Investigation report

B 2/2003 L

Translation of the Finnish original report

Aircraft accident at Enontekiö on June 25, 2003

OH-CVT

Cessna A185F

Onnettomuustutkintakeskus
Centralen för undersökning av olyckor
Accident Investigation Board Finland

Osoite / Address:	Sörnäisten rantatie 33 C FIN-00580 HELSINKI	**Adress:**	Sörnäs strandväg 33 C 00580 HELSINGFORS

Puhelin / Telefon: (09) 1606 7643
Telephone: +358 9 1606 7643

Fax: (09) 1606 7811
Fax: +358 9 1606 7811

Sähköposti: onnettomuustutkinta@om.fi tai etunimi.sukunimi@om.fi
E-post: onnettomuustutkinta@om.fi eller förnamn.släktnamn@om.fi
Email: onnettomuustutkinta@om.fi or forename.surname@om.fi

Internet: www.onnettomuustutkinta.fi

Henkilöstö / Personal / Personnel:

Johtaja / Direktör / Director	Tuomo Karppinen
Hallintopäällikkö / Förvaltningsdirektör / Administrative director	Pirjo Valkama-Joutsen
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Erikoistutkija / Utredare / Aircraft accident investigator	Hannu Melaranta
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Johtava tutkija / Ledande utredare / Chief rail accident investigator	Esko Värttiö
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Johtava tutkija / Ledande utredare / Chief maritime accident investigator	Martti Heikkilä
Erikoistutkija / Utredare / Maritime accident investigator	Risto Repo

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SUMMARY

On 25 June 2003, at 12.30LT there was an accident at Lake Ounasjärvi, Hetta, Enontekiö. A float-equipped Cessna A185F aircraft, owned by Polar Lento Ltd and registered OH-CVT, collided with water during take off. The aircraft was carrying a pilot and two passengers. The pilot and the passenger in the middle row survived with minor injuries but the passenger in the front right seat drowned. The purpose of the flight was a reindeer industry flight. The pilot intended to take the passengers from Lake Ounasjärvi to Lake Kalkujärvi, approximately 40 km Northeast.

30 June 2003, The Accident Investigation Board Finland appointed an investigation commission B 2/2003 L. The investigator-in-charge was chief air accident investigator Esko Lähteenmäki and members were MSc Ville Hamalainen and airline pilot Timo Wahe. The commission nominated professor emeritus Seppo Laine and meteorologist Tapio Tourula as experts to the investigation.

The pilot started the take off towards east along the lake. The head wind was approximately three knots. The waves were approximately 10 cm high. The pilot had trimmed the longitudinal trim in such way that the aircraft lifted off by itself from the float step and continued to climb. As the aircraft was climbing at a height of approximately 15 m, it suddenly rolled and yawed to the right. The pilot used full opposite aileron and full left rudder. The counter control measures were ineffective and the aircraft collided with water at an almost right angle. The aircraft nose had yawed more than 90º to the right. The aircraft capsized but remained afloat. The passenger on the middle row right-hand seat escaped onto the float. The pilot tried to unbuckle the seatbelt of the passenger next to him but was unable to locate the buckle. Finally he had to dive to the surface. The rescuers were able to get the passenger up from the aircraft two hours after the accident.

The investigators investigated the take off procedure used and the effect of the installed Robertson STOL (R/STOL) kit on the take off performance of the aircraft. In the R/STOL kit the aileron mechanism is mechanically connected to the trailing edge flap mechanism and the ailerons, for example, turn 13° down with a flap setting of 20°. The properties of the wing and aircraft were studied with aerodynamic aerofoil and flight mechanics calculations as well as with test flights. The test flight was flown with a flow indicator wool strings attached to the aircraft fuselage, vertical stabiliser, rudder and upper right wing surface. The movements of the strings were videotaped. The test flight was flown with the same type of aircraft as the accident aircraft with a similar modification and equipment status.

The investigation commission stated that the cause of the accident was the pilot's procedure to climb above the ground effect without reducing the pitch angle. The aileron and flap connection of the R/STOL kit of the aircraft combined with the aileron type caused the right wing to tip stall in take off configuration. The pilot did not recognise the stall and did not act in the required sense to recover.

The investigation commission recommended that the appropriate authority should take measures to inform pilots as comprehensively as possible about the stall behaviour of the Robertson STOL Cessna 185 aircraft. The aircraft flight manual supplement should also contain a warning of this. The commission also recommended that the Finnish Flight Safety Authority would revise the regulations OPS M3-6 and AIR M11-2 so that all persons on board must always wear a life vest during water operations.

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SYNOPSIS

On 25 June 2003 at 12.30 LT there was an accident at Lake Ounasjärvi, Hetta, Enontekiö. A float-equipped Cessna A185F aircraft, owned by Polar Lento Ltd and registered OH-CVT, collided with water during take off. The pilot and the passenger in the middle row survived with minor injuries but the passenger in the front right seat drowned. The flight was related to the reindeer industry. The pilot intended to take the passengers from Lake Ounasjärvi to Lake Kalkujärvi, approximately 40 km northeast.

The Accident Investigation Board Finland appointed on 30 June 2003 an investigation commission B 2/2003 L. The investigator-in-charge was chief air accident investigator Esko Lähteenmäki and members were MSc Ville Hamalainen and airline pilot Timo Wahe. The commission nominated professor emeritus Seppo Laine and meteorologist Tapio Tourula as experts to the investigation.

The investigation commission performed the field investigation at Enontekiö harbour and continued investigation at Enontekiö airport where the wreckage was transferred. A flap control system guide wheel flange was sent to Technical Research Centre of Finland 14 August 2003 for a damage surface analysis. The answer was received 26 August 2003.

The investigation commission perfomed test flights to study slow speed characteristics of a similar aircraft, OH-CDO, in Inari on 2 September 2003. The test flights were continued with the same aircraft to further study the stall characteristics in Inari on 1 July 2004.

The safety recommendations were sent for the Finnish Flight Safety Authority for possible comments on 16 December 2004. The answer was received on 27 January 2005. The investigation commission rewrote the first recommendation and sent it back to the Flight Safety Authority on 9 March 2005. The answer was received on 24 March 2005. The Authority did not have any comments to the final versions of the recommendations.

The investigation report was finished on 30 March 2005 and an English translation was written.

1 FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Events before the flight

The aircraft had been flown from Lake Kilpisjärvi to Lake Ounasjärvi, Enontekiö on the previous day. The fuel load had been close to the maximum at Lake Kilpisjärvi. The aircraft stayed overnight at the dock of the Hetta fishing harbour, Enontekiö, a harbour often used by floatplanes. The pilot completed the preflight checks before the passengers arrived and he also pumped water out of the floats with a hand pump. He had weighed the baggage and loaded some of it to the cargo pack under the fuselage and the rest to the cargo area aft of the seats. A person was overseeing the loading and helped in releasing the ropes and in disconnecting the aircraft from the pier.

1.1.2 Take off and the accident

Taxiing from the pier to the take off position went normally. The pilot checked the engine during taxiing. He took off towards east along the lake. The head wind was approximately three knots and the waves were approximately 10 cm high. The aircraft ground roll was approximately 500 m out of which the last 300 m was on the float step. The pilot noticed the head wind was somewhat from the left. The pilot had trimmed the longitudinal trim in such a way that the aircraft lifted off by itself from the float step and continued to climb. The rudder trim was set almost to the extreme right position.

As the aircraft was climbing at a height of approximately 15 m, it suddenly rolled and yawed to the right. The pilot used full opposite aileron and full left rudder. The pilot told afterwards that he also put his right foot on top of his left foot in trying to help pressing the pedal.

The counter control measures were ineffective and the aircraft collided with water at an almost right angle. The aircraft nose had yawed more than 90º to the right. Based on the aircraft damage and eyewitnesses the right wing hit the water first. After that the nose and the left wing hit water. The aircraft cartwheeled and also the tail hit the water. The aircraft capsized but remained afloat. Water was approximately 30 m deep at the place of the accident.

1.1.3 Events immediately after the accident

The passenger on the middle row right-hand seat escaped from the aircraft onto the float. The pilot unbuckled his seat belt and tried to unbuckle the seat belt of the passenger next to him but was unable to locate the buckle. Finally he had to dive to the surface. There were people at the scene with boats from the nearby shore approximately three minutes after the accident. One person dived twice but was unable to get the passenger up. There were personnel from Enontekiö fire brigade on the scene approximately 20 minutes after the first unsuccessful dive. One of them had scuba diving gear but did not manage to free the passenger. The aircraft was towed towards Hetta shore but got stuck in the bottom of the lake approximately 60 m from the shore.

After another diver had arrived the drowned passenger was released and brought to the surface. This happened two hours after the accident. The passenger was transported to the shore where a doctor pronounced him dead. The pilot's injuries were a cut to his face and bruises around the body. The surviving passenger received slight bruises to his head and body.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	-	1	-
Serious	-	-	-
Minor/None	1	1	-

1.3 Damage to aircraft

Aircraft was destroyed.

