.

1.18.7 *Actions taken*

EASA issued an emergency airworthiness directive (EAD) five days after the accident prohibiting all flights with the aeroplane type. Following initial technical examinations, no evidence was found that could indicate that an unsafe condition existed, the prohibition was then lifted on 25 July 2019.

In September 2019, the Swedish Transport Agency requested that the Swedish Parachute Association (SFF) check its procedures and ensure that the parachute clubs have knowledge of the importance of staying within allowable weight and balance limitations during parachute operations, and that procedures and routines are followed.

In close dialogue with the Swedish Transport Agency, SFF produced an action plan which was presented to the Swedish Transport Agency on 11 December 2019. Part of the SFF action plan was to ensure duties in the aircraft and the concept of Lift Manager was introduced. The lift manager is a parachutist with responsibility for preparing the lift for flight and exit for jumping as well as duties in the aircraft. Duties in aircraft includes e.g. load message to the pilot with jumper’s weights and total weight, jumper’s placement in aircraft with regard to weight and balance, ensure that rules are followed, eg seat belts, helmets, door and to follow the pilot’s instructions.

In 2020, SFF has developed a joint training plan for pilots in parachute operations which, among other things, includes developed instructions for initial and continuous flight training for pilots in parachute operations.

CASA, the Civil Aviation Safety Authority in Australia, has informed that Australian legislation requires that all passengers in an aircraft must be provided with a restraint that must be used during certain stages of flight or when directed by the flight crew. This requirement applies to parachutists as well with the exception that the restraint can be a single point restraint. By having a single point restraints installed a weight and balance calculation can be made as the location on the floor of each parachutist is defined by the location of the single point restraint. Once airborne the pilot is still responsible for ensuring that the parachutists remain within the predetermined areas so that the aircraft's centre of gravity remains within the approved limits. The pilot will be assisted in achieving this by inclusion of a load master and by the appropriate pre-flight briefing that is required to be given to the parachutists on board. Based on the above, the approved GA8-TC 320 flight manual supplement for parachute operations (C01-01-01) meets Australian legislative requirements that are applicable to parachute operations in Australia. Therefore, CASA at this time does not plan to make changes to the GA8-TC-320 approved flight manual supplement for parachute operations.

1.19 Special methods of investigation

None.

2. ANALYSIS

2.1 Planning and prerequisites

The mission was to drop eight parachutists from flight level 130 (approximately 4,000 metres). The load sheet that the pilot received prior to the flight did not contain any information about the weight of the parachutists or the total mass of the load. The pilot was thus unable to check or make his own calculation of mass and balance before the flight with the aid of the load sheet.

This circumstance did not deviate from previous flights and, according to information SHK has received from the parachute club, correct mass and balance calculations were not usually performed, instead previous experience was relied upon.

The load in question has retrospectively been deemed by the parachute club to be completely normal and flights with heavier parachutists have been performed previously without problems. The pilot has probably complied with the usual procedures at the parachute club, which may explain why the aeroplane, according to SHK's calculations, took off overloaded and tail heavy. Further information about the possibility of calculating mass and balance with the help of the aeroplane's aircraft flight manual can be found in section 2.6.3.

The forecast for Umeå Airport showed that the formation of towering clouds was expected during the afternoon. The images from the previous flight show cloud tops at an altitude of 3,700 metres, and a more or less complete cloud cover over the drop point.

Given that clouds was developing and rising, it was reasonable to expect cloud tops at higher altitudes than during the earlier flight. Consequently, there were small margins for releasing the parachutists at 4,000 metres from a planning perspective.

As SFF's regulations do not allow jumping without visual ground contact or intentional passage through clouds it is doubtful whether the prerequisites for performing the jump were in place.

SHK cannot know whether the pilot reflected on these conditions prior to the flight. In general, however, there may be a risk that a pilot in parachute operations, especially those with less experience and at the beginning of their flying careers in a parachute club, may feel real or perceived pressure from the parachutists to perform a flight even if the weather or load conditions are undesirable.

2.2 Sequence of events

In the absence of information from a cockpit voice recorder and a flight data recorder or video recordings of the entire sequence of events, it will not be possible to establish the exact sequence of the accident. The recordings there are exists and that are described in section 1.11 do however provide sufficient information to allow a probable sequence of events to be described. The data points provide information about the aeroplane's position at each point, but at the same time, say nothing about the aeroplane's attitude, i.e. the aeroplane's orientation in relation to the horizontal plane, at that time. In addition, there is no information about the aeroplane's position between these data points. If the aeroplane did not fly in a straight line between the points – which has been assumed in the calculations – there would of course be an impact on the calculations.

