Statens haverikommission
Swedish Accident Investigation Board

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Report RL 2008:09e

Aircraft accident to OE-KLA in international waters south of Trelleborg on 16 October 2006.

Case L-31/07

Statens haverikommission (SHK) Swedish Accident Investigation Board

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Statens haverikommission
Swedish Accident Investigation Board

2008-11-25 L-31/07

The Swedish Civil Aviation Authority

SE-601 73 NORRKÖPING, Sweden

Report RL 2008:9e

The Swedish Accident Investigation Board has investigated an accident that occurred on 16 October 2006 in international waters south of Trelleborg, involving an aircraft with registration OE-KLA.

In accordance with section 14 of the Ordinance on the Investigation of Accidents (1990:717) the Board herewith submits a report on the investigation.

Göran Rosvall Stefan Christensen

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1 Transcript of the radio and telecommunications traffic concerned.

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Aircraft; registration and type	OE-KLA, Diamond DA 40D
Class/airworthiness	Normal, valid Certificate of Airworthiness
Registered owner/Operator	Borås Flyg AB/Borås Flygklubb (Flying Club)
Time of occurrence	2006-10-16, approx. 21:08:00 hours, in darkness Note: Unless stated otherwise, all times are given in Swedish daylight saving time (UTC + 2 hours)
Place	Southern Baltic Sea, approx. 28 km south of Smygehamn. (posn. 55.05.1N, 013.23.3E.
Type of flight	Private flight
Weather	According to SMHI’s analysis: wind variable 5 knots, visibility 8-12 km, overcast with base 2000 feet and tops at 3000-4000 feet, temp./dewpoint approx. 10 °C, QNH 1025 hPa
Persons on board:	
crew members	1
Passengers	2
Injuries to persons	All fatal
Damage to aircraft	Destroyed
Other damage	Minor release of aviation kerosene and oil into the sea.
Commander:	
Sex, age, licence	Male, 42 years, PPL with night flying qualification
Total flying time	635 hours
Flying hours previous 12 months	57 hours Flying time information as provided during certificate renewal on 9 January 2006.

The Swedish Accident Investigation Board (SHK) was notified on 16 October 2006 that an aircraft with registration OE-KLA had an accident at approx. 21.08 hours on that day in international waters south of Trelleborg.

In accordance with the international agreement embodied in the Chicago Convention, Annex 13, concerning accident investigations, approved by Sweden and Austria as ICAO member countries[1], it applies in the case of accidents in areas that are not defined as national territory that the country in which the aircraft is registered also is responsible for investigating the accident.

An investigation therefore begun by the Austrian Accident Investigation Branch, AAIB[2] , with an accredited representative assigned by SHK. At the request of the Austrian Transport Department, Sweden and the SHK took over responsibility for investigation of the accident, on 6 December 2007.

The SHK representatives included Göran Rosvall, Chairperson, Stefan Christensen, chief investigator, and Sakari Havbrandt, technical investigator.

Liselotte Yregård was appointed the medical expert by SHK.

The investigation was followed by Gun Ström, Swedish Civil Aviation Authority.

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[1] ICAO: International Civil Aviation Organization

[2] AAIB: Austrian Accident Investigation Branch

Summary

The aircraft, a recently purchased Diamond DA 40, took off from Berlin for a delivery flight to Borås, Sweden. The pilot, and two other persons on board, were members at the local aero club in Borås. The flight was planned VFR at 6000 feet. The flight was carried out partly over clouds, were the tops were forecasted at 3000 – 4000 feet, and the cloudbase at approximately 2000 feet.

After having received the actual weather report the pilot decided to divert to Malmö/Sturup, which was the alternate airport, and commenced the descent. When the aircraft passed the altitude 3000 feet, as observed by the radar controller, it was noted that the aircraft started a steep right turn and rapidly lost altitude. At time 21:08 the radar echo disappeared from the radar screen. The accident site, about 28 km south of the Swedish coast, was located by a helicopter but no survivors could be found.

After a long salvage operation, the aircraft wreckage was recovered 23 days after the accident. At the investigation of the wreckage some electronic units found were taken for analyses. The evaluation of these units, together with data from radar stations, showed that the first part of the descent had been normal. At about 4400 feet a malfunction was registered, causing the auto pilot to disconnect.

The pilot, who was not instrument rated, probably lost control over the aircraft, when VMC no longer could be maintained. The aircraft entered a spiral dive with a sink rate up to 6400 feet/minute. At an altitude of about 1500 feet the aircraft went into a slight climb, where it could have been exposed to high g-loads. The aircraft then continued descending at a high rate, and hit the water surface almost vertically.

The accident was caused by VFR flying being planned and executed in such a way that VMC could not be maintained. A contributory factor was the malfunction of the autopilot.

Recommendations

The Swedish Civil Aviation Authority is in the international community recommended to work for a revision of the rules for flying under VFR in darkness over large areas of water or other areas with limited visual references *(RL 2008:09 R1).*

1 FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The first phase of the flight

The aircraft, a Diamond DA 40 registered OE-KLA, took off from Berlin/Schönefeldt for a flight to Borås/Viared. Earlier that day the aircraft had flown from Wiener Neustadt East in Austria with the intention of making an intermediate landing at Berlin to refuel and obtain an update of the weather conditions along the route and at the final destination. It was planned to perform the flight under VFR[3].

Initially the weather was good, with good ground visibility during the first phase of the flight, through Northern Germany and out over the coast. The clouds increased over the Baltic, becoming overcast near the Swedish coast. The flight was carried out at FL 60, i.e. 6000 feet with standard setting on the altimeters. According to the data that could be confirmed by recovered memory units, the aircraft was flown with the autopilot activated during cruise, and also during the first part of the descent.

During initial radio contact with area control at Malmö, the pilot requested the actual weather for both Gothenburg/Landvetter and for Malmö/Sturup. Viared at Borås is a small airfield without air traffic control or weather reporting. The flying distance to Gothenburg/Landvetter is about 35 km.

1.1.2 The second phase of the flight

After receiving the weather information, the pilot decided to change the destination to Malmö/Sturup airport and therefore requested clearance to leave the cruising altitude and descend, on a heading for Sturup. Communication with air traffic control at Sturup was normal during cruise and the first part of the descent, with no indications of problems on board. In connection with this, the pilot was also asked to change the transponder code[4].

The pilot received clearance to descend to 3000 feet and OE-KLA left the cruising level on a northerly course. According to the radar data the initial part of the descent was normal, with a descent profile that did not deviate from that which was expected. The last radio message from the aircraft was at 21:04:54, at an altitude of approximately 4300 feet, when the pilot read back the transponder code that had been assigned.

As the aircraft reached an altitude of approximately 3000 feet as indicated on the radar, it was noted that it began a steep right turn, which continued until the heading was assessed as being about 250°. Immediately afterwards there was an indication on the air traffic control radar screen that the transponder response was no longer being verified, and just after 21:08 the aircraft echo disappeared completely from the radar screen. The air traffic controller continued to call the aircraft by radio on different frequencies, and after a few minutes raised an alarm to the Rescue Centre, ARCC[5] to report a suspected accident.

The air traffic controller also requested help from other sources (including other aircraft in the vicinity) in gaining contact with OE-KLA. However there was no reply from the aircraft.

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[3] VFR: Visual Flight Rules

[4] Transponder: Electronic response unit on board an aircraft, whereby air traffic control assigns an individual code to each aircraft for radar identification.

[5] ARCC: Aeronautical Rescue and Coordination Centre, the Swedish Aeronautical Rescue Centre located outside Gothenburg.

1.1.3 *The accident*

After activation of the ARCC, several different rescue services were notified, with both airborne and maritime units from different countries. The assumed accident site was found by a helicopter at 22:10, and at 23:00 the first vessel arrived, which also recovered pieces of wreckage that could be found floating on the water surface. Several vessels then conducted a search of the area for wreckage and possible survivors.

The rescue mission was terminated at 01:25 and it could be concluded that OE-KLA had been completely destroyed, and probably with no survivors.

The accident occurred in darkness at position 55.05.05N, 013.23.26E, in the sea approximately 28 km south of Smygehamn.

1.1.4 *Graphical overview of the sequence of events*

The flight was documented by military radar stations in both Sweden and Germany. The images shown on the next pages are graphical representations of the radar data, based on recordings from Swedish military stations. Fig. 1 on the next page shows the actual route across the German mainland, continuing across the island of Rügen and out over the Baltic Sea. Fig. 2 shows a detailed illustration of the final three minutes preceding the accident.

The illustrations have been supplemented by data that was collected from the memory units in certain on-board electronic equipment, which was obtained and analysed.

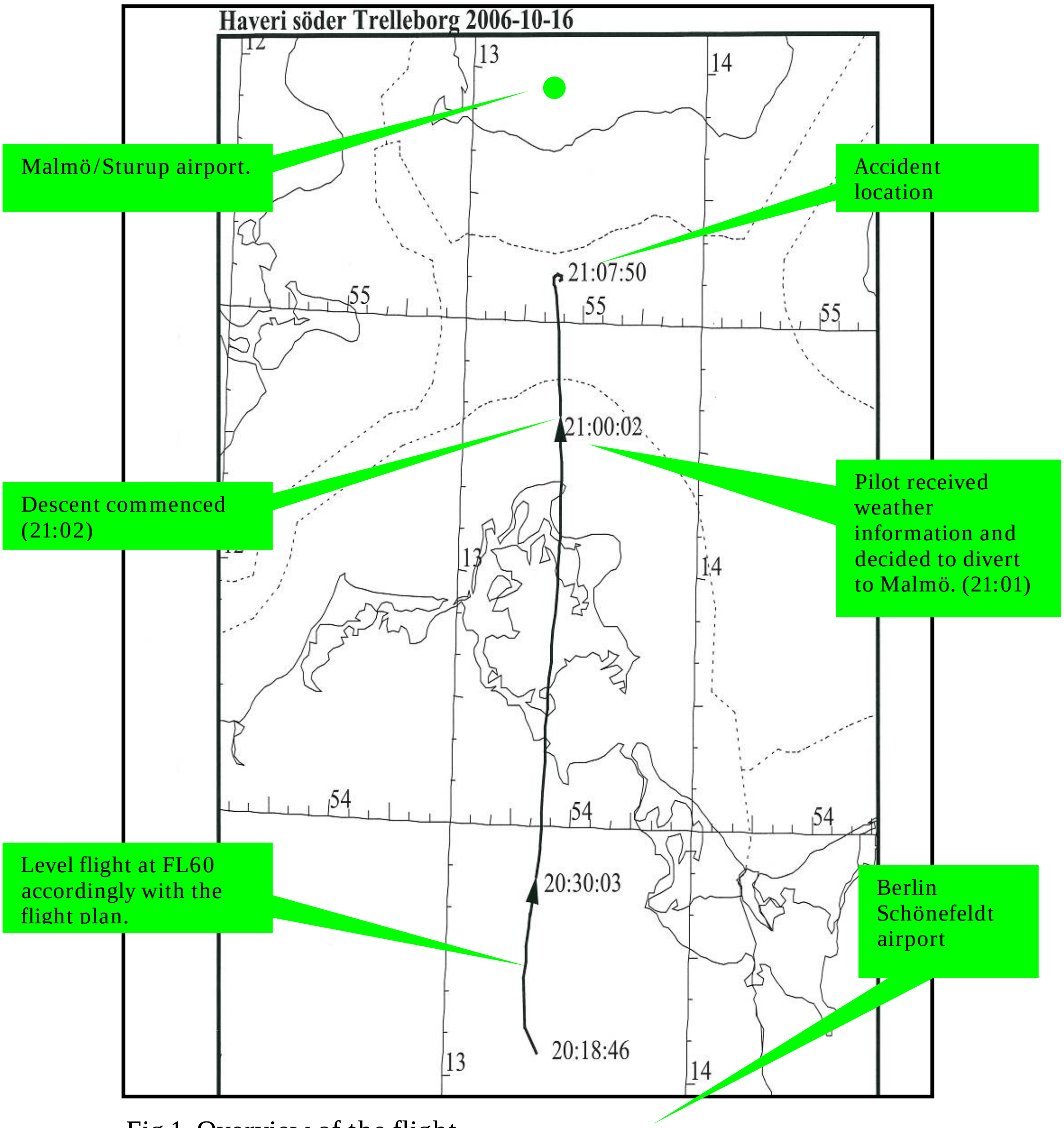

Fig 1. Overview of the flight.

