Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Büro für Flugunfalluntersuchungen BFU
Bureau d'enquête sur les accidents d'aviation BEAA
Ufficio d'inchiesta sugli infortuni aeronautici UIIA
Uffizi d'inquisiziun per accidents d'aviatica UIAA
Aircraft Accident Investigation Bureau AAIB

Final Report No. 2053 by the Aircraft Accident Investigation Bureau

concerning the accident

to the Eurostar EV-97 model 2000 version R ultralight aircraft

registration 9-249 (DK)

on 24 June 2006

at Ova Spin, municipality of Zernez/GR

31 km north-east of St. Moritz

Aéropôle 1, Route de Morens, CH-1530 Payerne

Ursachen

Der Unfall ist darauf zurückzuführen, dass durch einen Gewaltbruch die linke Flügelstruktur im Flug versagte, worauf das Flugzeug abstürzte.

Zum Unfall beigetragen hat:

- Ungenügende Festigkeit des Untergurts des Flügels.

General information on this report

This report contains the AAIB's conclusions on the circumstances and causes of the accident which is the subject of the investigation.

In accordance with art. 3.1 of the 9th edition of Annex 13, valid from 1 November 2001, of the Convention on International Civil Aviation of 7 December 1944 and article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the accident investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the German language.

All times in this report, unless otherwise indicated, are in the standard time applicable in Switzerland (local time – LT), corresponding at the time of the accident to Central European Summer Time (CEST). The relationship between LT, CEST and coordinated universal time (UTC) is: LT = CEST = UTC + 2 h.

Contents

Final Report

Owner	Private
Operator	Private
Aircraft type	Eurostar EV-97 model 2000 version R
Country of registration	Denmark
Registration	9-249
Location	Ova Spin, municipality of Zernez/GR
Date and time	24 June 2006, 18:36 LT

Synopsis

On 24 June 2006 at about 17:30 LT, the pilot took off from Mollis, where he was taking part in the "Microlight Fly-In" which was taking place there, together with a colleague on board his Eurostar EV-97 aircraft, registered in Denmark as 9-249, on a sightseeing flight towards the Engadine. When the aircraft had not returned to Mollis by the evening, a search was initiated. On the following day at about 15:00 LT, the wreckage of the aircraft was located by the crew of a search helicopter in the Ova Spin area on the Ofenpass road, in the municipal area of Zernez.

The occupants were fatally injured in the crash and the aircraft was destroyed. There was insignificant damage to the forest.

Investigation

The accident took place on 24 June 2006 at 18:36 LT. The notification was received by the AAIB on 25 June 2006 at approximately 15:00 LT. The investigation was opened on the same day at approximately 18:00 LT in cooperation with the Graubünden cantonal police.

Causes

The accident is attributable to the fact that the left wing structure suffered a forced rupture in flight and the aircraft crashed.

The following factor contributed to the accident:

- Inadequate strength of the lower spar cap of the wing

1 Factual information

1.1 Pre-flight history and history of the flight

1.1.1 General

The statements of the organisers of, and participants in, the 1st International Microlight Fly-In in Mollis, the statement of an eye witness and the traces found at the site were used for the following description of the pre-flight history and history of the flight.

The flight took place under visual flight rules.

1.1.2 Pre-flight history

It has been possible to license and operate aircraft of the new “Ecolight” category in Switzerland since 1 July 2005. In other countries, aircraft which are comparable in terms of their construction with Swiss Ecolight aircraft are designated microlights, ultralights, ultralight aircraft, ultra-léger motorisé (ULM), etc.

Under Swiss law, Ecolight aircraft must fulfil the following requirements, among other things:

- fixed-wing aircraft with three axis control with an area loading of at least 20 kg/m^2.
- a valid licence in accordance with the German LTF-UL licensing standards[1].
- compliance with the special Swiss environmental licensing regulations.
- presentation of a validation in accordance with the FOCA guidelines.

The aeronautical information circular (AIC) B 007/06 dated 30 March 2006 regulated and permitted for the first time the operation of foreign microlight aircraft in Swiss airspace.

In view of this new situation, on 24-25 June 2006 the Swiss Microlight Federation organised the first Microlight Fly-In at Mollis aerodrome. The event generated great interest and a large number of pilots registered to take part.

The Danish owner and pilot of the Eurostar EV-97 ultralight aircraft, registered in Denmark as 9-249, along with other Danish pilots, was one of the participants in the event. One colleague flew to Mollis with him onboard the Eurostar EV-97 and two other colleagues accompanied the aircraft in a Cessna 172. The two aircraft arrived in Mollis on 23 June 2006 at approximately 17:30 LT.

On the morning of 24 June 2006, both crews made a sightseeing flight in their aircraft in the Bad Ragaz region and made the return flight to Mollis via different routes.

The owner of the Eurostar EV-97 and his colleague planned another sightseeing flight later in the afternoon. The planned flight was via Bad Ragaz – Prättigau – Davos – Flüela Pass – Livigno – Bernina – Albula – Tiefencastel – Chur and back to Mollis. The pilots enquired about the envisaged route at the organiser’s wel-

1 LTF-UL – Notification of airworthiness requirements for aerodynamically controlled ultralight aircraft of the German Federal Aviation Office dated 30 January 2003

come desk and with various Swiss pilots. It was not possible to determine the extent to which they consulted the weather information provided by the organiser. Before the flight, the owner registered himself as pilot and his colleague as passenger in the organiser's 'declaration for local flight' list. Under routing he entered "Livigno" and the scheduled departure time was 17:30 LT. It could no longer be established whether the aircraft was refuelled before the flight.

1.1.3 History of the flight

The ultralight aircraft 9-249 took off from Mollis aerodrome at approximately 17:30 LT. In view of the brisk air traffic, no particular attention was paid to this take-off. This is why it was not possible to determine the precise take-off time. No information is available on the subsequent flight path.

At about 18:30 LT, an eye witness observed from the area of Zernez railway station for a few seconds a phenomenon in the sky in the area of the Ofenpass road which in hindsight might have signified the tailspin of the aircraft involved in the accident. Since he was not sure what he had seen, he drove his car twice along the Ofenpass road to check whether an aircraft had perhaps crashed. When he found no traces, he left it at that and only made his report when he had heard about the crash from the media.

In view of the impending thunderstorm in the mountains, the organisers were concerned when the aircraft had not returned to Mollis by 21:00 LT. They telephoned various aerodromes along the route and finally notified the Swiss search and rescue service as darkness fell.

On the following day, at about 15:00 LT, the wreckage of the aircraft was located by the crew of a search helicopter in the Ova Spin area on the Ofenpass road, in the municipal area of Zernez. The crew of the REGA helicopter which had been summoned was only able to confirm the death of the two occupants.

1.2 Injuries to persons

Injuries	Crew	Passengers	Total number of occupants	Third parties
Fatal	1	1	2	0
Serious	0	0	0	0
Slight	0	0	0	0
None	0	0	0	Not applicable
Total	1	1	2	0

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

There was insignificant damage to the forest.