Based on the data available, the flight initially proceeded normally. The aeroplane climbed in a south-westerly direction out over the sea where there was less cloud formation, which allowed the pilot – who was not qualified to fly under instrument meteorological conditions, e.g. in clouds – to climb above the clouds.

Once the aeroplane had reached the jump altitude, it was put into a holding pattern because of other traffic arriving at the airport. This resulted in the flight time at a higher altitude to be extended.

The pilot's communications with the tower indicates that the intended jump altitude was not possible because of cloud formation and that it was necessary to climb even higher. It is not possible to comment in retrospect on the exact appearance of the cloud formations.

Sensor data indicates that the aeroplane climbed to flight level 136 (approx. 4,150 m) and, having received clearance from the control tower, was approaching the drop point. The aeroplane had just over one kilometre left to the airport where the drop point was located, which equates to approximately 30 seconds, when the aeroplane suddenly dropped and changed heading. This coincides with the time the parachutists normally move backwards and prepare to open the door. SHK has calculated that in this phase the centre of gravity moves backwards, which makes the aeroplane longitudinally statically unstable.

When the aeroplane is longitudinally statically unstable the workload on the pilot and the need for rapid control column movements will increase. If the aeroplane is also subject to a change in its centre of gravity, the speed deviation may be surprising to the pilot and lead to overcompensation. A pitch disturbance in a nose-up direction can easily lead to a dynamic stall. Accordingly, the centre of mass moving to an unstable position can cause loss of control. If parachutists have been on the baggage shelf, which is reported to have taken place during the previous flight and has been seen on videos from other flights, the situation is exacerbated.

SHK's calculations have shown that the aeroplane's speed prior to deviating from its altitude and heading, was low and decreasing towards stall speed. As the aeroplane does not have any rudder trim, the pilot is required to compensate with right rudder in order for the aeroplane to fly coordinated. If this compensation is not sufficient in conjunction with stall, the aeroplane will roll and yaw to the left.

All the evidence indicates that the aeroplane stalled when, according to radar data, it made a sudden and descending turn. In doing so the aeroplane ended up in an uncontrolled state in the clouds.

The parachutists, who were not strapped down, have in this state been moved and thrown around in the cabin, although it is not possible to elucidate how this has taken place. However, these movements have probably contributed to changes in the centre of gravity that made the controlling of the aeroplane even more difficult. The parachutists may also have moved towards the pilot, which may have led to involuntary flight control deflection that led to the aeroplane being overloaded.

The analysis of the recorded sound from the engine and propeller indicates rapid changes in rpm. It sounds like an aeroplane that has entered a rotation with a strong sideslip. The time of these rpm changes coincides with the large variations in rate of descent and the point when the recordings of engine data stopped.

SHK's assessment is that during this time interval the aeroplane was overloaded and the right wing was broken off, which led to an intense rotation to the right. As a result of this, the stabiliser and the fin broke loose.

The videos of the final stage of the sequence of events that were shot from the ground, show that the fuselage, without the right wing, tail fin and stabiliser, rotated in the horizontal plane with the left wing pointing upwards.

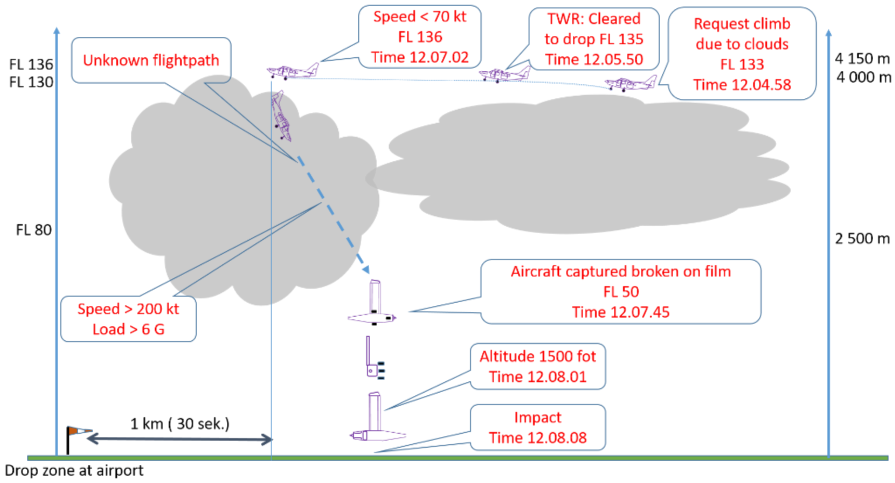

Figure 70. Analysis of the sequence of events (not to scale, times UTC).

