Statens haverikommission
Swedish Accident Investigation Authority

Final report RL 2016:02e

Accident on Björnö on 13 February 2015 with aircraft N164ST of the model PA46-500TP (Malibu Meridian), operated by a private person.

File no. L-15/15

2016-03-01

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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General points of departure and limitations

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 13 February 2015 that an accident involving one aircraft with registration N164ST had occurred on the island of Björnö, close to Stockholm Västerås Airport, Västmanland county, the same day at 12.03.

The accident has been investigated by SHK, as represented by Mikael Karanikas, Chairperson and Stefan Christensen, Investigator in Charge, Ola Olsson Technical Investigator, Tony Arvidsson, Deputy Technical Investigator, Jens Olsson Investigator specialising in Behavioural Sciences and Urban Kjellberg, Investigator specialising in Fire and Rescue Services up until and including 30 June 2015, thereafter Patrik Dahlberg.

The SHK investigation team was assisted by Exova Materials Technology AB, material experts, Magnic AB for audio analysis and XICE AB for an outline of the structural damage aspects from the crash. Ulf Björnstig participated in the investigation as an expert in survival aspects from a medical perspective.

Also participating, as an accredited representative of Canada, was Earl Chapman from the Transport Safety Board (TSB).

Pam Sullivan from the National Transportation Safety Board (NTSB) has participated as an accredited representative for the USA.

Magnus Axelsson has participated as advisor from The Swedish Transport Agency.

The following organisations have been notified: The International Civil Aviation Organisation (ICAO), the European Aviation Safety Agency (EASA), NTSB, TSB, the European commission and the Swedish Transport Agency.

Investigation material
Interviews have been conducted with the pilot, the two passengers, one ground witness and air traffic control staff at Stockholm Västerås Airport.,

A factual meeting was held on 3 December 2015. At the meeting, SHK presented the facts that existed at the time.

The following external investigations have been conducted in conjunction with the accident investigation:

- Examination of engine installation at Pratt & Whitney Canada (PWC).
- Examination of propeller by Hartzell Propeller Inc.
- Examination of the aircraft's fuel at Exova AB,
- Examination of the aircraft's Emergency Locator Transmitter (ELT) by Scandinavian Avionics A/S.
- The examination of the engine's Flight-data acquisition unit (DAU) by Genesys Aerosystems.

Statens haverikommission
Swedish Accident Investigation Authority

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Aircraft:	
Registration, type	N164ST
Model	PA-46-500TP, Malibu Meridian
Class, Airworthiness	Normal, valid Certificate of Airworthiness
Owner	Volando Aviation LLC
Time of occurrence	2015-02-13, at 12.03 hrs. in daylight Note: all times are given in Swedish standard time (UTC[1] + 1 hr)
Place	Björnö island, close to Stockholm Västerås Airport, Västmanland county, (position 59º34'18''N, 016º37'29'' E, 2 metres above mean sea level)
Type of flight	Private
Weather	According to SMHI's analysis: Wind south to south west 5-8 knots, visibility 8-10 km, clouds 5-8/8 with cloud base 2 000 - 2 500 foot, temperature/dp +1/0 °C, QNH[2] 1017 hPa
Persons on board:	3
Pilot	1
Passengers	2
Injuries to persons	Minor
Damage to aircraft	Destroyed
Other damage	Environmental
The pilot:	
Age, licence	47 years, CPL(A)[3]
Total flying hours	674 hours, of which 184 hours on type
Flying hours previous 90 days	55 hours, all on type
Number of landings previous 90 days:	39

Note:

The pilot also holds a helicopter licence. The flying hours and licence details in this report refer solely to the aeroplane licence.

[1] UTC (Coordinated Universal Time) is a reference for coordinated time anywhere in the world.
[2] QNH indicates barometric pressure adjusted to mean sea level.
[3] CPL(A) – Commercial Pilot Licence, Aeroplane.

SUMMARY

The aircraft, a Piper PA46-500TP Malibu Meridian, should carry out a private flight from Västeras airport to Prague. On board were a pilot and two passengers. Shortly after take-off an engine failure occurred and the pilot decided to make an emergency landing on Björnö Island, situated slightly to the right in the flight direction.

The aircraft hit the ground with the left wing first and then rolled a number of times before it came to a final stop. During the accident both wings and parts of the tail separated from the aircraft. The fuselage remained relatively undamaged during the crash course.

All three occupants escaped with minor injuries. A special study of the sequence of events shows that the impact, with the left wing first, caused the airplane's wings to act as shock absorbers, which greatly contributed to that the occupants only received minor injuries.

During the accident - which occurred next to a secondary protection zone for water supply to the city of Västerås – a significant amount of fuel leaked out from the wreckage. The accident site was decontaminated after the accident. Examination undertaken in the area after the accident has not showed any trace of residual contamination in the soil.

The engine failure was caused by damage to the engine's power turbine section. Most likely, the damage has been initiated in a labyrinth seal to the power turbine. The cause of the initial damage of the seal has not been established. The technical failure can not be assessed to be in a risk category where the risk of repeated failures of the same type is high.

The Swedish Accident Investigation Authority has in this report also highlighted the lack of photo documentation of accidents and incidents at Swedish commercial airports. From an investigation point of view this is particularly serious when - as in the current accident – it refers to aircraft where on board carried equipment as FDR amd CVR is not mandatory . For this reason SHK is recommending the Swedish Transport Agency to investigate how this deficiency can be remedied.

The accident was caused by damage to the power turbine which occurred over time, and that could not be identified by the engine's maintenance program.

Safety recommendations

The Swedish Transport Agency is recommended to:

- Investigate the requirements for CCTV cameras for investigation purposes to be installed at Swedish commercial airports. *(RL 2016:02 R1)*

- Work for that the issue of operational CCTV cameras on commercial airports for investigation purposes, is appropriately addressed in the international flight safety community. *(RL 2016:02 R2)*

- Increase the supervision and reliability for receiving emergency signals via 121.5 MHz at air traffic control units at Swedish commercial airports. *(RL 2016:02 R3)*

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Conditions

The aircraft, a Piper PA46-500TP Malibu Meridian, see figure 1, was to carry out a private flight from Stockholm Västerås Airport to Prague. One pilot and two passengers were on board. The aircraft had been parked in a hangar overnight and had initially taxied to a fuelling station at the airport where it was refuelled.

Figure 1. The aircraft in question. Photo: Harri Koskinen.

Pre-flight preparations were conducted as routine and without any known problems. The operational and weather-related conditions were good and no technical remarks had been noted in the aircraft's logbook.

The operational flight plan and calculations for performance, mass and balance for the flight had – according to the pilot – been conducted using a type related computer program.

1.1.2 Take-off

The aircraft taxied out via taxiways A and E to Runway 19; i.e., in a southerly direction. The take-off position from taxiway E meant that the available runway take-off distance was 1,980 metres. Take-off occurred at 12:02 hrs and initially continued as normal. After lift off , the pilot retracted the landing gear and wing flaps. Shortly thereafter, at an altitude of approximately 100 ft., the pilot called the air traffic control stating that they immediately wanted to turn back for landing on runway 01.

Air traffic control gave clearance for approach and landing on runway 01. However, no response was received from the pilot. The air traffic controllers in the tower could see how the aircraft levelled off and that the landing gear was extended again. The aircraft then lost altitude and disappeared behind a curtain of trees.

1.1.3 The crash

The aircraft hit the ground in an open area on the island of Björnö, in Lake Mälaren, just south of the airport. The area is partly open marshland with a number of large tree stumps. Upon impact, the aircraft initially hit the ground with its left-hand wing, initiating a rotation with both wings and parts of the tailplane separating from the aircraft's fuselage.

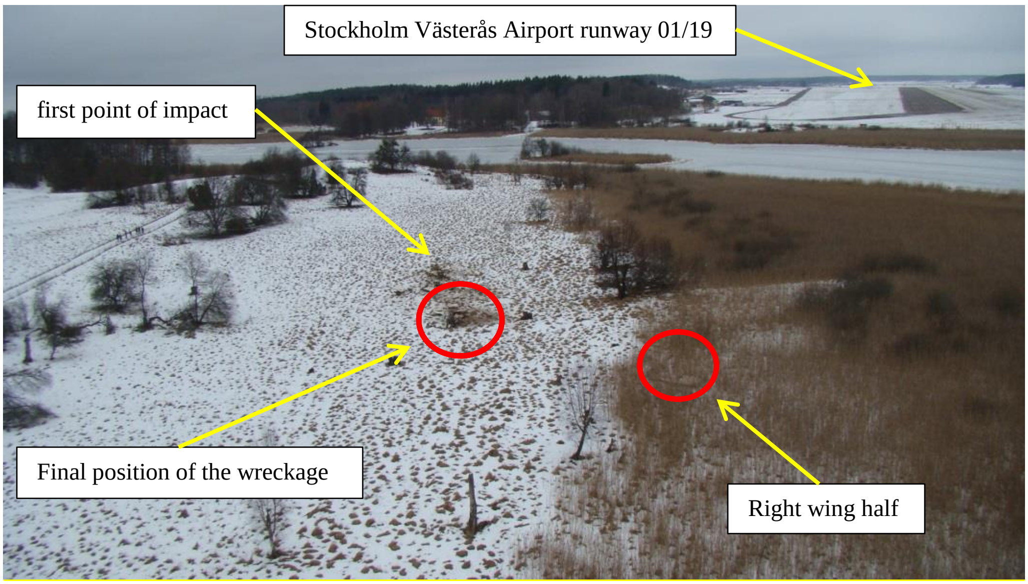


Figure 2. The crash site

The traces that could be measured along the wreckage path showed that the distance from the first point of impact with the left-hand wing leading to the final position of the fuselage was approximately 50 metres. However, the main part of the right-hand wing was found approximately 60 metres from the main wreckage, see figure 2. The approximate time from the initial impact until final stop has been estimated at just under four seconds. For further descriptions of the course of events and damage analysis, see section 1.15.

The three persons on board only obtained minor injuries from the accident and were able to leave the aircraft wreckage unassisted. Approximately six minutes after the accident, two persons, who had received information about the aircraft's problems during take-off, arrived at the scene via helicopter to provide assistance where necessary to those on board.

Radio signals from the aircraft's Emergency Locator Transmitter had been detected by a company at the airport; however, the signals had not been received by air traffic control at the airport.

The accident occurred at position 59º34'18''N 016º37'29''E, 2 metres above sea level.

1.1.4 Interview with the pilot

During the interview, the pilot told SHK that the aircraft in question. was for his own use. As the aircraft had been purchased used from USA, it had the American registration N164ST. The aircraft was undergoing a process at the time to be included on the Swedish civil aircraft register with the registration SE-MIC.

The intended flight was a private flight to Prague. According to the pilot, a routine inspection of the aircraft was conducted before take-off without any remarks or malfunctions detected.

The aircraft was fuelled at a refuelling station and remained parked there for an hour before take-off. In accordance with the flight manual, an additive to prevent ice building in the fuel was added during refuelling. After engine start, clearance was obtained for taxiing from apron 6 to the holding point at runway 19 via taxiways A and E. Due to other traffic, take-off was delayed by a few minutes.

The final checks before take-off were completed without any problems and flap position was set to 10° for take-off. Once clearance for take-off was received, the pilot set the engine to full power and commenced the take-off run. According to the interview, the pilot felt that the acceleration along the runway was “as normal”. Lift-off was performed at normal speed; climb was initiated and the landing gear and flaps were retracted.

Shortly after the clean up had been completed, the pilot felt that the engine lost power and to some extent was “choking”. Due to the low altitude, the pilot decided that there was insufficient time to conduct trouble shooting or start any procedures following the emergency checklist. Once he determined that the engine was no longer providing power, he called air traffic control and requested clearance to turn back to runway 01 for landing. According to the pilot, the altitude was insufficient for a turn, hence the pilot aimed for an emergency landing in the flight direction.

The pilot felt that the aircraft became difficult to control and that it was sliding during the continued loss of altitude. At this point, the airspeed was judged to be well over the aircraft's critical speed range, i.e. the time when a stall[4] might occur. The landing gear was again extended and flaps set to 10°. The pilot was unsure of whether the landing gear had been fully extended and locked before colliding with the ground.

In the pilot's opinion, there was no choice of location for the emergency landing. Just after the airport area – slightly to the right of the flight direction – there was an open area on Norra Björnö,

[4] Stall is defined as an aerodynamic loss of lift caused by exceeding the aeroplane’s critical angle of attack.

approximately 500 metres from the end of the runway. The pilot aimed for this area and felt that after this point, everything went very quickly. He was not of the opinion that the aircraft had stalled.

The pilot stated that the aircraft hit the ground "hard" with its left-hand wing first, then rolled a few times until it came to its final rest. The pilot – who had only received minor injuries from the accident – then switched off all electrical equipment. The passenger sitting in the right-hand seat was also conscious and only received minor injuries.

The rear-seat passenger was unconscious after hitting his head during the crash, but regained consciousness after a few minutes. All those on board left the aircraft via the rear door. The aircraft's ELT (Emergency Locator Transmitter) had been activated upon impact and was switched off by one of the passengers.

Once those on board had left the aircraft wreckage, the pilot received a mobile telephone call from air traffic control at Stockholm Västerås Airport. He then provided information of the event and the status of those on board.

For interviews with the witnesses and the others on board, see section 1.18.1.

1.2 Injuries to persons

	Crew members	Passengers	On board, total	Others
Fatal	-	-	0	-
Serious	-	-	0	-
Minor	1	2	3	Not applicable
None	-	-	0	Not applicable
Total	1	2	3	-

1.3 Damage to aircraft

Aircraft destroyed.

1.4 Other damages

The accident site is situated in the part of Björnö that is within the water protection zone in the area. At the time of the accident, the aircraft had been fuelled with approximately 500 litres of aviation fuel, of which most ended up leaking into the terrain.

Decontamination work was conducted using absorbents and the following day, the contaminated surface layer at the accident site was excavated. For further description of the environmental protection measures taken, see section 1.15.3.