1.4 Other damage

Approximately 170 l aircraft fuel and 10 l of engine oil spilled on the lake.

1.5 Personnel information

Pilot: Male, 54 years

License: CPL(A), valid until 15 February 2005

Ratings: Single Engine Piston (land and sea)

Medical Certificate class 1, valid until 15 August 2003

Flight experience	*Last 24 hours*	*Last 30 days*	*Last 90 days*	*Total experience*
All types	2 h 5 min 6 flights	25 h 15 min 54 flights	54 h 20 min 196 flights	2939 h 50 min 8125 flights
Type Concerned	2 h 5 min 6 flights	21h 10 min 51 flights	47 h 40 min 128 flights	357 h 10 min 1113 flights

The pilot had flown floatplanes 2176 hours, most of which on a Cessna 180 type aircraft.

1.6 Aircraft information

1.6.1 Basic information

Cessna A185F is a single piston engine equipped six-person all metal high wing construction. The aircraft had EDO 582-3430 floats, cargo pack and Robertson STOL kit (R/STOL, short take off and landing).

Aircraft:

Type:	Cessna A185F
Registration:	OH-CVT
Registration number:	1498
Manufacturer:	Cessna Aircraft Co, USA
Serial Number:	18502977
Year of manufacture:	1976
Certificate of airworthiness:	valid until 31 March 2004
MTOW:	1520 kg
Owner:	Polar-Lento Ltd
Operator:	Ivalon Lentopalvelu Ltd
Total hours of airframe:	4276 h

Engine:

Type:	Continental IO-520-D
Serial number:	293389-R
Manufacturer:	Teledyne Continental Motors
Total hours since overhaul:	1369 h
Fuel:	aviation gasoline 100 LL

Propeller:

Type:	Hartzell PHC-C3Y F-1FR/F8468A-6R 3-blade constant speed propeller

1.6.2 Certificate of airworthiness

Certificate of registration had been dated on 29 January 1991. Certificate of airworthiness was valid until 31 March 2004.

1.6.3 Weight and centre of gravity

The aircraft weight was approximately 1460 kg. Maximum take off weight was 1520 kg. The centre of gravity was within its limits, close to the forward limit.

1.7 Meteorological information

The closest weather station was at the Enontekio airport, approximately 10 km to the west from the accident site. The automatic METAR reports of the station reported:

At 12.20: wind 010°, 8 kt, variable between 340°-070°, visibility over 10 km, clouds 3-4/8 4400 ft and 5-7/8 7500 ft, temperature 17°C, dew point 7°C, QNH 1012 hPa.

At 12.50: wind 170°, 5 kt, variable between 130°-210°, CAVOK, temperature 17°C, dew point 6°C, QNH 1012 hPa.

The following wind data was also recorded by the station at Enontekio airport:

TIME	Average direction (10 minutes)	Average speed (10 minutes)	Maximum speed (1 minutes)	Minimum speed (1 minutes)
12.00	20°	3 kt	7 kt	0 kt
12.10	10°	5 kt	12 kt	1 kt
12.20	10°	8 kt	12 kt	4 kt
12.30	20°	5 kt	11 kt	0 kt
12.40	160°	3 kt	7 kt	0 kt
12.50	170°	5 kt	7 kt	2 kt
13.00	160°	5 kt	8 kt	3 kt

According to the weather radar and satellite data received from Finnish Meteorological Institute there were occasional cumulonimbus clouds around Northeast Lapland. The closest clouds were 10 km to the west and south of the accident site at 12 o'clock. The western cloud was disappearing and had moved 5 km closer to the accident site at 12.30 o'clock. The second cloud south of the accident site had moved south and was 12-15 km from it at 12.30 o'clock. The weather at the accident site corresponded to the weather at the Enontekio airport at the time of the accident.

There was no TAF (Terminal Area Forecast) at Enontekio airport, but the GAFOR (General Aviation Forecast) reported:

GAFOR, Areas 30-39 valid 06.00-15.00 local time

Weather: Light winds, occasional CB clouds, showers and possibly thunder

Wind forecast:

Surface	Variable 2-6 kt
2000 ft	Variable 5-10 kt
5000 ft	Variable 5-10 kt

Freezing level FL 060-070.

Occasional moderate icing and turbulence associated with CB

GAFOR EFRO valid 16.00-12.00 local time, areas 30-32 O, areas 33-39 O occasional D, showers, probability 30% at 12.00-15.00 local time, thunder showers.

1.8 Aids to navigation

Navigation aids had no effect on the accident.

1.9 Communications

There were no communications during the take off.

1.10 Aerodrome information

Lake Ounasjärvi in Enontekiö county was used as an aerodrome. The lake is approximately 11 km long and 750 m wide at the accident site. The direction of the lake is 070°-250°. The take off was to the easterly direction. The elevation of the lake is 287 m (942 feet).

1.11 Flight recorders

There were no flight data or cockpit voice recorders, nor are they required in this type of aircraft.

1.12 Wreckage and impact information

1.12.1 Accident place

Refer to chapter 1.10 Aerodrome. The co-ordinates of the place of the accident were 68° 23.2’ N 023° 40.5’ E.

1.12.2 Inspection of the wreckage

The wreckage was towed from the middle of the lake to the Hetta shore on the day of the accident. It had stuck to the bottom of the lake approximately 60 m before the shore and had been secured with ropes and surrounded with an oil barrier. The next day three large rubber tubes were attached to the floats to make sure the wreckage would not sink to the bottom during tow. Then it was towed to the harbour. It got stuck to the bottom approximately 10 m before the pier. A truck with a lifting arm was on the pier but because of the shortness of the arm the wreckage had to be dragged along the bottom for a short distance until it was lifted ashore.

The detailed inspection was performed ashore. The left door and both wing tips were not recovered.

The right wing was in its original shape. Only the right wing tip leading edge was dented and the tip was missing. The flap was extended 20°. The left wing was torn off from its attaching points and was bent all along. The wing came loose while the wreckage was lifted on ground. The flap was torn off and aileron was broken in two in the middle where the moving mechanism was attached. The fuselage was bent behind the cabin. Left elevator was damaged and the rivets of the torque tube were broken. Left side of the tail cone was dented. The upper part of the rudder was damaged and bent downwards. All four engine mounting points were broken and engine was loose. It broke off completely when the aircraft was lifted on ground. Left side of the engine oil reservoir was broken open and there were markings from an engine mounting point. The engine cover sheets were still attached to the engine.

Figure 1. The aircraft sustained extensive damage when hitting the water surface.

1.13 Medical and pathological information

A clinical autopsy was performed to the fatally injured passenger. The cause of death was drowning.

A blood sample from the pilot was also taken soon after the accident. It contained no alcohol.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Rescue activity

The accident had several eyewitnesses. The Lapland rescue centre received the first notification of an accident at 12.32 o'clock. The passenger on the right hand seat of the middle row escaped the wreckage through the left door opening as soon as the aircraft had capsized. The pilot opened his seat belt and tried to open the seat belt of the passenger sitting next to him but was unable to find it. Finally he had to dive to the surface. There were three boats at the accident site approximately three minutes after the accident. A man dived twice to the wreckage. He was able to reach the hand of the lifeless passenger but was unable to get him out of the cabin. It had then been approximately five minutes since the accident.

Enontekio fire brigade, medical transport and fire chief received the alarm at 12.34 o'clock. Two firemen left immediately for the accident scene and had a boat on a trailer with them. They arrived at the scene approximately 10 minutes later. One of them put on a diving suit and snorkel. He was unable to free the passenger. Another, more experienced diver, arrived the scene approximately an hour later. He was able to open the passenger seat beat, which had been tangled around the right angle of the passenger. The passenger was then pronounced dead by a doctor on the shore.

1.15.2 Survivability

Based on aircraft damage and eyewitness reports the collision with water was hard. The right wing tip hit the water first, aircraft cartwheeled and right wing hit the water. Also empennage hit the water as cartwheeling continued. Most injuries of the pilot and passenger were on the left side of their bodies. The fatally injured passenger had bent the flap lever to the left.

The passenger on the middle row, a 14-year-old boy, was a keen swimmer and diver and was able to dive out of the wreckage. He told the underwater visibility was limited but he was able to see the surface through the left door opening.

The pilot told he tried to open the seatbelt of the passenger but was unable to find the buckle. The passenger showed no life signs during his attempts. Finally the pilot had to dive to the surface.

The front seats were equipped with shoulder harnesses but neither person wore them. The fatally injured passenger had a bruise in his face, probably from hitting his face to the instrument panel. Wearing the shoulder harness could have prevented this from happening. The life vests were not used either. Wearing a life vest would not have prevented the passenger from drowning because his seat belt was not opened soon enough.

When a floatplane capsizes it will float on its floats upside down. Cessna 185 cabin roof remains at a depth of two metres. It is quite possible to exit the aircraft as soon as seatbelt and door are opened. The cabin was filled with water immediately in this accident because left door and windshield were torn off from the fuselage in impact. The water temperature was 8-10 °C.