2.3 Possibility of bail out

As the hinges on the pilot’s doors are located at the front of the doors, and because there was no emergency release function, these are practically impossible to open during flight with forward motion. After the aeroplane broke up and was rotating with the left wing straight up, the air pressure created a force corresponding to 150 daN on the right pilot door, which made it impossible to open. However, it is technically possible that the left pilot’s door could have been able to be opened at this stage. Nevertheless, the damage to the door indicates that it had been closed and locked at the time of the crash.

When it comes to the rear cabin door, it has been described as difficult to open at high speed, which is one of the reasons why the speed prior to and during jumping has to be relatively low. At higher speeds, it has probably been impossible to open because the aerodynamic drag increases in proportion to the speed squared.

It has not been possible to establish when the rear cabin door, which was in an open position at the time of the crash, was opened. Damage to the fuselage at the forward position of the door indicates that the door has hit the end of the rail with a relatively large force. The absence of damage to the locking mechanism suggests that the door was unlocked prior to the crash. This suggests that the door had been unlocked and able to move about on the slide rails during the sequence of events. However, one limitation is the g-forces that the door was affected by.

The practical possibility for those on board to get out of the aeroplane has been influenced partly by the g-forces they were subject to during the sequence of events, and partly by the circumstance that the parachutists have probably been thrown around in the cabin. In addition, it is likely that a very intense rotation to the right took place in conjunction with the wing breaking off. The aeroplane may well have rotated more than two revolutions to the right in the first second, when there was still lift on the left wing.

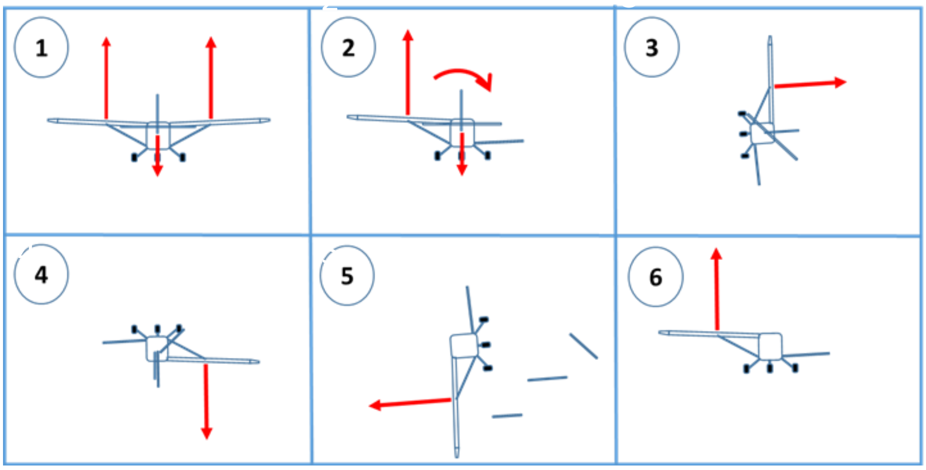

Figure 71. Forces present in conjunction with the wing rupture, separation of the stabiliser and tail fin.

This means that those on board have probably lost consciousness, at least temporarily, when these movements occurred.

Even if some of those on board had been conscious during the final stage of the sequence of events, the g-force longitudinally in the aeroplane was such that it likely made any attempts to move by own will in the aeroplane and climb out through the doors, which were at this stage above them, impossible. The inside of the cabin is also relatively smooth, with few places to grab hold of in order to allow a person to move around when subject to g-forces.

The large g-forces in conjunction with the crash were of such a magnitude that the crash was not survivable.

2.4 Complexity of the flight

Flying parachutists is, generally speaking, significantly more complex than normal private flying. The aeroplane is often close to its maximum mass and the centre of gravity is often close to the aft limit. Prior to the jump, the centre of gravity moves, at the same time as the pilot has to maintain a low speed with low engine output and navigate with precision to the correct position. The flight was also taking place at an altitude that is verging on that at which oxygen is necessary, which may entail a certain impairment of the pilot’s capacity.