1.5 Personnel information

1.5.1 Pilot

Person	Danish citizen, born 1940
Licence	Ultralight pilot's licence, issued by the Danish aviation authority on 03.07.1992
Ratings	Restricted national radiotelephony certificate
Medical fitness certificate	National Danish fitness certificate, class 2; valid till 09.01.2007

1.5.1.1 Flying experience

Total	> 992 hours
on the accident type	> 499 hours
during the last 90 days	> 60 hours
of which on the accident type	> 60 hours
Landings, total	> 2169
Landings during the last 90 days	> 75
Landings, total, on the accident type	approx. 500
Landings during the last 90 days on the accident type	75

1.5.2 Passenger

Person	Danish citizen, born 1950
Licence	Ultralight pilot's licence, issued by the Danish aviation authority on 16.10.1991
Ratings	Restricted national radiotelephony certificate
Medical fitness certificate	National Danish fitness certificate, class 2, valid till 25.04.2007
Flying experience	On 27.05.2004: 408 hours total flying experience

1.6 Aircraft information

Registration	9-249
Aircraft type	Eurostar EV-97 model 2000 version R
Characteristics	Single-engine ultralight aircraft, fully metal construction Two-seater, self-supporting low-wing aircraft, fully metal construction with fixed landing gear in nosewheel configuration

Manufacturer	Evektor – Aerotechnik A.S., Czech Republic
Year of construction	2002
Serial number	2002 1416
Owner	Private
Operator	Private
Engine	Rotax 912 ULS Four-cylinder engine, liquid-cooled cylinder heads, air-cooled cylinders, integrated reduction gear Continuous power: 69.9 kW (95 PS) at 5500 rpm Take-off power: 73.6 kW (100 PS) at 5800 rpm (for max. 5 min.) Manufacturer: Bombardier Rotax GmbH, Gunskirchen, Austria Serial number: 4 427 933 Year of construction: 2002
Propeller	Woodcomp Classic three-bladed propeller, adjustable on the ground Serial number: 2713683R Year of manufacture: 2002
Equipment	Basic equipment for visual flight with radio
Operating hours:	
Airframe	approximately 500 hours
Engine	approximately 500 hours
Propeller	approximately 500 hours
Empty mass	According to the manufacturer's report dated 16.05.2002, the empty mass was 284.8 kg. This value was shown on the aircraft's identification plate as 285 kg. According to the Danish regulations BL 9-6, edition 3, dated 19 June 2001, the operational empty mass for a two-seater ultralight aircraft is specified as max. 210 kg.
Maximum take-off mass	According to the test report by the Danish UL-Flyver Union and the technical data sheet of the Light Aircraft Association of the Czech Republic, the limit is specified as 450 kg.
Mass and centre of gravity	The mass of the aircraft at the time of the accident was approximately 467 kg. The centre of gravity was approximately 28.8% MAC (mean aerodynamic chord) with a limit of 20 – 34% MAC. The mass was above the maximum permitted take-off mass according to Danish standards.

Maintenance	Maintenance of the aircraft was carried out by the operator himself and confirmed in the aeroplane log book. The last maintenance tasks were carried out on 01.06.2006 at 478.3 hours (oil + brake fluid refilled/topped up) and on 21.06.2006 at 490.5 hours (2/10 oil refilled/topped up; check of engine ok). It is not apparent from the documentation whether this work corresponded to the 50/100 hour checks prescribed by the manufacturer. The last periodic condition check was carried out on 19.10.2005 at 396 operating hours by the Dansk UL-Flyver Union. Four manufacturer's mandatory bulletins applied to the aircraft with serial number 20021416: EV 97-004a; EV 97-005a; EV 97-006a; EV 97-007a. It is not apparent from the documentation whether these bulletins were implemented. Examination of the wreckage showed that Bulletin EV 97-005a (securing the screw on the throttle control) had not been implemented.
Technical limitations	Problems with the radio were noted in the log book on 17.06.2006. Rectification of the malfunction is not apparent.
Specified fuel grade	Gasoline RON 95, alternatively AVGAS 100LL
Fuel reserves	Tank capacity: 65 l The actual quantity of fuel on board could not be established. Gasoline was found in the fuel feed components. To safely complete the planned return flight to Mollis, including a reserve, approximately 28 litres, corresponding to two hours flying time, would have been necessary.
Airworthiness certificate (corresponding document)	Flight permission, issued by the Danish Ultralight Union on 19.10.2005 at 396 operating hours, valid for three years or max. 200 operating hours.
Certification	VFR by day

1.7 Meteorological information

1.7.1 General

The information in section 1.7.2 was provided by MeteoSwiss.

1.7.2 General weather situation

Switzerland was within the zone of a weak high-pressure area over the Baltic. Humid air was accumulating at the Alps from the south-west.

Gamet valid 12-18 UTC for the Eastern Alpine Switzerland Region:

SIG CLD: ISOL CB
Wind/temperature at 13 000 ft AMSL 260/15kt PS00
Wind/temperature at 8 000 ft AMSL 230/05kt PS11
0°: FL130

GAFOR

Gafor Switzerland valid 12 – 18 UTC:

Route 92, Bad Ragaz – Lenzerheide – Julierpass – Samedan, reference altitude 7500 ft AMSL: D D D
The reference altitude of 7500 ft AMSL relates to the altitude of the Julierpass.
D D D means:
Route 92, Difficult 12-14 UTC, Difficult 14-16 UTC, Difficult 16-18 UTC

GAFOR provides information on weather conditions (visibility/ceiling) on the main visual fight routes in Switzerland and is issued three times a day in the winter semester and four times a day in the summer semester. Depending on visibility and ceiling, a distinction is made between four different weather categories.

O = OPEN
D = DIFFICULT
M = MARGINAL
X = CLOSED

Weather phenomena hazardous to aviation such as turbulence, icing, etc. are mentioned in the aviation weather forecast and are not therefore taken into account in the GAFOR.

Weather categories					**Interpretation of weather categories**
Ceiling	Closed	Marginal	Difficult	Open	**Open**: no impediments to visual flight
2000 ft	**X**	**M**	**D**	**O** Oscar	**Difficult**: pilots trained in visual navigation can still fly
1500 ft	**X**	**M**	**D**	**D** Delta	**Marginal**: pilots very well trained in visual navigation and with precise knowledge of local conditions can still fly
1000 ft	**X**	**M**	**M**	**M** Mike	**Closed**: visual flight impossible
Reference altitude	**X**	**X**	**X**	**X** X-ray	
		2 km	5 km	8 km	
Ceiling definition: lowest cloud layer (with the same base) of at least 5 octas					

AIRMET

AIRMET valid 1400-1800 UTC SWITZERLAND FIR/UIR ISOL TS OBS AND FCST ALPS AND NORTH OF ALPS WESTERN PART OF SWITZERLAND MOV NE NC=

SIGMET

No SIGMET was issued on this day.

SWC, Windcharts

SWC, Windcharts valid 18 UTC.

The Significant Weather Chart issued by WAFC London shows OCNL CB between FL110 and FL350 south of the Alps (the SWCs cover the airspace between FL100 – FL450). The wind chart for FL100 shows winds from a south-westerly direction at 5-10 kt and a temperature of plus 6 °C.

Aviation weather forecast valid from 12-18 UTC

The aviation weather forecast contained the following relevant forecasts for the area of the accident:

South side of the Alps and the Engadine:

3-5/8 base 8 000-10 000 ft AMSL. Visibility generally over 8 km.

Local showers or thunderstorms probable, above all along the Alps.