The passenger told that the pilot did not give any safety briefing before take-off. The pilot told he gave the briefing including how to use the life vests, seat belts and doors.

1.16 Test and research

1.16.1 Control system inspection

The technical inspection focused on the control systems. The left wing had sustained extensive damage and the attachment points to the fuselage were broken. The wing was attached to the fuselage only by the aileron cables and by one of the flap cables. The other flap cable was broken. The flap had come loose when the flap rails were torn off. The aileron was damaged by still in its place.

The right wing was attached and relatively intact. The flap was 20° down and aileron in its place. The flap control lever in the cockpit was set 20°.

Before the fuselage and right wing were lifted ashore the left wing cables were cut and the wing lifted ashore separately.

Each part of the control system was inspected separately starting from controls and ending to the control surface.

Aileron control system

The left yoke was intact and the right yoke was missing. The chain connecting the two yokes and control cable were intact and properly secured. Left wing cable and interconnecting cable had been cut during the lifting of the wreckage ashore. The cable to the right aileron was intact and properly secured. Right aileron still moved when turning the yoke.

Left aileron cable ends to the aileron were intact and properly secured.

Elevator control system

Elevator control cables were intact and properly secured. They were loose due to the bent empennage. The movement of the yoke was still transferred to the elevator. The left elevator had been damaged and disconnected due to the rivet shear on the torque tube. The right elevator was intact and moved. All hinges were intact.

Elevator trim system

The elevator trim system position indicator showed neutral. Control cables were loose due to the bent empennage. The control chain was intact. The aircraft has a trimmable variable incidence tailplane. The tailplane was in the neutral position.

Rudder control system

Both right and left rudder pedals were intact. It would have been possible to remove the right side pedals before the flight but they had been left in place. Pilot side left pedal movement was limited due to the bent firewall. The control cables were loose due to the bent empennage. The cable movement was transferred to the rudder. The right hand cable had turned around the spring mechanism system axle after the empennage bent and cables became loose.

Rudder trim system

The rudder trim was 1/3 turn from the extreme right position. Trim mechanism was intact. The rudder trim system consisted of a spring attached to the rudder pedals.

1.16.2 Trailing edge flap system

The flap control lever was selected to 20° and had been bent slightly to the left. The locking mechanism of the lever operated in all positions. One of the left flap cables was broken in the accident and the other was cut during lifting of the wreckage ashore. The guide wheels were intact and in place. The flap had broken off from the wing alltogether with its rails. The flap moving mechanism was broken due to excessive bending forces. The connecting rods of the STOL-system between flap and aileron were intact.

The right flap cables and guide wheels were intact and in place. The connecting rods of the STOL-system between flap and aileron were intact. The right flap operated normally when the selection lever was moved. Also the aileron moved normally in unison.

1.16.3 Engine mountings and propeller

All four engine cast aluminium mounting legs were broken. Left side of the oil reservoir was broken and had damage marks from a mounting leg. There were no fatigue signs visible in the fracture surfaces.

One propeller blade was bent slightly forward and the other two blades were intact. There was a dent in the spinner.

1.16.4 Flap control system guide wheel investigation

When the right wing was unfastened from fuselage for transporting purposes, large forces were needed. During this a flap control system guide wheel was torn off. The investigation commission sent the wheel to Technical Research Centre of Finland for inspection of fatigue damage. The Research Centre concluded that the damage was not due to fatigue.

1.16.5 Slow flight characteristics test in Inari 2 September 2003

The investigation commission flew a test flight with a Cessna A185E, registered OH-CDO, to study its slow flight characteristics. The aircraft was equipped similarly to the accident aircraft; Robertson STOL, EDO floats, cargo pack under fuselage and three-blade propeller. The aerofoil shape of the two aircraft differed slightly because OH-CDO wing leading edge shape had been modified with the STOL kit. In the accident aircraft, OH-CVT, Cessna A185F, the corresponding wing leading edge shape had been manufactured at the factory. Also the floats were not exactly alike.

The air temperature was 9 ºC, QNH 1005 hPa, wind 180º and 5 knots. The aircraft TOW was approximately 50 kg less than MTOW.

Table1. Results of the test flight of 2 September 2003.

Configuration and power setting	***At-tempt***	***Stall warning KIAS***	***Stall speed KIAS***	***AFM data KIAS***
Clean stall, power idle				
Rolled to the right. Altitude loss approximately 400 ft.	5	71	51	61 **Floats**
Clean stall, approach power				
2500 rpm / 15 inHg. Rolled to the right.	2	71	45	
Clean stall, max power				
2500 rpm / 25 inHg. Pitch down followed by buffet, aileron effectiveness not lost.	2	61	38	
Flap 20º stall, power idle				
Slow roll to the right.	1	59	39	50
Flap 20º stall, approach power				
2500 rpm/ 15 inHg. Rolled to the right. Aileron effectiveness partially lost.	2	59	37	
Flap 20º stall, max power				
2500 rpm / 25 in Hg. Started decending, aileron effectiveness not lost. Rolled to the right slightly.	2	61	30	
Clean turning stall, approach power				
2500 rpm / 15 inHg / 15º bank Rolled rapidly to the right. Did not straighten before enough speed. Aileron effectiveness completely lost.	1	70	48	
Flap 20º turning stall, approach power				
2500 rpm / 15 inHg. As above in clean configuration. Altitude loss approximately 300-400 ft.	1	70	39	
Flap 20º turning stall, max power				
2500 rpm / 25 inHg. Small pitch down regained control effectiveness.	1	57	35	

The accident scenario when the aircraft was taking off was then simulated at 3000 ft. First idle power was set and altitude maintained, letting the airspeed reduce. When the airspeed was approximately 48 kt maximum power was applied and nose pitched up approximately 10º. This increased angle of attack at first 10º. This caused the right wing to stall violently and the aircraft rolled and yawed to the right. This happened at 55 kt. The aircraft was recovered using normal procedure with an altitude loss of 150-200 ft. The stall warning horn could be heard all this time. The simulation was repeated with same results.

After this the simulation was repeated several time but the violent right wing stall did not occur. It was also tried with a sideslip in both ways with the slip indicator ball approximately its width off centre.

Also a take-off and landing were attempted with a focus to the operation of the stall warning. The horn did not sound during take-off. The pitch angle was reduced immediately after lift off and flap angle reduced to 10º. As the speed increased to 70 kt the flap angle was reduced to zero.

On 9 September 2004, a test flight was flown to check the air speed indicator of OH-CDO. The indicated air speed was compared to GPS ground speed. The flight was flown in opposite directions so that the wind could be calculated. The resulting true air speed was reduced to sea level using international standard atmosphere. This speed was called equivalent air speed, and can be considered calibrated air speed as well. Figure 2 presents the calibrated air speed as a function of the indicated air speed.

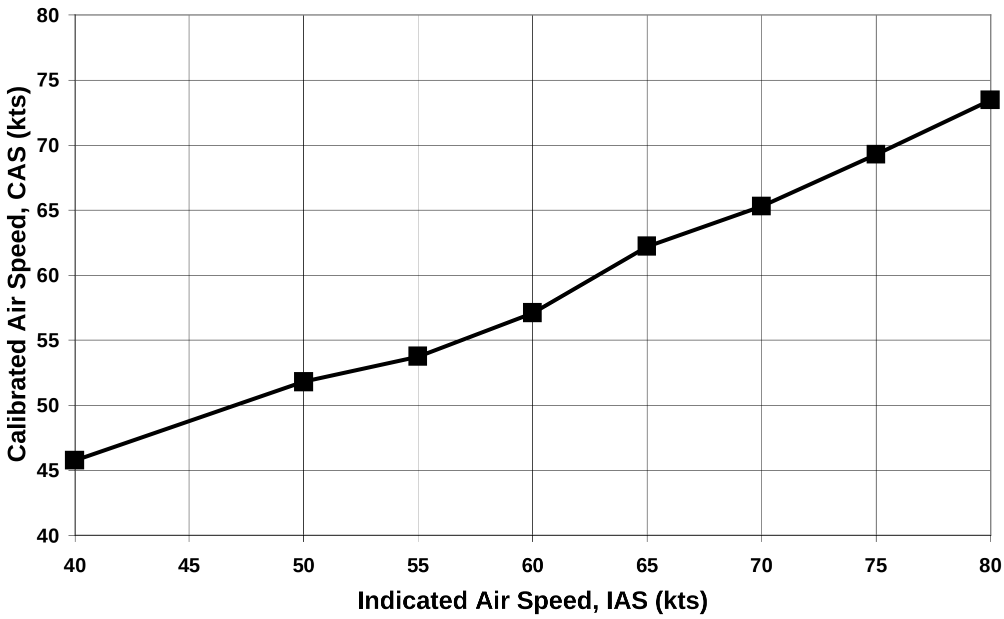

Figure 2. Calibrated air speed of OH-CDO as a function of indicated air speed

1.16.6 Theoretical calculations

Aerofoil lift and drag coeifficients

The idea was to study the aerofoil aerodynamics and to determine if a wing tip stall could cause the sudden roll and yaw of a Cessna A185F.