1.5 Personnel information

1.5.1 The pilot

The pilot was 47 years old and had a valid CPL(A) with flight valid operational and medical eligibility.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	0	12	55	674
This type	0	12	55	184

Number of landings this type previous 90 days: 39.
Type rating concluded on 1 June 2014.
Latest PC[5] performed on 1 June 2014 on the type.

1.5.2 The pilot's duty schedule

Not applicable

1.5.3 Other personnel affected

Not applicable

1.6 Aircraft

1.6.1 General

Piper PA-46-500TP is a single engine aircraft powered by a turboprop engine. It is low-winged, has a pressurised cabin and is certified for one pilot and five passengers.

1.6.2 Aircraft

TC-holder	Piper Aircraft Inc.
Model	PA-46-500TP (Malibu Meridian)
Serial number	4697064
Year of manufacture	2001
Actual gross mass, kg	2,200 (max. take-off mass)
Centre of gravity	Within permitted limits.
Total operating time, hours	2,767
Operating time since latest inspection, hours	40
Type of fuel loaded before event	JET A-1

[5] PC (Proficiency Check) – recurring check of flight crew competence.

Engine	
TC-holder	Pratt & Whitney Canada Corp.
Engine type	PT6A-42A
Number of engines	1
Serial number	PCE-RM0068
Total operating time, hours	2,767
Operating time since latest inspection, hours	40
Flight time since latest inspection, hours	Not applicable
Propeller	
TC-holder	Hartzell Propeller Inc.
Type	HC-E4N-3Q with 8501 blade
Serial number	HH1214
Total operating time, hours	2,767
Operating time after overhaul, hours	40
Operating time limitations, hours/cycles	None
Deferred remarks: None	

The aircraft had a valid Certificate of Airworthiness issued by the Federal Aviation Authority in the USA (FAA[6]).

1.6.3 *Emergency checklist*

The aircraft had an emergency checklist for *Engine Failure Immediately After Take-off*. This list contains instructions regarding recommended speeds, extension of landing gear and flaps, feathering the propeller and other steps to complete.

However, the pilot stated in his interview (see section 1.1.4) that there was not enough time for anything other than preparation for an imminent emergency landing.

1.6.4 *Calculation of the mass and balance conditions*

The aircraft was loaded to the maximum permitted take-off mass of 2,200 kilos. Its centre of gravity was within the approved balance range.

1.6.5 *Engine and propeller systems*

The aircraft was equipped with a turboprop engine, model PT6A-42A, manufactured by Pratt & Whitney Canada. The engine provides 500

[6] FAA – Federal Aviation Administration.

SHP and has a maximum rotation speed of 38,100 rpm. The model is a free-turbine engine, comprising a gas generator and a two-stage power turbine that powers the output propeller shaft via a gearbox that reduces the rotation speed.

According to details from the TC holder, the model has historically been very reliable. The propeller was of model HC-E4N-3Q, manufactured by Hartzell Propeller Inc. It is a 4-blade, hydraulically controlled propeller, with the possibility for feathering and reversing. The propeller is regulated to a rotation speed of 2,000 rpm.

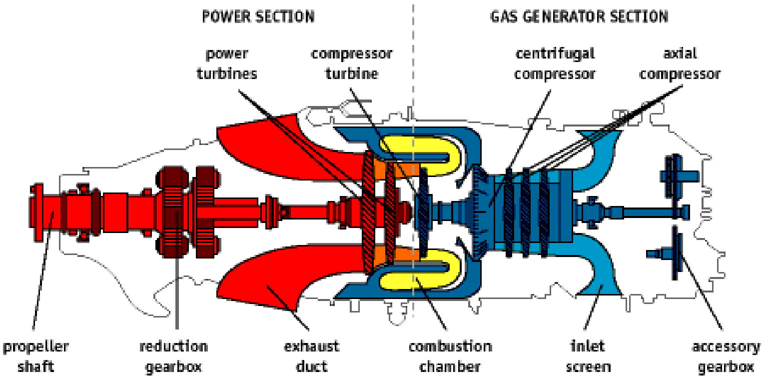
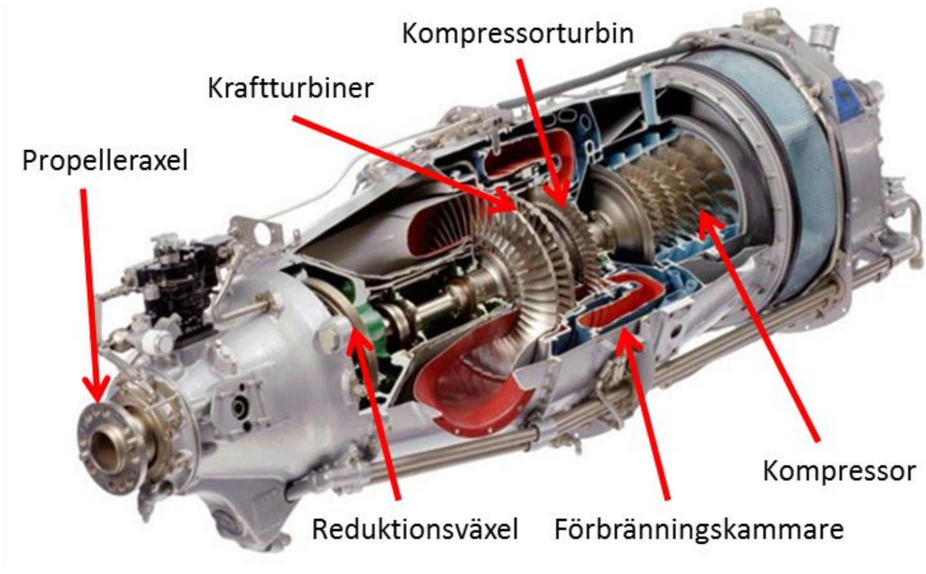


Figure 3. Principle outline of the PT6A's two sections.



propeller shaft power turbines compressor turbine

reduction gear combustion chamber compressor

Figure 4. Principle outline of PT6A. Source Pratt & Whitney.

1.6.6 Maintenance

A review of the aircraft's technical documentation shows that the annual inspection was performed on 19 December 2014, where the applicable FAA airworthiness directives were checked and implemented. At that time, the propeller had also undergone an overhaul and static balancing.

The latest Hot Section Inspection (HSI) of the engine was performed on 30 October 2008, after an operating time of 1,783 hours.

Comprehensive maintenance actions of the aircraft's avionics equipment were performed on 5 February 2015. The maintenance certificate of release to service from these actions were in accordance with EASA Part-145 and issued with registration SE-MIC.

1.7 Meteorological information

According to SMHI's analysis: Wind south to south west 5-8 knots, visibility 8-10 km, clouds 5-8/8 with could base 2 000 - 2 500 feet, temperature/dewpoint +1/0 °C, QNH 1017 hPa.

1.8 Aids to navigation

Not applicable

1.9 Radio Communications

Communication between the aircraft and air traffic control at Stockholm Västerås Airport has been saved. The recorded information from the accident has been used by SHK in the investigation.

The table in figure 5 presents an excerpt of the communication between the aircraft and air traffic control during the course of events. At the time of the accident, the aircraft in question had the callsign Swedcopter 964.

The radiocommunication was carried out in Swedish. The transcript in the table below has been translated to English by SHK.

Time (LT[7])	Air Traffic Control Västerås	Swedcopter 964 (aircraft)
11:55:18		*964 we are at apron 6 and ready for taxi.*

[7] LT – Local Time

11:55:23	*Swedcopter 964 taxi to holding point runway 19 via A and E, braking action on taxiways and apron medium to good.*	
11:58:23		*And 964 we are ready.*
11:58:26	*Swedcopter 964 line up runway 19 and wait*	
11:58:29		*Line up 19 and wait, 964.*
12:01:28	*Swedcopter 964, runway 19 cleared for take-off.*	
12:01:32		*Cleared for take-off runway 19, 964.*
12:02:27		*964 want to return for landning immediately runway 01.*
12:02:31	*964 cleared for approach runway 01.*	
12:02:36	*964, wind 180° 7 knots, runway 01 cleared to land.*	
12:03:59	*Swedcopter 964 tower?*	

Figure 5. Table of radio communication with the aircraft.

No further radio transmission from the aircraft was registered.

1.10 Aerodrome information

1.10.1 General

The airport had operational status in accordance with the Swedish AIP[8]. SHK has examined the static cameras installed in the airport area. However, no cameras pointed on the runway or approach sectors. Instead the apron and the parking areas were the main targets.

[8] AIP – Aeronautical Information Publication.

1.10.2 Air traffic control and equipment in the tower (TWR)

Air traffic control

Aviation Capacity Resources (ACR) are the suppliers of air navigation services at Stockholm Västerås airport. The airport is however responsible for the technical equioment in the tower. At the time of the incident, the tower was manned by two air traffic controllers, two trainee air traffic controllers and one air traffic control assistant. At the time, one of the trainees was in position and therefore carried out the communication with the aircraft provided in section 1.9.

The accident alarm was activated by one of the air traffic controllers when the aircraft disappeared out of sight. The contact established via mobile telephone with the pilot after the crash was also managed by one of the air traffic controllers.

ELT

At the crash, the aircraft's ELT was activated. The signal with frequency 121.5 MHz was received clearly through a receiver belonging to a company at the airport. However no signal was received by the tower. After the event, the failed signal has been investigated by ACR, and the following measures have been taken:

- SAAB ATM – who are responsible for servicing the tower's radio equipment – have conducted an inspection of the equipment after the event. Both receivers were inspected and approved, and no cause for disruption or malfunction could be established.

- Testing at the site of the accident was conducted on 29 January 2015, by using a portable radio transmitter using the frequency 121.5 MHz. At the time of testing, it was revealed that the signals could not be received by the receiver in the tower.

- ACR has stated that the cause of the missing ELT signal will be further investigated. The radio coverage in the area surrounding the airport will also be investigated and, if necessary, the antennae moved to reduce the risk of skip zones.

The applicable provisions for the monitoring of emergency frequencies at the time of the accident can be found in the Swedish Transport Agency Regulations and General Advice on Air Traffic Services (ATS), Chapter 3:

Section 11: When an air traffic service is to be performed, the communication channels necessary for aviation shall be available, and shall allow
1. radio communications with the aircraft currently present in the airspace under the guidance of air traffic control;

2. simultaneous monitoring of emergency frequencies, with the possibility to listen in from each workstation for air traffic controllers and AFIS personnel.
3. - - -

On 1 December 2015, the Swedish Transport Agency's regulations TSFS: 2012:51 entered into force. The regulations apply to the air traffic units that perform alarm services in aviation. To ensure two-way radio communication for emergency and urgent traffic, the following demands have been introduced:

Section 14, An air traffic control unit shall guarantee two-way radio communication via 121.5 MHz within controlled airspace and traffic information zones and traffic information areas. This is to secure reception and communication of emergency and urgent traffic messages.

ACR at the airport also stated that problems with receiving signals on 121.5 MHz had not been experienced previously. Upon previous testing of ELTs – conducted by aviation companies at the airport, amongst others – the signals were received.

1.10.3 Closed-circuit television (CCTV) at Swedish commercial airports

Background

Over the past 50 years, there have been major changes to the safety levels within commercial aviation. Consequently, the total number of aviation accidents and incidents has declined gradually over time. This can be attributed to several factors, with the development of technology and quality systems within the aviation industry being arguably the foundation of increased flight safety.

Another factor to positively influence aviation safety are the accident investigations that are carried out when accidents or serious incidents occur. These investigations do not simply aim to establish the causes; their ultimate aim is to prevent a repeat of the event by providing recommendations for changes to the areas where the root causes of an accident can be found. This work encompasses the whole spectrum of the aviation industry, from design and manufacture to the interaction between man and machine when the aircraft is in operation.

In the 1960s, recording equipment was developed for aircraft, with the aim of facilitating the investigation process in the event of an aviation accident or incident. The equipment generally includes a Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR). This equipment became mandatory (primarily for aircraft heavier than 5,700 kilos), beginning in Australia and later on in the USA. The sole purpose of this equipment is to store data for investigation purposes. Nowadays this is standard within the global commercial aviation industry.

The possibility of using this equipment to understand the aircraft's movement patterns – often in combination with an analysis of decisions made in the cockpit – has become the single most important tool when investigating modern day aviation accidents and incidents. However, data from the recording equipment alone are not always sufficient to provide satisfactory investigation results. Registration equipment is normally not installed on light aircraft.

SHK Factual collection

When investigating an aircraft accident, the investigating authority begins by gathering all the facts that will then form the basis of an analysis and any possible recommendations. Therefore the aforementioned recording equipment is a vital source of information. Nevertheless, in many cases the registered data need to be verified and examined against other sources that recorded the events in some form.

In certain investigations, SHK has used films or photographs as complements to the data that were recorded and obtained from the aircraft's equipment. In some cases – often accidents and incidents with light aircraft – video recordings and photographic material has formed the sole factual material from which the aircraft's movement patterns have been able to be closely examined.

The photos or film recordings that have been possible to use for investigation purposes often come from one of the following two sources:

- Films or photos from airport CCTV cameras that happened to be pointed towards the approach sectors or runway systems.
- Films or photos taken by media or private individuals.

However, it can be noted that films that have recorded events during an aircraft accident are rare elements in the factual collection obtained by the authority. In this context it should also be mentioned that accident statistics show that approximately 50 % of all aircraft accidents occur in conjunction with take-off/climb out or approach/landing, i.e. at the airport or in its vicinity.

Today, large parts of the society is monitored by CCTV. This may be anything from public spaces to shops and communications. Nowadays, the majority of larger airports have comparatively comprehensive interior and exterior CCTV systems, with the aim of monitoring for various security reasons. “Airside” monitoring tends not to include the manoeuvring areas, i.e. runways and taxiways. Instead it is limited to aprons, aircraft parking areas and the airport terminal areas.

There is currently no requirement for CCTV surveillance of the operative sections, i.e. approach sectors, runway systems and taxiways, at Swedish commercial airports.

CCTV surveillance is regulated by the Swedish Public Camera Surveillance Act (2013:460), which aims to meet the need for CCTV surveillance for legitimate purposes, whilst simultaneously protecting individuals from undue violation of personal integrity.