Hazards

In the mountains isolated thunderstorms probable, above all in the southern Alps.

Measured and observed values

Automated measurement network (ANETZ / ENET)

Measurements at 16:30 UTC:

Station	Elev. m AMSL	Elev. ft AMSL	Temp °C	Dewpoint °C	Wind direction degr.	Wind	Gusting to kt
Samedan	1705	5594	22	10	200	12	19
Robbia	1078	3536	26	11	240	7	15
Corvatsch	3315	10877	8	4	230	5	7
Scuol	1298	4259	24	8	070	8	15

Radio probes

The Milan radio probe (12Z) indicates variable winds at 1550 m AMSL of approximately 2-3 kt. The temperature was 18 °C and the dewpoint 6 °C. The instability indices (Boyden and Faust) indicate a pronounced thunderstorm trend.

The radar image taken at 16:30 UTC shows widespread echoes of convective activity. In the area north-east of Zernez a small echo can be identified, indicating possible activity in this area. This echo can also be identified on the preceding images (16:00-16:30). On later images (17:00-18:00) distinct echoes can be identified in the Lower Engadine and in the area of the Flüela Pass.

Satellite image

The visible satellite image taken at the time of the accident shows massive storm cells, especially in the central Alps and above the Po plain. In the area of the accident site various cells that are forming up can be identified.

On the basis of the existing information, it is possible to conclude that the weather conditions at the time and location of the accident were as follows:

Cloud	*2-4/8, base at approximately 10 000 ft AMSL, with local variations +-1000 ft*
Weather	*Convective activity in the vicinity of the accident site, but no thunderstorms*
Visibility	*15 km*
Wind	*Variable wind at 10 kt, gusting to 20 kt*
Temperature/dewpoint	*23 °C / 08 °C*
Atmospheric pressure	*LSZH 1013 hPa, LSGG 1013 hPa, LSZA 1014 hPa*
Position of the sun	*Azimuth 278°, elevation 25°*
Hazards	*Moderate turbulence due to the convective activity in the region*

1.7.3 Weather according to eye witness reports

The eye witness who observed the final seconds of the crash described the weather in the Ofenpass sector as fine with a few cumulonimbus clouds.

1.7.4 Typical thermal situation according to information from glider pilots

"*Generally, the Zernez – Piz Nuna – south Nuna area as far as the Ofenpass road is known to glider pilots for its very strong updraughts*. *These updraughts are frequently very "rough", i.e. they are associated with strong turbulence".*

1.7.5 Local weather conditions at the time of the accident

24 June 2006 was a thermally active day with cumulus clouds above the mountain ridges. The "Malojawind" was blowing in the upper Engadine. In the lower Engadine, valley wind was formed until mid-afternoon. Between 15:00 LT and 18:00 LT, there was shower activity between Martina and Prutz (A). Cold air from the shower cells caused the valley wind to abate. No thunderstorms were observed.

At the time of the accident, the thermals were abating. This was most clearly demonstrated by the increase in wind speed on the Weissfluhjoch and the Corvatsch and the waning "Malojawind" in Samedan.

The peaks in the vicinity of the accident site which generate the most intensive updraughts include the Munt Baselgia and the Piz Laschardella north of the Spölschlucht, and the Piz d'Esan south of Zernez. Extensive circulation of slope winds causes the air to descend over the middle of the valley. It remains an open question whether the convergence of the "Malojawind" with the cold air from the shower cells north-east of Scuol triggered updraughts in the area of the accident. According to one eye witness, the weather was fine with a few cumulus clouds.

1.8 Aids to navigation

Not applicable.

1.9 Communications

No radio contact was recorded.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

A portable GPS AIRNAV EKP III unit was found at the site of the accident. The unit was heavily damaged. When an attempt was made to read out the memories, it was found that no useful data was available.

1.12 Wreckage and impact information

1.12.1 Wreckage

1.12.1.1 Distribution of the wreckage

The main wreckage was on a rock outcrop, 50 metres above the bed of the Spöl, on the steep wooded slope west of the course of the river (see figure below, reference A). Large debris items were held by harnesses and control cables which became entangled in the trees. The main impact point was at 1600 m AMSL directly below a high-voltage line of the Engadine power station. The bodies of the two occupants and smaller parts of the wreckage were below the rock outcrop in the river bed and in the area of the Spöl's banks.

A debris field with parts of the cockpit canopy, canopy frame and loose items extended in an east-south-east direction over a distance of approximately 900 metres. The left wing was located along this debris field 470 m from the main wreckage, in steep scree, at 1720 m AMSL (see figure below, reference B).

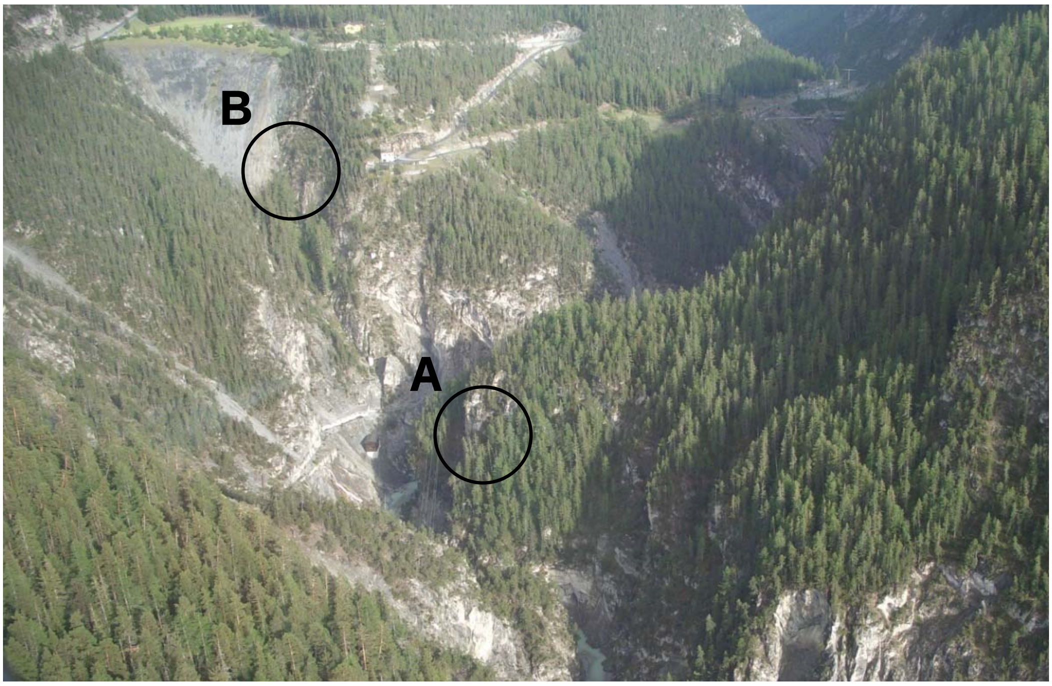

Figure 1 – General view of the site of the accident, looking east

1.12.1.2 Condition of the debris

The aeroplane was destroyed as a result of the impact. Only a few hard findings could be made concerning conditions before the event. It was possible to identify three main sections, in addition to smaller loose items of debris. The engine was connected to the front part of the cockpit via the engine mount. Part of the central fuselage structure with the right wing, badly damaged on impact, lay about 40 metres to the north of the nose section. This wing was connected to the fuselage section and the cover of the fuselage-wing joint was present. A little higher up, at half the height of the trees, was the right main landing gear and the tail section. The stabiliser surfaces, in particular the vertical stabiliser, were identifiable as such. Blocks of debris were suspended in the branches by a tangle of control cables and seat belts. The left main landing gear was in an isolated position beside the groups of debris.

