Investigation report

L2014-02

Aircraft Accident Resulting in the Death of Eight Skydivers at Jämijärvi on 20 April 2014

Translation of the original Finnish language report

OH-XDZ

Comp Air 8 Turbine

Onnettomuustutkintakeskus
Olycksutredningscentralen
Safety Investigation Authority, Finland

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SUMMARY

AIRCRAFT ACCIDENT RESULTING IN THE DEATH OF EIGHT SKYDIVERS AT JÄMIJÄRVI ON 20 APRIL 2014

On Easter Sunday, 20 April 2014 at 15:40 Finnish time (UTC + 3h) an accident occurred at Jämijärvi aerodrome when a Comp Air 8 aircraft, registration OH-XDZ, carrying skydivers crashed into the woods. In addition to the pilot there were ten skydivers on board. The pilot and two skydivers managed to bail out of the aircraft. Eight skydivers died in the collision with the ground.

The OH-XDZ was the first turboprop aircraft in the experimental category in Finland. It was built in Finland from an aircraft kit. The aircraft was not type certificated.

The Tampere Skydiving Club's (TamLK) skydiving event "Easter Boogie" was in progress at Jämijärvi aerodrome. Finland's Sport Aviators' Comp Air 8 aircraft was reserved for the event; with it skydivers were being carried to the altitude of 4 000 m.

The eighth Comp Air flight of the day reached the jump run, which was at 4 230 m over the southern runway of the aerodrome. The skydivers noticed that they had overshot the jump run and requested a new one from the pilot. The pilot increased engine power and simultaneously began turning to the left. During the turn the aircraft began to descend and its airspeed increased, which the pilot did not immediately realise. The pilot pulled on the control stick and the aircraft levelled out or went into a shallow climb. He reduced engine power to idle, in conjunction with which the airflow over the horizontal stabiliser probably decreased suddenly, which generated a rapid nose-down movement. As the angle of attack was decreasing a downward force was generated on the wing. The right wing's wing strut buckled upwards and the right wing folded down against the jump door around the wing root mountings. The aircraft lost its controllability instantaneously and began to rotate around its vertical axis in a flight condition resembling an inverted spin.

In the aircraft a decision to make an emergency jump was made. The wing which had folded against the jump door prevented exiting through the door. The pilot and two skydivers sitting at the front of the airplane bailed out through the pilot's door. The others did not have enough time to bail out. They died in the collision with the ground. The aircraft was completely destroyed in the collision and the fire.

There were several eyewitnesses to the accident and the emergency call was made immediately. The first third parties reached the accident site within six minutes. Skydivers on the ground immediately started a search to locate the ones that had bailed out of the aircraft. The first rescue unit reached the site 13 minutes after the accident. The number of survivors remained uncertain for a long time. The last victim was found inside the wreckage four hours after the accident.

The investigation revealed that it was likely that the centre of gravity of the aircraft was outside the flight manual's aft limit on the jump run. The rating requirements for pilots in skydiving operations are incompatible with the demands of the activity.

When the material of the right wing strut was analysed it became clear that there was a fatigue crack on the inner surface of the wing strut. The crack had formed over a long period of time and it was impossible to detect in visual inspections. No other pre-existing technical fault was found in the investigation of the wreckage.

A winglet structure was installed on both wings of the aircraft; the design comprised a wing extension at the plane of the wing and a winglet. The Permit to build-application did not mention these, nor had their effects on the aircraft's structural strength or flight characteristics been established prior to commencing the construction. According to the results of an analysis commissioned for the investigation the wing modifications increased the aerodynamic loads on the aircraft. The kit manufacturer had presented the load calculations of the original aircraft, but they were not given to the builders.

According to calculations the safety factor for the wing strut's actual stress resistance, given in the Permit to build, did not materialise at -1.8 g at the maximum weight. The minimum requirement as per Aviation Regulations was met.

Coordination and communication between the authorities that participated in the rescue operation did not succeed on all fronts; however, this had no bearing on the onset or extent of the damage. The need for psychosocial support was great. Later there were shortcomings in the arrangements for psychosocial support.

The cause of the accident was that the stress resistance of the right wing's wing strut was exceeded as a result of the force which was generated by a negative g-force. The force which resulted in the buckling of the wing strut was the direct result of a negative (nose-down) change in pitching moment, in conjunction with an engine power reduction intended to decrease the high airspeed.

The contributing factors were the following:

- There was a fatigue crack on the wing strut. Because of the damage to the aircraft it was not possible to investigate the mechanism of the fatigue crack formation. It is possible that, in addition to the stress caused to the aircraft by short flights and high takeoff weights, the temperature changes caused by the exhaust gas stream as well as vibration contributed to the fatigue cracking.
- The nature of skydiving operations generated many takeoffs and landings in relation to flight hours. A significant part of the operations was flown close to the maximum takeoff weight. These factors increased the structural stress.
- The pilot's limited flight experience on a powerful turboprop aircraft, his inadequate training as regards aircraft loading and its effects on the centre of gravity and airplane behaviour, the high weight of the aircraft and the aft position of the CG in the beginning of a new jump line and, possibly, the pilot's incorrect observation of the actual visual horizon contributed to the onset of the occurrence.

  During the turn to a new jump run the aircraft began to descend and very rapidly accelerated close to its maximum permissible airspeed. The pilot did not immediately realise this.

- The structural modifications on the wing increased the loads on the aircraft and the wing struts. Their effects had not been established beforehand. The kit manufacturer was aware of the modifications. No changes to the Permit to build were applied for in writing regarding the modifications. Neither the build supervisor nor the aircraft inspectors were aware of the origin or the effects of the modifications.

As a result of the investigation the Safety Investigation Authority, Finland issued five recommendations; three to the Finnish Transport Safety Authority, one to the European Aviation Safety Agency and one to the Ministry of Social Affairs and Health.

The Finnish Transport Safety Authority should:

- When required, limit the number of occupants in experimental aircraft and their use in skydiving operations based on risk considerations.
- Ensure that the experience and training of persons that supervise and inspect experimental aircraft construction meet the requirements of construction and modification control, and
- In conjunction with the recreational aviation safety project, ensure that the Finnish Aeronautical Association prepares generic guidelines for skydiving operations, around which associations build a training programme and proficiency checks for jump pilots.

The SIAF recommends that the European Aviation Safety Agency prepare specified theoretical knowledge and flight training requirements for pilots-in-command in skydiving operations.

The SIAF repeats the recommendation to the Ministry of Social Affairs and Health which was originally issued by the Investigation Commission of the Kauhajoki School Shooting in 2008. The Ministry should take steps to ensure that the plans, resources, responsibilities, and competent leadership for the provision of psychosocial support in major crises are available regardless of where the accident takes place or where the people involved come from.

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APPENDICES (in the Finnish only)

ABBREVIATIONS

AAD	Automatic Activation Device
AAII	Air Accidents Investigation Institute
ACO	Aircraft Coordinator
AIP	Aeronautical Information Publication
ARCC	Aeronautical Search and Rescue Co-ordination Centre
BFU	German Federal Bureau of Aircraft Accident Investigation
CA8	Comp Air 8 -aircraft
CPL	Commercial Pilot License
CYPRES	Cybernetic Parachute Release System
DNA	Deoxyribonucleic acid
DVI	Disaster Victim Identification
EASA	European Aviation Safety Agency
EFJM	Jämijärvi aerodrome
FAA	Federal Aviation Administration
FCU	Fuel Control Unit
FI	Flight Instructor
FinnHEMS	Finnish Helicopter Emergency Medical Services
GPa	Gigapascal
GPS	Global Positioning System
HEA	Psychological First Aid
hPa	Hectopascal
ICAO	International Civil Aviation Organisation
IRAN	Inspect and Repair as Necessary
JAR	Joint Aviation Requirements
KCAS	Knots Calibrated Airspeed
KIAS	Knots Indicated Airspeed

kN	Kilonewton
kt	Knot
MPa	Megapascal
mph	Miles per hour
N	Newton
NACA	National Advisory Committee for Aeronautics
Nm	Newton metre
NTSB	National Transportation Safety Board
Pa	Pascal
PPL(A)	Private Pilot License (Airplanes)
PV	Load Organiser
SEP	Single Engine Piston
SET	Single Engine Turbine
SIL	Finnish Aeronautical Association
SPR	Finnish Red Cross
STM	Ministry of Social Affairs and Health
SYNOP	Surface Synoptic Observations
TamLK	Tampere Parachuting Club
TAS	True Airspeed
TAYS	Tampere University Hospital
USPA	United States Parachuting Association
UTC	Co-ordinated Universal Time
VFR	Visual Flight Rules
VIRVE	Finnish Government official radio network/equipment
VPK	Voluntary Fire Brigade
WS	Wingsuit

SYNOPSIS

On 20 April 2014 at 15:40 an accident occurred at Jämijärvi aerodrome when an aircraft carrying skydivers crashed into the woods. Eight skydivers died.

Pursuant to Section 2 of the Safety Investigation Act (525/2011), Safety Investigation Authority, Finland (SIAF) decided to initiate safety investigation L2014-02. SIAF expert Kari Ylönen, M.Soc.Sc. was appointed as the team leader of investigation group. The members of the investigation group were Tii-Maria Siitonen, air safety investigator, Jaakko Lajunen, flight test technician, Timo Kostiainen, test pilot, and Pekka Martikainen, skydiving expert. Chief air safety investigator Ismo Aaltonen was appointed as the investigator in charge.

The SIAF sent a notification of the occurrence to the International Civil Aviation Organization (ICAO), the European Aviation Safety Agency (EASA), the Air Accidents Investigation Institute (AAII) of the Czech Republic and the National Transportation Safety Board (NTSB). Pursuant to ICAO Annex 13 the NTSB and the AAII designated their accredited representatives to the investigation.

The following SIAF experts were appointed to assist the investigation group: Kalle Brusi (analysis of recorded information), Päivikki Eskelinen-Rönkä (acoustic analysis), Timo Heikkilä and Vesa Palm (regulations), Mika Kosonen (type rating training), Jaakko Kulomäki (human factors), Lars Levo and Pekka Orava (air rescue), Esko Lähteenmäki (site investigation and engine investigation), Jukka Seppänen (psychosocial support), and Alpo Vuorio (aviation medicine).

The SIAF commissioned a special analysis of the material and cracking of the lower part of the right wing's wing strut, found at the site of the accident, from VTT Expert Services Oy and, later, an analysis of the wing strut's compression resistance. Analyses were commissioned from Patria Aviation/Engineering regarding the wing's aerodynamic loads and changes in the aircraft's pitching moment when engine power is being reduced. The data retained by the reserve parachutes' Automatic Activation Devices were downloaded at the manufacturer's laboratory, supervised by representatives of the German Federal Bureau of Aircraft Accidents Investigation (BFU) and the SIAF.

Despite several requests, the SIAF did not receive any requested information from the aircraft kit manufacturer during the investigation. Since the aircraft was the only one of its kind in Finland the investigators had to establish its construction and functioning from the material received from the builders and the photographs they had taken during the build. Also the verbal information received from the builders greatly benefited the investigation.

On 22 September, 2014, pursuant to Section 25 of the Safety Investigation Act, the SIAF sent a notification to the Finnish Transport Safety Agency (Trafi) and the NTSB, as regards a detected threat of an accident during the safety investigation, associated with fatigue cracking in the wing strut.