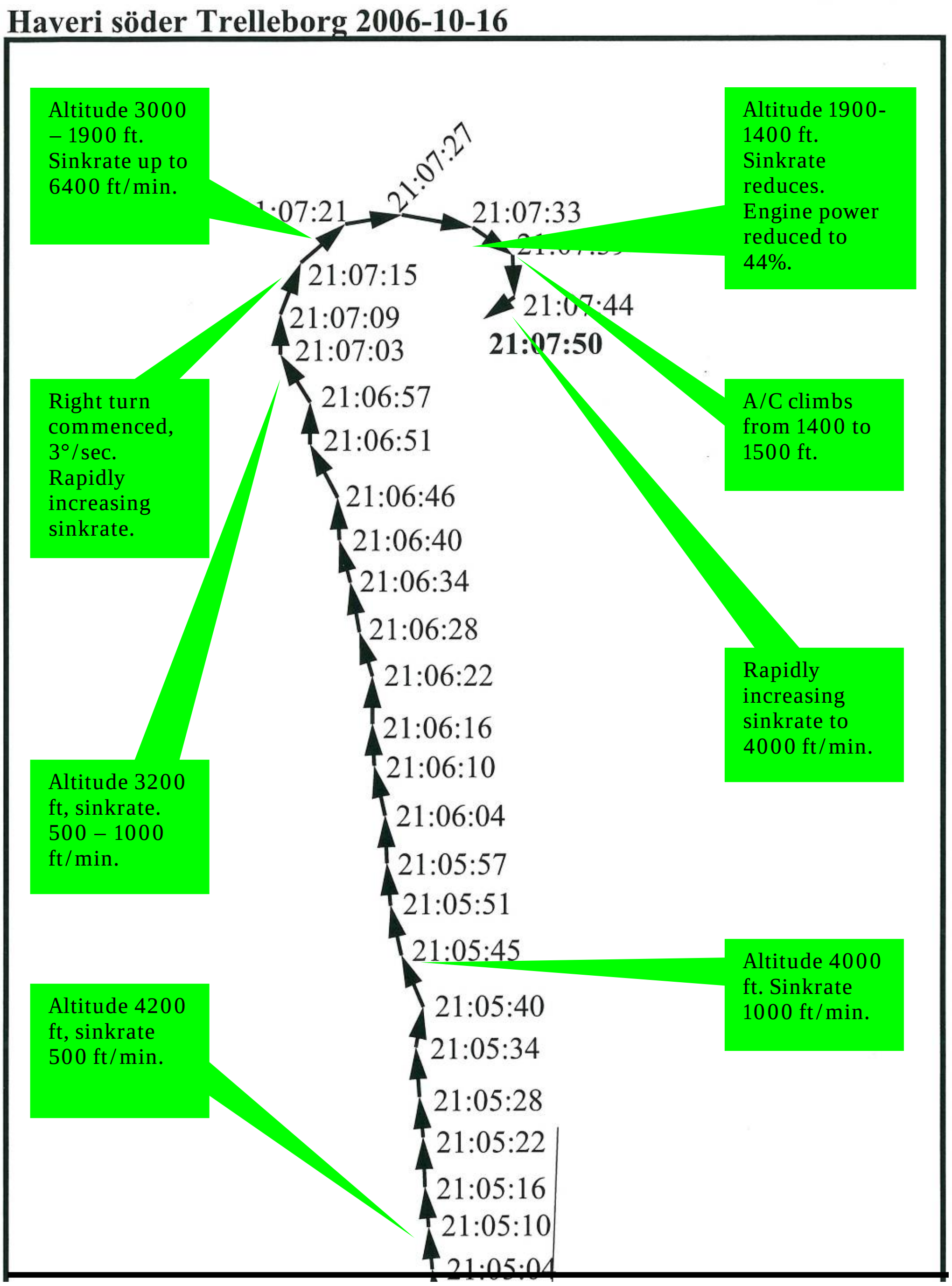

Fig. 2 Detailed graphic of the sequence of events.

1.2 Injuries to persons

	Crew members	Passengers	Others	Total
Fatal	1	2	–	3
Serious	–	–	–	–
Minor	–	–	–	–
None	–	–	–	–
Total	1	2	–	3

1.3 Damage to aircraft

Destroyed.

1.4 Other damage

Minor release of kerosene and oil into the sea.

1.5 Personnel information

1.5.1 *Pilot*

The commander, male, was 42 years old at the time and had a valid PPL.

Flying hours			
Latest	24 hours	90 days	Total
All types	About 4	Not known	635
This type	About 4.	Not known	Not known

Latest PC (Proficiency Check) carried out on 13 June 2005.
Flying for CRI SE[6] carried out on 5 October 2006

1.5.2 *The passengers*

The passenger in the front right seat was also pilot and had a valid private pilot’s licence. The passenger in the rear seat was also a pilot but did not have a valid licence.

1.6 The aircraft

1.6.1 *General*

The aircraft	
Manufacturer	Diamond Aircraft
Type	DA 40 TDI
Serial number	D4.008
Year of manufacture	2003
Gross mass	Max. authorised take-off/landing mass 1150 kg
Centre of mass	Not known
Total flying time	755 hours
Number of cycles	1639
Flying time since latest service	Service in conjunction with aircraft delivery from the factory.
Fuel loaded before event	Jet A1

Engine	
Manufacture	Thielert
Model	TAE-125-01
Number of engines	1
Engine	*No. 1*
Total operating time, hrs	755
Operating time since overhaul	*3*
Cycles since overhaul	1639

Propellers

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[6] CRI SE: Class Rating Instructor Single Engine. Type rating and check flight qualification for single-engined aircraft in the actual class.

Propeller manufacturer	Mt-propeller
Type	MTV-6-A/187-129
Propeller operating time	755 hours

The aircraft had a valid Certificate of Airworthiness.

Fig 3. The accident aircraft. Photograph source: Diamond Aircraft.

1.6.2 Status of the aircraft

The aircraft had been purchased by Borås aero club and was to be flown to their home airfield of Borås/Viared. The three on board at the time of the accident belonged to the group within the aero club that had been involved in completing the purchase. The aircraft purchase had taken place via the manufacturer, and the aircraft was collected from the Wiener Neustadt East airport in Austria. Before delivery the aircraft had been checked, inspected and test flown.

Among the remarks noted in the company's "*Work report & certificate release to service*" (work order N0: MSO 0600921 issued on 16 October 2006), were the following:

- The artificial horizon indicator did not work. The unit was exchanged and tested, with the result: "*tested ok*".
- Stiffness in the elevator trim servo. The unit was removed, adjusted and noted as working "*OK*" after reinstallation.
- Compass system deviation. Deviation checks performed and a deviation table fitted.

Apart from the above, a number of minor modifications were carried out and servicing performed, along with such minor repairs as lamps and a worn tyre. After the completed servicing work, OE-KLA was test flown by an inspector from Austro Control[7], "*check flight for export C*". SHK did not receive any indications of faults resulting from this test flight.

1.6.3 Equipment in the aircraft

The aircraft had a complete set of instrumentation. The equipment included dual altimeters, ILS/GS[8] receiver, transponder, GPS and a three-axis

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[7] Austro Control: The Austrian authority equivalent to the Swedish Civil Aviation Authority.

[8] ILS/GS: Localiser (lateral guidance) and glidepath receiver for instrument landing.

autopilot. On checking the equipment and inventory lists that were provided during the sale, SHK found no deviations from or errors relating to the expected standard.

Fig 4. Standard instrument panel in the DA 40. Photograph source: Diamond Aircraft

1.7 Meteorological information

1.7.1 *General*

According to an analysis obtained from SMHI (Swedish Meteorological and Hydrological Institute) the weather picture was dominated by high pressure in the applicable area. From Berlin, out over the German coast and up to latitude 55° N the weather was mainly clear, with an increasing amount of stratocumulus clouds at a height of 2000 – 3000 feet. The visibility along this part of the flight route was 10-15 km.

North of 55° N the cloud successively increased to become complete stratocumulus cover with a base of about 2000 feet and the tops varying between 3000 and 4000 feet. Visibility gradually deteriorated to between 8 and 12 km.

The meteorological conditions in the area of the accident:

- Wind:	At sea level:	variable 5 knots, +11°C
	at 2000 feet:	270°/10 knots, +6°C
	FL50:	320°/10 knots, +8°C
	FL100:	360°/15 knots, -1°C

- Barometric pressure: 1025 hPa
- No icing conditions
- No turbulence
- Surface water temperature + 13°C

1.7.2 *Forecasts and current weather*

Airport weather forecast for Gothenburg/Landvetter valid 17:00 – 02:00:

Wind 220°/6 knots, visibility more than 10 km, scattered clouds at 1500 feet, broken clouds at 2000 feet, 40% probability between 00:00 – 02:00 for broken clouds at 800 feet.

Airport weather forecast for Malmö/Sturup valid 17:00 – 02:00:

Variable wind 2 knots, visibility more than 10 km, scattered clouds at 3000 feet, 30 % probability between 22:00 – 02:00 for 300 m visibility in fog, with vertical visibility 200 feet.

Actual weather Malmö/Sturup:

20:20: Wind variable 2 knots, visibility 9 km in mist, overcast at 2100 feet, temperature/dew point 10/+9 °C, QNH 1026 hPa.
20:50: Wind variable 3 knots, visibility 8 km in mist, overcast at 2200 feet, temperature/dew point 10/+9 °C, QNH 1026 hPa.
21:20: Wind variable 2 knots, visibility 7 km in mist, overcast at 2300 feet, temperature/dew point 10/+9 °C, QNH 1025 hPa.

Due to the length of time since SHK took over the investigation, it was not possible to determine which type of weather briefing and/or what forecasts were given to the pilots before planning the final part of the route from Berlin.

1.7.3. *Verification of the forecast flying weather on the route*

After the accident SHK was contacted by a pilot who had flown, just over an hour ahead of the accident aircraft, through the same area on route from Berlin to Linköping, Sweden. That flight was carried out at a higher altitude (FL110), but initially along the same route as OE-KLA. The pilot had taken photographs during certain parts of the flight, including after take-off from Berlin and along the route in approximately the same area as where the accident occurred (see figures 5 and 6).

It is evident from the photographs that the weather forecast corresponded well with the actual weather conditions, with clear weather over Berlin and thickening clouds to the north. Over the Baltic it was broken and at times completely clear, but south of the Swedish coast the cloud layers became overcast. The pilot assessed the top as being at about 4000 feet (±1000 feet), and the base as being at about 2000 feet (±1000 feet).

Fig. 5.Weather after take-off from Berlin. Photograph source Daniel Hoffman

Fig. 6.Weather en route. Photograph source Daniel Hoffman

1.8 Aids to navigation

1.8.1 General

No errors or abnormalities were found or reported in respect of the ground-based navigational aids that were present along the planned flight route.

The on-board navigational equipment had operated without remarks on delivery, and there were no indications that the equipment was subjected to interference during the flight. Interference to certain parts of the aircraft navigational equipment are recorded in the autopilot memory unit, on condition that the autopilot is activated. No such interference was found recorded.