1.12.1.3 Findings from the examination of the wreckage

The instrument panel was only slightly deformed. However, the instruments were very badly damaged. The following switch positions were found:

Beacon	On
Fuel pump	On
Intercom (IC)	On
Ignition (2x)	On
Masterswitch	On
Transponder	Off (7000)

The left wing was found approximately 470 metres away from the main parts of the wreckage (fuselage).

The upper wing attachments were still held together by the mounting bolt and mounted to the upper spar cap by close-tolerance bolts. The fuselage-side part of the attachment had been torn out of the fuselage.

The wing-side attachment parts of the lower spar cap had been torn off from the wing. The lower spar cap – consisting of two flat aluminium profiles – as well as a piece of the wing spar web and the wing skin were torn apart. The fracture in the wing spar cap was in the area of the outermost close-tolerance bolt (cf. figure 2).

The lower wing attachments were still held together by the mounting bolt; they were missing at the wings final location but were found mounted on the fuselage wreckage. The remaining piece, torn off from the left wing, still connected to the attachment, was found at the same location.

From the findings above it is apparent that the lower wing spar cap of the left wing fractured in flight in the vicinity of the fuselage and the left wing was subsequently torn off.

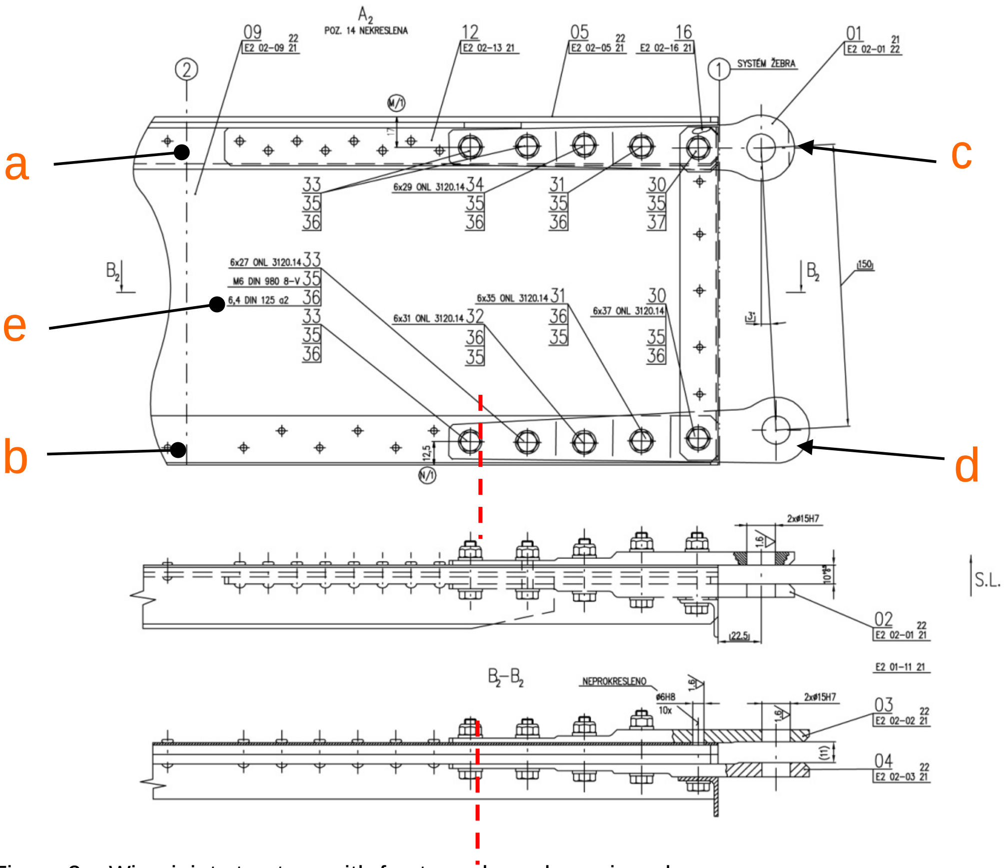

Figure 2 – Wing joint structure with fracture plane shown in red

a	Upper spar cap
b	Lower spar cap
c	Upper wing attachment
d	Borehole for mounting bolt in the lower wing attachment
e	Spar web

Figure 3 – Location of fracture of the lower spar cap of the left wing with visible outermost close-tolerance bolt

On the basis of the traces it can be concluded that the left wing separated from the fuselage at an unknown altitude. With it the cockpit canopy was also destroyed. The aircraft, now incapable of flying, then fell almost vertically to the ground in a tailspin. During this fall, the aircraft came into contact with the earth conductor of a high-voltage line, which runs directly above the crash location. At 18:36 LT this contact triggered a shut down at the Engadine power station and left minor damage on the earth conductor.

On the basis of the debris field, it can be assumed that the aircraft was moving in a westerly direction when the event occurred.

1.12.2 Accident site

Accident location	Ravine of the Spöl river, below Ova Spin in the Falcun area of the national park
Swiss coordinates	806 550 / 174 170
Latitude	N 46° 41' 12''
Longitude	E 010° 08' 21''
Elevation	1600 m AMSL 5250 ft AMSL
National map of Switzerland	Sheet No. 1218, sheet name: Zernez, scale 1:25 000

1.13 Medical and pathological information

An autopsy was performed on the bodies of both occupants. No indications of health problems which might have influenced the accident were found. The occupants died immediately as a result of the serious injuries suffered during the accident.

There was no evidence of exogenous substances (medicaments, drugs or alcohol) in either of the occupants.

1.14 Fire

Fire did not break out.

1.15 Survival aspects

1.15.1 General

The accident was not survivable.

The Eurostar EV-97 aircraft, registration 9-249, was not equipped with a ballistic rescue system (BRS). Such a rescue system is available from the factory as an optional accessory for the aircraft. In order not to impede fitting Ecolight aircraft with ballistic rescue systems due to weight restrictions, in Switzerland and other countries, but not in Denmark, the maximum take-off mass was increased to 472.5 kg for aircraft which are correspondingly equipped.

Ballistic rescue systems offer the possibility, particularly after structural damage, of bringing the occupants to earth safely on a parachute. In the present case the use of such a system would have offered the prospect of a less serious outcome.

1.15.2 Emergency transmitter

The aeroplane was not equipped with an aircraft emergency location beacon (ELBA).

1.16 Tests and research

1.16.1 Calculations and analyses on the wing structure

1.16.1.1 Construction regulations

The Eurostar EV-97 model 2000 version R aircraft involved in the accident was built according to Type Certificate Data Sheet No. ULL-03/98. The certification basis is stated in this document as follows:

"Airworthiness requirements of Sporting flying vehicles- Aerodynamically controlled ultralight aircraft UL2- part 1, issued by LAA[2] of Czech Republic on April 1, 1998 on the basis of authorization by Civil Aviation Authority, ref. No. 1539/P1-165/97".