The SIAF requested comments on the draft final report from the Ministry of Transport and Communications, the Ministry for Social Affairs and Health, the Ministry of the Interior, the Prime Minister's Office, from Trafi, Finavia Corporation, the Finnish Aeronautical Association, the National Police Board, the Border Guard, the Finnish Defence Forces, the Emergency Response Centre Administration, the Finnish Red Cross, Satakunta Emergency Department, Satakunta Hospital District, Pirkanmaa Hospital District, the Acute psychiatric clinic of the City of Tampere, the City of Vantaa Social and Crisis Emergency Centre, FinnHEMS Oy, Southwest Finland ELY Centre (Centre for Economic Development, Transport and the Environment), Pohjois-Satakunta joint municipal authority for basic services, Finland's Sport Aviators (Suomen Urheiluilmailijat ry), Tampere Skydiving Club, the Jämi Foundation, the NTSB, the EASA, the BFU, the AAII, and interested parties. The comments were received by 31.1.2015.

The comments were taken into consideration in the final report. A summary of the comments is included in Appendix 1 (only in the Finnish version of the report).

An abridged version of the investigation report was translated into English. The Finnish language investigation report is the original version. The report and the material used in the investigation are archived at the Safety Investigation Authority, Finland.

All times in this report are in Finnish daylight saving time (UTC + 3 h).

The investigation was completed on 16.4.2015.

1 FACTUAL INFORMATION

1.1 History of the flight

The Tampere Skydiving Club (TamLK) organised the skydiving event “Easter Boogie” at Jämijärvi aerodrome, in the Satakunta region, on Sunday 20 Apr 2014. The event started on Maundy Thursday, 17 Apr 2014 and was planned to end on Easter Monday, 21 Apr 2014. The aircraft reserved for the event were Finland’s Sport Aviators’ Comp Air 8 airplane (CA8, OH-XDZ), which was intended to be used to take skydivers up to 4 000 m, and the Tampere Skydiving Club’s own Cessna U206F (OH-CMT), to be used for jumps from lower altitudes.

On Sunday morning the cloud base hampered skydiving operations, which is why the activity started with student jumps from the Cessna. The pilot of the accident flight flew two flights on the Cessna. Once the weather improved he began to fly on the OH-XDZ. He flew two flights on it before he took a lunch break. Another pilot flew four flights on the airplane, following which it was topped up with 240 l of fuel. After refuelling the pilots changed duties again and the pilot of the accident flight flew yet another skydiving flight, landing at 15:25.

Ten skydivers boarded the airplane for the accident flight. Takeoff occurred at 15:28 from northern runway 27 of Jämijärvi aerodrome. The airplane climbed to 4 230 m AGL by making a wide, left turn. The pilot steered the aircraft to the jump run, which was over the southern runway. Some of the skydivers sitting at the rear rose to their knees, and two of them cracked the jump door open so as to check the jump run. The skydivers then gave instructions to the pilot as regards correcting the jump run. The pilot adjusted the heading following which he reduced engine power to idle, reducing airspeed to approximately 70-75 kt. Nonetheless, the skydivers noted that they had overshot the jump line and requested that the pilot take them to a new run. The skydivers closed the door.

The pilot increased engine power and, according to his account, simultaneously began to turn to the left at a 20-30 degree bank angle. He did not order the skydivers to return to their seats as he was homing in on the new jump run. At the end of the turn the occupants of the aircraft felt a downward acceleration which the skydivers experienced as a force pushing them towards the cabin ceiling. Approximately three seconds later the situation returned to normal. According to the pilot the airspeed was approximately 100 kt when they encountered the vertical acceleration.

A moment later the pilot noticed that the airplane was in a descent and that the airspeed had suddenly risen to over 180 kt IAS. According to the pilot the airspeed peaked at 185 kt. He attempted to end the descent by pulling on the control stick. The aircraft levelled out or went into a shallow climb. He reduced engine power to idle to decrease the airspeed. The pilot said that the pitch control stick forces were relatively high. The aircraft returned to level flight, or to a gentle climb. The longitudinal control force suddenly decreased and the airplane suddenly flipped forward past the vertical axis. One of the surviving skydivers said that he heard a crushing sound roughly at the same time; however, he was unsure of the precise point in time of the sound. The aircraft became uncontrollable and began to rotate around its vertical axis, akin to an inverted spin.

According to eyewitness videos the aircraft was turning to the left. The videos show that the right wing was buckled against the fuselage and that a vapour trail of fuel was streaming from the damaged wing. While the aircraft was spinning its left wing, which was intact, was pointing upwards and the airplane was falling with its right side forward.

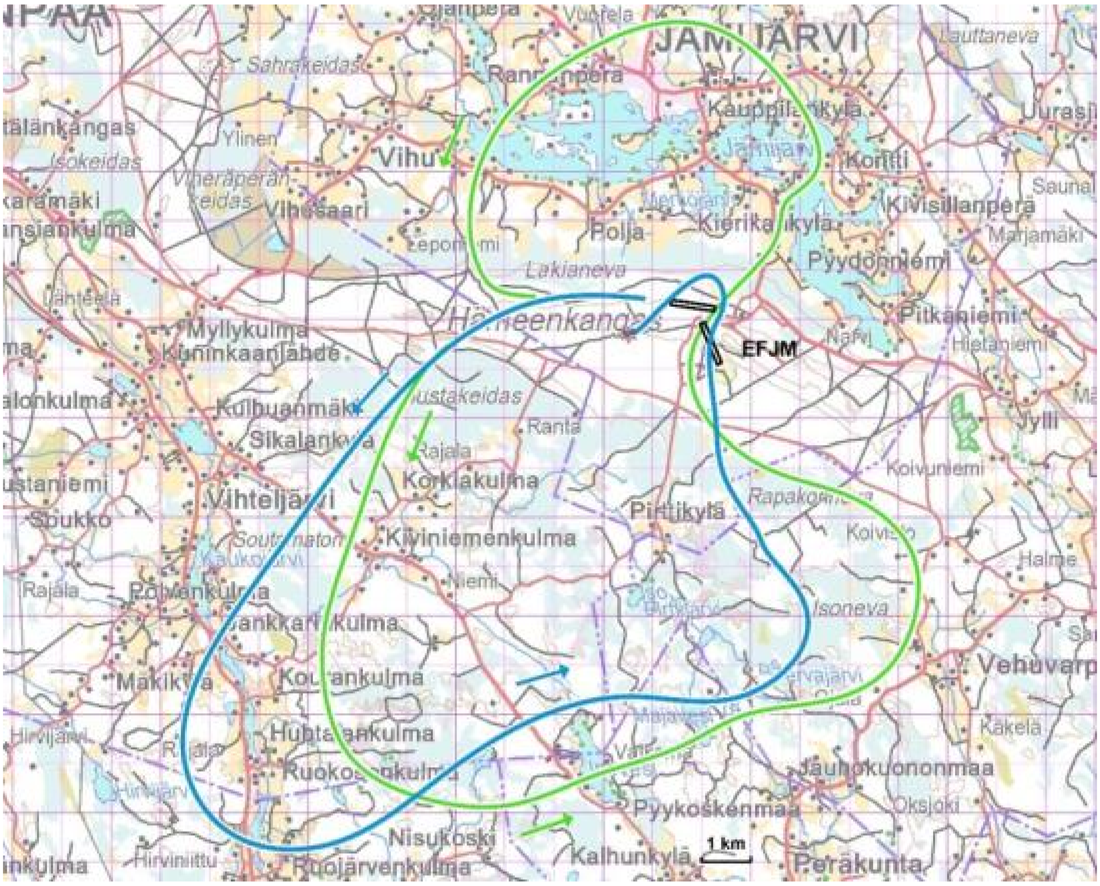


Figure 1. The tracks of the accident flight (blue) and the preceding flight (green) (Base map source: KTJ/Ministry of Justice/National Land Survey)

Shouts of “open the jump door, bail out immediately” were heard inside the airplane. The pilot concluded that the aircraft was so badly damaged that it was no longer possible to recover from the dive. He unbuckled his seat belts and opened the pilot’s door on his left at approximately 2 000 m. The pilot jumped out at approximately 1 800 m and opened his emergency parachute. Even though twists had developed in the parachute’s lines, the pilot managed to untangle them.

The skydiver sitting at the rear of the seat positioned next to the pilot (skydiver 3)[1] noted that it would be impossible for him to make it to the jump door. Therefore, he chose the pilot's door as a point of exit. It was extremely difficult to get to the door because the airplane was spinning. The skydiver sitting at the front of the seat positioned next to the pilot (skydiver 2) followed skydiver 3 on his way to the cockpit door and pushed skydiver 3 out of the door. Following egress, skydiver 3 immediately hit his head on airplane structures. The blow momentarily blurred his field of vision but he remained conscious. The Automatic Activation Device (AAD) opened the reserve parachute almost immediately after egress, at approximately 250 m.

While skydiver 2 was still behind skydiver 3 he grabbed the control stick, intending to reduce the g-forces caused by the spinning and make it easier to bail out of the airplane. He soon realised that the airplane did not respond to stick movements and exited through the pilot's door immediately behind skydiver 3. The skydiver who had occupied the furthest forward position (skydiver 1) assisted skydiver 2 in exiting through the door. The AAD of skydiver 2 opened his reserve parachute at approximately 200 m. After skydiver 2 had bailed out neither skydiver 1, situated closest to the pilot's door, nor the remaining seven skydivers in the rear of the cabin managed to bail out. The airplane collided with the ground at 15:40 and caught fire immediately.

The pilot landed approximately 300 m downwind from the wreckage. Skydiver 3 landed on a dirt road, some 60 m from the wreckage and skydiver 2 in the woods, approximately 40 m from the wreckage.

1.2 Injuries to persons

The immediate causes of death of the eight deceased skydivers were the serious injuries sustained in the collision with the ground. The pilot and skydiver 3 sustained serious injuries on their lower extremities. The shoulders of skydiver 2 became sore due to the forces generated by the opening of the reserve parachute.

Injuries	Crew	Passengers	Others
Fatal		8	
Serious	1	1	
Minor/None		1	

[1] In this report the skydivers in the aircraft are numbered in accordance with the chart used for calculating the aircraft's centre of gravity as per the flight manual (Figure 2).

1.3 Damage to aircraft

The aircraft was completely destroyed.

1.4 Other damage

Aircraft fuel leaked onto the ground.

1.5 Personnel information

Pilot in command

Age	37
Licences	Private Pilot Licence PPL(A), valid.
Ratings	All required ratings were valid. Class 2 EASA medical certificate, valid.

Flight experience (PPL)	Last 24 hours	Last 30 days	Last 90 days	Total experience
All types	2 h 35 min 7 landings	6 h 20 min 18 landings	9 h 05 min 28 landings	1 029 h 34 min 2 795 landings
On this type	1 h 55 min 5 landings	5 h 15 min 13 landings	7 h 05 min 18 landings	43 h 21 min 118 landings

According to his logbook the pilot had flown on 35 different aircraft types, most of which were sailplanes. He had also flown aerobatics, including upright tailspins, on gliders. When it comes to airplanes, prior to his CA8 training the pilot had the most flight experience on the following types and versions: AA-1A, C150, C152, C172, FR 172, C182, C206, PA-18, PA-25, PA-28R, PIK-15 and PIK-23.

The pilot had completed a parachute course in 1995 and had made altogether 40 or so jumps. The pilot received his first Glider Pilot Licence in 2005, the PPL(A) and a night rating in 2006, a glider instructor rating in 2008, an aero-tow rating in 2009 and a Motor Glider Pilot Licence in 2009. The pilot received theoretical knowledge and flight training for his CA8 type rating from 15-17 June 2013.