Calculations were made for:

1) Is the Cessna A185F aerofoil lift sensitive to
   a) small changes of the angle of attack near the stall (is the loss of lift sudden)
   b) movement of the boundary layer transition point
2) How the aerofoil lift and drag coefficients vary when the aileron angle is changed near stall.

The calculations were made using a panel method developed by Doctor of Science Risto Peltonen[1]. The method includes a boundary layer correction algorithm, which changes the pressure and friction coeifficients accordingly.

The aerofoil aerodynamics was calculated using the aerofoil station in the middle of the aileron. This was considered to be the best aerofoil to study the possibility of a tip stall. The aileron angle is 13° in the STOL take off configuration. The aileron hinge is on the wing upper surface and turning the aileron down creates a sharp corner on the surface. This could cause the upper surface boundary layer to separate at the hinge line causing the lift coefficient and aileron effectiveness to reduce. The hinge line is approximately at the 84 % chord measured from the leading edge.

Four cases were considered : Aileron angles 0°, 13°, 18° and 23°. The aerofoil Reynolds number had been approximately 2.7 million in the accident. Thus the calculations were made using Reynolds numbers of 2.0, 2.5 and 3.0 million. Also the amount of laminar flow causes slight variations to the aerodynamic behaviour. Laminar boundary layer separates more easily at a high angle of attack than turbulent boundary layer. Thus three cases were calculated: 1) natural transition (smooth surface), 2) upper surface transition fixed at 1 % chord, lower surface transition natural, 3) upper surface transition fixed at 1 % chord and lower surface transition fixed at 20 % chord. In practice the transition point varies according to the surface smoothness (manufacturing, dirt). All surface roughness moves the transition point forward.

Flight mechanics

Flight mechanics was used to study the aircraft behaviour when there is a rolling and yawing moment caused by right wing tip or whole right wing stall. Also vertical stabilizer

[1] Peltonen, Risto, A Numerical Method for Analysis and Design of Airfoils in Subsonic Flow, Helsinki University of Technology, Laboratory of Aerodynamics, Report A-20, 2000.

stall or loss of effectiveness was considered. (The vertical stabilizer can lose effectiveness due to wing wake or under fuselage due to cargo pack wake.)

A Cessna 182 aircraft was used because it was easier to find data for it[2]. There are some differences in the geometry between the C182 and the C185 but the general results of the calculations can be considered valid also for the C185. The effect of the floats and the cargo pack was not included in the calculations. The goal was to find out the movement resulting from the right wing stall and/or vertical stabilizer stall (or loss of effectiveness). Both, right wing complete and partial (tip) stall, were considered. The vertical stabilizer contribution to the stability derivatives was estimated[3].

The aircraft movement was estimated by integrating three equations: force equation sideways (side force, y-axle), moment equation around the longitudinal axis (roll, x-axle) and moment equation around the normal axis (yaw, z-axle). The results were aircraft side motion, bank angle and heading. The rudder and ailerons were kept neutral in the calculations. The aircraft speed and altitude were assumed to remain constant. Thus the results are valid only for a short period after the initiation of the movement, less than 5 s. However, the results give reasonably accurate initial roll and yaw rates.

Flight tests

Flight test were conducted:

- to find a situation where a sudden stall leading to wing drop is initiated.
- to find out where the stall begins (chordwise and spanwise).

Also it was intended to find proof:

- if the airflow separates from the upper surface of the aileron at speeds faster than the stall speed.
- if the airflow remains attached to the vertical stabilizer in all cases.
- if the airflow remains attached to the cargo pack and whether it causes wake that reduces the effectiveness of the fin.
- of the speed at which the sudden movement begins.

The aircraft right wing, flap and aileron upper surface and both sides of empennage, fin and cargo pack were covered with hundreds of 90 mm long wool threads for visualization. The thread movements were filmed on flight with five video cameras. Two cameras were attached to each wing strut and one on top of the fin. It was possible to understand the airflow direction and turbulence from the movement of the threads. There was also a

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[2] Roskam, Jan, Airplane Flight Dynamics and Automatic Flight Control, Part I, DARcorporation, 1995.

[3] Etkin, Bernhard, Dynamics of Flight, John Wiley & Sons, 1959.

sixth camera attached to the cabin roof filming the instrument panel and horizon as well as recording the cabin sounds.

Figure 3. Aircraft fuselage, empennage and right wing upper surface were covered with wool threads for visualization. Five cameras were used to film their movement.

1.16.7 Maintenance history of the aircraft

The aircraft had been damaged at the Enontekio airport in spring 2003 as a hangar roof collapsed during a storm. Upper wing surfaces, ailerons and flaps were, among other damages, dented and damaged. The aircraft had been flown to Rovaniemi airport for repairs. The damage had been repaired, flap system rails modified (SB 95-3) and right aileron cable and aileron connecting cable changed due to excessive wear. Also the windshield and wing tips had been changed. The wings had been painted and cabin roof lining had been changed. Scheduled 50 h maintenance had been completed and the floats installed.

The aircraft had had a rolling tendency already before the damage and had been uncomfortable to fly due to lack of aileron trim. This was due to the incorrect right wing geometric twist (washout) which was probably the result of a damage repair made earlier in the USA. During the right wing repair in Rovaniemi also the geometric twist was corrected to remove the rolling tendency. The work was done in accordance with the Cessna Maintenance Manual and with the Cessna wing jig. The maintenance organisation considered the repair to be so minor that it did not apply Flight Safety Authority acceptance for it (ref. Finnish air regulation AIR M2-1, 15 February 1996, section 5). The maintenance organisation did not do any formal certificate of airworthiness check or inspection (ref. Finnish air regulation AIR M16-1-, 15 February 1996, section 5). After the repair the rear spar asymmetric attachment bushings had been set to give wings maximum angle of incidence.

The repair and maintenance activities were finished on 20 June 2003 after which the engine was ran up and a test flight flown. These were perfomed by the same pilot who was involved in the accident. The engine run up and test flight documents were properly marked except that in the "level flight" part of the test flight document the following markings were missing: "stall speed clean ___ kias", "stall speed landing configuration ___ kias" and "stall warning ___ kias". The first two had been marked with a line "-" and the last with the word "OK". The maintenance company had given the aircraft a certificate of release to service after this.

According to the run up and test flight documents everything had operated normally. The pilot told the earlier rolling tendency had diminished due to the adjustment of the geometric twist. All together, the aircraft had flown 59 flights after the maintenance before the accident. From these flights there were no defects written in the technical log.

The investigation commission reviewed a document "Airworthiness checklist, test flight with floats" done 18 June 1999 by another pilot. The document was complete including stalls at 2000 ft. The clean stall warning was triggered at 64 kias and the aircraft stalled at 56 kias. The landing configuration stall warning was triggered at 58 kias and the aircraft stalled at 48 kias. The stalls were made with idle power.

1.17 Organizational and management information

The accident aircraft and pilot had originally been operating under Finnish air operator certificate of Polar-Lento Ltd. The Finnish Flight Safety Authority had not approved the maintenance manager of the company and had cancelled the certificate on 30 April 2003. After this the company applied the aircraft to be added to the certificate of Ivalon Lentopalvelu Ltd. The contract was written so that Polar-Lento Ltd would cover all fixed and variable expenses of the aircraft. Ivalon Lentopalvelu Ltd committed to operational responsibility. The Authority added the aircraft to the certificate of Ivalon Lentopalvelu on 2 May 2003.

The travel documents for the accident flight had been written under the name of Ivalon Lentopalvelu Ltd.

1.18 Additional information

1.18.1 Robertson STOL kit

The aircraft was equipped with Robertson STOL kit used to reduce the stall speed. The kit includes a connection between the trailing edge flaps and ailerons. Thus the ailerons turn downwards with the flaps and the aileron neutral setting changes with the flap setting (table 2). The kit also includes boundary layer fences on the wing upper surface.

Table 2. The flap and aileron angles with and without the R/STOL kit.

Flap angle	**Aileron neutral angle (STOL)**	**Aileron deflection angles (STOL)**		**Aileron deflection angles (standard)**	
	± 2 º	**Down**	**Up**	**Down**	**Up**
		± 2 º		**± 2 º**	
0 º	0 º	14 º	20 º	14 º	20 º
10 º	8 º	21 º	11 º	-”-	-”-
20 º	13 º	25 º	6 º	-”-	-”-
30 º	15 º	26 º	4 º	-”-	-”-
40 º	12.5 º	24 º	6 º	-”-	-”-

1.18.2 Previous Cessna 185 accidents

The investigation commission studied 479 of Cessna 185 aircraft accidents in the National Transportation Safety Bureau’s data base. It was not possible to know exactly how many accidents involved a R/STOL kit. A few accidents could have been attributed to the reasons discussed in this report but the probable cause was simply put “not enough air speed” and no test flight had possibly been flown.