The Ecolight aircraft certification authority (SMF certification authority) confirms in its letter of acceptance dated 24.02.2006 [translated from German]: "*….that the Evektor Eurostar EV-97 model 2000 Version R as described in specification No. 61155.4 (version No. 6/01.11.2005) of the German "Luftsportgerätebüro" and with the deviations documented in the annex is recognised in Switzerland as an Ecolight aircraft. Certification was effected in accordance with the German construction regulations LTF-UL[3] by the first certification authority (Luftsportgerätebüro/DAeC) and was validated on the basis of the manufacturer's information in accordance with the procedures described in the handbook of the SMF certification authority. A valid type certificate issued by the first certification authority is a requirement for this recognition."*

According to the specification, the maximum take-off mass for aircraft in the Ecolight category is 450 kg or 472.5 kg with an installed rescue system.

The following information and considerations relate to the wing structure or rather the lower spar cap and are based on the assumption that with a load, at a load factor of 4 g, the material used results in a reserve factor of at least 1.0 in relation to yield strength. At one and a half times the load, the reserve factor in relation to the ultimate strength of the material should also be at least 1.0.

Extracts from relevant paragraphs of the LTF-UL [translated from German]:

Extract from LTF-UL 307[4] „Material properties and strength characteristics" (page 312):

„1. The properties of the material shall be proven by a sufficient number of tests, so that the strength characteristics can be defined on a statistical basis.

2. The strength characteristics have to be defined in such a manner that it is very unlikely that a load-bearing structural component exhibits insufficient strength due to variations in material…."

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[2] LAA CR – Light Aircraft Association of the Czech Republic

[3] LTF-UL – Notification of airworthiness requirements for aerodynamically controlled ultralight aircraft of the "Luftfahrt-Bundesamt" of Germany, dated 30 January 2003

[4] The paragraph LTF-UL 307 is used twice in the current version of LTF-UL

Extract from LTF-UL 307 „Verification of strength“ (page 313):

“….Theoretical, mathematical verification of strength is accepted only if it is proven with respect to the chosen method of construction, on the basis of experience, that the method of calculation employed produces reliable results. Otherwise load tests must be carried out to furnish proof.”

Extract from LTF-UL 627 „Fatigue properties“:

“As far as feasible, the overall strength must be such that points with concentrated stress and high stresses are avoided and the effect of vibration is taken into account. Materials which possess poor characteristics in terms of crack propagation shall be avoided and it must be possible to check assemblies in the primary structure without difficulty….”

Paragraph LTF-UL 307 further specifies the requirement for a safety margin of 1.5 and the possibility of adding an additional safety factor.

1.16.1.2 Verification of strength by the manufacturer

For certification, the manufacturer of the Eurostar EV-97 aircraft loaded the wing of the aircraft in a static test until it ruptured.

A supplementary report by the aircraft manufacturer is based on the following aircraft data:

Maximum permitted take-off mass MTOM	=	480 kg
Airspeed v	=	170 km/h
Load factor n	=	+ 4 g

From this data, the aircraft manufacturer calculated the following static loading values, i.e. static stress analysis, for the wing test (with reference to the longitudinal axis of the lower wing mounting bolt x = 541 mm; x = 0 mm corresponds to the longitudinal axis of the fuselage):

Vertical transverse shear	Q = 7019 N
Bending moment	M = 10344 Nm

These values were calculated according to Weissingers method.

From the bending moment and the vertical distance of 150 mm between the upper and lower mounting bolts, the tensile load of the lower wing attachment is calculated as 68961 N.

According to the test documents, the wing structure failed at a wing load of M = 17454 Nm, corresponding to a tensile load on the lower wing attachment of 116360 N. The aircraft manufacturer indicated that the material used in the test had an ultimate strength of Rm = 515 MPa. The ultimate strength of the material used during the test is not known.

With reference to one and a half times the calculated load, a reserve factor of 1.125 results.

1.16.1.3 Verification of the wing loading

Within the scope of the investigation, the loading values (stress analysis) of the wing calculated by the manufacturer for the certification of the aircraft were checked.

The values employed are based on the following aircraft data:

Maximum permitted take-off mass MTOM = 450 kg
Load factor n = + 4 g

From this data, the following static loading values were calculated for the wing (with reference to the longitudinal axis of the lower wing mounting bolt x = 541 mm)

Vertical transverse shear Q = 7648 N
Bending moment M = 11891.5 Nm

These values were calculated according to Schrenk's method.

From the bending moment and the vertical distance of 150 mm between the upper and lower mounting bolts, the tensile force of the lower wing attachment is calculated as 79277 N.

This tensile force is 15% higher than that of the aircraft manufacturer; in these calculations, the fact that a MTOM of 450 kg was used as a basis, rather than the manufacturer's MTOM of 480 kg, was not taken into account.

1.16.1.4 Examination of the lower spar caps

1.16.1.4.1 Specification of the material

For the two flat profiles of the lower spar cap, the aircraft manufacturer used material with the designation PA 7. According to the aircraft manufacturer's information, the following mechanical properties were confirmed to him by the material manufacturer:

Ultimate strength Rm = 515 MPa

Yield strength Rp_{02} = 410 MPa

No information is available concerning ultimate strain and modulus of elasticity.

The aircraft manufacturer specifies a minimum ultimate strength of RM = 440 MPa.

1.16.1.4.2 Chemical analysis of the material

Element	**Sample 1A (rear profile)**	**Sample 1B (front profile)**
Si	0.22	0.2
Fe	0.19	0.18
Cu	4	3.8
Mn	0.75	0.7
Mg	1.5	1.4
Zn	0.015	0.013
Cr	0.027	0.027
Pb	0.007	0.006
Al	Remainder	Remainder

Table 1: Results of the chemical analysis (values in percentage by weight)

At the time of the investigation the nominal values for the PA 7 material were not available. From the measurements it is obvious that the material for the flat profiles was probably a wrought aluminium alloy of the AlCu4Mg1 (2024) type.

1.16.1.4.3 Mechanical properties of the material

Several hardness tests (total 36 test points) and tensile tests (total 12 samples) were performed on the two flat aluminium profiles A and B, which in riveted form constituted the lower spar cap in the area of the torn-off wing near the fuselage.

The ultimate strength of the rear profile A measured in the tensile tests and established from the hardness tests varied from 437 to 522 MPa and the Rp_{02} values varied from 333 to 402 MPa.

The corresponding values for the front profile B varied from 442 to 461 MPA and the Rp_{02} values varied from 338 to 352 MPa.

The established Rm values are up to 15% lower and on average 10% lower that the values attested by the profile supplier.

In the case of the Rp_{02} values, the figures are up to 19% lower and on average 13% lower than the profile supplier's attested values.

It is striking, in particular, that profile A exhibits very inhomogeneous strength values.

1.16.1.4.4 Comparative material testing

By chance, an aircraft type of the same construction was involved in an accident under non-comparable circumstances shortly after the present accident.

On this aircraft, material from the lower spar cap from the only slightly damaged right wing was tested in the same way for strength, for purposes of comparison. This produced the following values:

Rm	485 to 495 MPa for profile A
	366 to 385 MPa for profile B
Rp_{02}	375 to 380 MPa for profile A
	293 to 301 MPa for profile B

These values are up to 29% lower than the material values specified by the aircraft manufacturer.