The pilot had started flying skydiving flights in 2010. He had amassed most of his experience in skydiving operations on a C206 aircraft. Prior to the accident flight his total flight experience in skydiving operations was 186 h 45 min. According to the logbook the pilot had flown a total of 35 h 35 min of skydiving flights on the CA8 aircraft (OH-XDZ). In the early phases of his skydiving operations the aircraft was fitted with dual flight controls and an experienced pilot had flown along as a safety pilot. Prior to the accident flight the pilot had accrued 18 h 20 min solo flight time on the CA8. According to the journey logbook of the OH-XDZ, he had logged 11 h 20 min of actual airtime (counted from takeoff to landing) on these flights.

Judging by the skydiving flight markings in his logbook the pilot had recorded 10 min extra flight time[2] for each skydiving flight in comparison to the flight time recorded in the airplane's journey logbook. For example, on 8 Sep 2013 the pilot had flown 14 skydiving flights for which he had recorded 3 h 30 min flight time in the aircraft's journey logbook. The pilot wrote down 13:00 as the time of takeoff and 18:30 as the time of landing. For this he recorded 5 h 50 min of flight time, i.e. in all 140 extra minutes in the air.

Pilot's alertness

On the day before the accident the pilot flew in all ten skydiving flights from 12-17 o'clock. He participated in the skydiving event's get-together in the evening and went to bed in his hotel room at approximately 23:30. The next morning he woke up at 9:00. After breakfast he flew four skydiving flights. Following a lunch break and a short nap he flew one skydiving flight before the accident flight.

Skydivers

There was a load[3] of ten skydivers on board. The skydivers were seated as indicated in Figure 2, facing rearwards inside the cabin. Three skydivers were sitting on the two long benches in the airplane while the rest sat on the floor. No seat belts[4] were available for the skydivers.

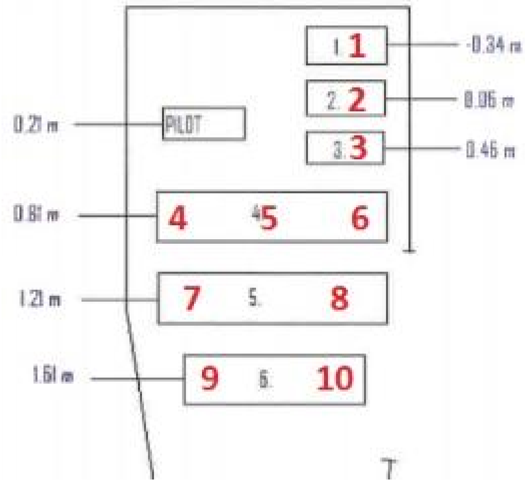
Skydiver 1 was seated on the floor at the front of the airplane, to the right of the pilot in the so-called pit. There were handles on the walls and the ceiling which made it easier to get into and out of the pit. Behind skydiver 1, toward the aft of the airplane on the right side of centreline, there was an approximately 25 cm tall bench on which skydivers 2 and 3 were seated. Behind the level of the pilot's backrest, on the centreline of the airplane, there was another short bench where skydiver 5, the load organiser, was seated. The rest of the skydivers sat on the floor, on both sides of the centre bench. They were positioned in such a pattern that skydivers 9 and 10 were at the very rear, close to the jump door.

2 Flight time is counted from the time when an aircraft moves under its own power for the purpose of takeoff until when the aircraft comes to rest after the flight. Note: this definition means the same as the commonly used concepts *block to block* or *chock to chock*, which are considered to commence at the time when the aircraft moves from its loading point for the purpose of flight and end when the aircraft comes to rest at the loading point after landing. (Aviation Regulation *PEL M1-3 Definitions*)

3 The term *load* is used to describe the number of skydivers on board. Correspondingly, the list of skydivers on the flight is the load list and the person in charge the load organiser. According to the instruction of the Finnish Aeronautical Association (Load organiser on a Skydiving Flight; 16.2.2003), in force at the time of the accident, the load organiser had to have a skydiving C licence, at the very least. On student flights the jump master acts as the load organiser. Load organisers are responsible for smooth and safe skydiving operations regarding their loads.

4 As per Aviation Regulation OPS M6-1 Parachute Operations, it is permissible to carry up to ten skydivers in an aircraft without seat belts, on the PIC's consent and on the skydivers' own responsibility.

Four skydivers were wearing wingsuits[5] (WS). Due to the nature of wingsuit jumping the WS jumpers were normally positioned at the front of the aircraft and were the last ones to exit the aircraft.



Hyppääjä nro.	Massa kg	asema m	kgm
1	85	-0,34	-28,9
2	85	0,06	5,1
3	85	0,46	39,1
4	85	0,81	68,9
5	85	0,81	68,9
6	85	0,81	68,9
7	85	1,21	103
8	85	1,21	103
9	85	1,61	137
10	85	1,61	137

Figure 2. The image on the left is the loading chart for ten skydivers as per the airplane's flight manual. The red numbers added to the image show where the skydivers were seated, in principle. The table on the right contains the flight manual's instruction for calculating the centre of gravity with regard to the skydivers.

Skydivers maintain their personal, jump experience and equipment information with the help of a waiver[6]. One skydiver's waiver was not found at all, another one's waiver was updated in 2012 and a third one's in 2013.

5 In a wingsuit there is fabric between the legs which facilitates gliding during freefall. The fabric between the arms and the torso make it possible to steer the glide. The fabric portions are locked ready for use with zippers. Whereas the zippers between the legs are normally already done up on the ground, the zippers between the arms and the torso are done up just before the jump.

6 According to the Tampere Skydiving Club's internal instructions, skydivers must update their personnel data forms (waiver) on an annual basis. By signing the waiver the skydiver pledges to follow the rules and regulations on skydiving operations. Waivers have become a standard control practice that supplements regulations and instructions.

Skydiver no.	Exit weight[1)] [kg]		Licence[2)] and the number of jumps	Note
	Load-list	Waiver (date)		
1	92	90 (4/2014)	D, > 1000	Wingsuit
2	97	95 (3/2014)	D, > 2200	Wingsuit
3	92	92 (3/2014)	A, 75	
4	100	102 (2/2013)	C, > 400	Wingsuit
5	95	90 (3/2012)	D, > 500	Load organiser
6	95	95 (4/2014)	B, 140	
7	120	115 (4/2014)	D, > 900	Wingsuit
8	93	92 (3/2014)	C, > 250	
9	76	77 (3/2014)	B, 100	
10	69	-	B, 120	

1) Exit weight = the skydivers weight in full gear.

2) Skydivers are rated into four classes, i.e. independent parachutists which are: students, tandem students as well as A, B, C and D-licenced skydivers. Class requirements are: A 25 freefall jumps, B 50 jumps, C 200 jumps and D 500 jumps. The instructions that entered into force after the accident refer to free-fall skydives as self-pull jumps.

1.6 Aircraft information

1.6.1 Aircraft

The Comp Air 8 Turbine is a high-wing airplane of mostly fibreglass construction designed by Aerocomp Inc. and is sold as a kit. A small amount of carbon fibre is also used in the design. Among other places, the aircraft type is used for skydiving operations in Brazil and Chile. The aircraft was registered in the experimental[7] aircraft category and it was the only one of its type in Finland.

The OH-XDZ was built for skydiving operations. According to its Permit to build[8], its carrying capacity, in addition to the pilot, was 8-10. It was possible to fit the aircraft with dual flight controls. The co-pilot's seat and flight controls were usually removed during skydiving operations. Compared to the basic model of the CA8 the OH-XDZ's kit included a wing with 12 inch winglets, a wider 52 inch body, a two-part windshield and wider engine cowlings. The required insurance was valid.

7 As per Aviation Regulation AIR M5-2 experimental amateur-built and non-type certificated aircraft belong to the experimental category. In addition to these, a rebuilt or significantly modified, type certificated aircraft can be accepted to this category upon application.

8 Pursuant to the amended Aviation Act of 13 Nov. 2014, Permits to build are no longer required for experimental builds (Section 42 of Aviation Act 864/2014).

The OH-XDZ was designed for day and night VFR operations. Only the pilot sitting on the left side had an instrument panel because, during the construction, a space had been reserved in the front right corner of the cockpit to accommodate one more skydiver. In the middle of the instrument panel there was a multi-function display incorporating a Dynon EFIS-D100 and a Garmin 196 GPS-device. The colour LCD display of the Dynon multi-function display displayed attitude information by means of an artificial horizon as well as heading, airspeed and altitude information numerically. Additionally, the instrument panel housed an analog airspeed indicator and altimeter as well as a turn and bank indicator. Engine displays were digital. The ailerons and the elevator were controlled with a control stick. In addition to two push-to-talk (PTT) buttons at the end of the stick there was a control switch for electrically operated aileron and elevator trim tabs.

Type	Comp Air 8 Turbine
Nationality and registration	OH-XDZ
Serial number	1
Manufacturer	Finland's Sport Aviators and two private individuals
Year of manufacture	2008
Operator	Finland's Sport Aviators
Running time and landings	809 h, 3 015 landings
Fuel	Jet A-1
Fuel capacity	687 l
Maximum takeoff weight	2 540 kg
Maximum load	1 232.5 kg
Limit loads[9]	+3.8…-1.9

Stall speeds and maximum airspeeds

Stall speeds and airspeed limits as per the OH-XDZ's flight manual:

Stall speed in a clean configuration (V_{s1})	59 KIAS[10]
Stall speed with 38 degrees flaps (V_{s0})	53 KIAS
Design manoeuvring speed (V_a)	145 KIAS
Maximum speed for normal operations (V_{no})	155 KIAS
Never exceed speed (V_{ne})	199 KIAS

Aerocomp Inc. Corporation's airspeed limits for Comp Air 7,8 and 10 Pilot's operating handbook:

Design manoeuvring speed (V_a)	179 mph = 156 KCAS[11]

9 The Permit to build was applied for in accordance with the kit manufacturer's figures +3.8…-1.8 @ 5600 lbs 200% safety factor. Pursuant to Aviation Regulation AIR M5-2 Experimental aircraft construction the limit loads must be, at least, within the range of +3.8…-1.5. Regarding these, the safety factor 1.5 must be used in structural design.

10 KIAS = Indicated airspeed in knots. The airspeed which the pilot reads on the aircraft's airspeed display. KIAS does not correct for position error in the pitot system (= positioning of the pitot tube and the static port, and the effects of the error between static pressure and free-stream pressure at different airspeeds), indicator error or the effects of compressibility.

Maximum speed for normal operations (V_{no})	179 mph = 156 KCAS
Never exceed speed (V_{ne})	227 mph = 197 KCAS.

Figure 3. Comp Air 8 OH-XDZ photographed in Räyskälä in 2009.

Powerplant

The aircraft kit included a turboprop engine, originally of model M601D, manufactured by Walter Aircraft Engines corporation (nowadays GE Aviation Czech s.r.o). This individual engine was manufactured in the Czech Republic in 1985 and it was completely overhauled by the manufacturer on 19 Jan 1989 at the running time of 1 500 h. According to the manufacturer the engine had gone to the Soviet Union after its overhaul.

There is no conclusive or consistent history as to the engine's use from 1989-2009. At some stage the engine was acquired by the American Diemech Turbine Solutions Inc. An IRAN[12] Millennium conversion was made in 2004. Following the repair the engine type was changed to Diemech M601D, because the engines overhauled by the company are not certified by the original manufacturer or the Federal Aviation Administration (FAA). It is only permissible to use such engines in non-type certificated aircraft.

Serial number	852035
Maximum continuous power	657 shp
Total running time	not known
Engine running time after IRAN repair	754 h.

[11] KCAS = Calibrated airspeed in knots. KCAS does correct for position error in the pitot system and indicator error. It does not correct for compressibility.