1.19 Useful or effective investigation techniques

There were no new investigation methods.

2 ANALYSIS

2.1 Take off and loss of control

The pilot taxied to the middle of the lake. The wind was easterly along the lake. The pilot told in the interview, that the take off went normally. He told, that the aircraft lifted to the float step "easily quite fast and I let it lift off by itself. It was well trimmed and it lifted off normally by itself". The pilot estimated that at an altitude of 10 m the aircraft suddenly rolled and yawed to the right. After this he tried to stop the movement by using full opposite aileron and rudder. He told the aircraft was gaining altitude and speed at this time. The pilot tried to stop the roll and the yaw and to continue take off. He did not consider aborting the take off or lowering the nose. The aircraft continued to roll and yaw and the nose dropped. The pilot held the yoke with two hands but did not remember whether he pushed or pulled.

The pilot did not know the speed at which the aircraft lifted off but he estimated that it is normally around 55 kt. He did not have any observations of the speed during the initial climb either. During the interviews with the pilot he never considered even possible the fact that the aircraft could have stalled.

When analysing the take off technique it is worth noting that the pilot did let the aircraft lift off and continue climb by itself. He did not try lowering the nose to gain airspeed or do any other active control.

A float equipped aircraft pitch angle needs to be reduced after lift off because otherwise the pitch angle increases by itself. This is caused by two factors. First, when the friction between floats and water disappears, an unbalanced pitch up moment remains. This moment depends on the float type. Secondly, when the aircraft climbs the ground effect reduces. This causes the downwash behind the wing to increase, the horizontal stabiliser angle of attack to change and the download on the stabiliser to increase. Thus there is also a pitch up moment. Both factors pitch the aircraft nose up unless the flight path is actively controlled by the elevator. It the aircraft is let to fly "by itself" there is a risk of exceeding the stall angle of attack. The pitch angle, flight path angle and angle of attack are presented in the figure 4. It must be noted that the angles change all the time but the pitch angle is always the sum of the flight path angle and angle of attack.

During take off it is also worth noting that the aircraft induced drag is less in the ground effect. Thus the aircraft accelerates easier close to ground or water.

Previous points clarify the need to positively control the aircraft during take off and initial climb to gain airspeed and not to exceed the critical angle of attack. The most important instrument during take off is the air speed indicator and a pilot should have an idea of the airspeed all the time during this critical phase of flight.

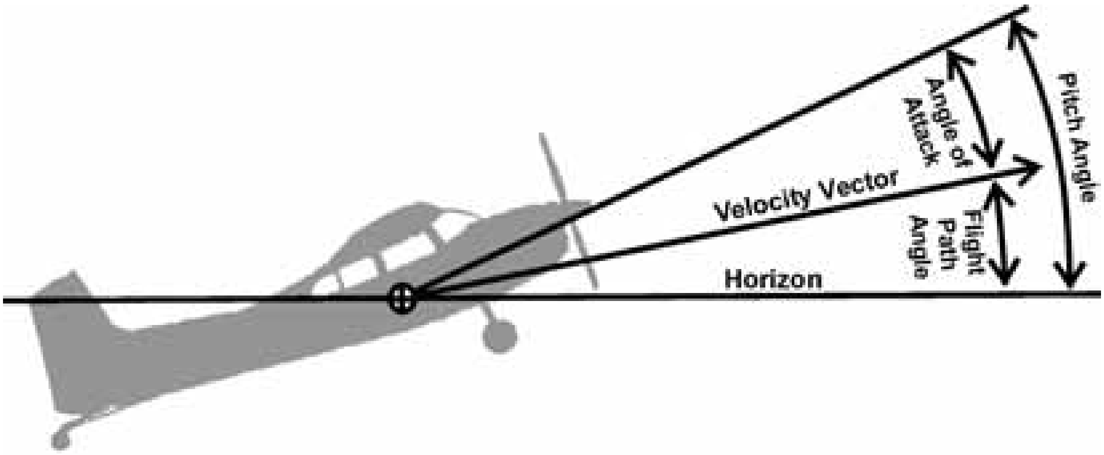

Figure 4. Presentation of the pitch angle, flight path angle and angle of attack. The velocity vector coincides with the flight path angle.

2.2 Pilot’s flight experience

The pilot obtained a private pilot’s license in summer 1988 and a commercial pilot’s license in 1991. After this he bought an aircraft of his own and started flying commercial flight in North-East Lapland. Most flights he flew with Cessna 180 aircraft equipped with floats in summer and skis in winter. Cessna 180 wings and fuselage are quite similar to Cessna 185 but the engine is less powerful.

Total flight time of the pilot was 2940 hours and the number of take offs and landings was 8125. The take off and landing count is exceptionally high when compared to the time because the flight time of a normal flight is relatively short. His float experience was 2176 hours. The flights in North-East Lapland are mostly reindeer industry or tourist taxy flights. Most flights have been to the lakes around the area. The home bases of the pilot have been Lake Ounasjarvi and Lake Kilpisjarvi.

Flight operations in the wilderness are difficult due to rapidly changing weather conditions. The take offs are usually conducted with TOW close to MTOW. The pilot had had no previous incidents or accidents.

Even though the pilot was quite experienced he had not practised stalls on Cessna 185. When flying the test flight after the last repair and maintenance he did not stall, either. Practising would have been important because there had been significant repairs to the wings, the right wing geometric twist had been changed and the angle of incidence of the wings had been changed. Information about stall speeds would have also helped the investigation. The pilot had no knowledge of the stall behaviour of the Cessna 185. His opinion was that the aircraft does not stall. It was possible to draw a conclusion from his interview that he was afraid to stall the aircraft. The opinion of the investigation commission is that every pilot has to know the slow speed and stall characteristics of his aircraft. Thus the pilot has to perform stalls at least during the check flights. According to the check flight documents the pilot had done stalls but the flights had not been flown with the Cessna 185.

2.3 Weather factors

Wind velocity changes can affect aircraft air speed in many ways. Usually airflow is turbulent where the speed and direction of the flow vary around their average values. The average velocity can also be zero and turbulence cause gusts in different directions. The turbulent vortices, gusts, are three-dimensional. When the accident day weather is analysed together with the local geographic features (terrain, orography, lakes) conclusions can be made about the probability of the maximum speed of a single gust.

One typical weather phenomenon in Lapland, mountain waves and associated turbulence, can be ruled out as extremely improbable. According to the upper wind charts and weather sounding data the winds were very light, approximately 10 kt, up to FL240. Such a weak base flow is incapable of causing mountain waves and associated weather phenomena.

The base flow was from North around the time of the accident. The accident site is behind the hill Jyppyrä (height 330 ft from lake surface) on the northern coast of Lake Ounasjärvi. Such a geographic feature causes turbulence behind it. The wind velocity is the main factor and the turbulence weakens as the distance grows from the hill. As the base flow was quite weak it can be assumed that the vortices the hill caused were weak at the accident site.

The weather data from Hetta and Kittila indicates that the wind was gusty as a result of the convective activity. Convection causes air to ascend and descend causing surface gusts. According to Hetta data, these gusts were 2-7 kt stronger than the base wind. This kind of gust strength is typical for a summer day. According to Sodankylä weather sounding the air mass was unstable and quite moist. This made it possible for the cumulonimbus cloud to form. There are also convective gusts above water surfaces but the water, being colder than the air, reduces the gust velocity.

The weather data from Hetta indicates that the base flow turned southerly approximately at the time of the accident. Also eyewitnesses confirmed this saying the change occurred after the accident. Other weather stations in Lapland did not register the base flow direction change. The wind probably changed as a result of the thunderstorm activity, when a downdraft turned outflow on the surface. The outflow boundary can move several dozens of kilometres away from the thunderstorm cell, weakening all the time, and it can last several hours. This happens especially when the base flow is weak. The satellite and radar images showed thunderstorm cells south of Hetta and it is possible that an outflow boundary was created and it changed the wind direction to southernly.

Strong outflow boundaries are associated with heavy turbulence. The eyewitnesses did not mention such and none was registered by Hetta weather station either. This makes it improbable that a strong outflow was present.

The wind direction also changes during climb due to wind shear, change of wind direction and/or strength vertically. In this case the base flow was weak all along the troposphere. The vertical temperature gradient made the air mass neutral or instable and an inversion-based wind shear is thus very improbable.

In conclusion it can be stated that the accident happened in normal weather conditions with a weak base flow and occasional convection gusts. It was also typical that the gusts overcame the base flow and wind direction varied.

It can be stated, based on the weather analysis, that Enontekiö airport weather data correlated well with the accident site conditions and the weather was not a factor in the accident. The weather conditions were actually better than the average Lapland weather.