1.16.1.4.5 Metallographic analysis

The cross-sections of the two aluminium profiles A and B were analysed metallographically at four points. The cross-sections correspond to the stressed cross-section; profile A relates to the rear profile without radius and profile B to the front profile with radius.

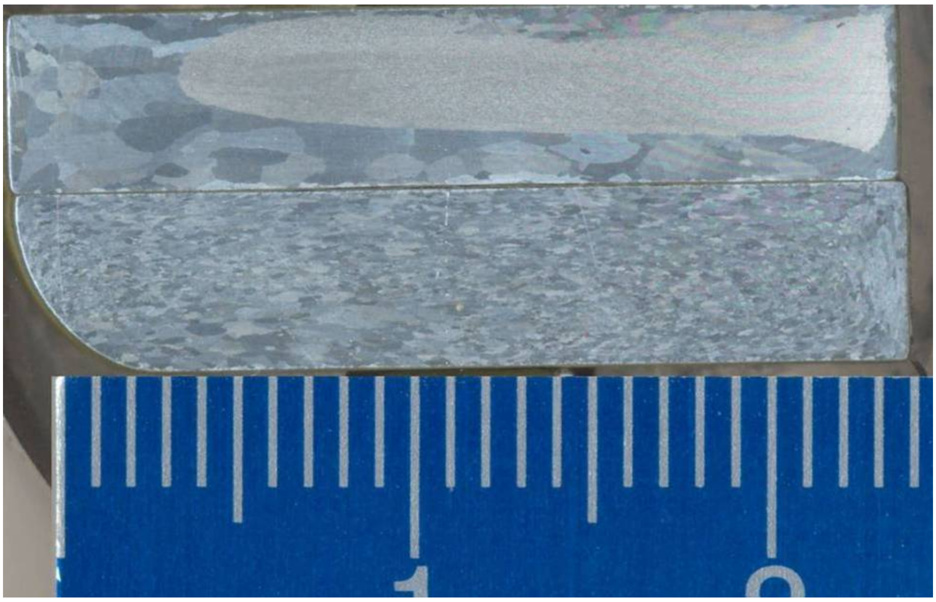


Figure 4 – Left wing, lower spar cap, looking from fuselage outwards
Overall view of the matrix of the two lower spar caps. 1A without radius; 1B with radius

On all the metallographic sections examined, profile B (with radius) exhibited a homogeneous – though rather coarse-grained – matrix.

In the case of profile A (without radius), all sections exhibited the typical indications of an extrusion weld; the inner part of the cross-section is relatively fine-grained and is surrounded by extremely coarse-grained material. This is a case of gross inhomogeneity in the profile. This defect in the material occurs in the fabrication of aluminium profiles in the block on block pressing technique: when the next press block is pressed, the new material flows in a tongue shape into the remaining material of the preceding press block. In this method – termed co-extrusion – this extrusion weld occurs in the transition between the individual blocks. Since it is of relatively lesser quality, the area of the profile exhibiting the extrusion weld must be cut out of the pressed strand and discarded.

The strength properties of profiles with extrusion welds have been analysed scientifically and published[5]. From these analyses, it is apparent that the presence of such extrusion welds considerably reduces the strength properties (large effect on fatigue life).

In comparison with fine-grained material, coarse-grained material exhibits considerably lower notch impact strength. Elongation at rupture is also lower. Materials with low notch impact strength react very sensitively to shock loading.

1.16.1.5 Fractographic analysis

The fractured surface of the two lower spar cap profiles were analysed fractographically. In view of the structure of the fractured surfaces, both fractures are ductile forced ruptures.

[5] Source information:

IWK-Aachen	Merkmale von Aluminium Strangpressprofilen
Akeret R.	Extrusion Welds – Quality Aspects
Valberg H.	Extrusion welding in aluminium extrusion
Nanninga N.	Effect of orientation and extrusion welds on the fatique life of an Aluminium alloy

Plastic deformation and the necking in the area of the fracture are present to a small extent. On the fracture surface of profile A (profile with the extrusion weld), two different types of ductile fracture are easily visible to the naked eye. The surface proportions of the two types match the metallographic analysis.

1.16.1.6 Consideration of the notch effect of individual structural components in a strength test

According to the LTF-UL construction regulations, the manufacturer must provide proof of adequate strength of the structure.

This may be provided, for example, by a calculation. In these calculations, any notch effects which are present must be taken into appropriate consideration (e.g. by reducing the material strength values). Fitting factors must also be taken into account in mechanical joints. This type of calculation also takes fatigue and loading due to shock into account.

The LTF-UL construction regulations allow a static fracture test to be carried out instead of providing mathematical proof. However, in such tests weak points in the structural elements, in relation to shock-type loading and fatigue, are neither detected nor taken into account.

On the aircraft involved in the accident, proof of adequate wing strength was provided only by means of a static test, in which the notch effect of the structure at the connecting point between the wing attachment and the lower spar cap was not taken into account.

1.16.1.7 Calculation of the lower spar cap stresses in the zone of the fracture

The calculations below are based on the values of the aerodynamic investigation; valid for the 4 g load factor and an MTOM of 450 kg.

Two different methods of calculation were applied; in the process, the nominal stress and the maximum notch stress in the area of the zone of the fracture of the lower spar cap were calculated.

If the wing is considered as a beam in flexion, the following stress values result:

Nominal stress	226 MPa
Max. notch stress	791 MPa

In the 2nd calculation method, it is assumed that 95% of the tensile force (of 79277 N) of the lower wing attachment is transferred to the two flat profiles of the lower spar cap and to the spar web. The remaining 5% is transferred to the skin of the wing. The second method of calculation is more realistic than the first; it was verified by means of a practical test.

The stress values calculated according to the 2nd calculation method with the 296.65 mm^2 cross-section are:

Nominal stress	254 MPa
Max. notch stress	889 MPa

Assuming that the notch stress is largely transferred by the plastic behaviour of the material, that a fitting factor of 1.15 should be applied and that the material values have to be reduced by 25% because of the stress concentration, the lower spar cap material used would have to possess an yield strength (Rp_{02}) of at least 389 MPa and a ultimate strength (Rm) of at least 584 MPa.

The minimum material values measured on the lower spar cap of the left wing of the aircraft involved in the accident are

for	Rp_{02}	=	333 MPa
and for Rm		=	437 MPa

The reserve factors for strength are therefore

at limit load	0.856
at ultimate load	0.748

These values are clearly below the minimum of 1.0.

1.16.1.8 Additional investigations on an aircraft of the same type

The material values were determined by means of additional investigations on the material of the lower spar cap of an aircraft of the same type.

The minimum values are:

for	Rp_{02}	=	293 MPa
and for Rm		=	366 MPa

The reserve factors for strength are therefore:

limit load	0.753
ultimate load	0.627

In the case of the information above, a fitting factor of 1.15 and a 25% reduction in material values due to the stress concentration were taken into account as well.