During the flight in question, there was also a meteorological situation with a large quantity of clouds which may have made it difficult for the pilot to see the real horizon even if the flight did not take place in clouds and the movement of the centre of gravity in conjunction with door opening, probably resulted in the aeroplane becoming longitudinally unstable. At this time, the existing checklist also specifies a number of actions that are to be carried out or supervised. Because the aeroplane lacks rudder trim, firm pressure on the right rudder pedal is required throughout the entire climb and until the jump. From the communications with the control tower it can be assumed that the pilot was mentally focused on and had planned to descend to the south after the parachutists had left the aeroplane, i.e. in the direction from which the aeroplane had come and where the climb over the clouds had previously taken place. The message that the pilot was instead to descend in a northerly direction has probably resulted in an increased workload and need for replanning.

Flying parachutists is therefore generally a complex operation, especially under the circumstances that were in place during the flight in question.

2.5 Pilot in command

2.5.1 *The pilot's general ability*

The pilot was eligible to perform the flight in question. However, he had limited flight experience and the majority of his flight time was from his training, which ended nine years before the accident. In addition, he had a break of four years before he regained his eligibility, eight months prior to the accident.

The pilot's experience was mostly in a Cessna 172, and during training. Stall training had been conducted, but almost always in an aeroplane with a centre of gravity towards the forward limit.

Flying the GippsAero GA8 with eight parachutists entails the centre of gravity being, in principle, always towards the aft limit or, as the investigation has shown, behind the aft limit, which reduces the longitudinal stability and makes the aeroplane more difficult to control.

According to the parachute club, the pilot had completed the training required in accordance with SFF's regulations and which may be regarded as complying with the requirement for familiarisation training under the European regulations, but there is no documentary evidence of this. However, there is no reason to doubt that the training actually took place. The circumstance that the person responsible for flight operations at Umeå Parachute Club went along as a parachutists on the second flight of the day suggests that there were no question marks regarding the pilot's perceived ability to perform the flight under the conditions that were present at that time. Nevertheless, as has already been stated, the meteorological conditions made the flight in question more complex than the two previous flights that day.

A couple of parachutists who were on board during the previous flight have stated that they reacted to the stall warning system sounding an unusually large number of times during the flight, in particular during the final approach to the jump. This suggests that the aeroplane's attitude was difficult to control, probably because it was tail heavy, during this flight as well.

SHK's overall assessment is that, with the limited flight experience the pilot had, which was also of a different type of aeroplane and flying, his ability was not on parity with the complexity of the flight under the conditions in question.

2.5.2 *Ability to fly and work out an abnormal state under instrument meteorological conditions (IMC)*

The pilot did not have an instrument rating (IR) but during his training between 2009–2011 he had completed 10 hours of instrument flight training.

The flight was planned, and was to be performed, in accordance with visual flight rules (VFR). This means that the pilot always must have external references to relate to. The aeroplane was equipped for instrument flight but this requires instrument training and regular practice of flying without external reference in order to retain this ability.

Humans have three systems for keeping their balance, sensation in the muscles, vision and the vestibular system in the inner ear. During flight, the sensation in the muscles is put out of action as the direction of gravity is dependent on the flight attitude and maneuvering. When flying through clouds, the only references come from the instruments. The inner ear has a system of semicircular canals and vestibular sacs that sense both lateral and angular acceleration. However, the inner ear does not sense slow changes.

When flying, vision is therefore the only balance system on which the pilot can rely. If the external references are lost, for example in clouds, this can result in disorientation, i.e. it is possible to be convinced that the wings are level when they are actually at an angle, or vice versa. A pilot who is trained in instrument flying has learnt to ignore the disorientation on the condition that the aeroplane has functioning instrumentation.

It is SHK's assessment that the pilot, just after the loss of altitude, ended up in clouds and in a flight state where there were no external references. The pilot was then forced in a surprising manner to switch to flying with only the support of the instruments and with an initially abnormal attitude, with a rapidly increasing dive angle and g-forces. This transition to instrument flying, especially given the pilot's knowledge and experience, involved little chance of regaining control of the aeroplane.

2.5.3 *Impact of hypoxia*

Information about the flight shows that the aeroplane was above 13,000 feet for eight minutes, which is above the applicable limit at which oxygen is to be carried and used. However, it is difficult to predict how an individual pilot will respond to hypoxia and whether it has in any way affected the sequence of events since the influence is individual.

2.6 Aeroplane

2.6.1 *Technical examinations*

No technical faults on the aeroplane that could have contributed to the accident have been identified during the technical examinations that have been conducted.

2.6.2 *The aeroplane’s construction and strength*

The aeroplane is certified in accordance with CS-23, which means, among other things, that the limit loads are +3.8 g and -1.5 g. A safety factor of 1.5 shall be used, which means that the ultimate load will be at least +5.7 g or -2.25 g.