1.11 Flight data recorder and cockpit voice recorder

1.11.1 Flight Data Recorders

Flight data recorder (FDR) or Cockpit voice recorder (CVR) were not installed and are not a requirement for this category of aircraft.

The aircraft was equipped with a fixed GPS, model Garmin G500. This model does not have any memory capacity that can be used for investigation purposes.

1.12 Accident site and aircraft wreckage

1.12.1 Accident site

The accident site is situated on the island of Björnö on Lake Mälaren, see figure 6. The distance from the end of the runway is approximately 0.5 kilometres.

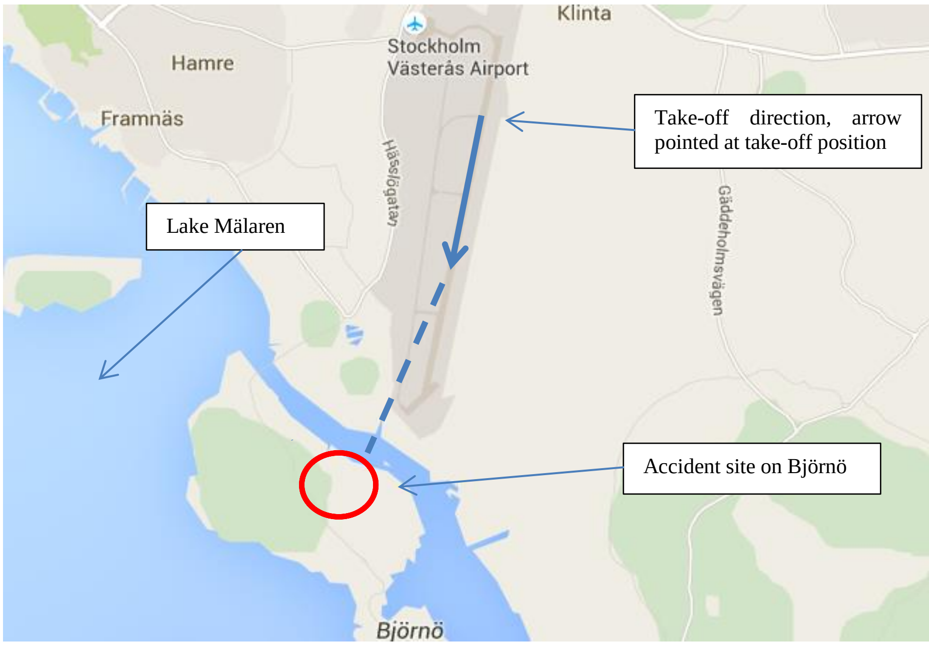


Figure 6. Map of Västerås with the accident site marked. Source: Google.

The area of the impact is an open meadow with occasional tree stumps. At the time of the accident, the area was partially covered in snow with only a thin ground frost layer.

1.12.2 Aircraft wreckage

The aircraft received significant damage. The fuselage rested on the right-hand side in the direction of the impact. Both wings had been broken off at their mountings to the fuselage. The left-hand wing was approximately 20 metres to the rear of the fuselage and the right-hand wing was found in the reed approximately 60 metres in front of the wreckage.

Figure 7. Site of the accident, with aircraft wreckage.

The major parts of the engine section had been broken off at the firewall that separates the cabin section from the engine. All four propeller blades were damaged and bent, but did not show any signs of damage that could indicate thrust upon impact. Both wing tanks were deformed in the accident, resulting in extensive fuel leakage.

The investigation of the accident site and the aircraft wreckage conducted on location identified no trace of bird strike or foreign object damage (FOD).

Figure 8. Site of the accident, with fuselage.

The fuselage was comparatively intact, without any large structural damage. All the seats were intact and had not detached from their mounts. The aircraft door on the left-hand side of the fuselage was mostly undamaged and had not been blocked, hence it could be used by those on board for evacuation after the accident. See section 1.15.5 for information about the safety belts.

After an initial examination at the accident site, the wreckage was moved to SHK's technical examination premises where a more detailed examination of the aircraft could be conducted.

1.12.3 Technical examination of the aircraft wreckage.

Engine and propeller

The examination carried out by SHK could not identify any defects or malfunctions that could be assessed to have influenced the course of events or the accident.

The engine, with its auxiliary components, was attached to the fuselage right side up. The engine mounts were partly detached at their mount to the fuselage at the firewall. The propeller remained on its shaft and showed signs of considerable bend damage to all blades. The engine was later dismounted from the wreckage and sent for technical examination.

Wings and control surfaces

Both wings had separated from the fuselage at their mounts. The right-hand wing had been broken off in two parts. The horizontal stabilizer had partially separated from the fuselage. The vertical fin had received damage from the impact, but remained attached to the fuselage. The main landing gear had received significant damage and was found underneath each respective wing. The nose landing gear had broken off at its mount and had separated from the fuselage.

Figure 9. The fuselage in the SHK hangar.

Each of the controls, control surfaces and control cables were examined as far as was practically possible and were deemed intact.

No trace of bird strike or FOD could be identified on any part of the aircraft wreckage.

The cabin

The aircraft cabin, with two seats in the front section and four seats (club seating) in the rear section were relatively undamaged. The seats remained in their mounts and each of the safety belts examined was intact.

The pilot seat and instrument panel were virtually undamaged after the accidents. Other panels and controls by the front seats only showed minor damage. SHK has examined the positions of all controls and settings that could be checked, but could not identify any deviations that might have affected the course of events.

The Manual Override Lever (MOR) was found outside of the normal OFF position, see section 1.16.3.

1.12.4 ELT

The ELT of type ME 406 mounted in the aircraft's rear-fuselage was activated during the event. The ELT is intended to transmit emergency signals in the event of an accident or emergency situation. Activation can be carried out manually via a button on the aircraft's instrument panel or automatically upon a deceleration of 2.4 G or more. When activated, radio signals are transmitted over two different frequencies, 121.5 MHz and 406 MHz.

121.5 MHz is a standardised emergency frequency within aviation and can be received by air traffic control units and aircraft who have tuned in the frequency on their communication radio. The 406 MHz emergency frequency transmits a coded signal that includes information about the aircraft's registration and model. Satellites then forward this to the Swedish Maritime and Aeronautical rescue coordination centre, JRCC. At the time of the accident, the code signal identifying the aircraft's registration was SE-MIC. The signal transmitted over 406 MHz had been received by JRCC as well as a Norwegian ground station.

After the accident, the ELT device was sent for a technical examination by a radio workshop. The examination could not find any errors or malfunctions to the unit or the transmitted emergency signals.

SHK conducted a visual inspection of the antenna cable and the antenna installed on the aircraft. The resistance of the antenna cable was tested and determined to be within approved values.

1.13 Medical information

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

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Provisions

Rescue services

Provisions on rescue services are found primarily in the Civil Protection Act (2003:778, Swedish abbrev. LSO) and the Civil Protection Ordinance (2003:789, Swedish abbrev. FSO).

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 and 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 and for searching for missing persons in certain cases. The municipality concerned is responsible for the rescue services, in accordance with Chapter 3, Section 7 of LSO.

For aircraft accidents that occur in Swedish territorial waters and the country's exclusive economic zone, LSO Chapter 4, Section 2 states that the authority appointed by the Government shall be responsible for the rescue services. This does not apply to watercourses, canals, harbours and other lakes than Vänern, Vättern and Mälaren. The authority shall also be responsible for searching for missing aircraft.

In Chapter 4, Section 2 of FSO[9] the Swedish Government has appointed the Swedish Maritime Administration to run aeronautical rescue services. The aeronautical rescue services are led from Sweden's Joint Rescue Coordination Centre, JRCC. In Västerås municipality where the accident occurred, the municipal rescue services are provided by Mälarens brand- och räddningsförbund (MBR).

If danger to life, health or property or damage to the environment cannot be prevented in any other way, LSO Chapter 6, Section 2, first paragraph, states that during a rescue operation, the rescue coordinator may give themselves and other participating personnel access to another person's property; cordon off or evacuate the area; use, remove or destroy property; otherwise perform actions on behalf of another to the extent that such action is justifiable in relation to the

[9] FSO – Civil Protection Ordinance (2003:789).

nature of the danger, the damage caused by the intervention and other general circumstances.

Safety investigation within civil aviation

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), LUO. In Sweden, the Swedish Accident Investigation Authority (SHK) is the authority appointed to conduct safety investigations.

Article 13 of the Regulation (EU) no. 996/2010 states that pending the arrival of safety investigators, no person shall modify the state of the site of the accident. An exception applies where such action may be required for safety reasons or to bring assistance to injured persons, or under the express permission of the authorities in control of the site and, when possible, in consultation with the safety investigation authority.

According to Section 9 of LUO, the investigating authority is entitled to have access to the site of the accident or incident. Where access is denied, the police may provide the necessary assistance.

In the event of an accident or incident being investigated, according to Section 11 of LUO, property assumed to be relevant to the investigation of an accident or an incident may not be interfered with without permission from the police or the investigating authority. This does not apply if the property is interfered with in order to save human life or if there are other exceptional reasons for doing so.

1.15.2 Alerts about the event

Directly after take-off, air traffic controllers in the control tower saw the aircraft level at a low altitude and extend the landing gear. In connection with this, the pilot requested to return to the airport for landing. The Air traffic control triggered the warning alarm at 12:02 hrs and the aircraft disappeared in a southerly direction, behind a curtain of trees.

After the aircraft had disappeared and was no longer visible from the control tower, it did not respond to calls and no signal was heard from the ELT.

SOS Alarm telephoned the control tower at 12:04 hrs to connect a three-way call with JRCC. After just under one minute of conversation, the air traffic controller realised that there was no participation from JRCC. The air traffic controller therefore ended the telephone conversation and telephoned directly to JRCC, informing them of the events. As the three-way telephone call did not work out as planned, information sent to JRCC was delayed by approximately one minute. It has since come to light that the three-way call malfunction was due to mismanagement by an SOS Alarm operator.

Testing of three-way telephone conversations between the operators are conducted over time, instigated by the airport. Test results from 2014 showed no problems with the three-way telephone call.

JRCC classed the matter as an emergency situation and alerted the rescue helicopter at the helicopter base in Stockholm. Control tower personnel obtained telephone contact with the pilot at 12:07 hrs. The pilot then provided details of the approximate position of the accident. Initially however, it was unclear whether the accident had occurred in Lake Mälaren or on land.

A helicopter from a company at the airport took off at 12:08 hrs. Minutes later, the helicopter informed the control tower that the three persons on board the aircraft could be seen on Björnö, an island nature reserve in Lake Mälaren, situated just south of the airport.

SOS Alarm notified the municipal rescue service, MBR at 12:10 hrs.

1.15.3 Initial rescue operation

The rescue coordinator from the airport's rescue services arrived first on the scene of the accident and made contact with the three people who had evacuated the aircraft. A few minutes later, at 12:22 hrs, the rescue coordinator from MBR and an ambulance arrived at the scene.

The status at the site of the accident was relatively static when the rescue services arrived. The aircraft wreckage lay broken across an open area along Mälaren's shore. Details obtained from the pilot stated that the aircraft had approximately 500 litres of aviation fuel in the wings at take-off. The rescue coordinators also noted that there was a strong smell of aviation fuel at the site. The three persons who had been on board the flight were deemed to have minor injuries and could walk to the ambulance unassisted. They were transported to hospital for examination.

As the accident site was localised to Björnö and not in Lake Mälaren, JRCC terminated the air rescue service at 12:28 hrs. At this time, the matter was handed over to the municipal rescue service, according to the MBR rescue coordinator. In cooperation with the rescue coordinator, the police then cordoned off the area around the wreckage by setting up barrier tape.

On account of the discharge of aviation fuel, the rescue coordinator requested that a salvage manager should be contacted. The rescue coordinator also requested that the municipality's Health and Environmental Protection Service be contacted and one of their representatives visit the site to help with the evaluation of the necessary measures to be taken due to the emission of aviation fuel and also its close proximity to the Hässlö municipal water plant.

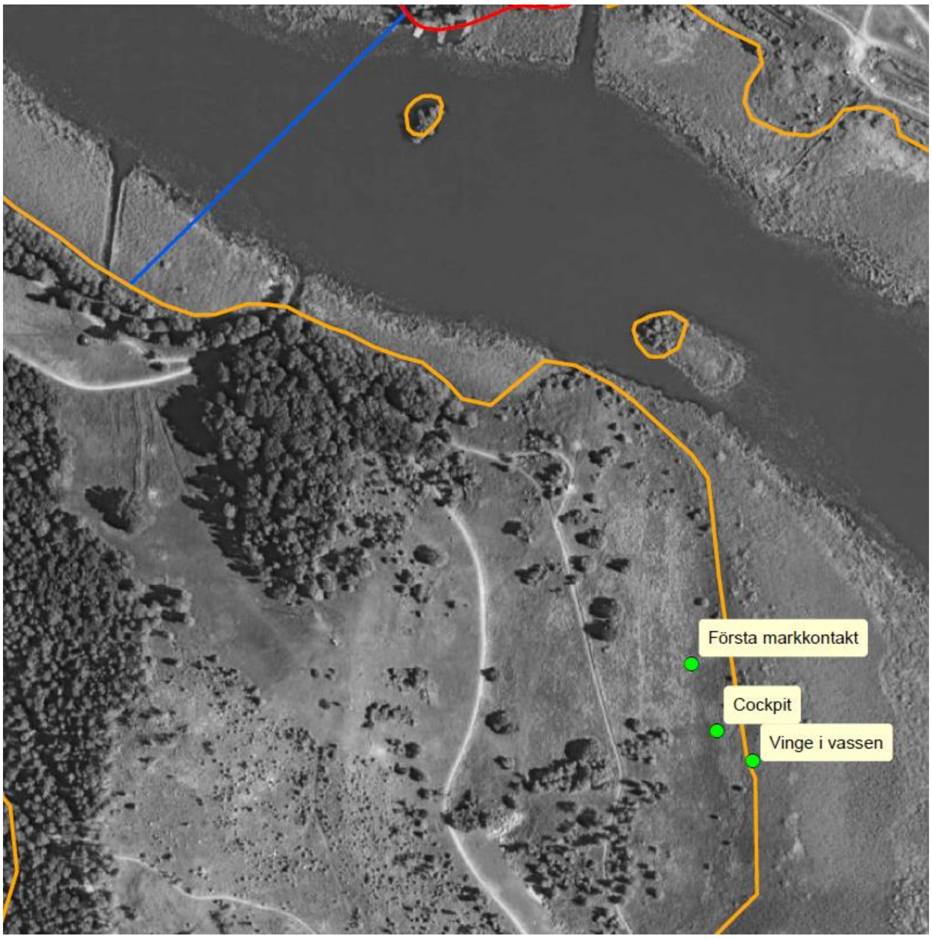
1.15.4 Continued rescue operation

Three inspectors from the municipality's Health and Environmental protection service arrived on site. Together with the rescue coordinator, they examined the scene to ascertain the spread and scope of the fuel spill. The point of impact for the accident was estimated to be just inside of a secondary protection zone for the city of Västerås' water supply.