1.16.1.9 Assessment of the joint between the wing attachment and the lower spar cap

The lower spar cap of the wing – consisting of aluminium – is connected to the lower attachment by close-tolerance bolts. The attachment and the close-tolerance bolts are composed of steel. The joint exhibits a high notch effect – i.e. it is very sensitive to shock and fatigue. The notch-stress concentration factor is 3.5, i.e. the lower spar cap experiences local stress values which are up to 3.5 times higher. The shock sensitivity depends on the notch-stress concentration factor and to a large extent on the shock sensitivity of the material, i.e. on the grain size, ductility and notch impact strength. These facts must be taken into account when providing evidence of strength.

In the fractographic analysis it was found that the rupture of the lower spar cap is a ductile forced rupture and that a fatigue rupture can be excluded.

In fractographic analyses, ruptures in the low-cycle range, resulting from a low number of load changes, are also categorised as forced ruptures, because no significant crack propagation precedes the actual rupture. It is therefore also possible that the rupture of the lower spar cap arose from the result of individual high wing loads.

In the case of notched structural components, each load ‘consumes’ part of the life of the component. This ‘consumption’ is dependent on the notch-stress concentration factor, the notch impact strength, as well as on the homogeneity, the internal structure and grain size, and the number, type and magnitude of the loads. The life of the component ends with its failure.

In the case of a structure which is sensitive to shock, a sudden load may cause a rupture of the component.

1.16.2 Cockpit canopy latch

Several fragments of the cockpit canopy frame were found. The fact that the catch handle was blocked in the open position stood out. Forensic examination of this component permitted the conclusion to be drawn that the catch handle was in the “CLOSED” position before the impact.

1.17 Organisational and management information

Not applicable.

1.18 Additional information

The specifications of the ultralight or Ecolight Eurostar EV-97 aircraft are presented in the manufacturer’s brochures and on its web pages. Among other things, the load factor is mentioned. The value of +6g/-3g g is mentioned under terms such as load factor (design) or *facteur de charge*. From the details it is not apparent that this figure represents the load at rupture and not the safe load, or rather the permissible operating limits of the aircraft.

1.19 Useful or effective investigation techniques

Not applicable.

2 Analysis

2.1 Technical aspects

2.1.1 Discussion of the test results

The examination of the fuselage attachment of the lower left wing spar cap on the Eurostar EV-97 aircraft involved in the accident, indicates that it had broken under the effect of force. Material fatigue as a result of high numbers of load changes could be excluded.

The examination of the two aluminium profiles from which the lower spar cap was manufactured, produced the following results:

One of the two profiles exhibits an extrusion weld, i.e. a substantial part of the cross-section exhibits a very coarse-grained structure and the material is therefore very inhomogeneous.

The presence of an extrusion weld reduces the mechanical properties of a profile considerably; the same applies to coarseness of grain structure. Profiles with extrusion welds or with a substantial proportion of coarse grain must not be used for highly-stressed parts.

Both profiles exhibit static mechanical properties which are up to 19% lower than those stated by the aircraft manufacturer. On average, the ultimate strength was 10% lower. Moreover, additional tests on sample material from an aircraft of the same type produced values which were up to 29% lower than the specification.

The aircraft manufacturer’s very stringent requirements of the material, with an ultimate strength of 515 MPa were not met.

Evidently quality assurance failed.

The difference between the value of the ultimate strength of Rm = 515 MPa used in the design and the minimum of Rm = 440 MPa required by the aircraft manufacturer is striking. According to LTF-UL 307 the value of RM = 440 MPa should have been used as the basis for the design of the wing structure.

Load calculations inherently yield results that can differ from the effective loading values. This has to be taken into account in the design of safety-critical structural components.

The wing was subjected to a static test for the certification of the aircraft. According to the test documents, the limit value test load was 18.5% lower than the value calculated during investigation.

Taking into account the ultimate strength of the material, on average 10% lower, and the limit value test load calculated within the scope of the investigation, the reserve factor indicated in the manufacturer’s evidence of strength is reduced to 0.826.

The following table indicates a summary of the reserve factors regarding to the ultimate strength of the material:

	Loading value Evektor Ltd	Loading value Evektor Ltd	Loading value BFU	Loading value BFU
MTOM in kg	480 kg	480 kg	450 kg	480 kg
Ultimate strength Rm of the material in MPa	515 MPa	463.5 MPa	463.5 MPa	463.5 MPa
Ultimate strength Rm of the material in % of 515 MPa	100 %	90 %	90 %	90 %
Bending moment referring to the bore hole for the mounting bolt in the lower wing attachment at a load factor + 4 g	10344 Nm	10344 Nm	11892 Nm	12684 Nm
Bending moment referring to the bore hole for the mounting bolt in the lower wing attachment at a load factor + 6 g	15516 Nm	15516 Nm	17837 Nm	19026 Nm
Bending moment according to the static fracture test supplied by Evektor	17454 Nm	-	-	-
Bending moment at failure reduced by 10% in respect to the lower ultimate strength of the material	-	15709 Nm	15709 Nm	15709 Nm
Reservefactor	1.1249	1.0124	0.8806	0.8256

Recalculation of the aircraft manufacturer's loading values using his minimum required ultimate strength of Rm = 440 MPa reduces the Reservefactor to 0.96.

The lower spar cap of the left wing ruptured at a point with high stress concentration and a significant notch effect. This weak point in the structure was neither detected nor recognised by the static wing load test carried out by the manufacturer. At points with a notch effect and high stress concentration, therefore, a static load test is not sufficient to provide proof of adequate structural strength. Furthermore this approach does not take into account any fatigue aspects.

The rupture of the upper spar cap and web was the consequence of the overloading subsequent to the rupture of the lower spar cap.

2.2 Human and operational aspects

The pilot flew his ultralight Eurostar EV-97 aircraft for years, regularly and often. His flying experience and level of training were good. He flew primarily in Denmark and neighbouring regions. During his participation in the Microlight Fly-In in Mollis he was for the first time faced with the specific peculiarities of flying in mountainous terrain. The fact that he obtained information from various pilots before the planned flight to Livigno shows that he was respecting this challenge.

The area in which the accident occurred is known to glider pilots for its strong turbulence and powerful thermals. Analysis of the weather conditions on the day of the accident in the Zernez area indicated a high probability of significant convective air currents.

It is conceivable that the pilot was taken by surprise by local turbulence. In the process, the structure of the aircraft must have been overloaded as a result of the forces induced by turbulence or possibly during a corrective manoeuvre, after a brief loss of control. The failure may have occurred at a relatively low load because of possible pre-existing damage to the spar cap.

3 Conclusions

3.1 Findings

3.1.1 Human and operational aspects

- The pilot was in possession of a pilot's licence for ultralight aeroplanes.
- The pilot had >992 hours total flying experience. Around 500 hours of this total had been flown since 2002 on the aircraft type involved in the accident.
- The pilot had no experience of flying in mountainous terrain.
- There was light cloud and good visibility in the area of the accident.
- It is highly probable that the atmosphere was convectively active, associated with strong turbulence.