Examination of the fracture surfaces definitively shows that the fractures have been caused by overloading. SHK’s calculations show that the aeroplane complies with the requirements in CS-23 and that the loads during the sequence of events have without a doubt been higher than +6 g. Because of this, it can be established with a high degree of assurance that the failures of the wing and the empennage were due to the aeroplane having been subjected to inflight loads beyond its certified structural limits.

2.6.3 *Aircraft flight manual and certification*

The aircraft flight manual and accompanying supplement provide no clear directions as to how the centre of gravity is to be calculated when carrying parachutists; only stating that they should be distributed evenly around the floor of the cabin. The only thing that describes in any way the movements of parachutists in conjunction with door opening and jumping is the statement that only five parachutists may be behind an imaginary line running perpendicularly across the aeroplane at the forward edge of the cabin door, a maximum of three of whom may be outside the aeroplane, and that the parachutists are to be informed that they are not to gather at the back for longer periods of time.

The type certificate holder has stated that mass and balance are to be calculated on the basis of instruction in the section in the aircraft flight manual on the aeroplane in cargo configuration, with the exception of the baggage shelf, which may not be used. It is SHK’s opinion that it is neither clearly specified in the supplement that the baggage shelf may not be used, nor are there any signs or the equivalent in the aeroplane to clarify that this is the case.

According to the type certificate holder method of calculating mass and balance prior to a flight with eight parachutists, two parachutists shall be placed in area 1A, two in area 1B and four in area 1C. The result of this method differ markedly from the calculation SHK has performed by weighing a loaded aeroplane. In addition, the type certificate holder’s calculation takes into account neither the change in the moment arms in conjunction with jumping, nor the individual masses of the moving parachutists. Naturally, there are major differences if the parachutists who are farthest back are much heavier than those who are further forward in the plane, even if their total mass does not exceed the maximum permitted.

It is SHK’s opinion that it is not possible for a pilot to perform an accurate centre of gravity calculation with the aid of just the aircraft flight manual and at the same time be certain that the aeroplane is within the permitted area throughout the entire flight.

The flight test performed and video-documented in order to meet the conditions of EASA’s document Special Condition SC-023-div-01 for an investigation of mass and centre of gravity change during and after departures of the parachutists does not contain calculations and determination of the centre of gravity location and its change. Without such calculations, it is not possible to determine whether the aircraft stays within the limits for which the aircraft is certified for. However, SHK can state that if the method specified by the type certificate holder is to be used in the calculation, the aircraft’s centre of gravity will be in that configuration – five jumpers with a total mass of 500 kg in cargo zone 1C, which is the only cargo zone useful if will calculate five jumpers behind the intended line, as well as two pilots with a total mass of 186 kg – to be behind the approved area. What the flight test and the video demonstration can be considered to show is that a test pilot has managed to drop parachutists under the current conditions without perceived aircraft control problems, rather than an investigation of mass and centre of gravity change.

The circumstance that the supplement states that the parachutists should not gather at the exit for too long before they exit and that the time taken to arrange a coordinated exit involving five parachutists behind the forward edge of the cabin door, up to three of whom are outside of the aeroplane, should be as short as possible. This indicates that the risk of a tail-heavy aeroplane hade been identified in these situations. From a flight safety perspective, however, it is difficult to accept this as the aeroplane should not too tail heavy for even a short period.

In accordance with CS-23.1589 (b) the aircraft flight manual shall contain appropriate loading instructions for each possible loading condition. The AMC for this section refers to GAMA specification 6.7, which in turn describes how there shall be procedures for calculating mass and balance for various phases of flight and for ensuring that the centre of gravity is within approved limits. As stated above, there is no such procedure for calculating mass and balance for the flight phase prior to and during jumping.

Against this background, it can be questioned whether the loading instructtions can be considered appropriate for parachute operations.

In summary, SHK’s view is that the flight manual, when it comes to calculating mass and balance in parachute operations, lacks clarity on several points and does not provide the pilot with a sufficiently good basis to be able to fulfil his operational obligations.

In the opinion of SHK, it is reasonable that this type of deficiency, in the case of aircraft that must be specifically approved for parachute operations, be noticed and remedied during the certification process. Therefore, there may be reasons for EASA to review the procedures for approving loading instructions in the certification of aircraft approved for parachute operations in order to increase the ability to detect such deficiencies identified in this case.