The salvage company enlisted by SHK to carry out the salvage of the aircraft's wreckage arrived at the accident site before the SHK investigators. At this point in time, a discussion arose with the rescue coordinator about their right to be on the accident site and move the parts of the wreckage.

When the SHK investigators arrived on scene, shortly after 15:00 hrs, the conditions and actions needed to be taken at the site were discussed. In this context, the investigators from SHK expressed that an investigation of the site should be conducted before the sorption agent was spread out over the area. This meant that the application of the sorption agent was delayed during the period needed for the SHK documentation and investigation of the aircraft wreckage and accident site.

In addition to the measures taken during the rescue operation, further decontamination was necessary, including excavation of the contaminated upper layer of soil. The Health and Environment inspector gave permission to hold off on this work until the following day. The SHK investigation has since shown that the site of impact was within the source water protection zone (see figure 10).



First ground contact
Cockpit
Wing in the reeds

Figure 10. Secondary source water protection zone boundary marked in yellow. The position of the first ground contact and larger wreckage parts are marked in green.
© Lantmäteriet Ref.: R61749_13002

Work at the accident site was then divided, allowing the SHK investigation to be conducted first and then be followed by work to spread the sorption agent. In the evening, once the aircraft wreckage had been removed from the scene, the aviation fuel that had collected in depressions in the ground and on the water surface was also dredged.

Whilst the actions of the rescue operation were being conducted, sanitation measures were also taken by removing the contaminated soil the day after the accident. Environmental protection measures concluded on 16 February at 13:00 hrs.

Examinations and analyses conducted in the area since the accident have not shown any traces of remaining ground contamination.

1.15.5 Position of and injury to those on board, and use of safety belts

Those on board only received minor injuries from the accident. The pilot was seated in the left-hand front seat, with one of the passengers sitting next to him in the right-hand front seat. The other passenger was seated in the right-hand seat on the row furthest back.

All of those on board were using three-point safety belts. The safety belts for the two front seats were equipped with inflatable airbags, manufactured by AMSAFE. The system is made up of inflatable sections in the lap belts. The airbags are filled by an inflatable device driven by an electronic control unit.

Once the sensors in the control unit feel a longitudinal force of 9 G, or more, in a period of approximately 40 milliseconds, the airbags in the safety belts are activated and provide increased protection for pilot and passengers. However the airbags were not activated during the accident.

The SHK investigation established that all safety belts were intact and functioned without fault when tested. None of those on board have stated that there was a fault with the safety belts, nor was there any hindrance to the evacuation after the accident.

Calculations performed by SHK suggest that the longitudinal force did not exceed 9 G over the time period needed to activate the installed airbags, see section 1.15.6.

1.15.6 Structural survival factors

As those on board only received minor injuries from the accident, SHK has decided to investigate the circumstances that made this accident survivable in more detail.

For many air accidents where collision with the ground – either partially or fully – occurs uncontrollably, there is a tendency for them to end in disaster for those on board. In the present case, the majority of the aircraft was demolished but the aircraft cabin remained almost intact when the accident occurred.

For further analysis of this part of the event, SHK has enlisted Bo Person from XICE AB to calculate the forces and energy absorption during the course of the accident. This section of the report only presents selected parts of the investigation which has in turn been appended to this report.

The following description of the accident events uses the first point of impact as the zero point. The figures for the respective sections are given in the estimated energy losses in Figure 11 below and in the graphs in Figures 12 and 13.

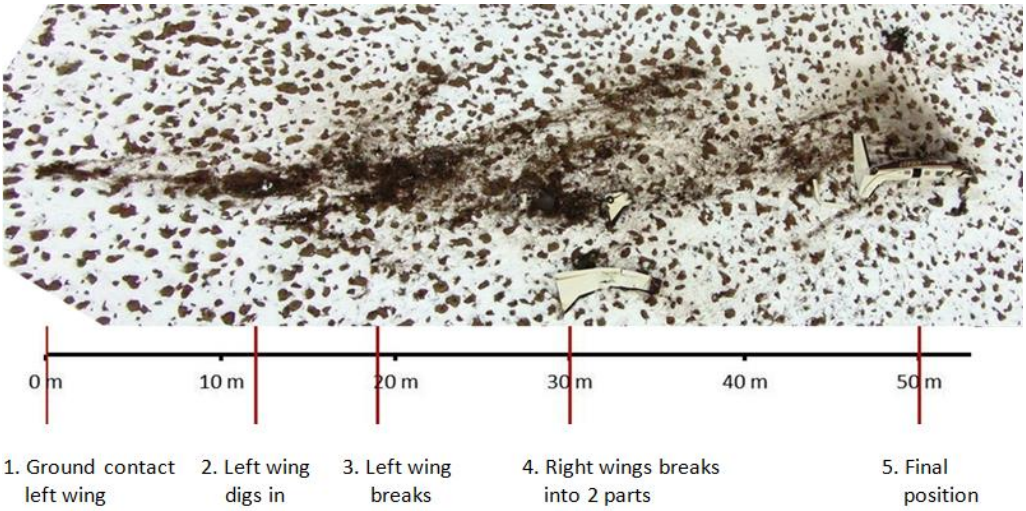


Figure 11. Image of accident trail and wreckage with reference points, taken from a drone (XICE AB).

1. The initial contact with the ground was when the tip of the left wing at a distance of 0 metres, most likely with certain remaining lift but moderate decent rate. In this instance the likely attitude was slightly nose-down.

2. Lift then decreased during increased bank angle, after which traces of sliding were present up until approx. + 12 metres, where the wing buried down into the ground. Damage to the wing indicates that at this stage, it had begun to push upwards and was simultaneously deformed.

3. At approx. + 18 metres, the left wing incurred loads so heavy that it broke off at the mount. This is supported by the deformations at the site of the breakage, which show that the wing was broken off facing “upwards”. The counter force to the fuselage initiated a rotation of the fuselage in a clockwise direction at the roll shaft.

4. The fuselage, with only its right wing remaining, hit the ground fairly “flat” during a powerful rolling rotation to the right. At this point, approx. + 30 metres, the nose gear broke off and the right wing hit the ground, upon which the external part detached and flew at a high speed, diagonally to the left and landed in the reeds at a distance of + 110 metres. The right wing stump simultaneously gouged a deep hole in the ground and detached.

5. The fuselage – now without the wings – bounced into the air once more at approx. + 40 metres. Ground traces at this position showed that the stabiliser hit the ground and the fin was deformed. In this position when the fuselage mostly was inverted, the forward speed reached zero. The aircraft fell to the left and came to rest in its final position (+ 50 metres).

The cracked panels between the engine and the cabin shows that the engine installation was subjected to a number of shocks to the side during the course of events. The finding shows that the deceleration of the aircraft was not a primary consequence of powerful shocks from the front, meaning that the engine installation was not compressed into the cabin, but shows that the deceleration largely was a result of forces from the side. This has most likely contributed to the fact that serious personal injuries could be avoided.

The division of energy loss over the course of the accident can be estimated as percentages according to the following:

Event position	1		2		3		4		5
Ground contact 25 %	0%		1%		9%		13%		2%
Force from air 39%		12%		6%		8%		13%	
Loss of mass 36%	0%		0%		20%		16%		0%
Total 100%									

Figure. 12. Table of energy losses.

From the table in Figure 12, it is understood that the predominant amount of the energy during the accident (61%) was absorbed by the relatively soft terrain below, in combination with the loss of the wings. The loss of energy being greater when the left wing came off than when the right wing broke off in two pieces was due to a higher speed at the time of the left wing's loss.

Using the above values as a base, the following estimates have been obtained of the energy and speed as functions of distance and time:

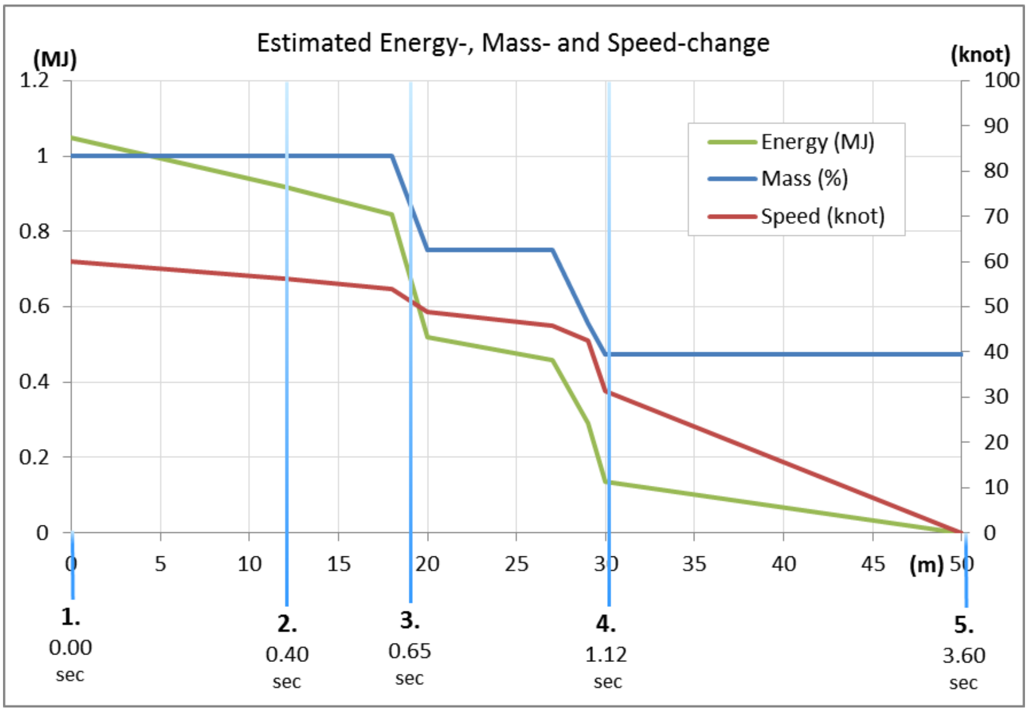


Figure 13. Graph of the changes that occurred during the course of the accident.

The graph in Figure 13 shows how the energy decreases over time and as mass reduces with the separation of the wings from the fuselage.

A linear estimate has been made of the braking G-forces in the direction of the aircraft's movement during the course of the accident. As the aircraft yawed during the course of the accident, the movement direction is not the same as the aircraft's longitudinal axis. The estimate is based upon the aircraft's angle of yawing at 0 metres being 60°; 45° at 30 metres; and 0°, at the final position.

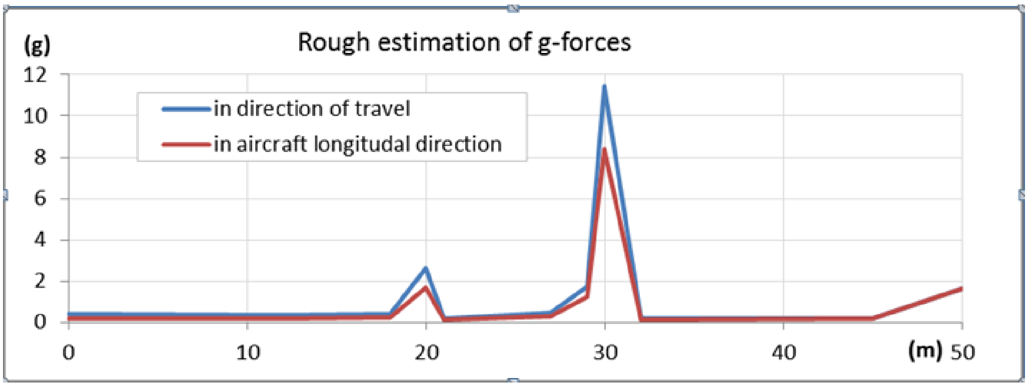


Figure 14. Graph showing the G-force over the course of the accident.

The diagram in Figure 14 shows that the G-force along the aircraft's longitudinal axis most likely reached approx. 8.5 G. This meant that the inflatable airbags installed in the front-seat safety belts and activated at a force of 9 G did not inflate during the accident.

1.15.7 *Medical survival factors*

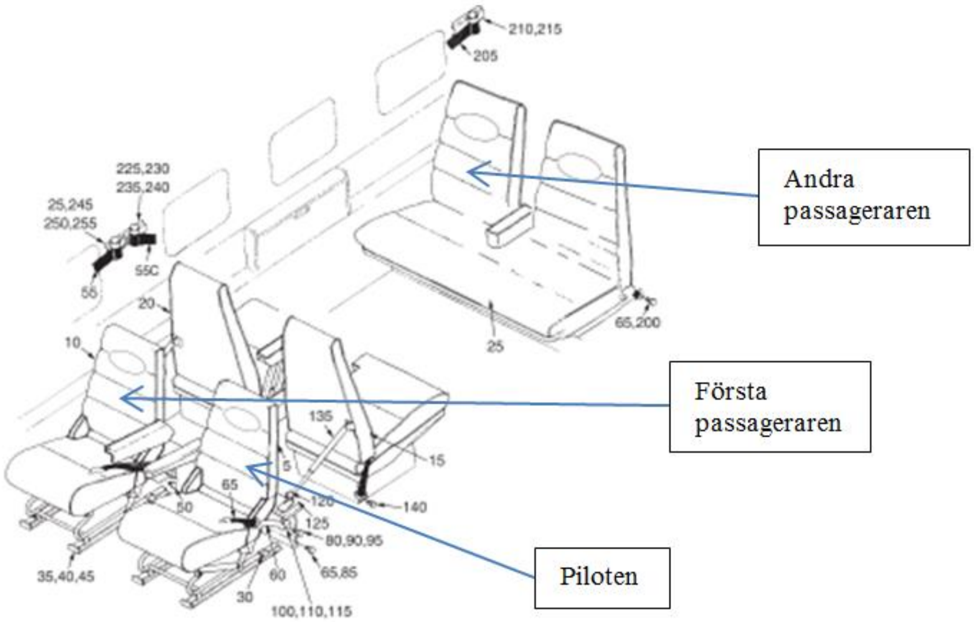
With the aim of investigating the medical factors behind the minor injuries obtained from the accident by those on board, SHK has enlisted Professor Ulf Björnstig from Umeå University.