[12] IRAN stands for Inspect and Repair As Necessary. This is typically done when the condition of an engine is unknown if it has been stored for long periods or it can be presumed to have suffered internal damage. **This is not the same as a complete overhaul**. The IRAN repair process is a means to bring an engine back to the manufacturer-recommended cycles, which are determined from its previous use, for example, from the engine's logbook. If the engine's running time has been, for example, 700 h and the maintenance cycle is 2000 h, the remaining running time after the completion of IRAN repair is 1300 h.

Propeller

The airplane had a 3-bladed V508D constant speed metal propeller, manufactured by Avia Propeller (formerly Avia n.p.). The aircraft's technical log describes the type as being V508D-AG. On 17 Jul 2008 the American Diemech Turbine Solutions Inc. carried out an IRAN repair on the propeller at the running time of 2 000 hours. As the propellers overhauled by the company are not certified by the original manufacturer or the FAA, it is only permissible to use them in non-type certificated aircraft.

The propeller came with the kit from the same supplier as the engine. The builders did not know the propeller's entire use history.

Serial number	310661730
Year of manufacture	1989
Total running time	not known
Running time after overhaul	809 h
Governor	LUN7815.02.

The engine's beta and reverse pitch ranges

During the landing roll it is possible to slow down using the propeller in the CA8. It is achieved by turning the blade pitch to an angle which makes it possible to use engine power to decelerate the aircraft during the landing roll. Such a blade angle is known as the beta range of operation. The beta range is also used in taxiing. Propeller blade angles can also be set to reverse thrust, i.e. to sufficiently high negative angles which make it possible to reverse the aircraft during taxiing.

In order to set the propeller to the beta range or reverse thrust the pilot lifts the throttle lock on the power lever to the upright position with the fingers of his right hand. Then the power lever can be pulled back, past the idle position. The purpose of the throttle lock is to prevent inadvertent throttle pulling below flight idle while airborne.

On a ferry flight from Utti to Jämijärvi, on 9 Mar 2014, the pilot of the accident flight made a mistake by accidentally pulling the power lever to the beta range below the flight idle when he was about to reduce airspeed during the approach. The more experienced pilot sitting on the right side of the cockpit immediately noticed the situation and the power lever was returned to the normal range. The situation was so short-lived that it had no effect on airspeed or attitude.

According to the flight manual the beta range is used during the landing roll to slow the aircraft down to taxi speed. While the use of reverse thrust may shorten the landing distance in emergencies, it is not recommended by the flight manual because the propeller wash pulls up debris off the runway into the propeller. Before increasing power during takeoff, according to the flight manual, one must confirm that the propeller is not in the beta range, i.e. that the beta lamp on the instrument panel is not illuminated.

Hub model Typ vrtule	Setting at minimum flight angle Nastavení min.letového úhlu	Beta-ring protrusion at minimum flight angle Vysunutí beta-kroužku při nimimálním letovém úhlu	BETA-range / BETA-pásmo	
			Flight angle at BETA-lamp on Letový úhel při rozsvícení BETA-lampy	Beta-ring protrusion at BETA-lamp on Vysunutí beta-kroužku při rozsvícení lampy
All models except / Všechny verze mimo V508D-AG with blades / s listy 84, 99A, 99B	15°		8°	
Only / Pouze V508D-AG with blades / s listy 84, 99A, 99B	10°	4,5 mm (0.177 inch)	3°	9,5 ±0,1 mm (0.374 ±0.004 inch)
All models / Všechny verze with blades / s listy 106	12°		5°	

Tabulka 11-1 Nastavení min. letového úhlu vrtulí řady V508 s regulátorem LUN7815 Table 11-1 Min.flight pitch adjustment of propellers V508 Type Series with governor LUN7815

Figure 4. Governor control values (Source: Avia propeller operation and installation manual E-1500.)

1.6.2 Maintenance history

According to Aviation Regulation AIR M5-3 the builder or owner of an experimental aircraft can also carry out annual inspections, periodic inspections, minor repairs and equipment maintenance.

The aircraft's maintenance programme was inspected and approved on 6 Aug 2009. A supplement to the maintenance programme was added on 6 Jan 2010.

Fuselage

The fuselage's maintenance cycles were 50 h and 100 h. An external visual inspection of the wing strut is included in both maintenance cycles. The maintenance programme had been followed.

Powerplant

According to the maintenance programme the first maintenance is carried out at 100 h from its introduction to use. After this, the maintenance cycle is 300 h or 400 starts, depending on which one comes first. The overhaul cycle of the engine is 1 500 h or 2 250 starts.

According to the aircraft's technical logbook the builders removed the engine on 20 May 2009 during test flights because a fault was discovered. The engine was sent to Diemech for repairs. During the repair it was discovered that the gas turbine bearing was damaged due to a blockage in the lubrication line. On 24 Jun 2009 an IRAN repair was carried out at the running time of 1 748 h. The builders reinstalled the engine on 21 Jul 2009.

The Fuel Control Unit (FCU) had been sent to the manufacturer twice, at 94 h and 430 h, respectively.

The builders completed the last 300 h maintenance on 7 Jun 2013 at the running time of 2 378 h. The last maintenance actions involved replacing the starter generator's carbon brushes on 23 Jun 2013 at the running time of 2 401 h, and changing one spark plug on 16 Aug 2013 at the running time of 2 482 h.

Propeller

The maintenance cycle of the propeller is 100 h and its overhaul cycle is 2 000 h or six years. Its use limit is 8 000 h.

According to the aircraft's technical logbook the builders had removed the propeller on 20 May 2009 and reinstalled it on 21 Jul 2009 in conjunction with the engine's removal and reinstallment. Following this, the builders regularly carried out the maintenance actions stipulated in the 100 h maintenance cycle. The builders completed the last 100 h propeller maintenance on 16 Aug 2013 at the running time of 2 734 h.

1.6.3 Weight and balance information

Weight

The last weighing and balance protocol was dated 13 Oct 2013. According to the protocol the empty weight was 1 307.5 kg and the maximum load 1 232.5 kg. Consequently, the maximum takeoff weight was 2 540 kg.

As per fuelling records 240 l of fuel were added to the airplane on 20 Apr 2014 at 15:00. According to the information available, the total fuel load after the refuelling was approximately 280 l. One skydiving flight was flown on the airplane after refuelling, which means that the airplane had approximately 230 l (184 kg) of fuel when it took off for the accident flight.

Ten skydivers climbed aboard the airplane. The usable weight of the aircraft, entered in the spreadsheet program which was used by the manifest[13] who acknowledged the skydivers' reports for being present, was 1 200 kg. The spreadsheet did not include the pilot's weight or any information as regards the fuel load. The list of jumpers, or *load list,* which was delivered to the pilot prior to the flight only showed the weights of the skydivers without their seating arrangement. The pilot was to compute the total weight of the airplane and the position of the centre of gravity as per the load list.

According to the load list the total weight of the skydivers was 929 kg. The weight of the pilot, including that of his emergency parachute, was 111 kg. In accordance with the investigation group's calculations the aircraft's ramp weight was 2 531 kg, i.e. nine kilogrammes below the maximum takeoff weight.

[13] The manifest is a functionary in skydiving operations who assigns skydivers into aircraft as per their reports for being ready, and sequences their preparedness for jumps in such a manner that the next load of skydivers is waiting for the landing airplane, ready to board the plane. The manifest prepares a load list with a spreadsheet program which the load organiser then delivers to the pilot.

Centre of gravity as per the flight manual

According to the flight manual the forward centre of gravity (CG) limit at the total weight of 1 297 kg is 0.306 m. The forward CG limit at 2 540 kg is 0.362 m. The aft CG limit for all weights at takeoff and landing is 0.515 m. The aft CG limit on a jump run is 0.610 m. The flight manual does not set CG limitations for any other phases of flight. The values given in the flight manual are determined on the basis of flight characteristic test flights. The test pilot's comments on the airplane's flight characteristics at different CGs were appended to the builders' application for a Permit to fly.

The aircraft had no seat belts for the skydivers, nor were their seating positions marked in the cabin. When it comes to inspecting the correct loading with regard to the CG, this was based on the pilot's visual estimate.

In the flight manual's loading chart (Figure 2) the skydivers were assigned numbers from 1 to 10 on the basis of their seating. The moment arms of these positions were given for the purpose of computing the CG. All skydivers sat in an aft-facing position. They are to board the airplane in a sequence that allows the last three skydivers to exit the airplane to enter first and be seated in the forward part of the cabin, one behind the other at positions 1-3 next to the pilot. Skydiver 1 sits on the floor with his back pushed against the cockpit's front wall (firewall). Skydivers 2 and 3 sit on a narrow bench next to the pilot, approximately 25 cm above cabin floor level. According to the flight manual skydiver 4 is to sit on the floor behind the pilot, next to skydiver 5 who sits on a bench, and skydiver 6, sitting on the floor. Skydivers 7 and 8 sit in the next row on the floor, as do skydivers 9 and 10 in the rearmost row. The moment arms of the skydivers sitting on the floor one behind the other, used in the spreadsheet program, were 40 cm apart from each other.

When the accident flight's fuel load and the flight manual's seating arrangement as well as the default weights for the pilot and the skydivers (85 kg each) are used in computing the centre of gravity, it is 0.509 m at takeoff. However, when the real weights of the accident flight's pilot and skydivers are used instead of the default values, the CG is 0.507 m at takeoff.

Determining the centre of gravity on the accident flight through testing

Judging by photos and videos taken from earlier skydiving flights on the OH-XDZ the seating of many of the skydivers in the cabin differed from the flight manual's loading chart.

In order to evaluate the airplane's CG the investigation group constructed a scale model based on the CA8's cockpit and cabin for the purpose of evaluating the actual loading on skydiving flights at different phases of flight. Since there were no precise blueprints, some dimensions of the aircraft were obtained from a CA8 being used in Chile. The dimensions of the pilot's seat and the measurements of the two benches in the cabin were estimated from photographs.

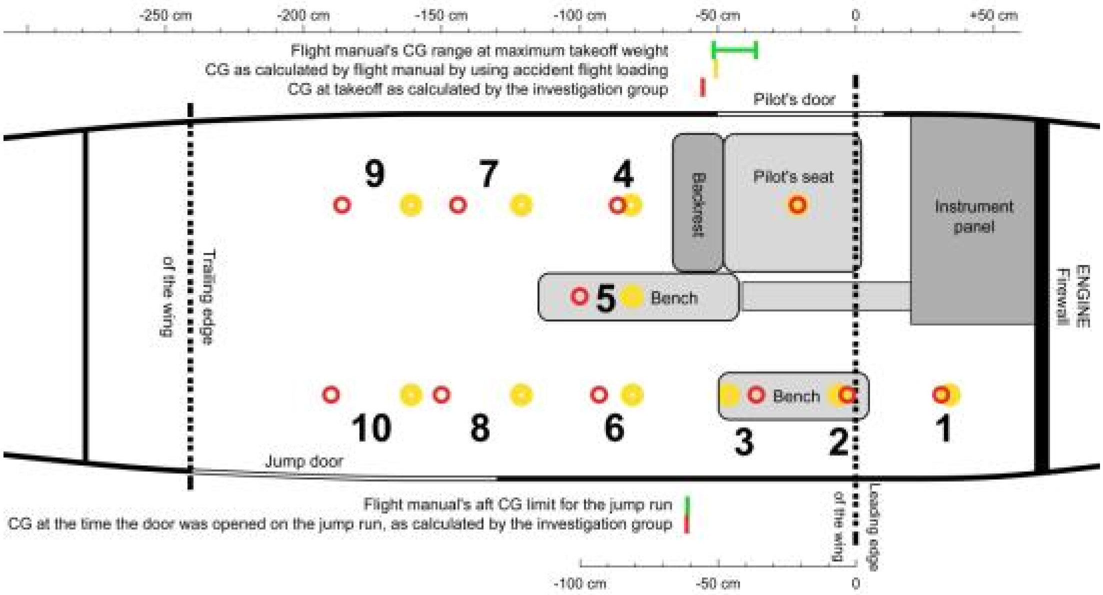


Figure 5. The positioning of skydivers in the aircraft as per the flight manual (yellow markings), and that in accordance to the investigation group's measurements (red markings).