2.6.4 *The engine monitoring instrument*

There are no signs of any engine problems in the data retrieved from the engine monitoring instrument EDM 800. However, it appears that the manifold pressure begins to decrease at 9,000 feet instead of 12,000 feet. According to information from the parachute club, the manifold pressure had decreased over time as the engine's operational time increased. Information they received from maintenance staff was that this was normal. SHK is of the opinion that this may be due to the wastegate valve was not adjusted or there was a minor leak on the turbo pressure side, but this has not been further investigated.

The registration of engine data suddenly stops. No direct explanation for this has been found. Having corrected for the instrument's timestamp, SHK has calculated that the recorded data stop in conjunction with the large variations in rate of descent, which have been calculated using the recordings from the ProTrack units, and the simultaneous rapid changes in engine rpm that were recorded by the CCTV camera.

The most likely answer is that the power supply to the instrument was cut. The alternative explanations are either that the instrument's power supply short circuited in conjunction of the failure of the right wing and empennage, or that those on board managed inadvertently to turn off the switch to Avionics Bus 1 during the state of uncontrolled flight. SHK deem the latter option to be more likely.

The data did not contain any of the rpm changes that were captured by the CCTV camera but the instrument does only record the engine parameters once every six seconds, which means that the uncertainty of the measurements is of at least the same degree. In addition it is not possible to correct the instrument's timestamp using the take-off time for the aeroplane with precision.

The fact that the aeroplane's transponder has transmitted information up to the point of impact may be explained by the fact that this unit receives power from Avionics Bus 2.

2.6.5 *Icing*

As described in section 1.6.6, the aeroplane is not approved for flight in icing conditions. Under the prevailing meteorological conditions, there has been a risk of icing in clouds at flight level 136. If the function of the aeroplane’s pitot tube was affected by icing, the information in the Aspen EFD will disappear and be replaced by a cross on the instrument’s display. Errors in the speed information can also occur when there is icing in the pitot tube. According to the aeroplane’s checklist for unintentional flight in icing conditions, the pitot heat shall be activated. The switch for pitot heat was in the off position.

Because the pilot was actively attempting to avoid flying in clouds, it is unlikely that the aeroplane was in clouds when it left the highest altitude and turned to the left. However, the aeroplane has definitely ended up in clouds shortly after this. Icing of the pitot tube has therefore probably not had an impact on the initial stage of the sequence of events. Nevertheless, the possibility that icing has occurred after the aeroplane entered the clouds in a state of uncontrolled flight cannot be excluded.

2.7 The regulations

One condition for conducting flights involving parachute operations in accordance with Part-NCO is that these operations are conducted within the scope of an organisation created with the aim of promoting aerial sport or leisure aviation. At the same time, the EU regulations do not place any requirements on this organisation that pertain to flight operations, e.g. in terms of the preparation of checklists etc. Instead, it is the individual pilot-in-command that is responsible for ensuring that such checklists are prepared and used. The pilot-in-command therefore has to conduct extensive risk management that is on a par with the requirement for an authorised air operator organisation.

There are no specific requirements for being a pilot-in-command for parachuting other than a private pilot licence and self-directed familiarisation with the aeroplane type. Accordingly, there are no rating or flight time requirements under the EU regulations, despite the complexity of this activity. On the other hand, towing gliders, towing banners and advanced flying that only subjects the pilot to danger require training and a rating in the licence.

It is SHK’s opinion that it can be strongly questioned whether a newly qualified private pilot with limited experience through their training has acquired the abilities required in order to comply with the obligations under Part-NCO in a satisfactory way when it comes to the specific conditions there are when flying with parachutist.

Following a similar accident in Finland in 2014, the Finnish Safety Investigation Authority recommended that EASA prepared specified theoretical knowledge and flight training requirements for pilots-in-command in skydiving operations.

The EASA's initial response was negative. The agency referred to applicable regulations that require the pilot to conduct a risk analysis and take action to compensate for risk found, for example theoretical training. In addition, the EASA did not believe that introducing a formal training programme for pilots in parachute operations was a proportional measure.

In a second response from 2016, the EASA maintained the same fundamental standpoint but stated that an analysis of parachute operations would be conducted in 2016. No results of this analysis have been reported. However, in unofficial contact with SHK, the EASA has stated that information about the risk involved in parachute operations will be presented on a website.

Regardless, it is SHK's opinion that this is not sufficient in order to ensure flight crew and passengers a sufficiently high level of flight safety.