Those on board generally experienced a deceleration from approx. 60 knots (110 km/h) to zero in 3.5 seconds, including the two pronounced deceleration peaks when each wing embedded into the ground and was broken off. This deceleration has been calculated to have had two peaks in the size order of 2–3 G in the direction of travel (or < 2g in x-direction, i.e. the aircraft's longitudinal axis) after 19 metres (0.65 seconds), and 11.5 G (or 8.5 G in x-direction) after 30 metres (1.12 seconds).

In addition, the combination of yaw (up to 60 degrees) and rolling movements of up to 180 degrees inverted position – as per section 1.15.6 regarding structural forces in different directions – affected those on board over the deceleration period.

Deceleration from 60 knots (110 km/h) over 3.5 seconds is generally viewed as mild deceleration. This can be compared with data from Col. John Stapp (U.S. Air Force) and his experiment in which he used himself as the test subject[10]. His repeated journeys in a rocket sled showed the limits the human body is able to endure. In the ultimate experiment, he braked within 1.4 seconds from around 1,000 km/h. This caused an application to the chest of approximately 46 G with limited injuries. This has since been used as background data in sectors such as the automobile industry when examining what the car safety belt system is able to handle.

[10] The experiment can be found on YouTube, by searching “John Stapp”.



Pilot First passenger Second passenger

Figure 15. Cabin layout for the aircraft in question, with the placement of those on board. Source: Piper aircraft.

It is possible that the first deceleration peak on the aircraft's longitudinal axis was minor, such as powerful braking in a car. However, when combined with the yaw and the rolling movements, it might have caused the passengers to fall “out of position” for being optimally caught by the safety systems over the remainder of the accident's events. See Figure 15 for the placement of those on board.

Upon the second and most powerful deceleration peak and its subsequent roll, it can be assumed that those seated on the right-hand side moved towards the right-hand side of the cabin and knocked into it when the roll stopped.

Being “out of position” can be suspected to have contributed to this. The human body also has a tendency to rotate out of the upper (chest part) of the safety belt, as the right shoulder is “held tight” to the chest by the belt on the right hand side, causing the upper body to rotate out of the belt. This corresponds to the presumed point of impact for the person sitting in the right hand front seat, who most likely hit the side window and/or its front frame with the face. This led to minor facial injuries.

It is difficult to judge how the rear passenger who received a concussion hit the cabin, however the movements were probably similar. Nevertheless, details are missing about the impact marks in the cabin and friction marks on the belts (to judge the way they rolled out, i.e. how far forward they were), as is an estimation of the forces to the side.

The pilot is very likely to have been further away from the injury-causing point of impact, particularly during the latter sequence of events and hence experienced the best outcome. Collectively, it can be established that the yaw/rolling movements “used” a large portion of the energy and also perhaps contributed to those on board coming “out of position,” causing them to receive a suboptimal application of the belt's chest component.

1.16 Specific tests and examinations

1.16.1 Examination of fuel

SHK has commissioned Exova AB to conduct an analysis of the Jet A1 fuel from the aircraft's wing tanks. The results of the analysis show that the initial boiling point (IBP) is abnormally low. This indicates that the fuel had elements of a lighter component, most likely petrol, of approximately 10%. The final boiling point is abnormally high, which infers a mixture of a heavier component, probably diesel.

The sample was also analysed with gas chromatography. Results from this examination indicate that the level of petrol included in the sample is between 5% and 10%. According to the engine's TC holder, the mixture of petrol and the heavier component in the fuel did not have any influence on the engine's performance or function.

1.16.2 Examination of the Data Acquisition Unit (DAU)

The aircraft was equipped with a data acquisition unit (DAU), manufactured by Meggitt Avionics Inc. The unit transforms analogue signals into digital ones, registers data for trend monitoring as well as exceedance of certain engine parameters. With support from Genesys Aero Systems, SHK has downloaded and examined data from the unit.

There were no data or exceedance parameters saved from the flight at the time of the accident. Nor were there any earlier data or exceedances registered that could be assessed to have influenced the event.

1.16.3 Initial examination of engine and propeller

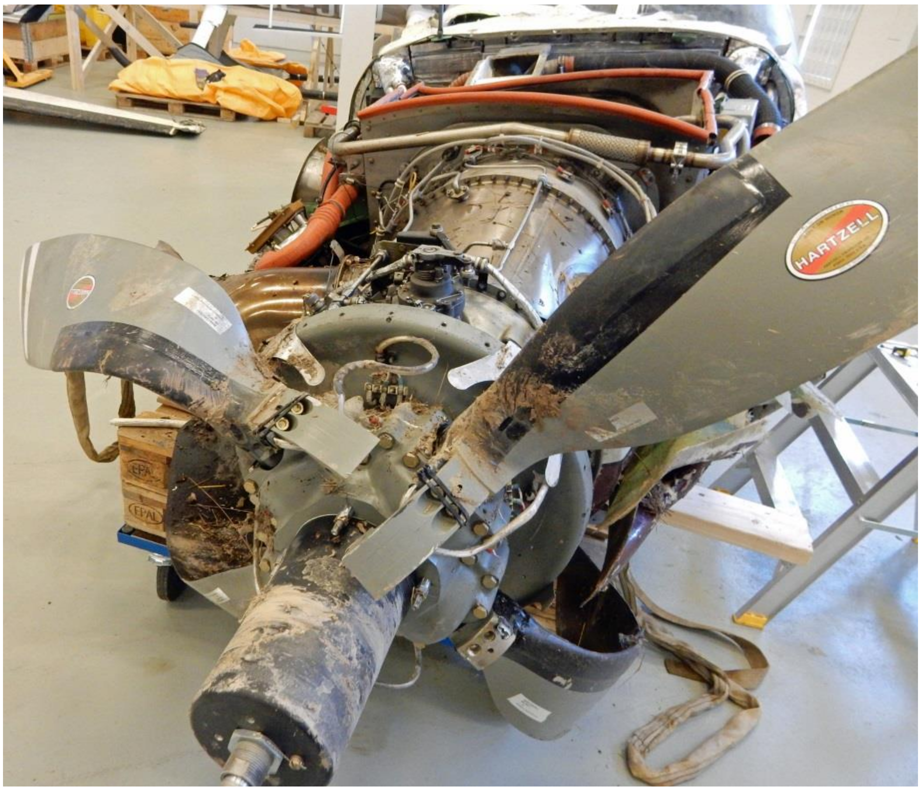


Figure 16. Propeller and engine.

SHK performed an initial examination of the engine and propeller. Damages were observed on the heavily bent propeller blades. A counter weight had been broken off from the propeller and was found loose in the spinner. Two of the blades could be freely rotated in the propeller hub. There were deformities to the engine's outlet section and exhaust pipe, as well as a minor oil leak from the underside of the engine.

There was residue of grass and soil present in the air intake, but no larger foreign objects. An examination of the fuel system showed no trace of contamination in the fuel filter. The examination also confirmed that there was fuel in the system. The engine and its auxiliary systems were otherwise relatively undamaged after the accident.

The Manual Override Lever (MOR) was outside of its normal OFF position. The MOR can be used to directly control the flow of fuel to the motor, should a pneumatic malfunction occur in the engine's fuel control unit (FCU). According to the engine's TC holder, Pratt & Whitney Canada (PWC), the position of the lever as it was found had little or no impact on engine performance.

No findings that could have prevented the normal function of the engine and propeller could be observed.

SHK decided to perform a more comprehensive and detailed examination of the engine and propeller with PWC. The engine with propeller were dismounted from the aircraft and placed in a transport box to be shipped to PWC. For transportation reasons, three propeller blades were cut off approximately 30 cm from their root.

Figure 17. Left-hand side of engine.

1.16.4 *Investigation of the propeller at PWC*

Figure 18. Propeller and engine upon arrival with PWC.

The investigation of the propeller at PWC was conducted by a representative from Hartzell Propeller Inc., under the supervision of SHK representatives. The investigation showed damage to all four propeller blades, which were bent backwards aft at midblade. Several broken pieces were found in the propeller hub. The blade knobs were fractured off two blades, and one bearing race was fractured into several pieces.

All of the preload plates had broken pieces, as well as marks and dents on the plates' surfaces. Two of the preload plates had impression marks, indicating a low blade angle upon impact. The characteristics of the damages to the propeller and blades indicated either low or no engine power upon the crash. No damage or problems were found that could have prevented normal function prior to the accident. All damages was consistent with those that occur upon a crash.

Figure 19. Examination of propeller blades.

1.16.5 *Investigation of the engine by PWC*

The investigation of the engine was performed by a representative from PWC, under the supervision of SHK representatives.

An initial examination of the engine showed limited external damages:

- Dents to oil tubes for the reduction gearbox;
- Firewall to the engine was deformed;
- Deformation on the exhaust case.

The engine was split at the flange that joins the gas generator section to the power turbine. Closer examination and a borescope inspection of the gas generator did not show any damages. Based on the condition of the gas generator, the decision was made to mount it to another power turbine (slave unit), to test the gas generator's function and its auxiliary systems on a test stand. Due to mismatch between the units, a normal engine rotation speed could not be attained. However the test did provide an indication that there was no defect to the gas generator.

Upon further examination and dismantling of the power turbine's first stator section, significant rubbing was found on the first stage of the power turbine's case caused by contact with the first stage blade tip shrouds. Damage caused by rubbing to the turbine casing covered over half of the periphery. The deepest damage was in the 10 o'clock position, see picture in figure 20, where the casing had been perforated.

Figure 20. The casing for the first turbine stage, perforated at 10 o'clock.

The blade tip shrouds in the first stage of the power turbine had rubbing wear around the entire periphery, with the largest wear diametrical to the smallest wear. A piece of metal was found tightly wedged between the first turbine stage and the second stator stage.

Figure 21. Damage to the blade tip shrouds in the first turbine stage.

Upon continued dismantling, it became clear that the piece of metal was part of the rotor section of the power turbine's labyrinth seal. It had fractured cirumferentially. The broken rotor section of the labyrinth seal shown in Figure 24, compared with an undamaged example of a rotor section in Figure 25. There was also significant rubbing to the inner diameter of the stator labyrinth seal section.

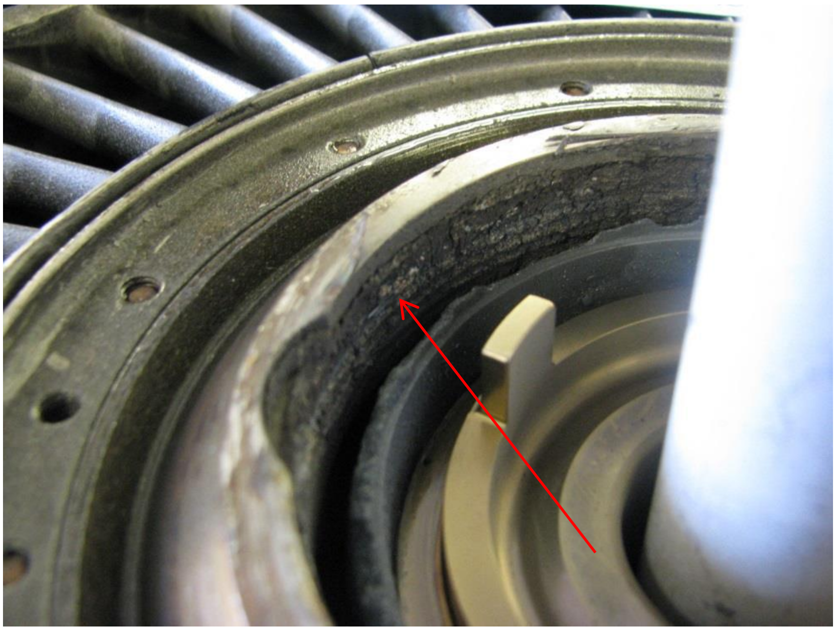


Figure 22. Damage to the inner diameter of the stator labyrinth seal section.

Figure 23. Broken section of labyrinth seal's rotor.

Figure 24. The broken rotor section of the labyrinth seal.

Figure 25. Comparison: New rotor section of a labyrinth seal.

With the second stage power turbine stator removed, damages were also discovered that had been caused by rubbing between the second stage of the tip of the power turbine's blade against the turbine casing. The rubbing wear was most prominent on one section of the blade. The most worn blade tips placed at 180 degrees against the least worn blade tips.

Figure 26. Second turbine section with damaged blade edges.

Figure 27. Rubbing damage in the turbine casing.

A laboratory investigation of the broken rotor section of the labyrinth seal showed evidence of cracks on the inner diameter of the rotor. No cracks were found on the outer diameter surface. This indicates that the cracking prograted outwards from the inner surface section of the rotor to the outer surface section.

An examination using a microscope showed an intergranular surface fracture. Hardness testing of the seal's material showed a low hardness value close to the area of the fracture and normal values outside of it. This indicates that the area of the fracture had been subjected to an increased temperature, which was most likely caused by significant rubbing.