A pilot and ten persons in full parachuting gear entered the scale model and positioned themselves at the places determined by photographs and videos from previous flights. The total weight of these skydivers came within 20 kg of the loading on the accident flight. Based on the measurements the cabin must have been really cramped, especially along the centreline, with ten skydivers inside.

According to measurements the width of the cabin (132 cm) did not make it possible for three normal-sized skydivers (skydivers 4-6) to sit side by side even if the one in the middle sits on the centreline bench. Skydiver 5, in the middle, must sit slightly to the front or to the back. According to the accounts of the survivors, and judging by photos and videos taken from earlier skydiving flights, skydiver 5 sits a bit towards the rear of the cabin. Therefore, as skydivers 4-6 are not seated in a straight row, the flight manual-specified moment arms of skydivers 7-10 on the last two rows are, in accordance with the measurements, unrealistic.

The table below presents a comparison between the flight manual-specified values and those achieved through measurements when skydivers are seated as tightly as possible, facing rearwards. As per the measurements the persons in positions 7-10, wearing full parachuting gear, sat at least 23-29 cm further back compared to the values given by the flight manual.

Position	Arm [cm]		Delta [cm]
	Flight manual	Measured	
Pilot	21	21	0
H1	-34	-31	+3
H2	6	3	-3
H3	46	36	-10
H4	81	86	+5
H5	81	100	+19
H6	81	93	+12
H7	121	144	+23
H8	121	150	+29
H9	161	186	+25
H10	161	190	+29

When the CG was computed by using the measured moment arms, the CG at takeoff on the accident flight was at 0.554 m, i.e. outside the aft CG limit given in the flight manual.

When the airplane approaches the jump run in normal skydiving operations the rearmost skydivers move towards the rear of the cabin to crack open the jump door for the purpose of catching site of the jump run, and to prepare for the skydive. This moves the CG towards the rear. The scale model was used to reconstruct a situation where skydivers 7 and 9 got onto their knees and skydivers 8 and 10 went to open the jump door and to catch sight of the jump run. In this case the CG, when computed with the actual weights of the persons on the accident flight, would have been at 0.612 m, i.e. slightly outside the flight manual's aft CG limit.

CG calculation spreadsheet program

Two student pilots received an Excel sheet on a CA8 type rating course organised in 2013. As far as they understood this was a spreadsheet for flight planning and calculating the OH-XDZ's centre of gravity. The logo of Finland's Sport Aviators (Suomen Urheiluilmailijat ry) was at the top left corner. The pilot of the accident flight had used the spreadsheet for CG calculation, at least, during the training and the consequent skydiving familiarisation flight training. When it comes to the values for skydiver seating and fuel moment arms, the spreadsheet markedly differed from the values presented in the flight manual. The CG position, and the way it changed in relation to varying fuel loads, was presented in a graph in the spreadsheet. The fore and aft CG limits given in the graph did not correspond to the limits given in the flight manual.

CG in formation skydiving

In accordance with *Section 7.2 Loading* of the flight manual of the OH-XDZ; *"Skydivers in the cabin must be positioned as far forward as possible at takeoff and landing. On the jump run the centre of gravity may exceed its normal aft limit, which facilitates multi-jumper group exits. According to flight test results, for instance, a 6-way group exit from outside with the four remaining skydivers preparing for the climb-out inside the airplane does not result in any specific flight control issues."*

In the flight test phase the abovementioned 6-way group exit, i.e. a simultaneous jump by six skydivers, was performed. When the Permit to fly was being applied for, the moment arms of such a group exit were given in the flight test report which was appended to the application. According to the flight test report the CG was at 0.626 m in this test jump situation. If the comparison uses the default value of 85 for the skydivers and the pilot, and if the fuel load corresponded to the weight on the accident flight, the computed CG is at 0.626 m even if the four remaining skydivers remained in their positions at the front of the aircraft. Both values exceed the flight manual's aft CG limit (0.610 m) on the jump run.

1.6.4 Equipment of the pilot and the surviving skydivers

This is included in the Finnish version only.

1.7 Meteorological information

According to the Finnish Meteorological Institute's (FMI) account of the accident day's weather, a weak front was passing towards the southeast over southern Finland. Scattered clouds mainly appeared at the medium and high levels, stretching from the Gulf of Bothnia to Lake Ladoga. During the day the warm front off the west coast of Finland gradually moved north.

At and around Jämijärvi aerodrome weak northeasterly surface winds prevailed in the afternoon; wind strength was approximately 4-8 kt[14]. According to the 15:30 radar wind sounding made at the Ikaalinen weather station the wind between 450 - 1 200 m was 050–070˚, 7 kt. At 3 000 m the wind data followed the weather model, blowing from the southeast at approximately 5-10 kt and turning into 5-10 kt strong southwesterly winds at the altitude of 4 500 m.

In Juupajoki's (80 km to the east from Jämijärvi) weather balloon sounding at 15:00 the wind was 200˚ 10 kt at 4 000 m. The corresponding sounding made at Jokioinen (110 km to the southeast from Jämijärvi) indicated that the wind at 4 000 m was 150˚, 10 kt.

[14] 1 knot = 0.5144 m/s = 1.852 km/h

Visibility at Jämijärvi and in its vicinity was good; it was approximately 40-45 km. At times altostratus appeared at approximately 3 500 m; in addition to this high clouds appeared. According to Niinisalo's (15 km to the west-northwest from Jämijärvi) synoptic code (SYNOP) at 15:30, medium-level cloud was reported to appear at 3 450 m, covering 7/8 of the sky.

Surface temperature was 13–14˚C and dew point 3–5˚C. According to the meteorological sounding an approximately 4˚C strong inversion appeared above 3.5 km. The medium-level cloud layer below the inversion was very thin; it is likely that no significant icing occurred. As per the FMI's meteorological account no significant turbulence or other significant weather phenomena occurred.

In accordance with the FMI's daily forecast of bird migration intensity for 20 Apr 2014, migration continued at a heavy rate in dry weather. According to the forecast, hawk soaring migration was intense from 10:00 to 15:00 up to 1 500 m. Even though no observational data are available as regards the actual migration, Ikaalinen weather radar received clear air echoes (birds and insects) up to approximately 1 200 m.

Special weather observations at Jämijärvi

Six skydiving flights were flown from 11:00 - 15:30 to the altitude of 3 500 - 4 000 m on the day of the accident.

On these flights that preceded the accident, pilots did not observe any specific turbulent layer. In the morning they had already noted the change in wind direction above 3 000 m. Since they did not penetrate the cloud on skydiving flights, no observations of any possible icing in cloud were made. Nor did the pilots report seeing any migrating birds.

The investigation group also explored the prevailing meteorological conditions by means of one wingsuit jumper's videocam recording. As per the recording the sky was clear above Jämijärvi airfield within a radius of five kilometres at least.

On the basis of the soundings and the skydivers' helmet-cam recordings who had made their dive before the accident flight, medium-level clouds at 3 500 m were visible in the direction of the jump run, to the north of the airfield. Cloud coverage increased towards the north, from 4/8 to at least 7/8.

As regards cloudiness the west-northwest sector, where the pilot probably looked when he commenced and continued the turn, was essentially similar to the north sector. Whereas cloud coverage at 3 500 m increased to 7/8 approximately 15 km from the airfield, it clearly decreased towards the south. In the direction where the pilot straightened out after having overshot the jump run the sky was clear in wide areas. Nevertheless, medium-level cloudiness also increased in this sector when looking further away from the airfield.

1.8 Aids to navigation

A Garmin GPS device installed in the instrument panel was used on the flight. The device was destroyed in the accident.

1.9 Communications

This is included in the Finnish version only.

1.10 Aerodrome information

Jämijärvi aerodrome (EFJM) is located in Jämijärvi municipality, approximately 26 km to the east-northeast of the city centre of Kankaanpää. Jämijärvi ARP coordinates are N61°46’43” E022°42’58”. Aerodrome elevation is 505 ft (154 m). The asphalt-surface northern runway 09/27 is 830 m long and 18 m wide. The bitumen-surface southern runway 15/33 is 830 m long and 15 m wide. There is a good deal of general and sport aviation activity at the aerodrome which is operated by Jämi foundation.

In the area around the Jämi Area, located at the aerodrome, accommodation and restaurant services, the Tampere Skydiving Club premises and the Jämi Areena, a multi-purpose facility, among other things, can be found.

1.11 Flight recorders

The aircraft had no flight recorders. The skydivers had recording altimeters and AADs which provided some information from the final phases of the flight. In addition a Protrac altimeter was found at the accident site. Its memory, however, was empty.

Altitrack altimeter

The Altitrack is a wrist-mounted recording altimeter manufactured by the Larsen & Brunsgaard company. The display is analog. The device is designed to activate at the time of exit, and to store information from the entire jump. Recording starts on the basis of the rate of change in air pressure. Its sensitivity can be adjusted.

The investigation group had access to skydiver no. 2’s device. The stored information was downloaded onto a computer and processed with software designed for a jump journal. The altimeter provided useful information from the final phases of the flight to the investigation. The activation of the device was adjusted to the most sensitive setting, at which a four second continuous descent at 25 m/s, at minimum, turns the recording on.

CYPRES

CYPRES, i.e. **CY**bernetic **P**arachute **R**elease **S**ystem, is an Automatic Activation Device (AAD) manufactured by Airtec GmbH. The device operates by measuring air pressure and its change. The investigation group had access to three EXPERT CYPRES 2 AADs. They were programmed to deploy the reserve parachute if the jumper's descent rate exceeded 35 m/s and the altitude was 225 m AGL. The device stores 30 seconds worth of pressure and temperature data. Every device had activated. Two of the AADs were worn by the skydivers who survived the accident; they remained intact. The third one was found inside the wreckage. The information contained by the AADs was downloaded at the manufacturer's laboratory, supervised by representatives of the German Federal Bureau of Aircraft Accidents Investigation (BFU) and the SIAF. Every inspected device had stored information from the accident flight.

1.12 Wreckage and impact information

This is included in the Finnish version only.

1.12.1 Accident site and items found

This is included in the Finnish version only.