As described in the preceding text, lift of parachutists is a complex operation that requires knowledge, skill and guidance to assist with decision-making. It is also reasonable for a parachutist who boards an aeroplane to expect that the pilot has the knowledge required in order to accomplish the task in a safe manner and familiarity with the risks associated with such operations. It is SHK's opinion that this cannot be ensured in any other way than through the pilot having completed a standardised practical and theoretical training programme and having been approved by a qualified instructor. Self-study of aircraft flight manuals or searching for information on the internet are thus not sufficient. The EASA's previous standpoints do not indicate how it has reasoned in respect of these points or how passengers, i.e. parachutists, are to be ensured that the pilot has the necessary theoretical and practical knowledge.

In this context, it can also be noted that towing gliders or banners, which does not involve any passenger transport and is, in SHK's opinion, significantly less complex and risky, require specific ratings. In SHK's opinion it is unsatisfactory that the requirements for parachuting operations are not set at least at the same level.

SHK is therefore recommending, as the Safety Investigation Authority in Finland has done previously, to the EASA that a formal training programme for pilots in parachute operations be introduced.

2.8 Supervision of parachute operations

As mentioned above, there was no functioning system that was used to calculate mass and balance prior to the flight. The load sheet obtained by the pilot did not have information about the weights of the parachutists or the total mass of the load. Furthermore, in SHK's opinion, it is not possible with the support of the aircraft flight manual alone to calculate mass and balance in a reliable way during all phases of flight.

In light of this, there is reason to conduct a general investigation of how these matters are handled during all parachute operations in Sweden. Consequently, the Swedish Transport Agency, in collaboration with SFF, should investigate this and, where necessary, take the appropriate action in order to ensure that accurate and reliable mass and balance calculations are being performed prior to every flight.

2.9 Collaboration between pilot and jump master

It is not practicable for the pilot to supervise the movements of the parachutists in the cabin. Inappropriate movements in the cabin must therefore be prevented by the parachutists' awareness of the problem, combined with supervision by the jump master.

The supplement to the aircraft flight manual emphasizes the importance of the jump master receiving a sufficient briefing on certain matters that are specified in more detail (see section 1.6.5) and which are then to be conveyed to the parachutists. In somewhat simplified terms, it may therefore be said that the jump master is the pilot's assistant in the cabin and the person who is able to ensure in practice that the directions that apply to the flight are enforced.

There are several images from flights where the parachutists at least for a short time have been located on the baggage shelf in the aeroplane before the jump and it was also reported that this took place during the previous flight, despite it not being permitted. However, it is not possible to say whether this was the case during the flight in question. This circumstance does however provide evidence that there is limited knowledge or understanding of what flight operational consequences this may have.

Consequently, the Swedish Transport Agency, in consultation with SFF, should take action in order to ensure that all licensed parachutists have such knowledge and that jump masters actively enforce the directions that apply to the flight.

2.10 Rescue operation

No obvious opportunities to improve how the rescue operation was implemented have emerged during the investigation. It was initially difficult to locate the crash site, but this was not due to any failings in terms of the emergency response or limited operational capacity. In spite of the large number of emergency calls received by SOS Alarm, initially none of the callers were able to identify or were close to the crash site. Nor was a position obtained from the ELT in the aeroplane, probable because it was not designed to withstand the very substantial forces involved in the crash.

Rescue resources have been called out without delay as soon as it was possible to narrow down an approximate area for the crash site. All resources relevant to the rescue operation have been called in and the available resources have started operating without delay. Cooperation and communication between the participating resources from municipal, regional, central government and voluntary organisations have functioned appropriately. Members of the public have also participated and made an active contribution. For example, individuals have helped to locate the aeroplane and have quickly transported rescue personnel to the island using private boats from the very beginning of the operation.

The resources put in place have also been managed well through activation of POSOM groups and resources for conducting debriefings.

2.11 Overall assessment

Achieving safety during a flight requires the combination of four factors – human, machine, task and environment – to be sound.

In this case, the pilot had limited experience of both normal flight and parachute lift. The aeroplane was tail heavy and the centre of gravity moved to the extent that the aeroplane became unstable. The task of navigating to a precise point at high altitude at the same time as a number of actions were to be performed in accordance with a checklist resulted in a heavy workload. The large amount of clouds made safe flying more difficult or impossible. The high altitude may also have reduced the pilot’s abilities as a result of hypoxia.

It is easy with hindsight to see that the combination of these four factors was unsatisfactory. However, it is probably not as easy for the pilot to realise this prior to the flight.