3.1.2 Technical aspects

- The aircraft was licensed for air traffic.
- The last periodic condition check was carried out on 19.10.2005 at 396 operating hours by the Dansk UL Flyer Union.
- No ballistic rescue system (BRS) was fitted in the Eurostar EV-97, registered as 9-249 DK.
- The mass of the aircraft at the time of the accident was higher than the 450 kg permitted in Denmark.
- The fracture of the lower left spar cap was a forced rupture. It is not possible to make any precise statement about the magnitude of the load.
- Part of the ruptured lower spar cap exhibited an extrusion weld and a structure with a high proportion of coarse grain. This resulted in a considerable reduction in quality.
- The mechanical properties of the material did not correspond to the assumptions used during the design of the wing.
- At the point where the lower wing spar cap ruptured, the sensitivity to shock and notch effect were high. The notch effect of the structure at the connecting point between the wing attachment and the lower spar cap was not taken into account.
- On the aircraft type involved in the accident, proof of adequate wing strength was provided only by means of a static test until it ruptured. The mechanical properties of the material used during the test are not known.
- At the outmost fixing point of the wing attachment, the lower wing spar cap exhibited inadequate strength due to inadequate quality of the material and an excessively low load assumption with reference to a load factor of +4 g.
- The design of the wing suspension construction did not meet the strength requirement of the German LTF-UL regulations.

3.2 Causes

The accident is caused by the fact that the left wing structure suffered a forced rupture in flight and the aircraft crashed.

The following factor contributed to the accident:

- Inadequate strength of the lower main spar of the wing.

4 Safety recommendations and measures taken since the accident

4.1 Safety recommendations

4.1.1 Adjustments to the construction regulations for Ecolight aircraft

4.1.1.1 Safety deficit

It has been possible to licence and operate aircraft of the new "Ecolight" category in Switzerland since 1 July 2005. Validation is based on the FOCA specifications and a valid licence in accordance with the German LTF-UL licensing standards.

The static load tests permitted according to the LTF-UL construction regulations as a complement to or substitute for mathematical proof of strength are insufficient to ensure the fatigue strength of the construction. This is because they cannot detect either existing stress concentration or points sensitive to notching and fatigue; nor do they take into account any variations in material quality. There is no requirement to specify a safety factor for safety-critical structural components.

In the LTF-UL construction regulations, the requirements relating to quality assurance of the material used are inadequate.

4.1.1.2 Safety recommendation No. 413

The Federal Office of Civil Aviation shall request the appropriate authorities to urgently implement appropriate measures to ensure the continued airworthiness of all aircraft of the type Evektor EV-97.

4.1.1.3 Safety recommendation No. 414

The Federal Office of Civil Aviation shall request the appropriate authorities to ensure that the findings identified in this investigation, specifically with regard to the dimensioning of safety-critical structural components and to quality assurance aspects, are taken into account in European regulations for comparable aircraft-categories

4.1.1.4 Safety recommendation No. 415

The Federal Office of Civil Aviation shall request the appropriate authorities (German Luftfahrt-Bundesamt LBA) to reappraise and, if necessary, amend the LTF-UL construction regulations and the licensing processes.

4.1.1.5 Safety recommendation No. 416

The Federal Office of Civil Aviation shall ensure that the LTF-UL construction regulations are amended with regards to quality assurance aspects.

Payerne, 20 October 2009 Aircraft Accident Investigation Bureau

This report contains the AAIB's conclusions on the circumstances and causes of the accident which is the subject of the investigation.

In accordance with art. 3.1 of the 9th edition of Annex 13, valid from 1 November 2001, of the Convention on International Civil Aviation of 7 December 1944 and article 24 of the Federal Air Navigation Law, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the accident investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident prevention, due consideration shall be given to this circumstance.

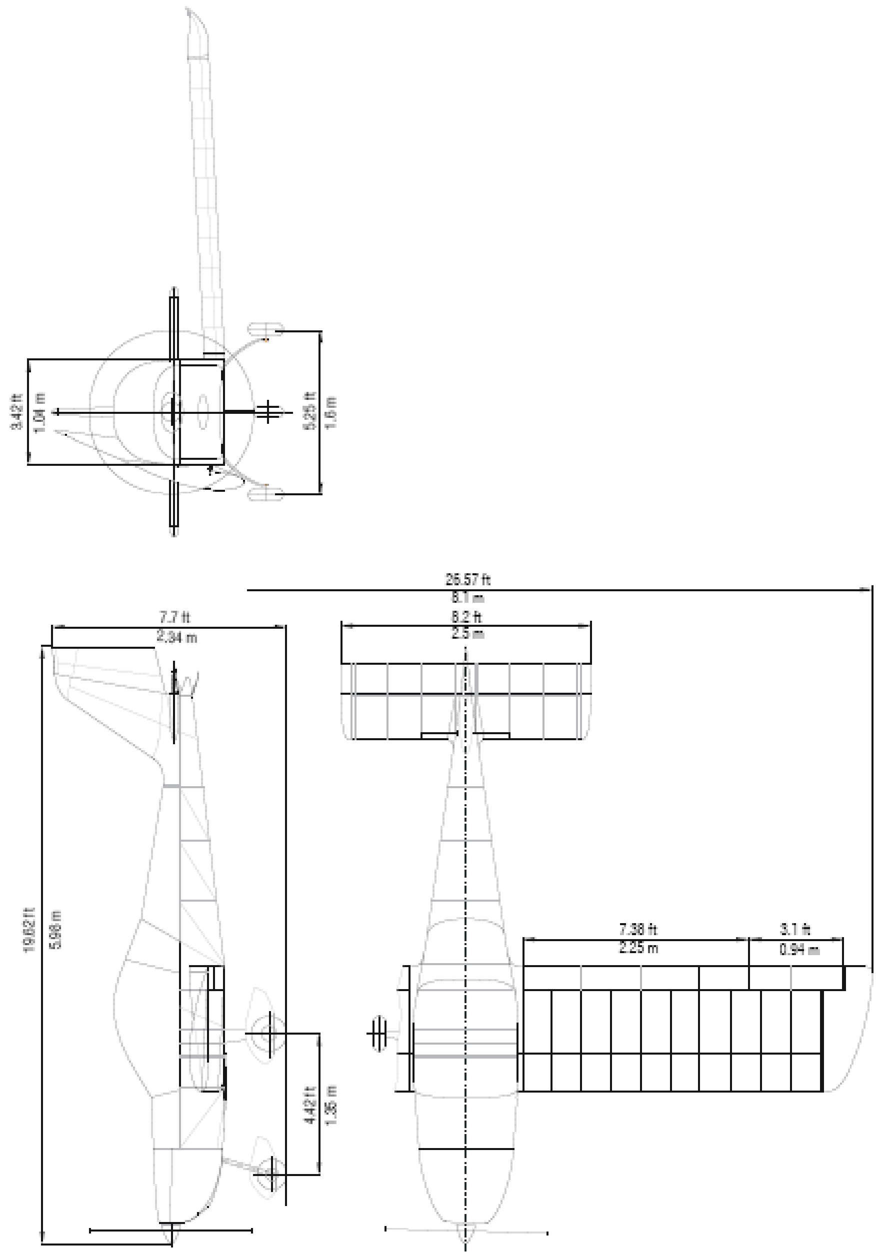
Annexes

Annex 1: Three-view drawing of the EV-97 Eurostar

AIRPLANE TECHNICAL DESCRIPTION, OPERATING, MAINTENANCE AND REPAIR MANUAL

EV-97 EURO STAR MODEL 2000 version R

2.2.2 Three-view drawing



2-4	Document No.: EV2000RNOSW	Date of Issue: 08/2005	Revision: -

Annex 2: Enlarged section from the national map, scale 1: 100 000

Grid 5 km