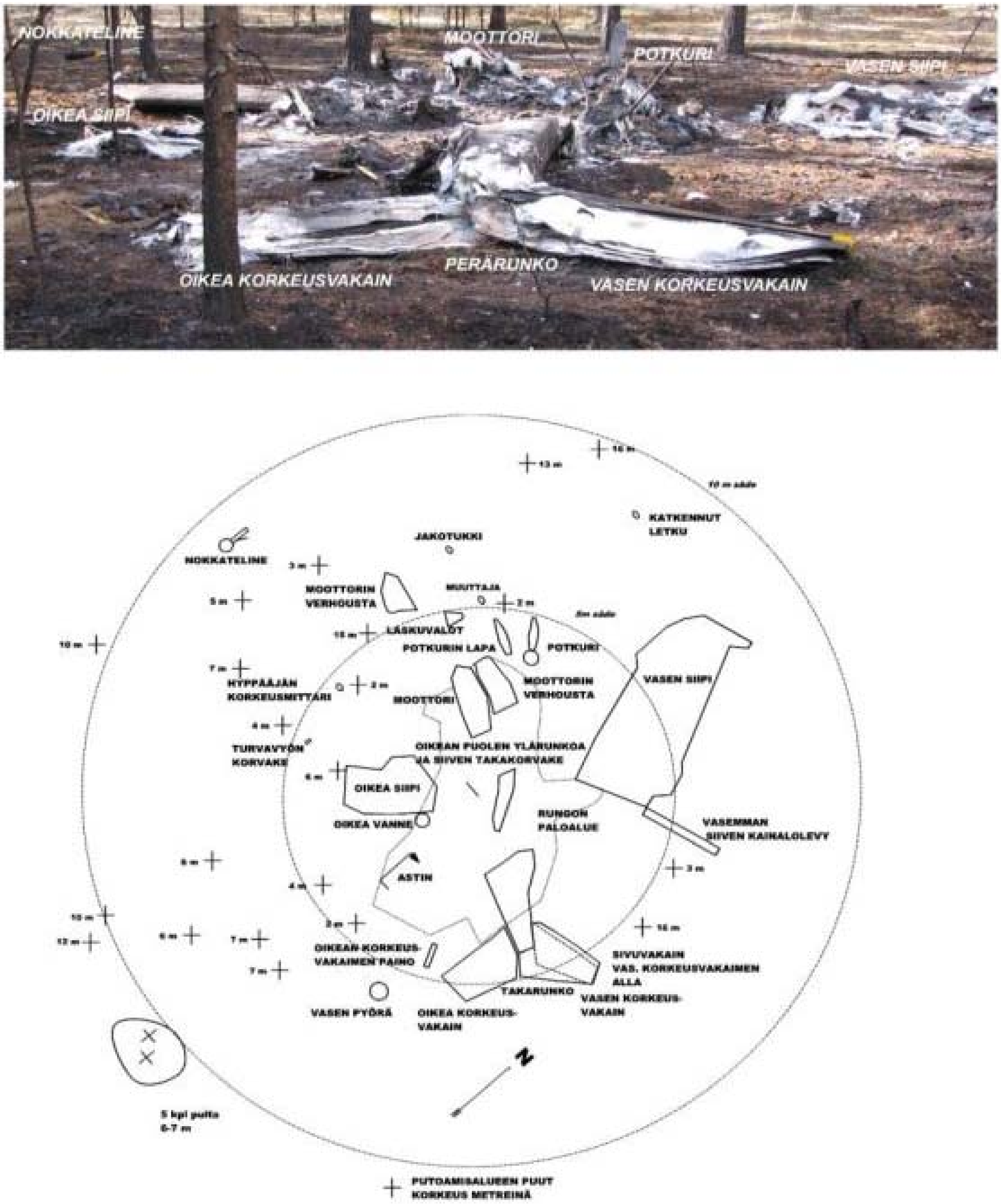


Figure 6. Photograph of the wreckage, taken from the tail end, and a diagram of the accident site. The diameter of the outer ring is 20 m.


Figure 7. The upper fillet between the right wing and the fuselage, found in the terrain.

1.12.2 Inspection of the wreckage

This is included in the Finnish version only.

Figure 8. The right wing's main spar fitting and the fuselage-side fitting.

1.13 Medical and pathological information

Post-mortem examinations were performed at the department of biomedicine of Turku University on the victims that died in the accident. The autopsies confirmed that the victims perished as a result of the serious injuries sustained in the collision with the ground. No signs of combustion gases were found in their respiratory tracts.

The result of the pilot's blood sample, taken immediately after the accident, showed zero blood alcohol. He is a casual smoker. His medical history does not present any evidence which could have appreciably contributed to his performance on the day of the accident.

1.14 Fire

The aircraft caught fire. The amount of fuel (approximately 100 l) in one wing tank and the resin in the reinforced plastic structure created the biggest fire load. The cloud of smoke could be seen from afar.

1.15 Rescue action and survival aspects

1.15.1 Emergency calls and dispatching

This is included in the Finnish version only.

1.15.2 Action of the people at the site

This is included in the Finnish version only.

1.15.3 Aeronautical Search and Rescue

This is included in the Finnish version only.

1.15.4 Aerial search conducted by TamLK

This is included in the Finnish version only.

1.15.5 Rescue services

This is included in the Finnish version only.

1.15.6 Aerial search conducted by the authorities

This is included in the Finnish version only.

1.15.7 Emergency medical care

This is included in the Finnish version only.

1.15.8 The Police

This is included in the Finnish version only.

1.15.9 Immediate psychosocial support

This is included in the Finnish version only.

1.15.10 Oil spill recovery

This is included in the Finnish version only.

1.15.11 Survival aspects

Egress from the OH-XDZ

The airplane had two doors. The pilot and the surviving skydivers exited through the pilot's door on the left side of the cockpit. The door was 90 cm x 110 cm in size. The door was hinged from the upper frame and it opened upwards with the help of a door pump. According to the survivors it was easier to exit the airplane as the door stayed open. Since the airplane was falling with its right side towards the ground, the survivors had to climb upwards to get out. Only one person could exit at a time because of the size of the door.

The jump door was on the right side of the fuselage, in the rear part of the cabin. Its dimensions were approximately 130 cm x 130 cm. The door frame was made of aluminium and its skin panel was made of a transparent 4.8 mm thick polycarbonate sheet. The door opened towards the nose, i.e. against the airflow, on two aluminium rails. The pilot could close the door with a handle on the left wall of the cockpit. It is not known whether there were any problems associated with opening or closing the door during test flights or skydiving operations. Some skydivers who had jumped out of this aircraft type said that, compared to the jump doors on other aircraft types, it took more power to open this door. Judging by videos, two skydivers together would normally open the jump door.

During the dive the right wing of the airplane was folded sideways against the fuselage. The position of the wing made the cabin darker and prevented the use of the jump door. In all likelihood the jump door was closed when the airplane collided with the ground.

The pilot's seat was fitted with a 4-point quick release harness. The skydivers had no seat belts.

Skydivers 1, 2, 4 and 7 were wearing wingsuits. They had probably not zipped their suits all the way. Rather, the zippers on their sleeves were undone. A fully zipped wingsuit limits arm movement especially and may hamper moving inside the cabin.

Figure 9. The pilot's door on the left and the jump door on the right. (Right photo: Teemu Hietakari)

Skydivers 1, 2, 4 and 7 were wearing wingsuits. They had probably not zipped their suits all the way. Rather, the zippers on their sleeves were undone. A fully zipped wingsuit limits arm movement especially and may hamper moving inside the cabin.

The airplane fell at the average rate of 75 m per second and it was rotating at approximately 134 degrees per second. The centre of rotation was on the nose of the airplane, or in front of the nose. As regards the attitude of the airplane, it was approximately - 10 degrees nose down and approximately 100 degrees banked to the right. The attitude and the flight condition varied from the averages during the fall. Factors affecting the flight track included the wind, skydivers and the pilot bailing out, the partly separated wing, the opening of the pilot's door, and the shifting centre of gravity caused by passengers moving inside the cabin.

Due to the centrifugal force, the load factor varied inside the airplane; at the pilot's position it was approximately 1.7 - 2.5 g and at the aft bulkhead it was approximately 3.4 - 4.2 g.

Functioning of the parachutes

The skydivers' reserve parachutes including the Automatic Activation Devices (AAD) and the pilot's emergency parachute functioned as designed. According to regulations student skydivers, tandem students and holders of A and B licences must use AADs in skydiving operations. According to the information collected by the Parachuting Commission of the Finnish Aeronautical Association three lives were probably saved in 2013 when AADs deployed reserve parachutes.

Skydiving clubs' internal regulations normally require the pilot to wear an emergency parachute even though national Aviation Regulations do not require such.

1.16 Tests and research

1.16.1 The accident flight

Eyewitnesses

None of the eyewitnesses to the accident flight had followed the aircraft on the jump run or the following turn. Two eyewitnesses had seen the aircraft in flight after the turn. One of them was at Jämijärvi airfield and the other one five kilometres away. They described the airplane making two nose-up movements followed by which it fell into the woods. Both of them said that the airplane was leaving a vapour trail at the time of their observations. Several eyewitnesses saw the final phase of the accident flight. Most of them had heard the airplane's unusual sound.

The investigation had access to two eyewitnesses' videos from the final stage of the fall. From these videos it was possible to estimate the aircraft's attitude and rate of rotation.

The aircraft's positional and altitude information

The OH-XDZ had no equipment which could record flight attitude or engine information. Many flight radars detected the airplane, and radar return material was used in analysing its flight path. The accuracy of, especially, altitude information varied. In the early phase of the flight the rate of recurrence of radar echoes compiled from different radars was rapid, but it was uneven and less frequent in the final phase of the flight. Flight related altitude information from the final phase of the flight was accrued from the altimeter of a skydiver who was on the accident flight and from the reserve parachutes' AADs. This enhanced the analysis of the flight path.

Acoustic analysis

Information on the accident flight's engine sounds was received from a helmet camera recording from a paraglider in flight. The acoustic analysis aimed to establish the engine's power setting and the propeller RPM while airborne. For purposes of comparative analysis, the engine and propeller sounds of a similar engine were recorded at different power settings and propeller RPMs.

Since the relative positions of the paraglider and the accident aircraft were constantly changing, and because of their considerable difference in altitude as well as the wind, radiocommunications and other background noise, it was not possible to precisely determine the engine settings or the propeller RPMs in the final phase of the flight.

Flight path analysis

In order to analyse the flight path the investigation group used eyewitness videos, compiled radar information, the skydivers' AADs and a recording altimeter. By means of compiled radar information it was possible to create a very accurate flight path in the XY plane. However, the diminishing number of radar returns towards the end of the flight made it more difficult to determine the flight path and the airspeed of the aircraft. By adding the information from the skydivers' equipment the airplane's hitherto imprecise altitude information became precise during the left turn which followed the interrupted jump run. The airplane's attitude information was computed on the basis of the estimated flight path. The computed attitude information is only illustrative in a normal flight condition, i.e. before the aircraft came to be in a flight condition resembling an inverted spin. It is not possible to reliably estimate the angle of attack of the angle of sideslip. For this reason it is not possible to accurately assess the flight condition at the onset of the dive or during it. The flight which preceded the accident flight was modelled using the same method.

After the jump run, a little below 4 200 m AGL, the airplane turned to the left at the approximate bank angle of 45 deg to the heading 210 deg. At first the altitude began to gradually drop, and as the glide angle increased the ground speed exceeded 200 kt. The altitude at this time was approximately 3 850 m AGL.

By means of using ground speed information accrued through a few radar plots during the final phases of the flight, the flight path analysis and weather sounding information from the accident day, the investigation tried to determine the aircraft's airspeed information. On the basis of the calculations the airspeed possibly peaked at 188-194 KCAS. The corresponding indicated airspeeds are 202-209 KIAS, presuming that the calibration graph in the OH-XDZ's flight manual is linear at airspeeds exceeding 170 kt. In the flight test phase the OH-XDZ's pitot system error was not demonstrated at airspeeds exceeding 170 kt. It was difficult to precisely determine the momentary maximum airspeed with the basic information at hand.

Following an approximately 20 sec long glide the flight path then changed into a shallow climb for a few seconds. At this point in time the altitude was approximately 3 850 m AGL. After this the airspeed clearly decreased. The airplane fell for 55 seconds in a flight condition resembling an inverted spin before it collided with the ground.