1.8.2 ATC route plan

The delivery flight of OE-KLA was planned with two legs, with the first leg being from Wiener Neustadt East to Berlin/Schönefeldt. The final leg was originally planned from Berlin to Borås, but was changed during flight after decision by the pilot. The flight was based on a flight plan that the pilot telephoned in to Arlanda briefing immediately before take-off, according to the following transcript (all times are UTC):

```
FF ESMMZFZX
161638 ESSAZPZX
(FPL-OEKLA-VG
-DA40/L-SD/C
-EDDB1710
-N0120A060 DCT NRG DCT SALLO DCT VEY DCT MISMA DCT
-ESGE0240 ESMS
EET/SALLO0120 RMK/N VFR NIGHT DOF/061016 ORGN/ESSAZPZX
```

Line 6 of the flight plan shows that the pilot planned for the flight to proceed at “A060”. This abbreviation means Altitude 6000 feet and involves an altitude where the term “flight level” with a standard setting of the altimeter is used, so the correct statement should have been “F060”, i.e.

Flight Level 60. This flight level is planned and normally used only for IFR[9] traffic.

In the case of VFR flying below F100, normally “odd” flight levels at 500 foot intervals are used in accordance with a predetermined rule with respect to the average course of the flight. In this case the flight could have been planned at either FL055 or FL065. After SHK interviewed the Arlanda briefing staff, an explanation for this deviation from the standard could not be found. Nor was it possible to clarify whether the deviation was initiated by the pilot or the flight plan recipient at Arlanda briefing office.

Line 6 also defined the planned route (the abbreviation DCT stands for Direct). After take-off from Berlin/Schönefeldt (EDDB) the route was planned to pass the Neu Brandenburg (NRG) beacon, with an entry point into the Swedish Flight Information Region over the Baltic (SALLO), the Vedby beacon in Skåne (VEY), and via the intersection (MISMA) directly to Borås/Viared (ESGE) with a planned flight time of 2 hours 40 minutes. Malmö/Sturup was selected as the alternate airport. The pilot also stated that the flight would be carried out VFR during darkness.

1.9 Communications

The radio communications between the aircraft and air traffic control were recorded and have been obtained by SHK. The entire radio traffic during the applicable time period, and communications between the air traffic controllers, was transcribed and is appended at Appendix 2 of this report. Below is a transcript of the radio messages exchanged between the control centre at Malmö and OE-KLA:

MMX: Malmö ATC, south.
OLA: OE-KLA

Time	*From*	Rem	Information
20.54.52	*OLA*		Malmö control Oscar Echo Kilo Lima Alfa.
20.54.58	*MMX*		Oscar Echo Kilo Lima Alfa, Malmö.
20.55.01	*OLA*		VFR flight plan goes from Berlin to Borås and flight level 65 .., 60 and squawk[10] 3240.
20.55.13	*MMX*		Oscar Lima Alfa, that is understood.
20.55.18	*OLA*		Thanks for that. Do you have any weather over Malmö for me?
20.55.23	*MMX*		Yes, weather at Sturup, are you ready to receive it?
20.55.27	*OLA*		Oh, yes.
20.55.29	*MMX*		So the wind is 160 degrees 2 knots, visibility 8 kilometres in fog....overcast at 2200 feet, 10 degrees and the dewpoint is 9, QNH 1026.
20.55.50	*OLA*		Yes, thanks for that, QNH 1026.
20.56.50	*OLA*		Malmö, Oskar Lima Alfa, can you help us with the weather for Gothenburg?
20.56.55	*MMX*		Yes, we’ll get back to you with that, and you are clear to enter Malmö TMA at flight level 60.
20.57.01	*MMX*		Cleared into Malmö TMA, 60, Lima Alfa.

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[9] IFR: Instrument Flight Rules.

[10] Squawk: The aviation technology term for transponder code.

20.58.53	MMX		Oscar Lima Alfa, I now have the weather for Gothenburg.
20.58.55	OLA		Yes, please.
20.58.57	MMX		Yes, Landvetter, then, and the visibility is more than 10 kilometres, overcast at 1700 feet and 1024 is QNH.
20.59.08	OLA		Yes, thanks for that, Lima Alfa.
21.01.24	OLA		Malmö, Oskar Lima Alfa, we need to reroute and go to Malmö instead.
21.01.31	MMX		Do you want to “divva” and land at Malmö-Sturup instead of Borås?
21.01.36	OLA		Yes, we think the weather is too bad up there, so we’ll start with Malmö in any case.
21.01.40	MMX		Understood, we will arrange that for you.
21.01.42	OLA		Can we descend to 3000 feet to start with?
21.01.45	MMX		Oscar Lima Alfa, yes, descend to 3000 feet. QNH is 1026, transition level is 50.
21.01.52	OLA		1026, (transition) 50, Lima Alfa.
21.03.34	MMX		Oscar Lima Alfa, please set your transponder to 2715 instead.
21.03.39	OLA		2715, Lima Alfa.
21.04.49	MMX		Yes, Oscar Lima Alfa, transponder was 2715.
21.04.54	OLA		2715.

It is noteworthy that the air traffic controller, when reading out the weather at Malmö/Sturup, stated that the visibility was 8 km in *fog*. According to the METAR: at 20:50 the weather was 8 km visibility in *mist*. The expression “divva” refers to “diversion” in English, which in standard phraseology means an alteration, i.e. in this case the alteration to the destination initiated by the pilot from Borås to Malmö/Sturup.

1.10 Aerodrome information

Both Malmö/Sturup and Gothenburg/Landvetter had status in accordance with AIP[11]. No known deviations were noted in respect of the status of Borås/Viared.

1.11 Flight recorders and voice recorders

The aircraft was not equipped with recorders only intended for these purposes. However there was other electronic equipment that was capable of making certain recordings. The GPS in the aircraft, which included a recording function, could not be found during the recovery or while searching the wreckage.

1.12 Accident site and aircraft wreckage

1.12.1 Accident site

Southern Baltic Sea, approx. 28 km south of Smygehamn.
(posn. 55.05.1N, 013.23.3E.)

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[11] AIP: Aeronautical Information Publication – aeronautical information of a long term nature.

1.12.2 *Aircraft wreckage*

On impact with the water the aircraft disintegrated completely. The illustration at figure 6 below shows the aircraft parts that were brought up from the sea bed and retrieved from the surface. Those parts of the aircraft and its equipment that were not recovered can broadly be summarised as follows:

- Parts of the rear fuselage
- Parts of the landing gear
- About 80% of the tail section
- Parts of the rear wing spar
- One propeller blade
- Certain instrumentation, including the GPS
- The emergency transmitter
- On-board documentation

Fig. 7. The aircraft wreckage. Photograph source: SHK.

The engine and parts of the cabin comprised the largest parts that were recovered. The remaining parts of the aircraft, which were mainly composed of glass fibre/carbon fibre composites, were only found as fragments, most of which were retrieved from the surface. It has not been possible to determine the instrument settings and control positions, since the remains of the instrument panel were severely damaged on impact.

During the examination of the wreckage that took place by SHK, no traces or signs indicating a collision with an object or birds were found.

1.13 Medical information

Nothing indicates that the mental and physical condition of the pilot was impaired before or during the flight.

As a result of the post-mortem examinations of the remains of those on board, there were no signs of illness or medical changes that would have been assessed as affecting the sequence of events leading to the accident.

1.14 Fire

Not applicable

1.15 Survival aspects

1.15.1 General

At the moment of impact, the aircraft probably struck the water surface at a steep angle and at high speed. According to images from the ROVs[12] that were the first to reach the wreckage, and which could later be confirmed by the first diving team, the aircraft had totally disintegrated. Among the larger sections of the aircraft that could be identified and recovered were the engine and parts of the cabin.

The appearance of the wreckage seems to indicate that the impact forces in the accident were considerable. The chances of surviving this type of accident are almost negligible, and all the indications are that those on board died immediately on impact.

The type ACK E 01 emergency transmitter was not activated during the accident and was not found during the recovery or while searching the wreckage. There was no emergency signal detected from the transmitter.

1.15.2 The search and rescue efforts

When the aircraft failed to respond to radio calls from different stations, the airborne search and rescue organisations were activated. In Sweden the ARCC (Aeronautical Rescue Coordination Centre – previously called Cefyl) is responsible for the management and co-ordination of the search and rescue efforts in the case of aviation accidents. The following table is a summary of the procedures concerning this particular accident:

21:08	The echo from OE-KLA disappears from the radar screens.
21:10	ARCC in Gothenburg is notified by an alarm call.
21:13	The Danish emergency helicopter is notified by an alarm call.
21:16	The Swedish Navy emergency helicopter is notified by an alarm call.
21:19	A general radio call is made to all units in the vicinity of the presumed location of the accident.
21:22	Coastguard vessel KBV 583 receives the radio call and heads towards the presumed accident site.
21:25	The German coastguard is notified by an alarm call.
21:26	A German ship is sent towards the accident site.
21:26	A German emergency helicopter is sent towards the accident site.
21:26	A further German ship is sent to the accident site.
21:27	A Swedish rescue vessel is sent towards the accident site.
21:35	The Danish coastguard sends out three vessels.
21:40	The Swedish coastguard sends an aircraft.
21:51	A further two German ships are sent out.
22:10	A Danish helicopter locates the accident site.
23:00	The first vessel arrives at the accident site and finds wreckage floating on the surface.
23:00–01:15	The arriving vessels search the whole area for survivors of the accident.
01:25	The search and rescue efforts are terminated.

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[12] ROV: Remote Operated Vehicle. Unmanned underwater search vehicle equipped with lights and cameras.

1.15.3 Recovery

The recovery of the aircraft wreckage turned out to be lengthy and dramatic due to a number of hindering factors. During the time that recovery took place, the AAIB was the organisation responsible for the investigation, but for practical reasons handed over the management and operational aspects to SHK. The work of recovering the aircraft wreckage involved several organisations, and altogether took 23 days. The factors that mainly hindered the task were:

- Weather. During the recovery operations two storms with strong winds passed over the accident area.
- Wave height. During the storms (and for various periods in between), the sea conditions were difficult, with waves that at times reached four metres.
- Water depth. In normal conditions the depth of water at the accident site was 42 metres. This depth complicated the diving and the working conditions, due to the high pressure, so that saturation diving[13] was the method that was eventually adopted.
- The seabed conditions. The seabed at the accident site consisted of a thick layer of loose sediment. This meant that any movement caused a cloud of sediment that reduced visibility to about 50 cm.
- Currents. The location in the southern Baltic where the accident occurred has very powerful underwater currents, which caused great difficulties in both the planning and the execution of the recovery work.

The search operation for the aircraft wreckage was carried out with resources from the Swedish coast guard, who after locating the wreckage, also started the recovery operations. Due to the depth at the accident site however, the divings had to be assigned to a civilian off shore company. The bad weather conditions led to that the Coast guard vessel, in spite of reinforced anchor systems, could not be secured over the accident site. SHK therefore applied at the Swedish Armed Forces for permission to dispose HMS Belos[14], which was granted. After a coordinated operation the wreckage of OE-KLA was recovered by HMS Belos on November 10, 18:48.

1.16 Tests and research

1.16.1 Examination of the aircraft wreckage

It was concluded that the aircraft completely disintegrated on impact with the water. Both wings had remained attached to the aircraft fuselage, but only the front wing spar was found. Figure 8 below shows an image of the aircraft's front wing spar, with carbon fibre reinforcement on the top of the spar. Both pressure and tearing damage were noted on the spar.

Only a small part of the tail remained, so it is difficult to say for certain whether this part of the aircraft was still attached to the fuselage at impact or not. It could also be seen that the landing gear was bent forward on impact. It was not possible with the parts that remained to tell for certain whether the aircraft was intact on impact or not.

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[13] Saturation diving: The air in the diving cylinders is replaced by a gas mixture (trimix or heliox), which permits longer working times at great depths.

[14] HMS Belos is a special designed vessel for submarine rescue operations.

Fig. 8. The front wing spar. Photograph source: SHK.

At the request of SHK certain parts were dismantled from the aircraft wreckage and sent to the manufacturer's laboratory for examination. Nothing in this examination indicated otherwise that the aircraft was complete on impact. It was established that both wings were attached to the fuselage at impact. The damage analysed as being present on the wing spar was probably caused by an almost vertical impact, whereby the wing spar, when the nose hit, was exposed to a forward force, and a fraction of a second later exposed to a backward force when the wing hit the water.