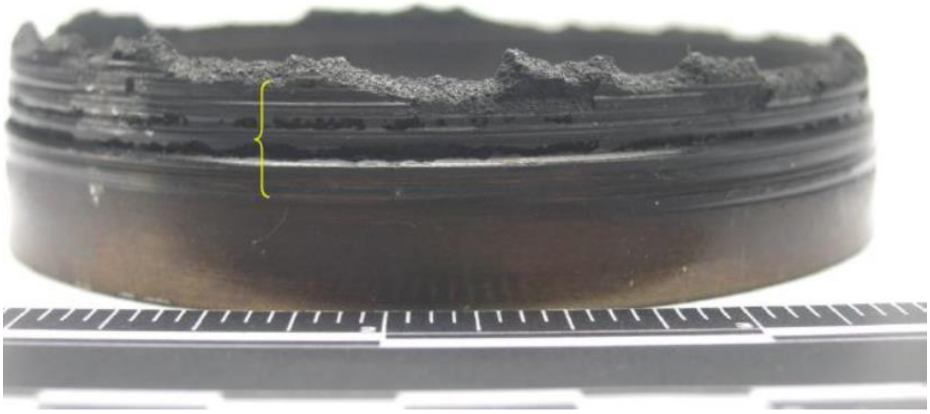


Figure 28. Rotor labyrinth seal.

Metallographic examination of a cross-section of the fracture's surface of the air seal confirmed an oxidised intergranular fracture surface, with oxidised secondary cracks.

A Hot Section Inspection (HSI) had been conducted after 1,783 hours of the operation time (TSN). There is no documentation of any remarks regarding the damages observed in the power turbine. According to PWC it would probably be difficult to discover the incipient damages in the power turbine during this particular inspection.

An examination of the engine's technical documentation showed that one component belonging to the propeller control system known as “Beta Block” had been replaced more frequently than normal. Since the operation time (TSN) from the aircraft being new, the beta block had been replaced a total of 9 times, with a trend of shorter intervals. Replacement hours were at 790, 1275, 1532, 1783, 1965, 2115, 2234, 2397 and 2544 TSN.

This component has no set replacement period; it is replaced “on condition,” once the unit for some reason becomes worn out or has malfunctioned. In this case, it is worth noting that the trend of the more frequent replacement of this component on this aircraft induvidual is clearly identifiable.

Inspection of the fuel control unit (FCU) showed that the throttle lever maximum stop screw had been set outside of the recommended limit. One FCU component, the “bypass valve diaphragm” had been marked with a manufacturing date of the third quarter of year 2000. Hence it was not within the six-year service life recommended by the FCU manufacturer, Honeywell.

An examination of the gear box showed that the propeller shaft had been broken off inside the gear box. Analysis of the crack surface on the propeller shaft showed a fracture with a shear angle caused by an overload. No indication of fatigue breakdown could be established.

An examination of the other engine components showed nothing noteworthy that may have contributed to the accident.

1.17 Operator's organisation and management

Not applicable

1.18 Additional information

1.18.1 Interviews

Reference has been made to the SHK interview with the aircraft pilot in section 1.1.4.

The passenger in front right-hand seat

The passenger who was seated next to the pilot stated that he perceived everything concerning the flight as normal. After the aircraft had been fuelled and prepared for flight, the two passengers and the pilot had lunch at the airport.

Due to other air traffic, they had to wait for a short while in take-off position, before taking off. During the take-off run, everything felt normal. Once they were airborne – approximately in line with the runway threshold – the problems started. The passenger noted that the pilot first contacted the tower for clearance to turn around; however, he quickly saw that they were losing altitude and would be forced to make an emergency landing. He thought that the aircraft was flying "uncoordinated" as the engine had lost effect but had not noted any warnings or other signals during the course of events.

According to the passengers, the left-hand wing was the first to impact with the ground, after which the aircraft rolled over a number of times. As it was rolling, the passenger hit his head on the side window and noted that his face was bleeding. Once the aircraft had come to a complete stop, the passengers and the pilot focused on trying to arouse the passenger in the rear seat who had lost consciousness during the accident.

The passenger in the back seat regained consciousness after approximately 1–1.5 minutes.

Passenger in rear seat

The passenger seated in the rear seat felt that the initial events, with taxiing and take-off, were completely normal. Take-off had occurred with one step flap position (10°).

After this, the passenger has no recollection of events up until he stood by a road together with the police and ambulance personnel.

Witness at the airport

The witness was in a hangar at the airport and was going out to collect the post. When he came out, he witnessed the aircraft's take-off. Once the aircraft was airborne, the witness noticed abnormal sounds coming from the aircraft.

The engine noise was different and sounded muffled. The witness also thought that the aircraft looked as if it was slipping through the air during the incident. The aircraft lost altitude and disappeared out of sight. Shortly thereafter, a clattering sound was heard.

The witness ran back to the office and turned on a communication radio used by the company to listen to the emergency frequency 121.5 Mhz. Clear signals from an emergency locator transmitter could be heard. The witness then informed some other staff present, who immediately started up a helicopter. The intention was to fly towards the accident site to help those on board if possible. This took place approximately six minutes after the accident.

Once the helicopter was airborne and they had localised the accident site on Björnö, they could establish that all three on board the aircraft had evacuated the wreckage. Air traffic control was informed of this via radio and the response was received that air traffic control had been in contact with the pilot via telephone and had been informed that all those on board had survived the accident.

The helicopter landed close to the accident site and assisted those on board who had only received minor injuries. Baggage from the aircraft was loaded into the helicopter, which then flew back to the airport once emergency services personnel had arrived.

Air traffic control at Stockholm Västerås Airport

At 12:00 hrs, an instructing air traffic controller with a trainee were to relieve the earlier instructor and trainee. Once the transfer of the work situation was completed – 12:02 hrs – Swedcopter 964 (SWC964) started the take-off roll from runway 19. The previous trainee remained in position when SWC964 was seen to level out at a low altitude, approximately 100 ft. across taxiway B.

Nothing untoward at take-off could be ascertained from the interviews other than when the climb ceased and the aircraft's flight path was changed.

1.18.2 Measures taken

See section 1.10.2 regarding measures taken with ELT equipment at the airport.

1.19 Special methods of investigation

None.

2. ANALYSIS

2.1 Operative

2.1.1 Flight conditions

The external flight conditions were good: a clear and cold day without precipitation or any other complicating factors. The aircraft had been parked in a hangar overnight, meaning de-icing had not been assessed necessary. According to the interview with the pilot, there was nothing out of the ordinary or that could have disrupted their routines to such an extent that it would constitute a risk of impairing their attention.

There were no technical remarks noted in the aircraft's logbook. The aircraft had been fuelled prior to the particular take-off, but the oil and fuel analysis carried out does not indicate any contamination or anything else that could have affected the function of the engines.

The commander stated that he had carried out an external inspection of the aircraft prior to take-off and did not notice anything abnormal. SHK therefore assumes that the pilot assessed the aircraft to be airworthy from a technical viewpoint for the flight in question. No other observations – either from the pilot or the passengers – have been deemed to have affected the aircraft or execution of the flight.

Overall, SHK considers the technical and operational conditions for carrying out this flight as good.

2.1.2 Take-off

After a short delay, the pilot received clearance to line up runway 19 for take-off. The take-off position from the intersection at taxiway E meant that the pilot did not use full runway length for take-off. The reduced runway length at take-off is not assessed to have affected the subsequent series of events.

According to the pilot, maximum power was used during take-off, in accordance with normal procedures. Acceleration and engine thrust for the first part of the take-off was deemed normal. No other facts have come to light that indicate that this part of the take-off was affected by external factors of any form, such as FOD or bird strike.

It is therefore considered ascertained that the pilot and the others on board felt that the take-off run until lift off was like a normal take-off with a fully-functioning aircraft.

2.1.3 The engine failure

Based on the facts that have arisen from the interviews with those on board and witnesses on the ground, it can be established that the engine problems occurred seconds after lift off, when the aircraft was at an initial climb of approx. 100 feet. They state that the engine disruptions felt as though the engine was losing thrust and at the same time began to sound different and the engine “choked”.

In such circumstances, a pilot flying a single engine aircraft has limited options. As there was no way to avoid a landing of some kind, the pilot had two choices: Continiue in the forward direction or, attempt to turn back to the airport. At the very low altitude the aircraft was flying when the malfunction occurred, there was no time to read any checklists or other measures to potentially diagnose the problem or restore power.

The completed engine examination shows that the engine breakdown was such that there was no way for the pilot to restore engine power.

The request to return to the airport to air traffic control by the pilot may be viewed as a combination of ensuring the possibility to return and simultaneously informing air traffic control of the emergency situation that had arisen.

Given the circumstances of a heavily loaded aircraft flying at relatively low speed and at low altitude, SHK is of the opinion that an attempt to return to the airfield would most likely have led to a significantly more serious accident. Previous accounts of similar situations show a large number of accidents in which the aircraft has stalled during a turn when attempting to return to the airport.

Consequently, the pilot's decision to continue straight ahead for an emergency landing is viewed as well founded, considering the particular circumstances. The emergency checklist that shall be used upon engine loss in conjunction with take-off was not used. Even if some points of the checklist should have been performed, SHK is of the opinion that these actions would have only been likely to marginally influence the sequence of events.

A commercial aircraft in a similar situation with two crew members would possibly have enabled certain actions to be performed. It is unreasonable, however, to place the same demands regarding a private pilot operating a single engine aircraft.

2.1.4 Emergency landing

When the decision was made to attempt to land straight ahead, the pilot was faced with limited options. In the take-off direction, i.e. southwards from the runway extension, was Lake Mälaren. At that time, the lake was covered with ice of an – to the pilot – unknown thickness.

The pilot then made the decision to attempt an emergency landing on the island of Björnö, directly south of the airport and essentially in the flight direction of the aircraft. After a minor change of the heading, the aircraft was steered towards the open space on the island where an emergency landing was judged to be possible. At the same time, the pilot extended the landing gear and wing flaps.

The pilot stated that during this period, the aircraft was difficult to control and to an extent it began to slide as it lost altitude. This can probably be explained by the decreasing torque and influential side forces from the propeller stream when the engine thrust decreased.

Despite the fact that the pilot stated that the speed was well over the critical speed range, SHK believes that the deceleration at this time was pronounced and the aircraft was rapidly approaching stall. In this critical situation that arose it is however understandable that the pilot did not prioritise reading the aircraft's airspeed indicator.

Guided by the marks in the the ground caused by the impact and partially verified by witness statements, it is verified that the aircraft hit the ground with its left wing first at an estimated bank angle of 30–45°.

The cause of the bank is likely to have been the aircraft stalling in the final stage and turned over to the left just before impact. This indicates that the final stages of the flight were not fully controlled. The pilot has limited memory of the final seconds; however, SHK deems it unlikely that a controlled emergency landing would have been performed with a high bank angle to the left.

Overall, SHK is of the opinion that the given circumstances in this emergency situation led to exceedingly limited manoeuvring room for the pilot. The desire to reach the area on Björnö to carry out a controlled emergency landing overshadowed likely the pilot's attention to the prevailing situation with a rapidly decreasing speed.

This led to a low speed situation that prpbably resulted in an uncontrolled stall during the final stage of the course of events .

Remark

The pilot does not share SHK:s analysis of the the final stage in the course of events, but believes that the airspeed throughout the event has been over the aircraft's stall speed, and that the side impact was not a result of a stall over the wing.

2.1.5 *Survival aspects*

The investigations presented in sections 1.15.6–7 show how a wide range of circumstances contributed to this accident being survivable. The most influential structural factors contributing to the fact that the cabin section only received minor damages can be summarised as follows:

- The angle at which the impact occurred enabled the wings to act as shock absorbers.

- The side impact – and a minor “nose down” attitude – meant that the engine was not forced into the cabin and that there were no strong frontal forces.

- The relatively low speed resulted in a low energy output.

- The nature of the terrain absorbed a large portion of the energy over the course of events.

- The robust construction of the fuselage (pressurised cabin) contributed to the limited damage to this part of the aircraft.

The major factors contributing to those on board avoiding any serious injuries can be summarised as follows:

- The, from a medical perspective, “gentle” progression of the accident; the energy was used by both the aircraft itself and the underlying terrain.

- The moderate deceleration – calculated to approximately 8.5 G lengthways.

Nevertheless, the minor injuries sustained were likely a result of the combined yawing and rolling movements causing the passengers at the right-hand side to slip out of their shoulder straps during the course of the accident.

Figure 29. Final position of the fuselage in the field.

Generally, the reasons why this accident did not lead to an unfortunate outcome can be explained for the most part by referring to circumstances that could not be influenced, but were rather of a lucky and temporary nature. The impact occurred at such an attitude and bank angle that the aircraft's wing construction formed both a deformation zone and decelerator during the event.

2.1.6 Engine investigation

SHK considers that the sequence of the events primarily initiated in the power turbine's labyrinth seal, even though this cannot be established with full certainty. This is based on the significant oxidisation of the seal's surface fractures and the occurrence of secondary oxidised cracks. Rubbing wear has been found between the rotor and the static part of the labyrinth seal. Once the rubbing began, a thermal expansion of the seal led to further rubbing then generating even more thermal expansion.

Rubbing and abrasion has led to material being lost in the labyrinth seal's rotor which consequently led to an imbalance in the power turbine. This imbalance then led to rubbing between the first and second stage turbine blades against a small area on the turbine's housing. In conjunction with further materials becoming abraded on the turbine blades and seal, the imbalance within the turbine became greater over a longer period of time.

The failure of the labyrinth seal occurred by overload in an area within the seal that had been exposed to an increased temperature. This is indicated by an intergranular crack growth. The localised high temperature comes from heat caused by friction that resulted from the rubbing of the outer surface of the rotor in the seal.

Replacements of the Beta Block, which had become more frequent since operating time 790 TSN, can likely be linked to vibrations in the propeller shaft caused by the rubbing and wear in the labyrinth seal. This also includes the contact of the turbine blades against the turbine casing and the resulting imbalance in the turbine. This indicates that the damage had been caused over a long period of time.

Even though in hindsight these more frequent replacements of the Beta block can be seen as an indicator of other underlying problems, SHK believes that it is unreasonable for maintenance organisations to be able to recognise such a malfunction as a sign of other potential problems in the engine's power turbine unit. For this to be possible, additional symptoms would be necessary.