2.4 Test flight after the maintenance of the aircraft

The repairs made to the aircraft wings and the change of the angle of incidence could have changed the slow flight characteristics of the aircraft. These possible changes should have been verified during the test flight. Finnish air regulation AIR M1-5 states in paragraph 4.6.1: *"After aircraft maintenance all systems worked on must be tested so that their correct operational condition is verified. This may require a test flight."*

The investigation commission has the opinion that the repairs were major (ref. Finnish air regulation AIR M2-1 section 5) and a test flight was mandatory. The Flight Safety Authority should also have inspected the certificate of airworthiness after the repair in accordance with the Finnish air regulation AIR M16-1 section 5.

In this case the most important part of the test flight would have been to verify the slow flight and stall characteristics. They were not verified and thus the maintenance organisation should not have given the aircraft certificate of release to service.

After the repair the rear spar asymmetric attachment bushings had been set to give the wings maximum angle of incidence. The bushings change the angle of incidence of the wings approximately 0.2 degrees, which does not, in the opinion of the investigation commission, significantly change the slow flight characteristics of the aircraft.

2.5 Flight characteristics of the Robertson STOL –aircraft

The test flight on 2 September 2003 proved that the R/STOL kit reduces the stall speed of the Cessna 185E. Thus the margin between the stall warning and stall speed is greater than in a normal Cessna 185.

The directional stability of the test flight aircraft was inadequate. This is typical for all Cessna 185 aircraft with floats and cargo pack. The aircraft tend to sideslip and active rudder control is needed to keep a zero sideslip angle. The aircraft also tend to roll to the right when stalled.

R/STOL aircraft has a slower aileron response than the standard aircraft when the trailing edge flaps are down. Several R/STOL Cessna 185 pilots have mentioned this fact. The video recording from the test flight in summer 2004 pointed out that the flow separated from the upper aileron surface when the aileron angle was 13 degrees downwards. This phenomenon also causes the sluggish aileron response.

The aircraft can also be equipped with another STOL kit, Horton STOL, which a quite similar to R/STOL but does not have the interconnection between the flaps and the ailerons.

The aircraft had been extensively modified; it had been equipped with floats, under fuselage cargo pack, R/STOL kit and three-blade propeller. All of these, excluding the cargo pack, had a Supplement Type Certificate. There were no documents about the combined effect of the modifications. Thus the aircraft did not have a flight manual supplement specifying the take-off procedure or speeds.

This lack of operating flight manual supplement is common to many general aviation aircraft that have undergone several modifications.

2.6 Results of the aerofoil calculations

2.6.1 Aileron neutral

The airflow stays attached to the aerofoil upper surface from the zero lift angle of attack to an angle of attack of 8 or 9 degrees. Larger angles cause the airflow to separate from the upper surface before the trailing edge. Fixing the transition point does not alter significantly the stall behaviour or the c_{lmax}. The c_{lmax} is reduced from 1.6 to 1.56 at a Reynolds number $3\cdot10^6$. Reynolds numbers $2.5\cdot10^6$ and $3\cdot10^6$ give a stall angle of attack of α_s = 15 -16 degrees and c_{lmax} = 1.58 –1.6 using natural transition. When the transition was fixed on the upper surface or both surfaces the corresponding values were α_s = 14 - 15 degrees and c_{lmax} = 1.52 – 1.56. Thus the stall characteristics are not altered by the cleanness of the wing.

2.6.2 Aileron angles 13 and 18 degrees

Aileron angle 13 degrees. The Reynolds numbers $2.5\cdot10^6$ and $3\cdot10^6$ give a stalling angle of attack of α_s = 13 degrees and c_{lmax} = 1.7 –1.73 with natural transition and α_s = 13 degrees and c_{lmax} = 1.67 – 1.70 with the fixed transition on upper surface or both surfaces.

Aileron angle 18 degrees. The Reynolds numbers $2.5\cdot10^6$ and $3\cdot10^6$ give a stalling angle of attack of α_s = 12 degrees and c_{lmax} = 1.62 –1.65 with natural transition on upper surface and fixed transition on lower surface and α_s = 11-12 degrees and c_{lmax} = 1.58 – 1.62 with the fixed transition on both surfaces.

The maximum lift coefficient and the stalling angle of attack have been reproduced in the table 3. The results also show that the maximum lift coefficient increases slightly with the aileron down 13 degrees compared to the neutral position, for example from 1.6 to 1.73 with the Reynolds number of $3\cdot10^6$.

Aileron angles 13 and 18 degrees reduce the stalling angle of attack 2 and 4 degrees respectively, compared to aileron neutral. This causes the wing lift coefficient to increase because a flap angle 20 degree also reduces the flap area stalling angle of attack. However, it must be noted that the wing tip stall margin reduces and there is a greater tip stall risk.

Table 3. Maximum lift coefficient and stall angle of attack with different aileron angles. Transition fixed on both surfaces. $Re = 3 \cdot 10^6$.

Aileron angle	c_{lmax}	Stall angle of attack
0	1.56	15
13	1.70	13
18	1.62	11

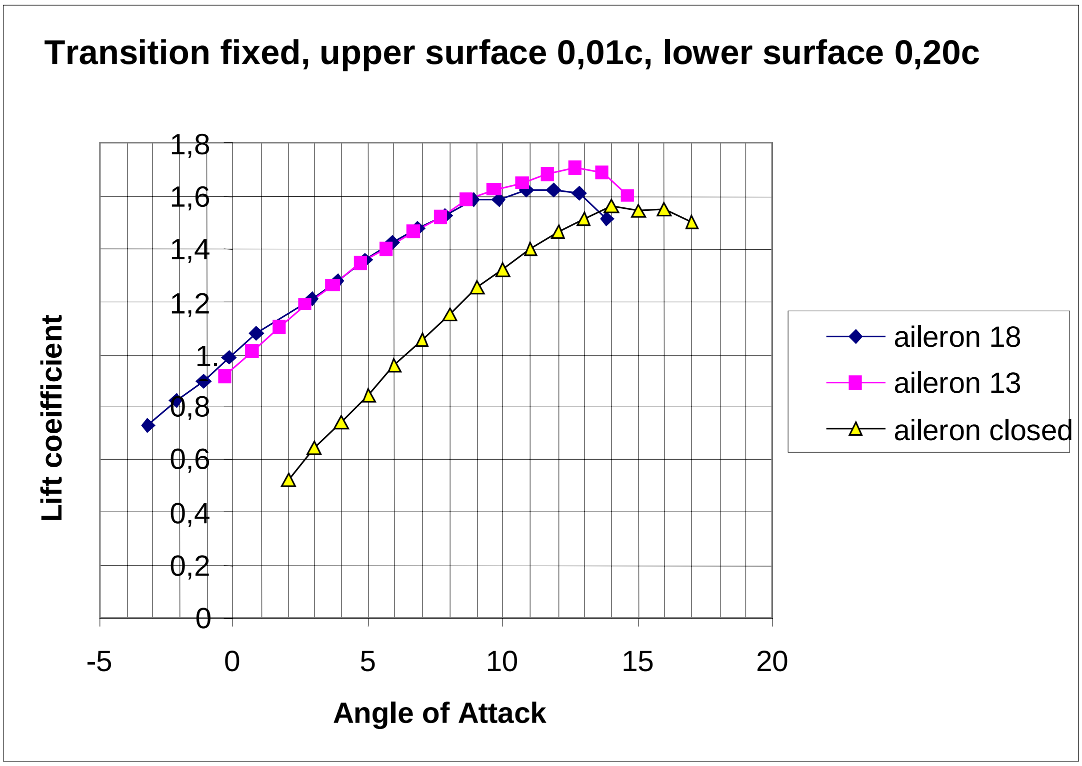

Figure 5. Lift coefficient as a function of the angle of attack with different aileron angles. Reynolds number is $3 \cdot 10^6$ and transition is fixed on the upper surface to 0.01*c* and on the lower surface to 0.20*c*.

Following conclusions can be made from the figure 5:

- When the aileron is in an angle the stall occurs at a smaller angle of attack than when the aileron is neutral.
- The maximum lift coefficient and stall angle of attack are smaller at the aileron angle 18 degrees than at the aileron angle of 13 degrees.
- The slope of the lift coefficient (derivative) is smaller when the aileron angle is more than zero because the airflow separates from the upper surface.
- If the angle of attack is more than 9 degrees, the aileron angle of 13 degrees produces more lift than the aileron angle of 18 degrees. Therefore increasing the aileron angle reduces lift.

As a summary of the aerofoil calculations it can be stated that in the take off configuration with ailerons at an angle of 13 degrees the whole wing maximum lift coefficient increases and thus the stall speed decreases compared to the clean wing case. It must be pointed out, though, that there is a tip stall tendency. There can also be a problem that, as the aileron is already at a 13-degree angle, increasing the aileron angle will not increase lift. The other aileron then produces the roll control moment when its angle is decreased. The roll control effectiveness is thus less than in the clean configuration.

2.7 Results of the flight mechanic calculations

The loss of effectiveness of the vertical stabiliser, for example due to wing wake, does not seem to be enough to cause yaw and roll moments as large as encountered on the accident flight. The calculations were done using a step sideslip angle input, a step yaw rate input or a step roll rate input.