1.16.2 Examination of the FADEC

In connection with the recovery operation, much importance was placed on the recovery of the computerised engine control unit, the FADEC (Full Authority Digital Engine Control). The FADEC is a unit that, among other things, electronically converts the pilot's engine power adjustments and other engine parameter controls to a mechanical setting of the engine values. The FADEC unit also contains memory functions which can store certain information. The parameters that can be recorded by this memory unit are as follows:

- Engine speed
- Engine power
- Ambient air pressure
- Cooling water temperature
- Air temperature
- Oil temperature
- Oil pressure
- Fuel pressure
- Oil temperature in the landing gear
- Electrical voltage to the FADEC

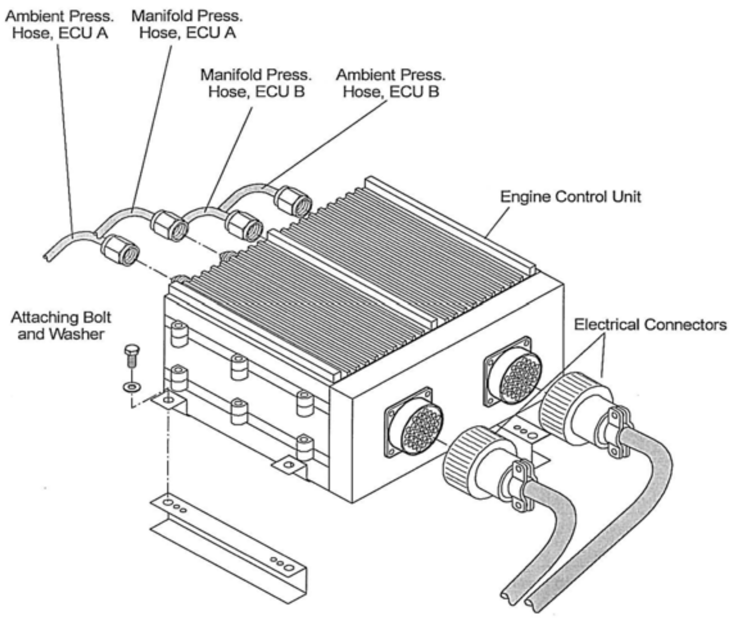
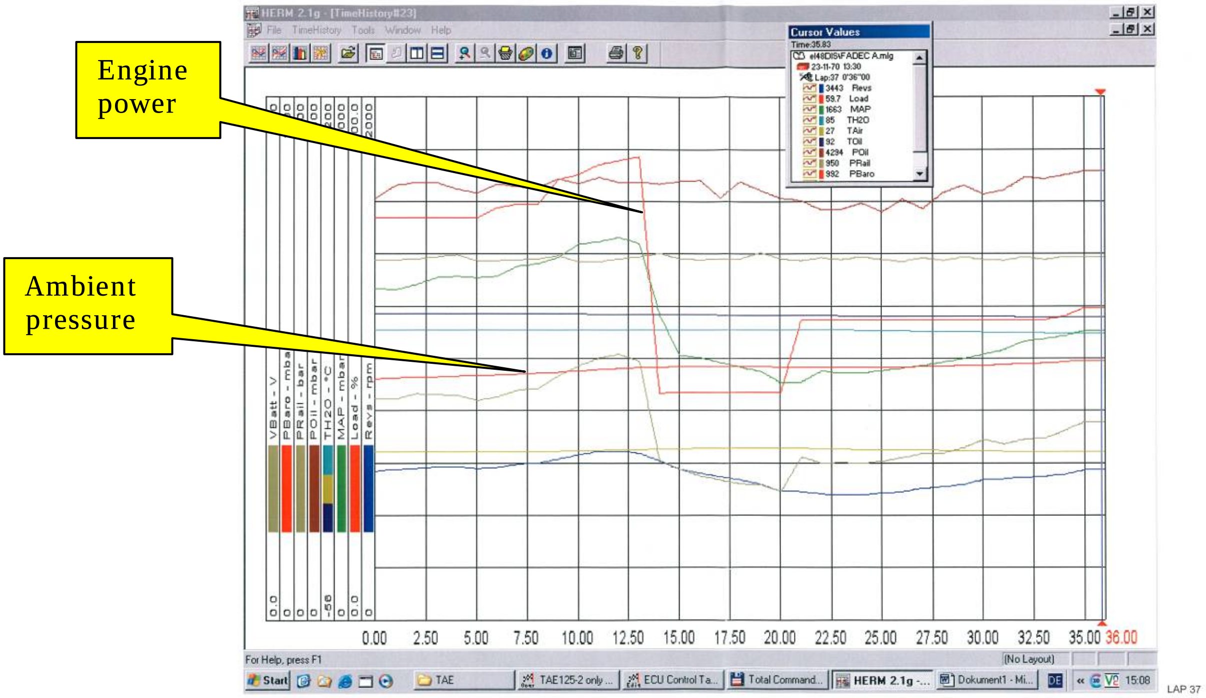


Fig 9. Drawing of the engine FADEC

Once the aircraft wreckage had been located, the FADEC unit could be found and recovered. During the recovery it was seen that the unit had some external damage, but was generally in relatively good condition. After recovery the FADEC unit was preserved in water and taken together with the other wreckage to the hangar at Malmö/Sturup which SHK was able to use for the purpose. A representative from AAIB collected the unit for transport to the engine manufacturer’s laboratory in Hamburg for analysis.

After being dried out, the unit could be connected up and the memory function checked. The damage caused by the accident had not affected the recording function of the unit. All the parameters could be read for analysis. Those parameters that were of the greatest interest for the continuing investigation were the engine values, for evaluating possible malfunction, and the ambient air pressure for conversion to values indicating the aircraft altitude. All the recorded values were presented in tabular form, but certain values have, via a special program, been converted into graphics for visual presentation. The parameters involved are presented in diagram form in figure 10 and depict the final 36 seconds of flight. All the examinations and read-outs from the FADEC unit were monitored by an AAIB representative.



Cursor Values
Time:35.83
el48DIS\FADEC A.mlg
23-11-70 13:30
Lap:37 0'36"00
3443 Revs
59.7 Load
1663 MAP
85 TH2O
27 TAir
92 TOil
4294 POil
950 PRail
992 PBaro

Fig 10. Graphic showing the engine FADEC parameters. Note that increasing ambient air pressure signifies reducing altitude.

Engine read-outs

Read-outs of the recordings of individual engine parameters clearly showed that the engine had been delivering power throughout the entire accident sequence. The power output was normal at cruising height and during the initial part of the descent. During the later part of the accident sequence, at a phase where the high descent rate transitioned to a climb, the engine power reduced for a period of six seconds, thereafter increasing.

The power output during the various phases of the flight was as follows:

Cruise flight at 6000 feet	83 %
Descent, 6000 feet to about 1400 feet	77 %
During six seconds, at about 1400 to 1500 feet	44 %
From about 1500 feet to impact	57 %

Other recorded parameters that were associated with the engine or its systems showed normal, or in the situation relevant, values, without any faults or abnormalities being observed.

Ambient air pressure read-outs

The recorded barometric values show the current air pressure and were used to calculate the aircraft altitude and vertical speed during different phases of the flight. The values were also compared with the radar images of the sequence, which were recorded by both Swedish and German military radar stations. The composite image of the aircraft heights show that during the cruise and the initial descent the readings are completely normal, and with the expected values in respect of sink rate, among other things. It could also be noted that the altitude was maintained very accurate during cruise.

In connection with a steep turn to the right, which started at about 3000 feet altitude, the sink rate increased rapidly. The aircraft descent slowed somewhat at about 1900 feet, and then at about 1400 feet went into a climb of about 100 feet. At this stage of the flight the engine power decreased. From about 1500 feet the descent rate increased again and remained more or less constant until impact with the water.

The vertical speed during the various phases of the descent was as follows:

- 6000 feet to about 4400 feet (autopilot disconnects): -500 ft/min
- 4400 feet to about 3200 feet -700 ft/min
- 3200 feet to about 1900 feet - 6400 ft/min
- 1400-1500 feet +1700 ft/min
- 1500 feet to impact -4000 ft/min

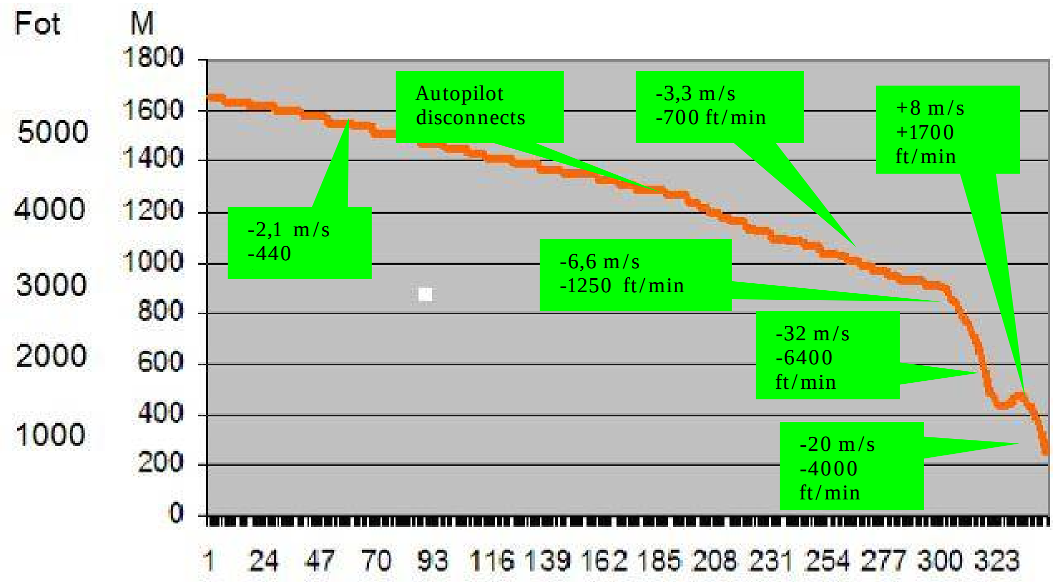


Fig 11. Graphic showing the vertical movement of the aircraft.
(Annotations: Fot = Feet, M = Metres, horizontal axis shows seconds)

1.16.3 *Examination of the autopilot*

This particular aircraft was equipped with a Bendix/King (Honeywell) KAP 140 autopilot. This is a multi-axis autopilot with servos to automatically control the aircraft course, bank angle and height. The KAP 140 is also equipped with a configuration module, the KCM 100. This unit records the events and faults in a computer memory that is primarily intended for maintenance and servicing of the autopilot.

The KCM 100 module records a large number of parameters associated with the autopilot functions, of which the most important can be summarised as follows:

- Internal faults in the autopilot and servo systems.
- Faults in associated systems (information from various flight instruments and navigation units from which the autopilot receives information).
- External influences (G forces)

In order to be able to further clarify the final phase of the flight, SHK therefore decided to try to find this unit. The history that possibly could be recorded was information about faults, both in the autopilot and in associated systems that send information to the autopilot. The KCM 100 memory was found in damaged condition in the aircraft wreckage and taken in hand.

Fig 12. The autopilot's KCM 100 unit. Photograph source: SHK.

On removal from the aircraft wreckage it was found that the unit was quite badly damaged, and also corroded. After contacting the manufacturing company, the unit was sent to the Honeywell laboratory in Kansas, USA, for examination.

During the examination the KCM 100 unit was connected to test equipment and found to contain information that could be decoded. After removal of data from earlier flights, the examination could be concentrated on analysis of the events recorded during the flight in question. Recording had taken place during the period from activation of the autopilot after engine start in Berlin until the recording stopped in connection with impact.

Apart from certain recordings that took place in connection with an internal test cycle in the autopilot, associated with activation, nothing abnormal was recorded during the first part of the flight. Climb, level flight and the initial part of the descent were, according to the FADEC, performed with the autopilot activated, and had functioned without recording any events and/or faults.