Figure 30. Damages to the turbine blades.

The final stage, in which the rotor section of the labyrinth seal was fractured and the turbine blade perforated the turbine casing, most likely occurred suddenly just after lift off.

The loss of engine power was caused by the power turbine losing a great portion of its efficiency due to the tips of the turbine blades perforating the turbine casing, and the fact that the important tip clearance between the tips of the turbine blade against the turbine casing was lost. The course of events were also maintained by the friction which arose between the parts.

The propeller shaft broke off as a result of shear force that occurred upon impact, constituting secondary damage.

The findings that were discovered in the FCU and the Manual Override Lever (MOR) did not contribute to the events.

2.2 Rescue operation

2.2.1 Air rescue operation

The prospect of initiating a rescue operation was delayed at JRCC due to a problem with the three-way telephone call occurring when SOS Alarm, JRCC and the airport air traffic control tried to connect. Air traffic control was unable to hear JRCC personnel. This has been put down to human error at SOS Alarm.

The short delay to the three-way telephone call was of little significance as the aircraft's position could be localised quickly via a telephone conversation between the airport air traffic control and the pilot, in addition to the aviation company's helicopter immediately discovering the aircraft's wreckage and three survivors on Björnö.

2.2.2 *Municipal rescue operation*

Parallel operations

Once the air rescue operation had been terminated, the municipal rescue operation began, according to what was stated by the rescue coordinator at MBR. In a previous investigation of rescue operations (see RM 2013:02, appendix 1), the Swedish Accident Investigation Authority noted that the tenor of LSO does not provide the margins for an authority to await the initiation of a rescue operation should another authority already be performing one, if the conditions are otherwise met in accordance with LSO and FSO.

The recommendations provided by SHK in the aforementioned report have been passed on to the Swedish Civil Contingencies Agency (MSB).

SHK believes that there were grounds to instigate a municipal rescue operation as soon as it became clear that the accident site was on Björnö and not in the waters of Lake Mälaren. This applies irrespective of the time difference – in this case relatively short – from the moment the accident site had been localised until JRCC terminated the national rescue service and the municipal rescue service was initiated.

It should be clear to both national and municipal rescue services that it is the individual authority itself who decides whether a rescue operation shall be launched based upon the criteria specified in LSO. Parallel operations might therefore take place, which also presumes that the involved authorities cooperate in accordance with the LSO demands.

Rescue operation to limit environmental damage

According to information from the rescue coordinator, there was reason to commence a rescue operation to limit environmental damage in accordance with LSO, despite the situation at the accident site having been relatively stable, considering the release of approximately 500 litres of aviation fuel near to the Hässlö water plant and source water protection zone.

SHK considers the evaluation and decision to take action for a rescue operation following directions in LSO to be justified by the events and the given circumstances – one example being the threat to the water source.

The emergency actions taken during the rescue operation were intended to limit the further spread of leaking aviation fuel. The chosen method was to spread a sorption agent to bind the aviation fuel, whilst waiting for the contaminated layer of earth to be removed after the subsequent sanitation stage. Free fluids containing aviation fuel that were present in indentations in the ground and on the surface of the water were pumped out.

It is difficult to retroactively assess how effective the actions have been. Actions that were able to limit the spread of the aviation fuel and damage to the environment have nevertheless been deemed both essential and urgent. Emergency actions were justified by factors such as the site being located in close vicinity to or – as was later shown – within the source water protection zone and also inside a nature reserve.

In parallel with the rescue operation, certain sanitation actions such as excavation were also carried out. The sanitation actions were judged to be less pressing than the actions during the rescue operation. At the same time, it appears as though the rescue operation could possibly have ended earlier once the salvage manager became involved and aware of the situation at the site of the accident. The task of the salvage manager lasts until the insurers of each object, or the owners themselves, are prepared to take responsibility for the damage.

Accessibility of accident site

The cooperation at the accident site between the various authorities involved was not frictionless. This resulted in the prioritisation of the different operational tasks on site being less than optimal. In the discussions with the rescue coordinators, the accident investigator from SHK and the inspectors from the Health and Environmental Protection Service, the SHK representative requested that no measures be taken in the area until the Investigation Authority's examination of the site was complete. The rescue coordinators did not obstruct the SHK investigators from accessing the accident site; they accepted the plan of action and the circumstances put in place by the accident investigator.

It can however be noted that better cooperation could probably have led to a method allowing for both the application of the majority of the sorption agent at the same time as the investigation of the accident site could be conducted.

Figure 31. Picture from the scene of the accident showing leaked fuel.

A consequence of the way the work on the site was distributed was that the efforts to distribute sorption agents by the rescue services were delayed. This is unfortunate, considering the risk of the negative effects on the area's water source, for example. With hindsight and with all these available facts, it can however be established that there is nothing to indicate that the delay to the environmental rescue operation has led to any negative consequences.

Both SHK and the rescue services are of the rightful opinion that their recommended actions at the scene of the accident were supported by law. The prioritisation which came to apply – that the accident investigation took place before the environmental protection operation – is of course questionable and shows that the overlapping powers in certain circumstances can result in problems for the reactions from the authorities.

The events emphasise the importance of well-developed cooperation between the authorities involved, with early contact and sensitivity – this also applies to SHK – to ensure that the correct priorities are made and with that, the conditions are enhanced for working suitably and in parallel.

2.3 ELT

In the accident at hand, the failure of the ELT signal did not play a decisive role for locating the fuselage and the accident site. Nevertheless, this must be viewed as circumstantial. Had the conditions been different, e.g., another accident site location or darkness/reduced visibility, the ELT signals would have been crucial for the efforts to localise an aircraft wreckage.

SHK considers it to be unsatisfactory that such an important part of the safety equipment at a large commercial airport was not performing reliably. According to the appropriate regulations, air traffic control units must ensure two-way radio communication over the 121.5 MHz emergency frequency.

The importance of a satisfactory ELT function at airports is emphasized by the fact that over half of all accidents or serious incidents take place in conjunction with take-off and landing, or in the vicinity of the airport.

SHK therefore believes that the Swedish Transport Agency should improve the supervision of this form of air traffic control equipment at Swedish passenger airports.

2.4 Installation of operational CCTV cameras at Swedish passenger airports.

There is a considerable presence of CCTV monitoring at airports, usually with the aim to prevent, detect and investigate crime. Cameras are used less often for the purpose of preventing or investigating accidents. In the areas of Swedish airports where the risk for serious incidents or accidents are at their highest – approach zones, runways and taxiways – there is almost no presence of CCTV monitoring.

SHK can make great use of image materials in investigations and feel that it is unfortunate that access to film or photo documentation of events – at an airport or in its close vicinity – is based on random factors. Private individuals that happens to film an event, or a camera that is being used to monitor any potential trespassing happens to catch parts of the series of events in an accident.

At the time when this report is published, SHK is investigating another accident at a major Swedish airport (accident at Malmö/Sturup, (L-61/15). No film material is available for this case. This accident also included an aircraft for which on board recording equipment is not mandatory.

SHK also notes that, in retrospect, a number of SHK's aviation investigations of accidents at passenger airports have had to be conducted without the documenting materials that, under these circumstances, would have been desirable.

CCTV monitoring is a sensitive issue when it comes to integrity and there is basic protection in the Swedish Instrument of Government against significant invasions of personal privacy (Chapter 2, Article 6, Swedish Instrument of Government). Consequently, measures of this nature may only be taken in accordance with the law.

The Swedish Public Camera Surveillance Act provides regulations regarding the conditions for CCTV monitoring, stating that such actions are subject to permission. When assessing whether or not a permit shall be issued, one of the factors to be observed is whether the monitoring is needed to prevent accidents or for other similar purposes.

SHK is of the opinion that there should be CCTV monitoring of the airport areas where there is the greatest risk of serious incidents and accidents. This would facilitate the investigation of such events and could therefore be a legitimate purpose. Examples of ways to safeguard against any invasion of personal integrity could be to introduce regulations similar to those governing an aircraft's FDR and CVR. In this case, this would mean that photographic materials may not be made available or used for any purpose other than for the safety investigation.

The Swedish Transport Agency shall work for the achievement of the transport policy objectives, including the adaption of formation, function and use of the transport system in such a way that nobody is killed or critically injured, the Agency should consider if the use of CCTV cameras, in the long term, could contribute to the meeting of those objectives.

The possible introduction of CCTV monitoring also raises questions about costs, possibilities to document aircraft movements during varying meteorological conditions like low visibility or precipitation, and ultimately the socio-economic benefits. The range of the equipment also varies from simple small webcams to major camera systems used for RTC (Remote Tower Control) where both costs and function vary considerably.

Which systems that could be suitable for use, and are economically justifiable is not possible to say in the current situation, even if it appears likely that it will be in the lower end of the range. The footage from the airport cameras would definitely found a wider basis for the authoritie's investigations, and would contribute to more robust and safer analyzes, enhancing the opportunities to take adequate measures to prevent a reocurrence.

A decision on these questions is depending on a closer evaluation of the conditions. Since it is primarily the safety investigating authority that benefits from any photodocumentation can such an evaluation be made in consultation with SHK.

At the same time, the matter should be actively placed on the international agenda, for example through the work conducted by the International Civil Aviation Organization (ICAO) and the European Aviation Safety Agency (EASA).

2.5 Summarising assessment

The accident came as a result of a sudden emergency situation, resulting in an emergency landing for which the pilot did not have sufficient time to perform any other action than to attempt to manoeuvre the aircraft. It can be established that the impact was not fully controlled; it occurred in an aircraft that was most likely in the initial stage of a stall.

The aircraft's speed and attitude upon impact resulted in the exterior parts of the aircraft functioning as shock absorbers. The nature of the terrain below meant that the fuselage remained relatively intact, resulting in those on board being able to escape serious injury.

SHK notes that the fact that those on board did not receive any serious injury is down to circumstances that could only be partly influenced. Regardless of the sequence of events at the impact, the pilot's decision to continue straight ahead probably laid the foundation for the - from a survival aspect - fortunate outcome of the accident .

The cause of the engine failure behind the accident has been found to be rubbing and wear to a seal in the engine's power turbine section. Even though PT6 is an incredibly common engine model, this malfunction cannot be considered to pose such a risk that the chance of repeated malfunctioning of this type is high.

Therefore, the Swedish Accident Investigation Authority does not provide any safety recommendations regarding the design of the engine or its maintenance schedule.

3. CONCLUSIONS

3.1 Findings

a) The pilot was qualified to perform the flight.
b) The aircraft had a valid Certificate of Airworthiness.
c) The aircraft's mass and balance were within the allowed limitations.
d) Engine failure occurred at an altitude of approx. 100 ft.
e) The emergency landing was conducted straight ahead into an open space on the island of Björnö on Lake Mälaren.
f) Upon impact, the left wing was the first to hit the ground and the aircraft reached a stop after approx. 50 metres.
g) The fuselage was relatively undamaged after the accident.
h) The aircraft's wings and the characteristics of the underlying terrain were able to absorb the major portion of energy upon impact.
i) The air bags mounted to the safety belts in the front seats were not inflated during the accident.

j) The longitudinal deceleration force of the accident has been estimated at approx. 8.5 G.
k) Damage from rubbing between the rotor and the static parts of the labyrinth seal in the engine's power turbine section were identified.
l) Rubbing damage was identified on the tip of the blades in the first turbine stage and the turbine blade tips in the second turbine stage and the turbine casing.
m) Incipient rubbing damages to the labyrinth seal has most likely caused an imbalance within the power turbine that increased over time.
n) The beta block unit of the aircraft had been replaced over closer intervals leading up to the accident.
o) The rotor part of the labyrinth seal was fractured off and the turbine blades perforated the turbine casing.
p) ELT signals sent from the aircraft over the 121.5 MHz frequency were not received by the control tower.
q) The three-way telephone call initiated by SOS Alarm did not function as it should have.
r) JRCC classed the event as an “emergency situation” and initiated the air rescue.
s) The accident site was localised from on board a helicopter belonging to the aviation company.
t) The three persons on board evacuated the aircraft themselves.
u) At the scene of the accident, the three on board were assessed to have received minor injuries.
v) Approximately 500 litres of aviation fuel disbursed in connection with the accident.
w) The accident site was located within a secondary source water protection zone.
x) Municipal rescue operations were carried out to limit environmental damage.
y) A lack of cooperation was noted between the investigators and authorities tasked with responding to environmental emergencies.

3.2 Cause

The accident was caused by damage to the power turbine which occurred over time, and that could not be identified by the engine's maintenance program.

4. SAFETY RECOMMENDATIONS

The Swedish Transport Agency is recommended to:

- Investigate the requirements for CCTV cameras for investigation purposes to be installed at Swedish commercial airports. *(RL 2016:02 R1)*

- Work for that the issue of operational CCTV cameras on commercial airports for investigation purposes, is appropriately addressed in the international flight safety community. *(RL 2016:02 R2)*

- Increase the supervision and reliability for receiving emergency signals via 121.5 MHz at air traffic control units at Swedish commercial airports. *(RL 2016:02 R3)*

SHK respectfully requests to receive, by June 1st 2016 at the latest, information regarding measures taken in response to the recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas   Stefan Christensen

Appendix:

Investigation from XICE AB regarding structural forces at the impact. (Issued only in Swedish).