The wing tip stall (tip is here defined as the aileron part of the wing) causes both the sudden yaw and roll, even without the step inputs. The yaw rate is approximately 15 degrees in three seconds. If it is assumed that the vertical stabiliser loses effectiveness the yaw rate is even faster, the aircraft yaws approximately 25 degrees and rolls 50 degrees in three seconds. Even this seems to be slightly slower than during the accident flight. Thus only the tip stall and fin ineffectiveness do not explain the accident.

If it is assumed that the whole right wing stalls at the same time so that the lift coefficient is reduced by 0.3 or 0.6 and the drag coefficient is increased by 0.06 or 0.12, the roll rate is approximately 45 degrees in two seconds (first case, 0.3 and 0.06) and approximately 90 degrees and yaw rate 10 degrees in two second (second case, 0.6 and 0.12). It was assumed that the left wing had not stalled and vertical stabiliser was functioning normally. The assumed reductions of the lift coefficient and increases of the drag coefficient are possible for the wing. Figure 6 presents aircraft bank angle and heading in both cases. The faster movement is likely to be as fast as the accident flight.

When calculating the yawing moment caused by the wing stall, only the right wing profile drag increase was taken into account. The asymmetric induced drag caused by the asymmetric lift was not taken into account. It was also not taken into account that the right wing effective angle of attack increases when the aircraft rolls to the right and the relative wind changes. The left wing effective angle of attack reduces accordingly. This causes the right wing total force vector to turn forward and the left vector backward. Both this effect and the asymmetric induced drag cause, in theory, left yawing moment which opposites the right wing profile drag increase caused right yawing moment.

During the flight tests the aircraft was rapidly pitched up after the power increase. It was thus also calculated how the gyroscopic forces affect the movement but the effect was found to be of no importance.

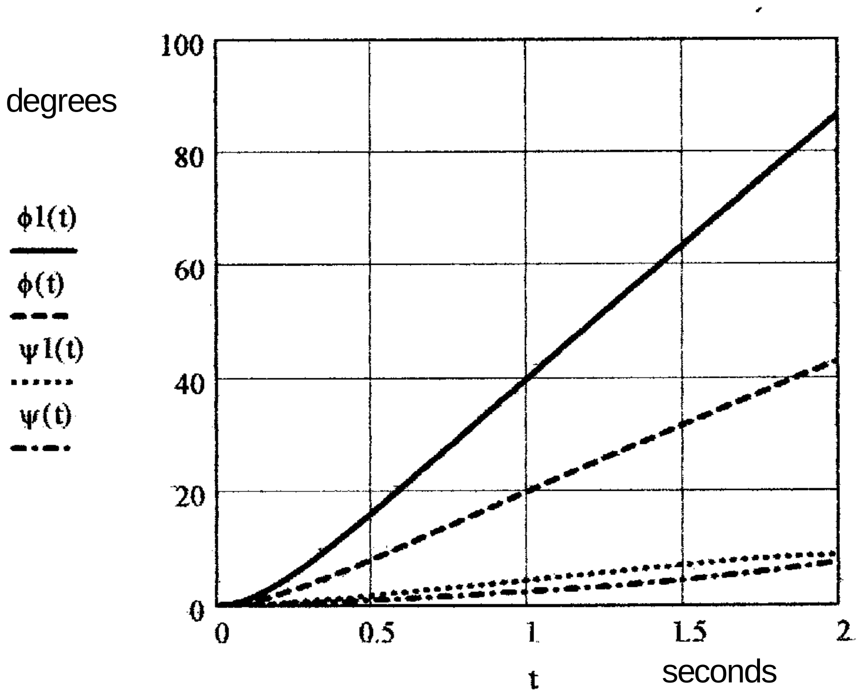

Figure 6. Cessna 182 aircraft bank angle φ and heading ψ changes as a function of the time *t*, when the right wing lift coeifficient reduces by 0.3 (0.6) and the drag coeifficient increases by 0.06 (0.12) at time *t* = 0. Curves φ1 and ψ1 correspond to the values given in parenthesis. Equivalent Air Speed is 55 knots.

2.8 Results of the flight tests

The accident situation was simulated during the test flight so that the indicated air speed was reduced to 40-45 knots with engine on idle power. After this full power was set. When the aircraft accelerated through 50-55 knots the aircraft was pitched up 10 degrees using the artificial horizon. The aircraft rolled to the right on five attempts from fourteen attempts and rolled 50-70 degrees in two seconds. The simultaneous heading change was 10-20 degrees. The movement would have continued but the incipient spin was recovered. On nine occasions nothing significant happened and the aircraft remained under control even at a speed of 40 knots and cross controls.

The flow was visualized by the wool threads and the flow direction could be analysed as well as separation and stall. In the cases when the aircraft rolled to the right the flow separated first from the right wing tip and immediately after this from the right wing root.

The separation line progressed rapidly from the trailing edge to the leading edge and led to the sudden roll.

The sudden aircraft roll was immediately stopped and the aircraft recovered when the angle of attack was reduced by moving the yoke forward.

Figure 7. Right wing with flaps up and aileron neutral. The flow is attached to the wing upper surface.

With the engine idle and air speed reduced to stall, no sudden roll was induced with or without the flaps. The aircraft stalled normally, pitched down and did not roll significantly.

With the aileron at an angle of 13 degrees and air speed of 80 knots or less, the flow separated from most part of the aileron (figures 7 and 8). The phenomenon was not investigated at faster air speeds.

The wool threads showed that the flow was disturbed on both sides of the vertical stabilizer at stall speed with engine idling. The flow speed around the empennage is less than the aircraft speed and thus the fin effectiveness is reduced. This is caused mainly by the wing wake. Increasing power setting attached the flow to the vertical stabilizer a moment after the power increase initiation.

Figure 8. Flap in take off position (20°), when the aileron is at a 13° angle, air speed 80 kt. The flow separation can be seen from the wool threads.

The flow on the sides of the cargo pack under fuselage remained attached even at wing stall and thus it does not seem to affect the flow on the empennage.

2.9 Conclusions from the calculations and test flights

It was possible to suddenly stall the aircraft at a speed of 50-55 knots in the take off configuration causing right roll and pitch down. This was caused by the sudden right wing tip stall. A safe stalling behaviour is such that the flow separation starts from the wing root trailing edge and progresses slowly towards to leading edge and wing tip when the angle of attack is increased.

The cause of the right wing tip stall was the aileron angle of 13 degrees. The aileron angle is unfavourable especially in the aileron system utilized by Cessna and having a hinge on the upper surface. Thus aileron angle causes a sharp edge to form on the upper surface. The air is unable to flow around such a sharp edge and stay attached.

Figure 9. Airflow separation from the right wing tip when stall begins.

The asymmetric propeller wash caused the aircraft right wing to stall first. The fact that the sudden roll to the right requires the complete right wing to suddenly stall corresponds well to the aerofoil and flight mechanical calculation results.

The exact reason, why the right wing tip stalled and the aircraft rolled to the right only approximately every third attempt, is not known with certainty. The tip stall was possibly caused by the small control differences in increasing the angle of attack during the test flights. However, it can be deducted that the phenomenon is rare and has thus gone unnoticed until now.

Because the flow is separated from the upper aileron surface with the aileron at an angle of 13 degrees with speeds up to 80 knots, the aileron control effectiveness is reduced when compared to the clean configuration with flow attached to the whole surface. The flow separation from the upper aileron surface was evident also in the aerodynamic calculations.

Figure 10. Airflow separation from the whole right wing during a complete stall.

Even though the flow is disturbed around the vertical stabilizer at engine idle and low speed, the flow reattaches rapidly after engine power setting is increased. This indicates to only a slight loss of effectiveness of the fin and cannot explain the rapid movement. On the other hand, the directional stability of the aircraft is reduced even at higher speeds due to the under fuselage cargo pack and the floats. They both reduce the directional stability of the aircraft. They do not, however, significantly contribute to the rapid movement discovered during the test flights.

The accident scenario was simulated during the test flights. The engine was at maximum power, flaps were set at 20 degrees and the pitch angle of the aircraft was increased. The aircraft and the R/STOL kit had been approved in accordance with the American CAR 3 -regulations. The regulations specify that the stall tests are done by slowing the speed slowly with partial engine power. The scenario simulated during the test flights occurs also when the missed approach is initiated from a small speed. In the opinion of the investigation commission the purpose and meaning of all aviation regulations must be understood so that the aircraft behaviour is predictable in all phases of flight, also missed approach initiation. The sudden movement discovered during the test flights should also be mentioned in the aircraft flight manual.

2.10 Take off procedure according to the aircraft flight manual

The investigation commission wanted to study the official take off procedure. No such procedure was found from the aircraft flight manual. The flight manual has been written for the aircraft with standard wheel configuration. There is a flight manual supplement for the float conversion but without R/STOL kit. There is also a flight manual supplement for the R/STOL kit but without floats. There was no take off procedure and target speeds for an aircraft fitted with both floats and R/STOL kit.