Apart from events, the KCM 100 also records the relative time, i.e. the time axis begins from zero when the autopilot is activated. The times stated below are calculated on the basis of information from the KCM 100, the FADEC and radar data. During the descent a number of events were recorded in the KCM 100 unit's memory:

- The first recording took place at about 4400 feet height at an calculated time of 21:04:36, when the KCM 100 unit recorded the warning *"roll invalid"*.
- The next recording took place at about 1400-1500 feet height at an calculated time of 21:07:37 (23 seconds before impact), when the KCM 100 unit recorded the warning *"accel reasonability check failed"*. This warning was repeated twice before the impact.

Roll invalid:

According to the autopilot manual there are four possible reasons that can give rise to a *"roll invalid"* recording.

- A fault in the turn & bank indicator.[15]. If a fault occurs in the turn & bank indicator, this will also be logged in the KCM 100 memory via another error code. No such recording was found.
- Fault in the autopilot servo.
- Fault in the autopilot computer.
- Harness wiring fault.

When the *"roll invalid"* warning activates, the following takes place:

- The autopilot disconnects.
- An audible warning sounds in the cockpit for two seconds.
- A red "R" lights up on the KC 140 autopilot display.

Accel reasonability check failed
This error code records that the aircraft has been subjected to an overload (excessive G force). This recording takes place when the G loading is 0.8 G greater than the previously logged average G force for one second.
The mode that records overloading operates whether the autopilot is activated or not.

All the examinations and read-outs from the KCM 100 unit were monitored by a representative of the United States FAA[16].

1.16.4 G forces

General
G force is a term that is used to measure the loading exerted in various conditions, for example on an aircraft in a steep turn or entering into a climb. The normal positive load is 1 G, which is equivalent to the gravity exerted on a person on the ground, or an object at rest or during constant movement. If an opposite force of 1 G is exerted, zero G is exerted, commonly called weightlessness.

Aircraft are designed to be able to cope with load forces within certain stated limits, which vary according to the designed use of the aircraft. An aircraft for civilian use is normally designed and certified with a lower load tolerance than, for example, a military aircraft.

In the case of this particular type of aircraft, the DA 40, the following G loads are applicable:

• Maximum permitted certified positive G load	3.8 g
• Fracture load limit (after adding a factor of 1.725)	6.55 g
• Manufacturer's testing	8.0 g
• Maximum load that the elevator can generate at a speed of 200 knots	11.0 g

Effects on humans
Human tolerance of G forces varies greatly, depending on several factors. A well-trained pilot can withstand very high G forces. The tolerance for normal people varies, depending on such factors as health, age, physical condition, etc. Symptoms of increasing G load are "gray-out" (vision impaired), "black-out" (complete loss of vision), and at high loadings partial

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[15] The turn & bank indicator is a gyro-based instrument that shows aircraft movement in the lateral plane.

[16] FAA: Federal Aviation Administration. (United States of America civil aviation authority)

or long-lasting unconsciousness. Spatial awareness[17] is also affected negatively by increasing G loadings.

This condition arises when subject to high G forces in the +Gz direction (head to feet), which cause temporarily reduced blood pressure and blood flows. The organs which are primarily affected are the retinas of the eyes and parts of the brain.

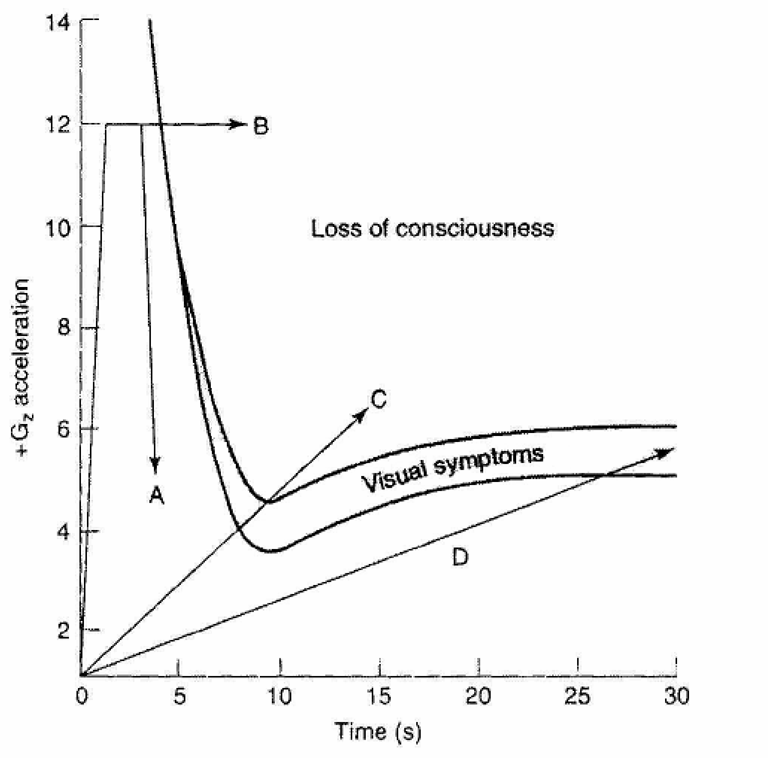

Fig 13. G load symptoms.

In the diagram at Fig. 13 above, it can be seen that the symptoms of G loading depend greatly on the duration. Differences in the symptoms and reactions relate to the following alternatives:

A. A rapid, short term increase in loading to 12 G can be tolerated without suffering visual symptoms.

B. If 12 G is applied for more than 4 seconds, loss of consciousness can occur without being preceded by eye symptoms.

C. Under a moderate increase of G loads the compensatory mechanisms in the body fail to keep up, and loss of consciousness occurs, being however preceded by visual symptoms.

D. In the case of a slow increase of G loads, the compensatory mechanisms in the body do manage to operate, and symptoms occur at higher G loads.

1.16.5 Calculation of flight path and G loads

SHK engaged Kungliga Tekniska Högskolan (KTH – the Swedish Royal Institute of Technology) to perform a calculation of the actual flight path of OE-KLA and the loads to which the aircraft may have been subjected during the final phase of the flight. The investigation was based on the following:

- Radar positions from the Swedish military radar services.
- Recorded data from the aircraft FADEC.
- Aircraft data and performance from the manufacturer.

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[17] Spatial awareness: The capacity of an individual to be oriented and aware of the surroundings.

From the applicable data and performance, it could be determined that an air speed of at least 155 knots would be required to theoretically exert a load of 8 G. To reach a load of 11 G would require a speed of at least 200 knots.

With a theoretical model a software model of the flight path was created using available radar data, showing the possible flight path during the final period of the flight.

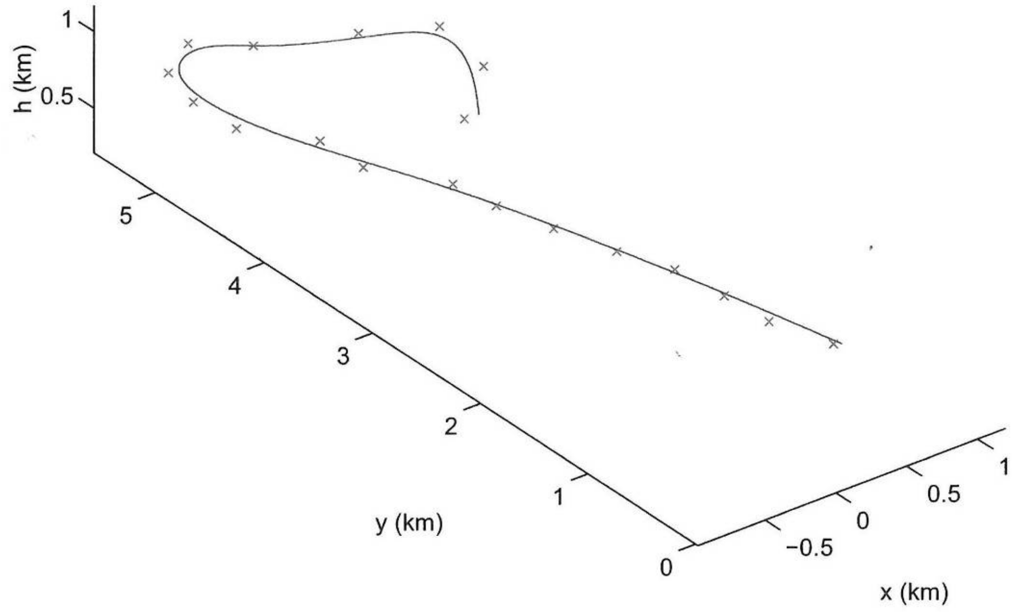

Figure 2.3: The smooth trajectory together with radar track coordinates.

Fig 14. Model of the theoretical flight path with the radar co-ordinates inserted. Graphic source: KTH

Taking into account the fact that the recorded radar data has a certain margin of error, a calculation shows that the aircraft speed reached 200 knots in theory, which is a condition for arriving at 11 G, the maximum that the elevator, according to the manufacturer, could generate. The acceleration calculation did not however indicate any high G loads, since the calculated values are equivalent to a load of about 2 G.

The calculations based on the FADEC recordings were no different from the calculations performed using radar data as a basis. The load during the climb was calculated to be about 2 G. In both cases, however, the theoretical load could be higher if the climb was accompanied by a turn. Since the angle of bank is not known in this context, the theoretical maximum load on the aircraft could not be properly determined.

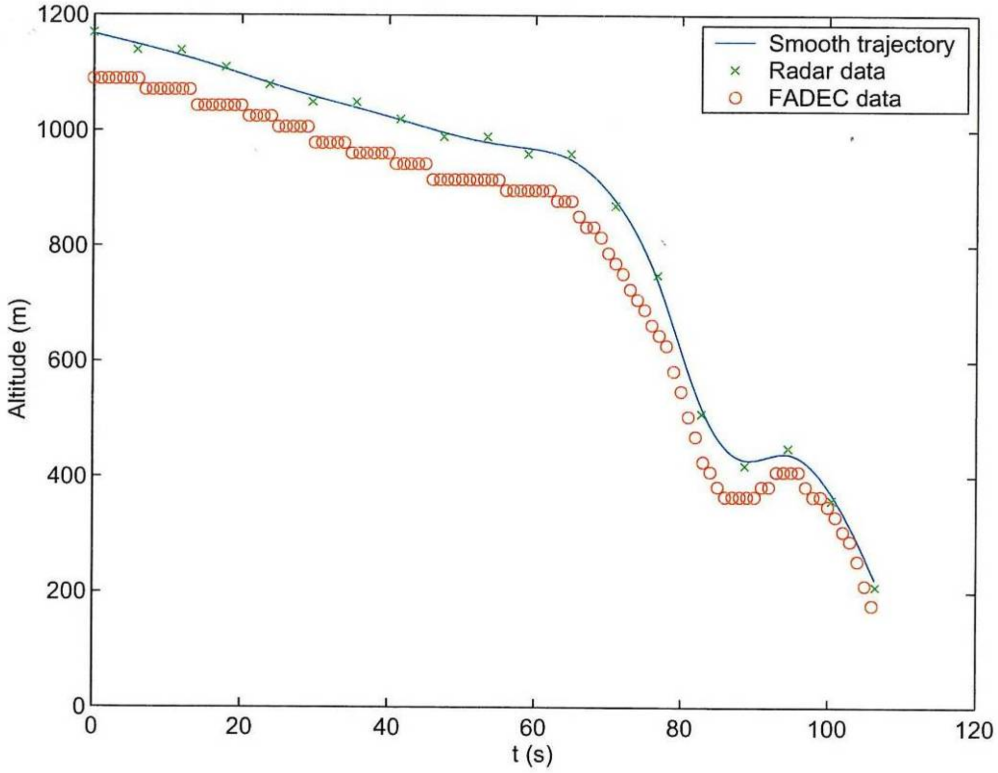

Figure 2.5: Altitude time histories.

Fig 15. Graph of altitude against time using data from the FADEC and radar respectively. Graphic: KTH.

The calculation of the aircraft altitude curve that was obtained from the ambient air pressure recordings in the aircraft FADEC, show close agreement with the equivalent values from the radar data. There are a greater number of points shown in fig. 15 above from the FADEC recording, as these are recorded every second. The equivalent values from the radar station were only recorded at every sweep, which occurred every 6 seconds.