According to application regulations, the pilot shall conduct a risk analysis in order to identify existing risks and take compensatory actions. Questions can be asked of what opportunity an inexperienced pilot, without formal training for the task, has to do this in an appropriate manner. Furthermore, it can be difficult as a newcomer to question something that has been going on for some time.

Of course, a pilot should be permitted to be inexperienced in the beginning but it should, in that case, be compensated for by making the other three factors less complicated. For example, you can choose to fly with a lighter load and in better weather.

The fact that parachuting is not to intentionally take place through clouds is the only criteria that provides guidance in respect of clouds for parachute operations that SHK has found in regulations and manuals. Consequently, there is a lack of guidance concerning the quantity of clouds, altitude of the cloud base and cloud tops.

The fact that there are no aids to decision-making in the form of, for example, numerical minima for the cloud situation, means that it is up to the pilot to assess whether to cancel or terminate a flight. For a pilot who is new to the activity and does not have formal training, it may be difficult to make an assessment that is in balance with their experience. It may also be difficult to make and assert another assessment than that proposed by more experienced people in the organisation.

In light of this, SHK believes it is essential that a pilot involved in this activity receive formal training that supports their potential to make good decisions.

It is SHK’s understanding that the lack of formal training, absence of a system for determining the centre of gravity and lack of support for flight operations have been decisive factors in terms of how the flight developed into an accident.

3. CONCLUSIONS

3.1 Findings

a) The pilot was qualified to perform the flight, but had limited experience of the aeroplane type and of flying with parachutists.
b) The aeroplane had a valid Certificate of Airworthiness and a valid ARC.
c) No mass and balance calculation was conducted prior to the flight.
d) There was no functioning system for calculating mass and balance.
e) There was no formal training for pilots involved in parachute operations.
f) The aeroplane took off overloaded and with a centre of gravity aft of the permitted area.
g) The prevailing meteorological conditions made the flight more difficult.
h) The airspeed was low and decreasing when the aeroplane was approaching the jump point at the airport at flight level 136.
i) The centre of gravity moved aft, which made the aeroplane longitudinally statically unstable.
j) With around 30 seconds to go until the airport and where the jump point was located, the aeroplane stalled, made a sudden turn to the left and entered clouds in a rapid descend.
k) The aeroplane ended up in an uncontrolled state in the clouds.
l) There was little chance of regaining control of the aeroplane.
m) The speed exceeded 200 knots and large g-forces broke up the aeroplane.
n) In the final stage of the sequence of events, the aeroplane rotated in the horizontal plane with its left wing pointing up, while the right wing, stabiliser and fin were missing.
o) There was little chance of bailing out.
p) The crash was not survivable.
q) The altitude exceeded the limit at which oxygen is to be carried and used.
r) No technical faults on the aeroplane that could have contributed to the accident have been identified during the technical examinations.

3.2 Causes/contributing factors

The control of the aeroplane was probably lost due to low airspeed and that the aeroplane was unstable as a result of a tail-heavy aeroplane in combination with the weather conditions, and a heavy workload in relation to the knowledge and experience of the pilot.

Limited experience and knowledge of flying without visual references and changes to the centre of gravity in the aeroplane have probably led to it being impossible to regain control of the aeroplane.

The following factors are deemed to be probable causes of the accident:

- The lack of a safe system for risk analyses and operational support, including data for making decisions concerning flights, termination or replanning of commenced flights.
- The lack of a standardised practical and theoretical training programme with approval of a qualified instructor.
- The lack of a safe system for determining centre of gravity prior to and in conjunction with parachuting jumps.

4. SAFETY RECOMMENDATIONS

EASA is recommended to:

- Consider introducing a formal training programme for pilots in parachute operations. (See section 2.7). *(RL 2020:08 R1)*
- Review the approval procedures of mass and balance documentation when certifying aircraft approved for parachute operations. (See section 2.6.3). *(RL 2020:08 R2)*

The Swedish Transport Agency is recommended to:

- As part of its oversight activities, ensure that there are appropriate loading instructions or equivalent in place and adhered to for parachute operations. (See section 2.8). *(RL 2020:08 R3)*
- With support of SFF, take measures to ensure that licensed parachutists have sufficient knowledge of aircraft mass and balance and flight operational consequences when moving around in the aircraft and that the Pilot/Commander receives the support necessary to maintain the rules that apply to the flight. (See section 2.9). *(RL 2020:08 R4)*

The Swedish Accident Investigation Authority respectfully requests to receive, **by 9 December 2020** at the latest, information regarding measures taken in response to the safety recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas Ola Olsson