Appendix

Utredning av haveri med Piper PA 46 Meridian på Björnön, Västerås den 13 feb 2015

Bo Persson
XICE AB

Rapport, SHK Dnr L-0015/15, 26 aug 2015

Sammanfattning:

Anledningarna till att kabinsektionen av flygkroppen klarade sig med begränsade skador kan sannolikt fastställas till:

- Det sneda nedslaget, vilket medförde:
  - Att motorn inte trycktes in i förarkabinen
  - Energiupptagning då vingarna gick av
- Den relativt låga farten
- Underlagets beskaffenhet
- Den robusta konstruktionen av flygkroppen (tryckkabin)

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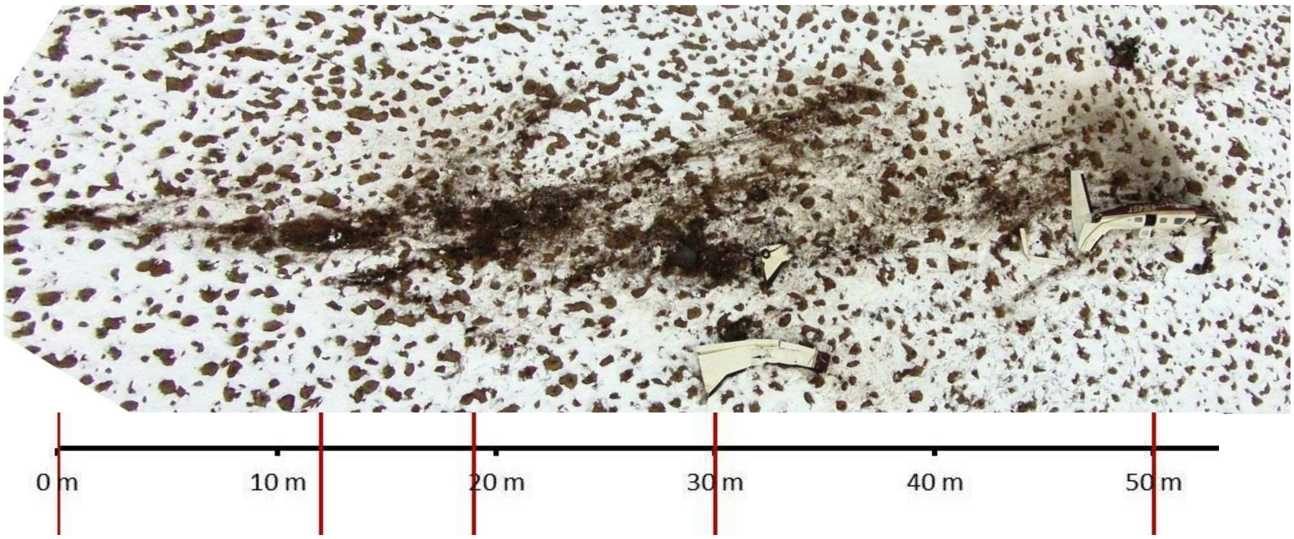
1. Olycksplatsen:

Marken på olycksplatsen utgörs av en stubbåker, snötäckt med fläckvis barmark. Avsaknad av tjäle och att marken bestod av fuktmättad jord gör det lättare att se var och hur kraftiga islagen har varit. Spåren av uppsprätt jord kan också lätt spåras på den halvt snötäckta marken.

Drönarbild av olycksplatsen:



1. Markkontakt vänster vinge
2. Vänster vinge gräver
3. Vänster vinge går av
4. Höger vinge går av i 2 delar
5. Slut-positon

För att försöka få en bild av olycksförloppet, har flygbilder (drönarbilder) och markbilder av olycksplatsen studerats, samt orsakade brottskador undersökts. Även samtal med piloten om hans minnesbild av olyckan har gjorts.

2. Analys av Olycksförloppet:

Enligt samstämmiga uppgifter från pilot och passagerare har planet träffat marken med vänster vinge först under vänstergir. Aktuella farter och attityder kan endast uppskatts.
Sannolikt har planet haft låg fart och stallat vänster vinge ner i marken under pågående vänstergir.

1. Markontakt vänster vinge

   Första markkontakten uppvisar ”släpande” spår och kan inte varit speciellt kraftig.
   Troligen har planet haft tillräcklig lyftkraft som sedan avtagit under ökande vänstergir.

2. Vänster vinge gräver

   Planet har här förlorat större delen av sin lyftkraft och vänster vinge gräver kraftigt i marken.
   Sannolikt har vingen börjat deformeras kraftigt. Skadorna på vingen tyder på att vingspetsen trycks ”uppåt”, vilket stöder att planet har girat mycket kraftigt.

3. Vänster vinge går av

   Det kraftiga islagsmärket samt spåren av uppsprätt jord snett åt vänster tyder på att vänster vingen utsatts för så stora laster att den gått av vid vingroten. Detta stöds också av deformationerna vid brottområdet som visar att vingen gått av ”uppåt”. Motkraften mot kroppen orsakar en rotation kroppen medurs kring rollaxeln.

4. Höger vinge går av i 2 delar

   Troligen har kropp med höger vinge slagit i marken ganska ”platt” under kraftig höger rollrotation. Noställlet tar i marken och går av. Höger vingen ”daskar” i marken varvid vissa delar lossnar och yttre delen av vingen omedelbart går av och far iväg med hög fart snett åt vänster, ca 60 m bort in i vassen. Rotationen av kroppen har avtagit men fortsätter och höger vingstump gräver ett djupt hål i marken och går av. Motkraften mot kroppen då vingstumpen går av, och det faktum att tyngdpunkten nu utan vingar ligger långt fram p.g.a. motorvikten, medför sannolikt att kroppen vrids upp med nosen i färdriktingen.

   Flygplanskroppen utan vingar ”studsar” nu upp i luften under måttligare rollrotation åt höger. Det första som tar i marken igen är höger delen av stabilisatorn. Spår på marken 3-4 meter snett bakåt höger tyder på detta. Rollrotationen avtar när stabilisatorn lossnar. Dock forsätter rotationen så pass mycket att fenan går i marken och deformeras. I detta läge, nästan helt upp och ner, är farten i färd riktingen nästan noll och kroppen faller ner åt vänster och stannar där. Det är troligen i detta skede passageraren i högra sätet slår i kabinväggen.

5. Slutposition

   Under förloppet har motorn endast blivit utsatt för stötar i sidled, inte rakt framifrån. Därför har inte motorn trycks in i kabinen, men den uppspruckna plåten mellan motor och kabin vittnar om flertalet stötar i sidled.

3. Uppskattningar och beräkningar:

Då olycksförloppet endast kan uppskattas och mer exakta siffror saknas, krävs ett antal antaganden för att en beräkning av energier, farter och tider ska kunna göras.
Beräkningarna är därför inte på något sätt precisa, men kan kan ändå ge en ungefärlig bild av olyckan.

Vid första markkontakt (position 1.) har antagits följande:

Fart = 60 knop
Total massa = 2200 kg

Detta ger en startenergi = 1.048 MJ (MegaJoule)

Det ända vi med säkerhet vet är att energin vid slutpositionen (position 5.) är noll.

Därför har en skalfaktor införst, så att effekten alla uppskattade värden till slut resulterar i att energin är noll. Detta har gjorts genom en iteration efter att alla nödvändiga antagande gjorts.

Följande har antagits:

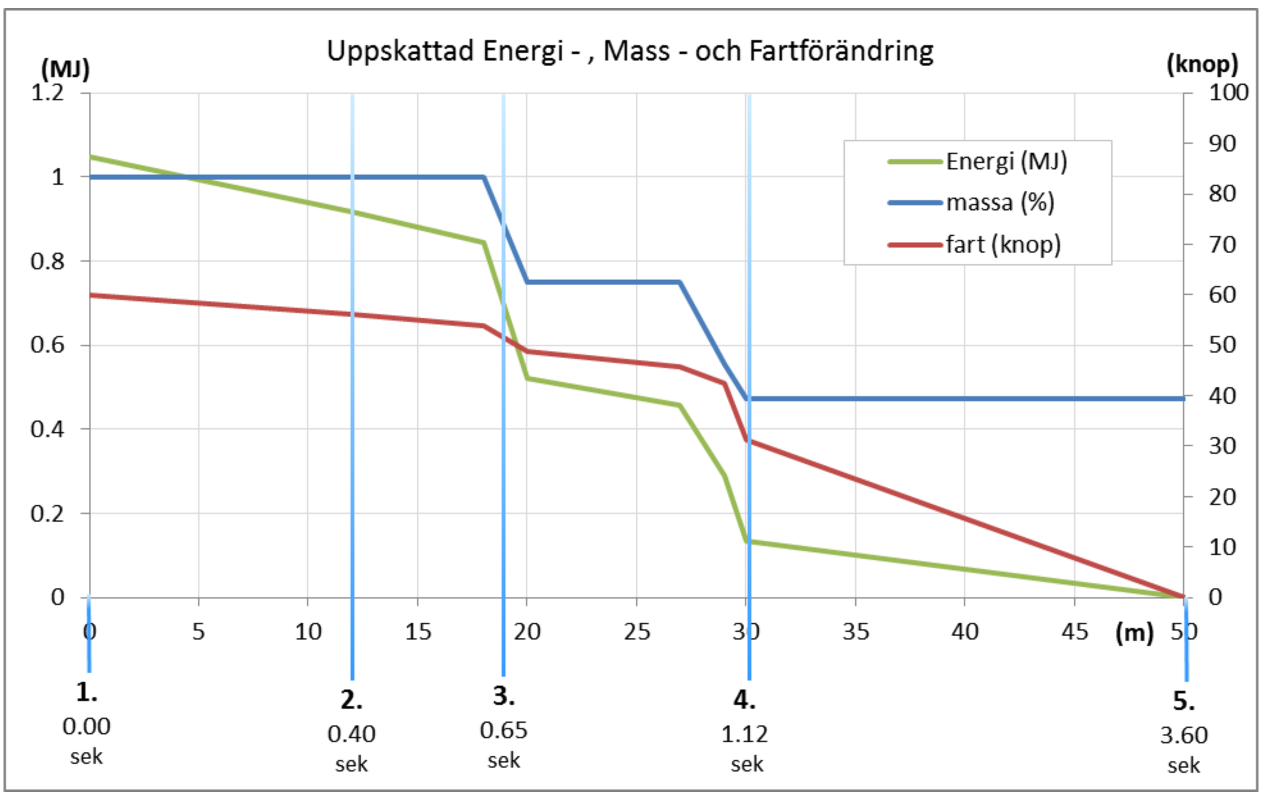
Energiförluster p.g.a. markontakt = 25 % av startenergin.
Energiförluster p.g.a. luftkrafter har antagits vara propotionella mot kvadraten på farten integrerade över tiden.
Energiförluster p.g.a. massförlust då vingar går av.

Fördelning av energiförluster:

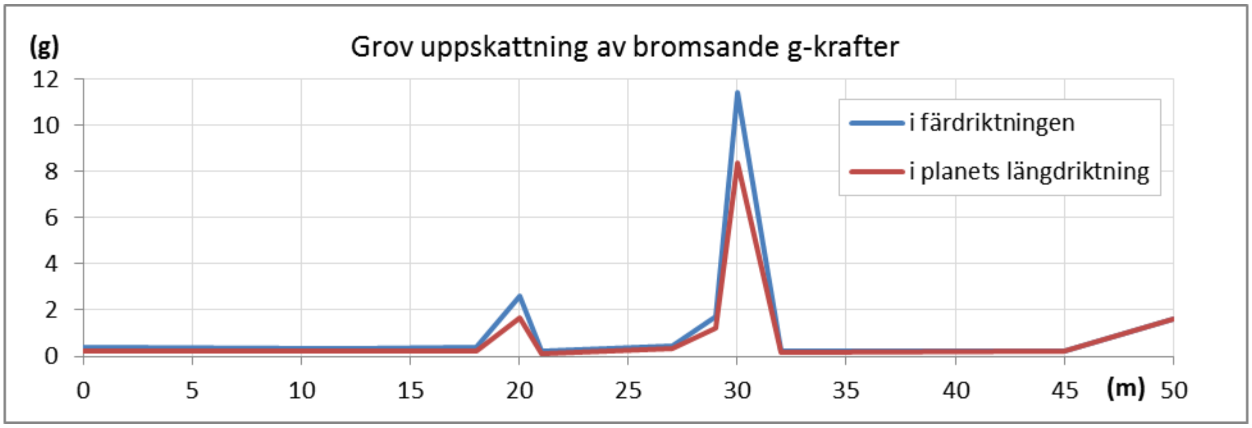
Förloppsposition:	1.		2.		3.		4.		5.
Markkontakt (tot: 25%):	0%		1%		9%		13%		2%
Luftkrafter (tot 39%):		12%		6%		8%		13%	
Massförluster (36%):	0%		0%		20%		16%		0%
Ger total: 100%									

(Kommentar: Att energiförlusten är större när vänstervinge går av med ett brott än när högervinge går av med två brott, beror på att farten var mycket högre då vänstervingen går av.)

Med dessa antagna värden fås följande uppskattningar av energi och fart som funktion av sträcka och tid:



Vidare har en mycket grov, linjär, uppskattning av bromsande g-krafter i färdriktningen gjorts. Observera att färdriktningen inte är detsamma som planets längdriktning då planet girar. Uppskattningen bygger på antagandet att flygplanets girvinkel vid 0 m är 60 grader, vid 30 m 45 grader och 0 grader i slutposition.



4. Slutsatser:

Den främsta orsaken till kabinsektionen utan större skador är sannolikt det sneda nedslaget. Hur sned är mycket svårt att uppskatta, men troligen minst 45 grader, sannolikt mer.

Detta har medfört att motorn inte blivit utsatt för någon kraftig stöt rakt framifrån, och därmed inte tryckts in i kabinen och orsakat allvarliga personskador, vilket är relativt vanligt vid haverier av enmotoriga flygplan.

Det sneda nedslaget orsakade även att vingarna fick ta de första kraftiga stötarna och gick av. Detta innebar en kraftig energireducering. Ju kraftigare energimiskning, ju mindre energi finns kvar som kan orsaka skador.

Den relativt låga farten gjorde att utgångsenergin var relativt låg.

Den mjuka marken medförde att själva islagen i marken blev ”mjukare” alt. ”segare” och därmed avsevärt mindre lokala energikoncentrationer och g-krafter. Hade marken varit hård, exempelvis betong- eller asfaltbana, hade sannolikt de lokala energikoncentrationerna varit så höga att tryckkabinen skadats och där även risken för antändning av bränslet hade ökat. Endast en mycket grov uppskatting av g-krafternas storlek har kunnat göras. Dock har inte g-krafterna i planets längdriktning varit tillräckligt stora (9 g) för utlösa de installerade g-bältena.

Den robusta kabinkonstruktionen (tryckkabin) gjorde att den klarade de sista islaget utan svårare skador.