1.16.6 Further search at the accident site

When SHK took over the investigation, it was decided to undertake further search of the accident area in the southern Baltic. The offshore company that had previously been engaged were given the assignment to search the accident site – and a suitably large area around it – with the principal aim of finding the aircraft tail section and/or other wreckage parts.

This task was carried out between 22 and 23 January 2008 using a vessel equipped with sonar and ROV. No further wreckage could however be found during the search, so the task was ended.

1.17 Organisational and management information

Not applicable.

1.18 Other

1.18.1 Equal opportunities aspects

This event has also been examined from the point of view of equal opportunities, i.e. against the background that there are circumstances to indicate that the actual event or its effects were caused by or influenced by the women and men concerned not having the same possibilities, rights or obligations in various respects. Such circumstances were however not found.

1.18.2 Environmental aspects

During the accident there was a minor release of aviation kerosene and oil into the sea.

1.18.3 VFR and IFR

OE-KLA was equipped for instrument flying, i.e. flying without visual references. It can be difficult to understand why not all pilots can utilise the on-board equipment to be able to fly in all weather conditions. To explain the difference between VFR and IFR it can to some extent be said that the basic training for private pilots comprises of about 40 flying hours, of which about five hours consist of instrument flying training. Training of private pilots is intended to provide qualification to fly in visual meteorological conditions, i.e. what is often called "clear weather".

In order to extend this qualification to also include flying under IFR, one must both have gained further experience and undergone supplementary training that in terms of flying hours is longer than the entire basic training for a VFR pilot. This training provides authorisation to fly "in clouds", i.e. in IMC, instrument meteorological conditions.

1.18.4 Survival aspects when flying under VFR in IMC

A group of researchers at the University of Illinois, USA, carried out a study in 1991 concerning the ability of private pilots to control an aircraft in IMC without having received specific training for this. A group of randomly selected pilots with only VFR qualification flew a simulator where the visual references were removed, so that they had to rely on their instruments. The aim was to see how well these pilots could control the aircraft in these altered conditions.

All 20 pilots who participated in the study lost control of the aircraft when the visual references were removed, and they were forced to go over to involuntary instrument flying. Most of the pilots ended up with altitude fluctuations in the form of vertical swings, or diving in a spiral. The parameters that differed between the pilots were the time for control to be lost, which varied from 20 seconds to 480 seconds. The average time for the pilots to lose control was 178 seconds, i.e. just under three minutes. This study has often been referred to as: *"178 seconds to live"*.

To some extent losing control means that one becomes spatially disoriented. The balance organs in the body can for example send signals to the brain that you are in a steep left turn, when in actual fact you could be upside down. As a VFR pilot one becomes accustomed to co-ordinating visual references with the physical effects of flying, such as G loads, banking, etc. As an IFR pilot one learns to disregard the body's senses to a certain extent, and instead rely on the indications given by the instruments. After training, IFR pilots learn to replace the visual horizon with the artificial symbols on the aircraft's artificial horizon.

1.18.5 Spatial disorientation

The pilot's (crew's) *"spatial orientation"* is a part of the pilot's (crew's) situation awareness and can be defined as a correct perception of the aircraft's position, movement and attitude in relation to the ground or another aircraft. Spatial orientation is derived from information from vision, the muscles and the vestibular (balance) organ, along with the information provided by the flight instruments.

In the case of spatial disorientation (SD) one is unable to perceive the aircraft's position and/or movement and/or attitude in relation to the ground or another aircraft. If one only relies on one's sensory organs there is a very great risk of SD, especially if the visual cues from the ground/water, horizon and cloud formations are unclear. In flight, vision is the main organ of balance and it is above all that part of the vision field that stands for comprehension of space orientation and movement (peripheral vision) that is important to avoid SD.

SD is normally divided into three types:

Type I: What one does not experience as SD *(unrecognized)* because the cognitive process is not embracing the sensory or instrument information that exists *(central error)*.
Type II: One experiences that there is disorientation *(recognized)* and it takes a certain amount of time to sort this out.
Type III: Disorientation is experienced that has a strong effect on the pilot *(incapacitating)* and brings about severe anxiety and fear.

SD type I is the most common problem in today's aircraft and helicopters, due to the amount of complex information that need to be handled, while at the same time as a pilot one has to correctly assess the flying situation.

Examples of human factors that contribute to the generation of "*central errors*" can be:

- faulty mental focusing,
- stress,
- complacency and
- oxygen deficiency or G load effects.

SD types II and III are also usually termed "*input errors*" since one is receiving incorrect signals from the sensory organs to the higher cognitive centres in the brain.

Other human factors that may contribute:

- flying experience (both total and current),
- instrument flying training,
- physical and psychological health,
- the influence of/after-effects of alcohol and drugs, and
- general cognitive factors.

Examples of factors in aircraft and flight situations that often affect the propensity for disorientation:

- transition between IFR and VFR flying, weather factors, lighting conditions
- poor visibility, isolated single lights,
- high altitude or dynamic light flow on the peripheral system,
- terrain without contours or water without texture (flat calm, undisturbed snow surface),
- slow acceleration and "*below the threshold*" acceleration changes,

- small and poorly located flight instruments, symbols that are difficult to interpret and
- high manoeuvrability of the aircraft.

1.18.6 Applicable rules for VFR flying

General

The rules that are applicable according to BCL[18] D 3.2 in respect of the planning minima for distance VFR[19] flying state that the weather, according to available meteorological information shall be better than or at least equal to:

During daylight: 5 km visibility and 1000 ft cloud base (scattered clouds)
During darkness: 8 km visibility and 2000 ft cloud base (scattered clouds)

In certain conditions it is permitted to carry out distance VFR flights above clouds (“VFR on top”). The following planning requirements must then be fulfilled:

- The flight must take place in the absence of clouds and in VMC[20].
- At the destination airport only scattered clouds may be present (no more than half the sky covered in clouds).
- The visibility and the cloud base may not be less than 5 km and 1000 feet respectively at the intended destination airport.

Definition of flying conditions in darkness

It is not permitted to fly VFR above clouds in darkness. The current BCL regulations define darkness as:

A condition which is considered to exist during the time between sunset and sunrise when due to reduced daylight an appearing unlit object cannot be clearly distinguished at a distance exceeding 8 km.

On that particular day, sunset was at Gothenburg/Landvetter and Malmö/Sturup at 18:05, with an estimated time for the end of civil twilight at 18:44 for Gothenburg/Landvetter and 18:42 for Malmö/Sturup respectively.[21].

1.18.7 Bird strike

General

SHK has evaluated the conditions for a bird strike to have occurred.

The bird strikes that are reported show a clear seasonal pattern, with most occurring during the spring and autumn. The autumn migration mainly takes place in August and September, although a large number of birds also leave the country during October. Specific routes are followed. When birds leave the Swedish mainland, most species choose a route that involves the shortest distance over open water, i.e. via Denmark. A smaller proportion fly via Bornholm to the German and Polish mainland. Most bird strikes occur in the morning hours when there is most activity.

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[18] BCL: Bestämmelser för civil luftfart (the Swedish Civil Aviation Regulations)

[19] Distance VFR: Flights that extend for further than 25 nautical miles from the take-off point.

[20] VMC: Visual Meteorological Conditions.

[21] Information obtained from the US Naval Observatory.

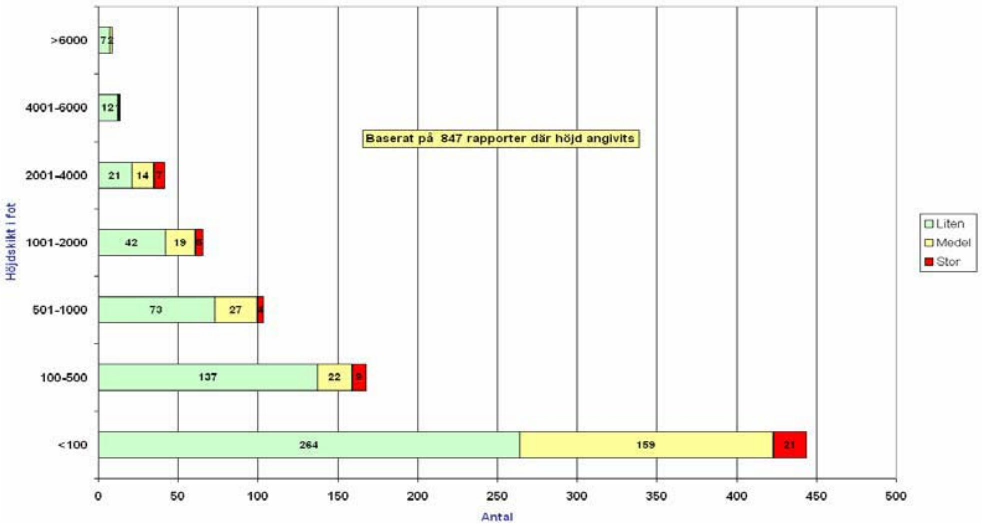

Fig 16. Bird strikes reported to the Swedish Civil Aviation Authority during 1998 – 2005. Number of collisions per height band and bird size. Graphic source: Swedish Civil Aviation Authority.
(Annotations:
Based on 847 reports stating the altitude
Altitude band in feet
Small (green) – Medium (yellow) – Large (red)

Altitude bands

Most bird strikes take place at altitudes of below 500 feet. As a rule, most migrating birds fly at altitudes lower than 3000 feet. Birds have no special organs to be able to fly for example in clouds, they must have visual references to maintain flight and orientation. It is however known that birds can fly through thin cloud layers with the intention of finding altitude bands with favourable winds. It can as a rule however be said that birds fly below clouds, and preferably in daylight[22].

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[22] Sources: The Swedish Civil Aviation Authority and Ornithology.com, USA

2 ANALYSIS

2.1 General

The accident to OE-KLA took place over the sea and in darkness. There were no survivors or witnesses to the accident. Radio messages sent from the aircraft did not indicate any problems or conditions that could throw any light on the sequence of events.

The analysis by the SHK resulting in this report is based on the limited facts that could be obtained from the aircraft’s electronic units, together with the radar images that were recorded. The investigation cannot therefore claim to definitively describe the exact events of the accident, but presents what SHK believes to be the most probable sequence of events and the reasons that led to the accident.

2.2 Planning conditions

2.2.1 The weather for route flying

The conclusions in this analysis of the weather conditions are based on the assumption that the pilot obtained current route and airport forecasts while on the ground at Berlin. Airport forecasts are not subjective assessments, to the extent that meteorologists may interpret them differently. The assessment of the weather en route could however be interpreted and assessed differently, depending on what meteorological body that is consulted. SHK has proceeded on the basis of the area weather forecast issued by SMHI for that particular route, and assumed that pilot of OE-KLA received equivalent meteorological information at weather briefing in Berlin.

The meteorological conditions, according to the weather forecasts on that particular evening, show that the flight could be planned and executed below clouds, without coming into conflict with the valid minima for VFR route flying. These conditions applied both in daylight and darkness, as the lowest values in accordance with the SMHI area forecast were a 2000 feet cloud base and 8 km visibility. These values exceed the minimum requirements for VFR route planning in daylight and are equal to the lowest values that are permissible in darkness.

2.2.2 Planning for VFR flight above clouds

According to the ATC flight plan, the flight was planned for 6000 feet but performed at FL60, meaning that in its later stages the flight was probably “on top”, i.e. above clouds. SHK has not found any explanation as to why the flight was planned at a level that is normally used for IFR traffic. One consideration when performing the entire flight “on top” would mean that the planning would be made more difficult since the weather at the destination airport at the estimated arrival time would have to be taken into account, and also the estimated time of the onset of darkness, since VFR “on top” is not permitted in darkness.