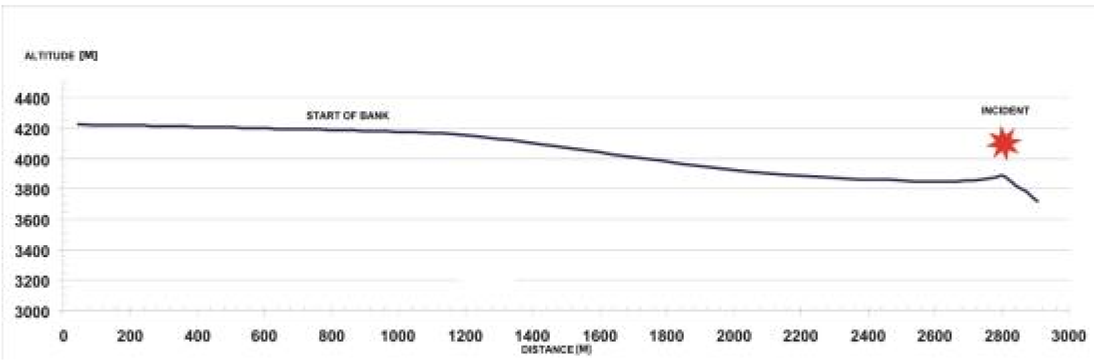


Figure 10: The OH-XDZ's altitude from the end of the jump run to the time of the incident.

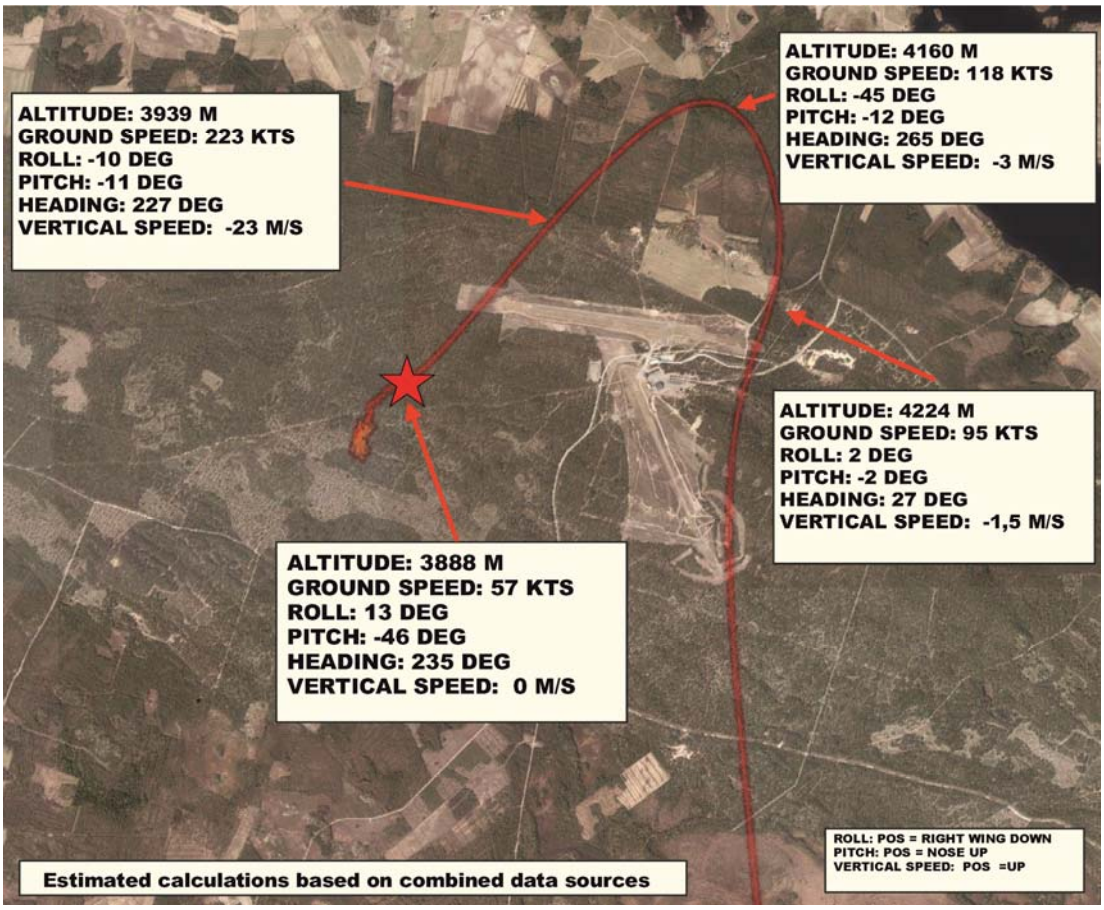


Figure 11: The final phase of the flight path of the accident flight (Aerial photo: Land Information System in Finland (KTJ)/Ministry of Justice/National Land Survey)

1.16.2 Material inspection of the right wing's wing strut

The SIAF commissioned an analysis of the material and fracture characteristics of the lower part of the right wing's wing strut, found at the site of the accident, from VTT Expert Services Oy. Surplus wing strut material was provided as a reference. The goal of the analysis was to examine the fracture mechanism of the lower part of the wing strut. Of particular interest was whether the wing strut's perpendicular or longitudinal fracturing occurred when the strut was cold, i.e. when airborne, or in the collision with the ground, or did it occur in the fire that followed the crash. The aim was to also evaluate the directions of the relevant force vectors, and to analyse the wing strut material. VTT's research report is attached as Appendix 2 (note: in Finnish only).

Figure 12. The analysis focused on the lower part of the right wing strut.

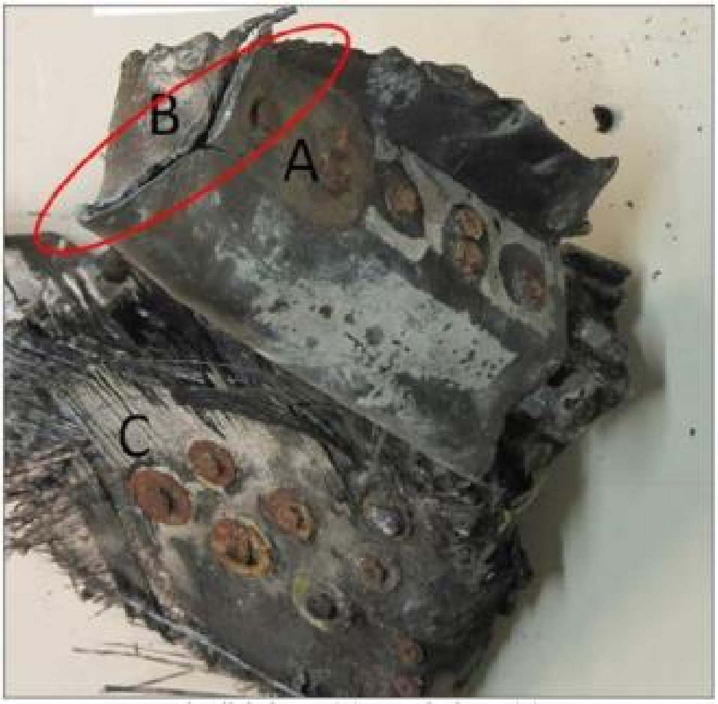


Figure 13. The lower part of the right wing strut found at the accident site. “A” indicates the upper surface of the strut. “B” indicates the upwards bent lower surface and “C” shows the burnt lower surface of the fuselage.

The analysis included the following steps:

- The part was documented with photography.
- The part's fracture surface and shape characteristics were visually analysed with a stereo microscope (Stereo-OM) to determine the cracking directions.
- Metallographic cross section samples were made of the part, selected from the most intact section and perpendicular to the fracture plane, which were then used in analysing the microstructure of the aluminium with an optical microscope (OM).
- Details of the fracture surfaces and microstructure were evaluated using a Scanning Electron Microscope (SEM), and then analysed with an Energy Dispersive Spectrometer (EDS) attached to the SEM.
- The material's chemical composition was analysed with an optical emission spectrometer (OES) from the least damaged location.
- The hardness of the part's material was measured in Vickers hardness values (HV).

The results show that the wing strut material is most likely EN-AW6106(EN AW-AlMgSiMn) [15], temper designation T6. The wing strut which was damaged in the accident was considerably softer than the reference sample. Intense grain-coarsening and precipitation at grain boundaries were seen in the microstructure of the damaged wing strut material. The intense grain-coarsening and grain boundary precipitation had occurred at high temperatures. The hardness and the microstructure of the fractured wing strut material had changed in the post-crash fire.

In order to analyse the fracture surface of the crack (Fig. 12), samples were cut from the lower part of the broken wing strut and a non-through thickness crack was bent open. The fracture surfaces were investigated visually and their features were studied in more detail with a stereo microscope. Details of the fracture surfaces were examined with a scanning electron microscope (SEM), and analysed with an energy dispersive spectrometer attached to the SEM. Both secondary electron (SE) and backscattered electron (BE) analysis were used in the fractography.

The crack originated behind the leading edge of the profile, at the top, and propagated in both directions transversely in relation to the profile. At the level spot in the middle of the profile the fatigue crack turned lengthwise, towards the edge of the fastening inside the profile. The red colour in figure 15 illustrates the area where the crack started and the yellow colour the areas to which it continued.

[15] Standards EN-573-3:2013 (E) /1/ and EN-755-2:2013(E) /3/ specify the chemical composition limits of wrought aluminium and wrought aluminium alloys and the forms of products made of such metals. Temper designations are shown by temper designation codes, consisting of letters and digits appended to the standard codes used to denote alloys.

Figure 14. During the material analysis samples were cut from the fracture surface and the crack itself. (Photo: VTT)

Figure 15. Propagation of the crack in the wing strut (Photo VTT.).

Necking was observed in the wing strut’s cross-sectional fracture surface sample, which indicates that the fracture surface had been subjected to tensile stress perpendicular to the fracture surface and parallel to the free surface and longitudinal axis of the strut. The stereo microscope image of the fracture surface shows that part of the surface was covered with a dark deposit and the rest was a shiny, more metal-resembling, fracture surface. Apart from aluminium and silicon, less magnesium was found on the shiny surface compared to the areas covered with the deposit. The detailed microscopic analysis of the fracture surface shows that the fracture surface had at least partly melted due to excessive heat exposure. This occurred in the post-crash fire.

The SE micrograph of the opened crack is shown in Figure 16. The ovals in the image mark the areas of the old crack as well as the intermediate and final stages.

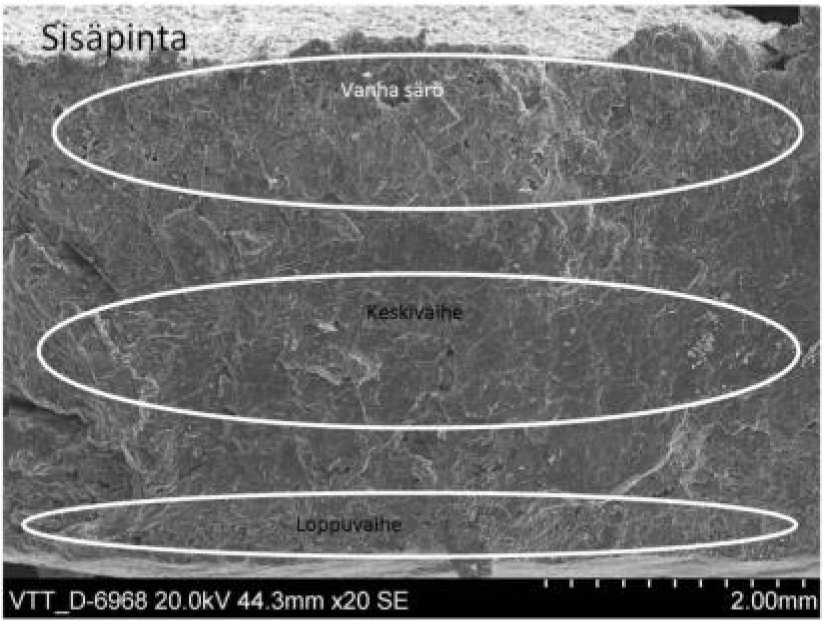


Figure 16. An SE image of the fracture surface of the opened crack. (Photo: VTT)

An older crack was discovered on the fracture surface of the opened crack which began on the strut's inner surface. The crack has propagated from the inner surface of the strut towards the outer surface.