The R/STOL supplement states that a normal wheel aircraft take off is done with the flap setting of 20 degrees. The rotation speed is 43 knots and the initial climb speed is 50 knots. When the close-in obstacles are no longer a factor the speed is increased to 65 knots and flaps are raised.

The R/STOL supplement states also that the STOL take off is done with the flap setting of 30 degrees. The rotation speed is 37 knots and the initial climb speed is 42 knots. The flaps are raised to the setting of 20 degrees after lift off. When the close-in obstacles are no longer a factor the speed is increased to 65 knots and flaps are raised.

The calculations and test flights perfomed during the investigation proved that the STOL take off speeds are slightly too slow and there is a risk of stalling. The wing stalled at a speed of 50-55 knots during the test flights when the angle of attack was rapidly increased approximately 10 degrees. It seems to be very important to increase speed near ground or water to over 65 knots before starting to climb. One should not turn during the initial climb.

2.11 Use of the safety vests during water operations

There are 1-3 float aircraft capsizings each year in Finland. The normal capsizing happens during taxiing. Despite this there have been no fatalities by drowning in the last thirty years with type-certificated aircraft. However, there is a dangerous situation with every capsizing.

According to the Finnish air regulation OPS M3-6 section 5, there must be suitable life vests for each occupant located nearby so that they can be accessed easily. In addition, regulation AIR M11-2 states that the life vests must be contained inside plastic bags, which are easy to open. In practise the vests are inside a strong plastic bag, which has a ripping string for easy opening. The vests are usually inside the glove compartment, door pocket or pockets on the backside of the seats, as in the accident aircraft. If vests are needed in an emergency it takes dozens of seconds, even minutes, to put them on. If a forced landing must be done from a cruise altitude it is theoretically possible to have enough time to put them on. If an aircraft capsizes during take off, landing or taxying there is not enough time. To have the life vests practically available in all phases of flight requires that they should be on all the time.

All persons on boats naturally wear life vests but sea and floatplane operators do not usually wear them. This is caused by the fact that the wearing of the vests is not mandatory and by the fact that the certification of airworthiness inspection standard requires the vests to be stored in their original plastic bags.

The aircraft life vests are not very rugged because they are intended to be used only once in an emergency. There are also rugged approved (TSO) life vests to be used regularly, which can withstand wear. These vests are also quite comfortable to wear and could replace the vests currently used.

A floating jacket or automatically operating life vest is not practical in an aircraft. Their buoyancy prevents diving, which is often needed to get out of a capsized aircraft.

2.12 Cause analysis of the accident

2.12.1 Key event

As the aircraft was climbing at a height of approximately 15 m it suddenly rolled and yawed to the right and lost altitude. The full counter control measures used by the pilot were ineffective and the aircraft collided with water.

2.12.2 Causal factors

Direct causal factors

The investigation commission considered that there were three direct causal factors to the accident:

The first factor was the incorrect take off procedure used by the pilot. He let the aircraft continue climbing after getting airborne without reducing the pitch angle to gain airspeed. This procedure caused the angle of attack to increase and right wing to stall.

The second factor was the tip-stalling tendency of the R/STOL kit. The kit incorporates a link between the flaps and ailerons and the ailerons turn downwards in the take off configuration. Turning ailerons downwards is unfavorable especially with the aileron mechanism used by Cessna when the hinge line is on the upper surface. Thus turning aileron down causes a sharp angle on the upper surface and induces flow separation. This led to a sudden right wing tip flow separation. The flow separation of a normal standard Cessna aircraft begins from the wing root area, which is favorable and safe.

The third factor was the wrong action by the pilot to recover from the situation. When the aircraft begun to roll to the right the pilot applied full left aileron and rudder. Probably he did not try to push yoke forward to unstall the wing. The collision with water could probably not have been prevented even with the correct stall recovery actions but the consequences of the collision could have been reduced. The full opposite aileron can also be considered as a wrong action because the right aileron turned downwards and worsened the right wing tip stall. On the other hand, the aileron control must have been a reflex movement for an unexpected roll.

Indirect causal factors

The pilot told the investigation commission that he had never stalled the aircraft involved in the accident and was unable to recognize the stall during the take off. He thought that the aircraft would not stall at all. The pilot considered the stall to be so abnormal flight condition that he did not practise it. He did not perform any stall manoeuvres after the last maintenance even though the aircraft wings had been off, both had been repaired and their angle of incidence had been altered.

On the accident day weather conditions were optimal for the take off. The pilot considered the take off to be easier than normal. Thus his attitude caused him not to positively control the aircraft and reduce the pitch angle, but instead continue climbing after getting airborne.

Another factor contributing to the serious consequences of the accident was the fact that the pilot and the passenger on the right front seat did not wear shoulder harnesses.

3 CONCLUSIONS

3.1 Findings

1. The pilot had a valid commercial pilot's licence CPL(A), single engine piston land and sea ratings and medical certificate.
2. The aircraft had a valid certificate of airworthiness and certificate or registration.
3. The technical inspection of the wreckage did not reveal any malfunction or defects before the accident.
4. The pilot let the aircraft continue to climb after getting airborne without reducing the pitch angle to gain airspeed. This procedure caused the angle of attack to increase and the right wing to stall.
5. The aileron and the flap connection of the R/STOL kit of the aircraft combined with the aileron type caused right wing to tip stall in take off configuration.
6. The pilot did not recognise the stall and did not act in the required sense to recover. The pilot's actions can be considered to have been intuitive.
7. The pilot told the investigation commission that he had never stalled the aircraft involved in the accident. He considered the stall to be so abnormal flight condition that he did not practise it.
8. The pilot had not flown stall tests in accordance with the test flight program after the damage repair even though the wings had been significantly repaired and the wing angle of incidences had been altered.
9. The maintenance organisation considered the repair to be so minor that it did not apply Flight Safety Authority acceptance for it nor did it do any formal certificate of airworthiness check or inspection.
10. The maintenance organisation had given the aircraft certificate of release to service even though the slow flight and stall characteristics had not been verified during the test flight.
11. Front seat shoulder harnesses and life vest were not used during the flight.
12. The wearing of the life vests is not mandatory according to the Finnish air regulations.

3.2 Probable cause

The pilot let the aircraft continue to climb after getting airborne without reducing the pitch angle to gain airspeed. The aileron and flap connection of the R/STOL kit of the aircraft combined with the aileron type caused right wing to tip stall in the take off configuration. The pilot did not recognise the stall and did not act in the required sense to recover.

4 RECOMMENDATIONS

The calculations and flight test proved that the link between the flaps and ailerons of the Robertson STOL kit and the aileron mechanism used by Cessna exposed the wing to a tip stall. This led to a sudden roll movement of the aircraft.

1. The investigation commission recommends that the appropriate authority should take measures to inform pilots as comprehensively as possible about the stall behaviour of the Robertson STOL Cessna 185 aircraft. The aircraft flight manual supplement should also contain a warning of this.

The wearing of the life vests is not mandatory during water operations according to the Finnish air regulations. Instead, they are placed in their plastic bags in the cockpit and in the cabin.

2. The investigation commission recommends that the Finnish Flight Safety Authority would revise the regulations OPS M3-6 and AIR M11-2 so that all persons on board must always wear a life vest during water operations.

Helsinki 30 March 2005

Esko Lähteenmäki
Investigator-in-charge

Timo Wahe
Member

Ville Hämäläinen
Member

Seppo Laine
Expert

Tapio Tourula
Expert

LIST OF SOURCES

The following material is stored at the Accident Investigation Board Finland.

1. The accident report of the pilot
2. The police record 6390/S/30042/03
3. The autopsy of the deceased (not public, JulkL 24 §)
4. The Lapland emergency service emergency and accident file
5. The records of the hearings
6. The copies of the aircraft documents
7. The operative flight plan of the accident flight and the flight ticket
8. The weight and balance analysis of the accident flight
9. The documents of the baggage on board
10. The copies of the previous maintenance work lists and the certificate of release to service
11. The copies of the previous maintenance test run and test flight documents
12. The aerodynamic calculations of the Cessna A185F aerofoil II, Seppo Laine, 8 October 2004
13. The aircraft motion due to the stalling of the wing and/or vertical stabilizer, Seppo Laine, 10 November 2004
14. The record of the wreck disassembly, Juhani Mäkelä and Arvo Keskinarkaus, 5 July 2003
15. The findings of the damage mechanism of a flap control system guide wheel, Technical Research Centre of Finland, 25 August 2003
16. The air speed indicator of the aircraft OH-CDO calibration flight document, 9 October 2004
17. Weather data from the accident day
18. The correspondence related to the accident
19. The comments of the Finnish Flight Safety Authority to the safety recommendations
20. Summaries of the accidents to the Cessna 185 aircraft in the United States and Canada
21. Photography and video records