The ATC flight plan had Borås/Viared as destination. The airport forecast for Gothenburg/Landvetter predicted good visibility and scattered clouds at 1500 feet, with broken cloud cover at 2000 feet. These values implied that planning for “on top” VFR was not possible, since the planning minima at the destination airport only allow scattered clouds to be present. According to the flight plan the arrival at Borås/Viared was estimated to be 21:50, which would be about three hours after dark, according to the BCL definition. It should therefore not have been possible to perform the flight in accordance with the submitted flight plan while complying with the BCL regulations.

The airport forecast for Malmö/Sturup indicated good visibility and scattered clouds at 3000 feet. The group that contained a 30% risk of fog would take place after the estimated arrival time, on condition that the flight had an alternative plan to decide en route to fly directly to Malmö/Sturup as alternative airport. Taking only the airport weather forecast into account, planning for “on top” VFR should have been possible. With an estimated flight time of 1 hour 40 minutes, the arrival time at Malmö/Sturup would be 20:50, about two hours after dark. Nor could flying directly to Malmö/Sturup be possible using “on top” VFR.

2.2.3 Alternative planning

The weather at the departure airport was good, with the take-off and first part of the flight performed in daylight. There was therefore nothing in the planning or operation to prevent this part of the flight to be under VFR at FL60. Nor were there any clouds beneath causing any breach of the regulations.

An ATC flight plan can be filed with a certain route, altitude and destination. It is definitely permitted – and not unusual – to change the route, altitude and destination while in flight, if there are reasons for this. In this particular case it is not unlikely that the pilot had an alternative operational plan prepared, involving descent below clouds and a change of destination to Malmö, if the weather would not permit flying to the original destination in accordance with the flight plan.

The operational plan, i.e. the operational en route plan, could not be determined since all the on-board documentation disappeared in the accident. It is however very probable that the pilot had such an alternative plan, since the choice of alternative airport was Malmö. In the case of normal planning for a flight to Borås, without apprehension that due to weather it might not be possible to complete the flight, Gothenburg/Landvetter would be used as an alternative in the ATC flight plan. In this particular case it is possible that the pilot thought of taking a decision in respect of the destination when the basis for such a decision in the form of the latest weather forecast was obtained. The decision to follow the alternative plan was taken at 21:01 when the pilot asked to divert to Malmö instead of continuing the flight to Borås.

2.2.4 Influence of the weather

Route- and area forecasts are not definitive and can be interpreted in different ways. Even if the weather forecast permits flying according to the regulations, local clouds and/or deteriorating visibility can occur along the planned route. When flying a long distance over water in darkness, external references may be very quickly reduced to a minimum, due to even minor changes in the weather situation. Flying over the sea in darkness in hazy weather can, according to SHK, be equated to IFR flying, since the references for safe assessment of the aircraft position and attitude may be missing.

In such conditions a pilot can therefore involuntarily and unpredictably enter clouds, for example during a descent, and thereby enter IMC without warning. In such a situation it is of vital importance that the autopilot is working and is used, and also that all the flight instruments are operating and giving correct indications, so that a VFR pilot will have a reasonable chance of managing to get out of this situation.

As OE-KLA flew out over the Baltic Sea, darkness was beginning to fall. According to the pilot who had earlier flown along this route, there were scattered clouds and some clear gaps in the area south of latitude 55. When the pilot began the descent towards the cleared altitude of 3000 feet, he could very well have believed that there were no clouds between the aircraft and the water surface.

2.3 The first phase of the sequence of events – possible causes

2.3.1 Bird strike

The combined assessment of the conditions on that particular evening do not indicate that OE-KLA might have collided with a bird. The route of the flight was not along any of the documented bird migration routes, and the time of the evening was such that a bird strike would have been unusual.

If a bird strike had occurred, it would have been in the altitude band between 4300 feet (where the last radio transmission took place) down to 3000 feet, where the right turn started. Collisions in this altitude band are unusual, as most bird strikes occur at much lower altitudes.

In the autumn migration the birds fly south. With the weather conditions present at the time of the accident, birds would have started from the south of Sweden and climbed through the overcast cloud layer, which according to the forecast was at 3000 - 4000 feet, to get “on top”. Such behaviour, of birds voluntarily going through IMC, would in that case be a very unusual, and an event unknown to ornithology. The aircraft wreckage showed no damage or bird remains that would have indicated a bird strike. In the opinion of SHK, the probability that a bird strike would have caused the accident is very low.

2.3.2. Engine malfunction

The readouts and analyses that were carried out on the parameters in the FADEC do not indicate that there was any technical problem or malfunction to influence the sequence of events. The engine was working and delivering power at various levels up to the moment of impact with the water. According to the recorded data the engine even continued to operate during the load peaks with high G forces that occurred in the final stages of the flight.

Nor did the associated system values that were recorded in the FADEC memory show any faults, faulty operation or abnormal values that could have affected the functioning of the engine. It is therefore not probable that any mechanical fault in the engine, or its associated systems, caused the accident.

2.3.3. Flight instrument malfunctions

When comparing flying over land in daylight and flying over water in the dark, it can be said that a VFR pilot in the latter case must trust the flying instruments to a much greater degree than usual in order to check the aircraft’s position and attitude, since the visual references are highly reduced.

The normal reference line, i.e. the horizon, is often obscured, and the pilot must rely to a much greater extent than usual on the instruments. OE-KLA had a complete set of instrumentation. The artificial horizon, which in this situation is one of the most important instruments for controlling the attitude of the aircraft, had not functioned satisfactorily during the delivery servicing that was carried out on this particular aircraft. The unit was changed, and after this no problems were found in respect of horizon indication or the other flight instruments.

The autopilot memory unit, KCM 100, has a recording function for the flight and navigational instruments that supply information to the autopilot. This means, for example, that if the artificial horizon or the directional gyro should malfunction, this is logged as an event in the memory of the unit. No such events or failures were recorded as error codes in the unit's memory, so it is unlikely that the accident was caused by a fault in any of the flight instruments.

2.3.4. *Autopilot malfunctions*

When flying under VFR in darkness the autopilot is sometimes a vital aid to the pilot, when it comes to checking the aircraft position and attitude. According to the recorded data, the autopilot in OE-KLA was active during the flight. During the descent, at an altitude of about 4400 feet, the warning “roll invalid” was recorded in the autopilot's memory unit, which meant that the autopilot was automatically disconnected.

It has not been possible to determine the reason why the “roll invalid” warning was activated. It is however unlikely that a fault in the turn and bank indicator caused the warning, as this would also have been recorded as an error code in the unit's memory. No other fault or incorrect function in the autopilot was logged.

At the time when the autopilot disconnected, the pilot had to unexpectedly and reluctantly transfer to manual flying. This is reflected somewhat in the variations in the speed of descent and course changes that were recorded below the altitude of 4400 feet. This is however completely normal since the autopilot controls the movements of the aircraft much more precisely than a pilot could when flying manually.

The conditions for a safe continuation were however worsened drastically when the autopilot was no longer available. From an altitude of 4400 feet and with an approximate sink rate of 1000 feet/minute it was only a minute left before entry into the underlying cloud layer, that the pilot was perhaps not even aware of. The cloud tops were forecasted as being between 3000 - 4000 feet.

When such a vital system as the autopilot is disconnected, to start with this is an unwelcome surprise for the pilot, with both audible and visual warnings in the cockpit. Once the faulty function is diagnosed, the normal reaction is to find out the cause, so as to if possible rectify the fault. Since the passenger in the right hand seat was a trained pilot, it is probable that both the pilot and the passenger were preoccupied by the faulty function of the autopilot when OE-KLA flew into the underlying clouds.

SHK doubts that the autopilot caused the accident. On the other hand, some form of fault in the autopilot probably contributed to the development of the continued sequence of events in the first phase of the accident.

2.3.5. *Loss of control*

It is probable that the entry into cloud came as a surprise to those on board OE-KLA. According to the radar operator at Malmö ACC who was in contact with the aircraft, a steep turn began at an altitude of 3000 feet.

When an aircraft enters cloud during darkness, dramatic and immediate changes take place in the overall flight conditions. In a second the calm air is replaced by the disturbed air that to some extent always is present in clouds. Flashes from the aircraft's strobe lights are reflected by water droplets and immediately present a disturbing and blinding effect.

When analysing the conceivable reactions on entering cloud, one should bear in mind that this probably came as a shock for those on board, where the pilot certainly had a heightened level of stress due to the autopilot fault. The reaction of the pilot in this situation, to try to turn back towards the direction where he had earlier had experienced safe and familiar flying conditions, is, against this background, understandable.

The possibility of dealing with this new situation in a safe way was however limited. Without instrument flying training, with a heightened stress level and an autopilot that was no longer working, the chances were slim that the situation could be resolved. Unplanned sharp turns in IMC bring about a drastic change in the situation for a pilot without IFR training, where the loss of flight control and attitude are more the rule than the exception in these circumstances.

During the turn OE-KLA began a diving spiral motion with a rapidly increasing rate of descent of up to 6400 feet/minute. Presuming that the cloud thickness was about 1000 feet, it would have taken less than 10 seconds to go through the clouds. The high rate of descent was probably the result of pitching forward. When OE-KLA broke out of the underside of the cloud, it was most likely in a steep dive and at a high rate of descent, probably also turning.

Due to the disorientation that is often the result of a non-instrument-trained pilot flying into cloud, in that case the pilot’s appreciation of the flying situation is far from the true situation, on gaining visual contact. In the conditions of darkness and mist that obtained, it is not certain that the pilot immediately noticed the water surface below. It probably takes several seconds for the body’s senses to restore the references and balance so that the new situation can be “taken in” and identified.

According to the radar images and data from the FADEC, at about 1900 feet a recovery from the dive towards the water surface commenced. At about 1400 feet the recovery became a climb of about 100 feet. The whole of this recovery manoeuvre probably resulted in increased loading on the aircraft and on those on board.

2.4. The second phase of the sequence of events

2.4.1 *The climb*

The reason for the climb that was recorded as being between 1400 and 1500 feet cannot be established for certain. If the pilot on emerging from clouds quickly could regain spatial awareness and orient himself with the aid of normal references, it is possible that the manoeuvre was pilot-initiated with the intention of stopping the dive and returning to a normal flight attitude.

In the case of a loss of control, the aircraft could have entered into a completely unpredictable flight situation. It is for example fully possible that the aircraft at some stage entered an inverted position and/or combined this with a diving spiral-like flight path. It is also documented that large fluctuations in altitude can be the result of a loss of control. This can result in accelerating movements in the form of vertical swings, with large variations in altitude and vertical speed. The “climb” that was recorded at 1400 feet could have been the continuation of an uncontrolled manoeuvre, which at just that altitude translated into a climbing movement.

2.4.2 *Theoretical loadings*

According to the calculations that were carried out, both the radar and FADEC data clearly show that a load of about 2 G was exerted during the climb. This value could in reality have been higher, since there are no facts available to indicate the attitude and flight situation of the aircraft during this particular manoeuvre. A large bank angle would for example have further increased the G load.

In the opinion of SHK it is not likely – if not completely ruled out – that the loading was high enough for the aircraft to break up in the air. On the other hand, there was the possibility of some influence in the form of a degree of deformation occurring during this load.

The fact that only a small portion of the aircraft tail section was recovered, and the remainder could not be found in the supplementary search of the sea bed, *could* indicate that parts broke off the aircraft while airborne. Since this part of the aircraft was light weight, it could also have happened that the tail section was carried away by wind or currents if it was detached on impact.

Human tolerance of G loads varies greatly, depending on several factors. In respect of individual status, some form of physical effects could have affected those on board in the case of high G load. From 1500 feet until the impact, the aircraft movements, power output and rate of descent were relatively constant. This could mean that the pilot – and the others on board – were more or less incapacitated by the effects of high G loads for the approximately 20 seconds that remained before impact into the sea.

2.4.3 The impact

Examination of the aircraft wreckage indicated that it entered the sea at a steep angle and at high speed. Analysis of the forces that acted on, among other things, the wing spars and other parts of the aircraft did not indicate or imply that there was any deformation in the air before the impact.

As mentioned in the introduction to this analysis, it is however not possible to determine the precise sequence of events during the final phase of this flight. SHK would therefore like to leave the question open in respect of a possible breakage or deformation of the aircraft’s tail section caused by high G load.

3 CONCLUSIONS

3.1 Findings

a) The pilot was formally qualified to perform the flight.
b) The aircraft had a valid Certificate of Airworthiness.
c) The ATC flight plan did not conform to the applicable planning rules for VFR flying.
d) The autopilot ceased to operate during the descent.
e) The engine was operating throughout the entire accident sequence.
f) The descent rate increased to 6400 ft/min.
g) The wreckage showed no signs of a collision or deformation before impact with the water.
h) Data shows that the aircraft began to climb during a brief period of the accident sequence.
i) The autopilot memory unit recorded overload.
j) The theoretical G load amounted to 2 G, but in certain circumstances could have been higher.
k) Only a small part of the aircraft tail section could be found.
l) The impact with the water took place at high speed and at a steep angle.

3.2 Causes

The accident was caused by VFR flying being planned and executed in such a way that VMC could not be maintained. A contributory factor was the malfunction of the autopilot.

4 RECOMMENDATIONS

The Swedish Civil Aviation Authority is in the international community recommended to work for a revision of the rules for flying under VFR in darkness over large areas of water or other areas with limited visual references. *(RL 2008: 09 R1).*

Transcript of the ATC tape recording.

Audio files recorded by Malmö ATC in connection with the accident to OE-KLA on 16 October 2006. Some of the recorded files have no time information. In cases where a message could be identified on several different files, these files could however be time-stamped.

Time: UTC
Local time: UTC + 1 hour

From:	Source of message.
OLA	- OE-KLA
MMX	- Malmö ATC, South, Executive
TWR	- Malmö Tower
MMXS	- Malmö ATC, South, Planning
GOT	- Gothenburg ATC
Berlin	- Berlin ATC
Baltic	- Baltic 14 B
NWA201	- Northwest 201
VAS691	- Atran 691 (Aviatrans Cargo Airlines)
BLF645	- Bluefin 645 (Blue 1)
ONUR	- Onur Air 1522

Notes

& - Internal aircraft telephone

Information: Interpretation of information

[Square brackets]	SHK's comments or information
(Parentheses)	Interpretation of the message is uncertain
?? .	Denotes information that could not be interpreted, due to interference or for other reasons.
?	Means that a question has been asked or that the interpretation is uncertain.

Information from Malmö South, executive position (aud files).

Time	*From*	**Comments**	**Information**
18.54.52	*OLA*		Malmö control Oskar Erik Kalle Ludvig Adam.
18.54.58	*MMX*		Olle Erik Kalle Ludvig Adam, Malmö.
18.55.01	*OLA*		VFR flight plan goes from Berlin to Borås and flight level 65 .., 60 and squawk 3240.
18.55.13	*MMX*		Olle Ludvig Adam, that is understood.
18.55.18	*OLA*		Thanks for that. Do you have any weather over Malmö for me?
18.55.23	*MMX*		Yes, weather at Sturup, are you ready to receive it?
18.55.27	*OLA*		Oh, yes.
18.55.29	*MMX*		So the wind is 160 degrees 2 knots, visibility 8 kilometres in fog....cover ... cover, cloud cover at 2200 feet, 10 degrees and the dewpoint is 9, QNHelge 1026.
18.55.50	*OLA*		Yes, thanks for that, QNH 1026.

18.56.50	OLA		Malmö, Oskar Ludvig Adam, can you help us with the weather for Gothenburg?
18.56.55	MMX		Yes, we'll get back to you with that, and you are clear to enter Malmö TMA at flight level 60.
18.57.01	MMX		Cleared into Malmö TMA, 60, Ludvig Adam.
18.57.05	MMX		Baltic 14 Bravo, contact Malmö 128.175.
18.57.09	Baltic		Malmö 128.175 Baltic 14 Bravo, goodbye.
18.57.14	MMX		Goodbye. Northwind 201, descend to Flight Level 70.
18.57.17	NWA 201		(Clear) descend down Flight Level 70 Northwind 201.
18.57.25	MMX		Northwind 201, information Foxtrot is valid at Sturup, QNH is 1026.
18.57.32	NWA 201		Affirmative ma'am, Foxtrot(on board).
18.58.53	MMX		Olle Ludvig Adam, I now have the weather for Gothenburg.
18.58.55	OLA		Yes, please.
18.58.57	MMX		Yes, Landvetter, then, and the visibility is more than 10 kilometres, the sky is covered with cloud at 1700 feet and 1024 is QNH.
18.59.08	OLA		Yes, thanks for that, Ludvig Adam.
19.00.32	VAS 691		Malmö Control, Good evening (Atran) 691, descending level 200, inbound NORVI, Foxtrot on board.
19.00.44	MMX		Atran 691, Malmö, good evening, radar contact, intention ILS approach in a left hand circuit runway 17.
19.00.53	VAS 691		Expecting ILS approach runway 17, left hand circuit, 691.
19.00.58	BLF645		Malmö Control good evening, Bluefin 645, Flight Level 294, descending 280.
19.01.04	MMX		Bluefin 645, hello, radar contact, fly KOTAM VENOM to intercept ALMA 3 Charlie runway 22. .
19.01.10	BLF 645		KOTAM VENOM, ALMA 3 Charlie for 22, Bluefin 645, thank you.
19.01.16	MMX		Bluefin 645, descend to flight level 230.
19.01.20	BLF 645		Descend to flight level 230, Bluefin 645.
19.01.24	OLA		Malmö, Oskar, Ludvig Adam, we need to reroute and go to Malmö instead.
19.01.31	MMX		Do you want to "divva" and land at Malmö-Sturup instead of Borås?
19.01.36	OLA		Yes, we think the weather is too bad up there, so we'll start with Malmö in any case.
19.01.40	MMX		Understood, we will arrange that for you.
19.01.42	OLA		Can we descend to 3000 feet to start with?
19.01.45	MMX		Olle Ludvig Adam yes, descend to 3000 feet. QNHelge is 1026, transition level is 50.
19.01.52	OLA		1026, (transition) 50, Ludvig Adam.
19.03.34	MMX		Olle Ludvig Adam, please set your transponder to 2715 instead.
19.03.39	OLA		2715, Ludvig Adam.
19.04.49	MMX		Yes, Olle Ludvig Adam, transponder was 2715.
19.04.54	OLA		2715.
19.09.19	MMX		Northwind 201, continue left to heading 150.

19.09.23	NWA 201		Continue left heading 150, Northwind 201.
19.09.29	MMX		Olle Erik Kalle Ludvig Adam from Malmö, can you hear me?
19.12.21	MMX	&	For your information we have a possible accident at sea, just north of DALOX.
19.14.49	MMX		(Onur) 1522, fly direct to TELMO.
19.14.53	ONUR		Direct to TELMO, (Onur) 1522.
19.14.56	MMX		Olle Erik Kalle Ludvig Adam from Malmö.
19.20.29	VAS 691		(Atran) 691 approaching NORVI.
19.20.32	MMX		Atran 691 turn left now to heading 220, cleared approach, report established.
19.20.38	VAS 691		Heading 220, call established, 691.
19.20.43	MMX		This is Malmö transmitting on Guard, Oscar Echo Kilo Lima Alfa, do you read Malmö?
19.20.54	MMX		Olle Erik Kalle Ludvig Adam, Malmö transmitting on the distress frequency. If you read Malmö, please squawk ident.
19.22.38	MMX		Malmö transmitting on the distress frequency to Olle Erik Kalle Ludvig Adam. If you read us, try to transmit.

Information from Malmö South (Sigurd), planner position (wav files).

Time	***From***	**Rem**	**Information**
	Berlin	&	Good evening, (VISION BACKLI) Oscar Echo Kilo Lima Alpha, he is 10 minutes late.
	MMXS	&	Okay, thank you.
	GOT	&	Gothenburg.
	MMXS	&	Hello, this is Malmö Sigurd, I just wonder what you have for weather at Landvetter.
	GOT	&	Good. Yes, good and good, visibility 10 and overcast 1700 feet.
	MMXS	&	Overcast 1700, visibility 10.
	GOT	&	Mm, 1024.
	MMXS	&	1024, thanks.
19.03.13	TWR	&	Hello, tower here.
19.03.14	MMXS	&	Hello, Sigurd.(Did you get a) strip for Olle Erik Kalle Ludvig Adam.
19.03.19	TWR	&	Noo, we didn't.
19.03.21	MMXS	&	No you can write one then.
19.03.23	TWR	&	We'll take it from the beginning, what's it called?
19.03.25	MMXS	&	Yes, what's up, what happened now, wait let's see here. Olle Erik Kalle Ludvig Adam, Malmö.
19.03.31	TWR	&	Mm.
19.03.33	MMXS	&	Transponder 2715.
19.03.34	TWR	&	Mm.
19.03.35	MMXS	&	One (dev), he would land at Borås, but (now he's going to you, flying) VFR.[In the background can be heard "Olle Ludvig Adam, the transponder was 2715"]
19.03.40	TWR	&	Okay.

19.03.42	MMXS	&	One DA40, estimated Sturup in te.. a quarter, quarter of an hour, perhaps.
19.03.50	TWR	&	Okay, thanks.
		&	
	??	&	(Eskim)
	MMXS	&	That was Sigurd. Do you have a follow-up for an Olle Erik Kalle Ludvig Adam to Borås?
	??	&	Yes, I have.
	MMXS	&	You, if it divvas now, and it does.
	??	&	Aha.
	MMXS	&	Is it really going to Sturup, then they send a (diva), so really I don’t need to tell you that, do I, or?
	??	&	Yes, it doesn’t hurt, because .. the problem is .. otherwise I have, I have the follow-up responsibility and such from, and you will land before I miss it. In just this case (it shouldn’t) make any great difference. But then I know that in any case.
	MMXS	&	So you know then, yes.
	??	&	You take it yourself with Sturup ...
	MMXS	&	Yes, I’ve taken it with Sturup. But don’t I need to say it to Gothenburg either? Because they have of course got a strip for it really?
	??	&	I can of course ring them.
	MMXS	&	You can do that, then.
	??	&	Good.
	MMXS	&	Bye.
	MMXS	&	Sigurd
	TWR	&	Yes, hello, tower. It was you who called about that VFR that diverted. It’s not as if he had a problem.
	MMXS	&	No, but he’s now disappeared from the radar screen, so I don’t know.
	TWR	&	Yes, we saw that.
	MMXS	&	He didn’t say anything before, he was only talking about the weather before.
	TWR	&	Okay.
	MMXS	&	Do you have contact with him, or?
	TWR	&	Okay, hi.
	TWR	&	No, we don’t, we’re trying here now.
	MMXS	&	Olle Kalle, (him, that one there) we can’t get hold of him. So it actually looks as if he’s gone into the sea.
	TWR	&	You can’t get hold of him?
	MMXS	&	No. You saw too (how he went down, of course).
	TWR	&	Mm. Berlin, can ?? get hold of him?
	MMXS	&	He was here on our frequency when it happened.
	TWR	&	Yes.
	MMXS	&	?(But we can of course try).
	TWR	&	Okay but then (we’ve all tried).
	MMXS	&	Yes.
		&	Or can be on 135.. We have 34.975, haven’t we?
	Berlin	&	Berlin.
	MMXS	&	Hello Malmö Sierra, you sent me a VFR

			before, Oscar Echo Kilo Lima Alpha, and he disappeared from our radar overhead, just north of SALLO, so could you try to reach him on the frequency 121.5, maybe he can hear you if he is ...
	Berlin	&	Okay what is the call sign again, because I am not, I didn't.
	MMXS	&	Oscar Echo Kilo Lima Alpha.
	Berlin	&	Yes, Wilco.
	MMXS	&	Yeah, thank you.
	MMXS	&	Sierra.
	Berlin	&	Berlin, we tried to call him two times, but there was no answer.
	MMXS	&	No answer. Thank you anyway.
	Berlin	&	Bye.
	MMXS	&	Bye.