Typical features of fatigue fracture, e.g. striations, were observed in the analysis of the intermediate stage of the old crack. In the EDS analysis of the intermediate stage's fracture surface, aluminium, magnesium and silicon as well as some carbon and oxygen were found. The cracking was caused by flexural or bending fatigue. The EDS analysis of the final stage showed aluminium, silicon, magnesium and some carbon. The crack's final stage was ductile, which is typical for the residual fracture in fatigue cracking. The results on the fracture surface analysis show that part of the fracture is old and shows typical characteristics of flexural fatigue failure.

Because of the damage to the aircraft it was not possible to investigate the mechanism of the analysed fatigue crack formation, or other possible faults in the right wing strut or its mountings. Judging by soot marks visible in photographs taken before the accident the right wing strut had been exposed to the engine's exhaust gas stream. It is possible that, in addition to the stress caused to the aircraft by short flights and high takeoff weights, the temperature changes caused by the exhaust gas stream as well as vibration had contributed to fatigue cracking.

1.16.3 Analysis of the wing strut's tension and compression resistance

The SIAF commissioned an analysis of the wing strut's tension and compression resistance from VTT. The analysis concerned an intact wing strut equal to the one on the OH-XDZ. The analysis was performed on a wing strut profile obtained from the builders, and it covered the calculation of the wing strut's cross-section properties and the testing of the material. The report in included in Appendix 3.

On the basis of a photograph obtained from the builders the length of the wing strut profile is 2 092 mm. By using photographs and measurements from the damaged parts the distance between the wing strut's mountings was 2 152 mm. When the assembly instruction's upper mounting point at 1 765 mm from the wing root and the installation angle of 30 degrees are taken into the calculations, the resulting length of the wing strut is 2 038 mm. The analysis computed the buckling resistance for both of these values.

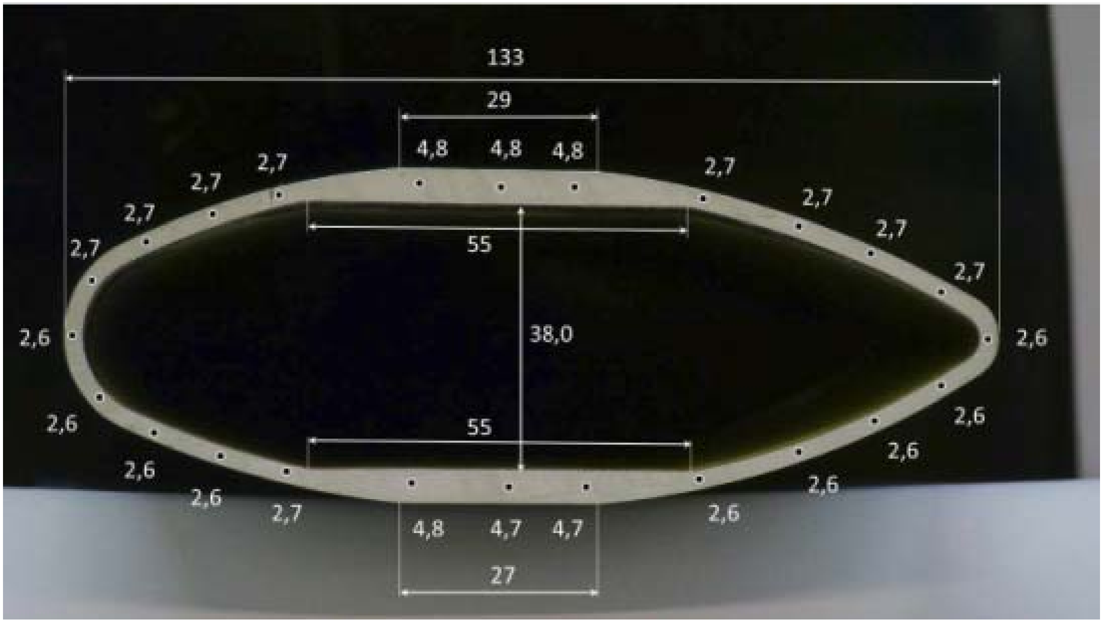


Figure 17. The wing strut's cross-section dimensions (mm) (Photo VTT.).

In order to calculate the tension and compression resistance of the wing strut two through-thickness tensile tests were performed. The longitudinal test rods were taken from the upper and lower surface of the profile. The characteristics determined from both test pieces were nearly analogous.

The mechanical properties of the wing strut are as indicated in the following table:

Calculation basis	Nominal strength	Tested strength (2 tests)
Yield strength (0.2 limit)	f_y = 200 MPa (min)	f_y = 282/282 MPa
Tensile strength at break	f_u = 250 MPa (min)	f_u= 297/297 MPa
Elongation $(L_0 = 5{,}65\sqrt{S_0})$	A = 8 %	A = 11,0/11,2 %
Modulus of elasticity	E = 70 GPa	E = 69,1/67,1 GPA

Both test pieces meet the requirements set in standard SFS-EN 1999-1-1 (2009) (nominal value for the modulus of elasticity) and EN 755-2 (2013) (other nominal values), even though the modulus of elasticity is slightly below the nominal value. The measured strength greatly exceeds the nominal value.

The compression resistance of the rod was calculated using the MathCad program on the basis of the aforementioned standard SFS-EN 1999-1-1 (2009). The significance of the initial curvature was estimated in accordance with the initially slightly bent column compression theory.

The strengths without safety factors were calculated on the basis of the nominal values, the 282 MPa yield strength derived through the tensile strength test and the 68.1 GPa average modulus of elasticity. Judging by the results the compression resistance of the wing strut corresponds to 20-22 % of the tensile resistance as per SFS-EN 1999-1-1 when the calculations use nominal values, and 14-16 %, respectively, when the calculations use measured values.

The estimated compression resistance of the wing strut is 38-48 kN (excluding safety factors). The inexactness of the estimate is due to the calculation parameters used and the fact that it was impossible to reliably determine the precise length of the wing strut (L≈2.1 m).

The wing strut's tension resistance was 268 kN.

1.16.4 Wing modifications' effect on the aerodynamic loads on the wing and the wing strut

The builders designed and installed a structure on the wingtips comprising wing extensions at the plane of the wing and wing tip devices, i.e. winglets. The modifications extended the wingspan by 1.14 m, i.e. approximately 11 %. The winglet profile was the NACA 64010 aerofoil, height 23 inches (58 cm), root chord 39 inches (99 cm) and tip chord 11 inches (28 cm). The angle between the winglet and the wing was 95 degrees. The manufacturer of the kit did not provide ready-made winglets for the aircraft. However, according to the builders they had received confirmation, verbally and by e-mail, that the manufacturer approved the installation of a winglet structure on the OH-XDZ as per the builders' drawing. Neither the significance of the changes to the structural integrity nor their effects on flight characteristics were determined prior to the build. Pertaining to this the builders explained that they had been shown the previously calculated load calculations at the manufacturer's plant. However, they were told that they could not obtain the calculations as they were only intended for internal use at the factory.

The kit that was delivered did not include structural drawings. The SIAF, through the American transport safety authority NTSB, requested drawings, load calculations and other relevant information from the manufacturer as regards the aircraft. Nevertheless, Aerocomp Inc. did not provide them.

The SIAF commissioned an evaluation from Patria Aviation/Engineering regarding the effects of the OH-XDZ's wingtip modifications carried out in the build phase on the aerodynamic loads on the wing and the wing strut as well as on the behaviour of the aircraft in a situation which illustrates the chain of events associated with the accident. Since the wing strut and its mountings in the kit have remained unchanged throughout the history of the CA8, the comparison was carried out on the basic wing which came in the manufacturer's kit. Patria's report is included in Appendix 4.

Figure 18. The winglet's main dimensions.

A simple textbook method was applied to determine the wing's lift coefficients; based on this the wing extensions and the winglets on the OH-XDZ generally increased the wing root's aerodynamic bending moment by 18-25 % in comparison to the wing that came with the kit. The alteration also increased the wing strut's aerodynamic tension and compression resistance effects correspondingly, i.e. by 18-25 %. In the further analyses an estimated value of 23 % was assigned to the increase in the aerodynamic bending moment.

The absolute forces in one flight condition on the wing struts of the OH-XDZ and a reference aircraft using the kit's basic wing design were computed by using aerodynamic calculations and the wing's estimated inertial force. The evaluated symmetrical flight condition corresponds to the aircraft's maximum airspeed at approximately 200 KCAS and at -1.9 g.

By using the maximum weight of the aircraft, 2 380 kg, and a CG at the permissible aft limit, the lift loading the wing was isolated from the entire aircraft's lift. The compressive force on the OH-XDZ's wing became 32.4 kN, which is 27 % higher than that of an aircraft using the basic kit's wing design, i.e. 25.5 kN. These values are estimates and they include uncertainties as regards the loading and the flight condition of the aircraft. The effect of the fuselage is not taken into consideration and the wing is assumed to be a rigid, non-flexing member.

The following table shows a comparison of compression forces on the wing strut, and associated safety factors, at the flight manual's maximum weights and airspeeds. The estimated compression resistance of 38-48 kN, as per the VTT report, was used in determining the calculated safety factors.

	Aircraft built in accordance with the kit		**OH-XDZ**	
Document	Kit manufacturer's reported values[1)]	Aviation Regulation[2)]	Values reported in the Permit to build	Aviation Regulation[2)]
Safety factor	2.0	1.5	2.0	1.5
Acceleration[3)]	-1.8 G	-1.5 G	-1.8 G	-1.5 G
Calculated[4)] compressive force on the wing strut	25.9 kN	21.6 kN	32.8 kN	27.3 kN
Calculated safety factor	1.47–1.85	1.76–2.22	1.16–1.46	1.39–1.76

1) Kit manufacturer's value (-1.8 G 5600 lb safety factor 200%)
2) Aviation Regulation *AIR M5-2 Experimental aircraft construction*
3) The negative limit load of the OH-XDZ and the kit manufacturer's flight manuals is -1.9 G
4) Scaled as per Patria's report (Appendix 4 of this investigation report, section 3(3)) to the maximum weight with certain assumptions.

The aforementioned forces were also scaled in accordance with the estimated accident weight of 2 500 kg, which resulted in the following results for the OH-XDZ's as well as the manufacturer's negative limit load of -1.9 g: 34.0 kN for the OH-XDZ and 27.0 kN for the basic wing.

The aircraft's behaviour during a change in flight condition

The second phase of the evaluation analysed the equilibrium of the OH-XDZ in straight and level flight at approximately 200 KCAS, which immediately preceded the incident, and a possible disruption of this equilibrium.

In addition to the test pilot's flight test report from 2009 the calculations utilised general flight mechanics literature. This made it possible to fairly accurately estimate the location of the entire aircraft's neutral point, i.e. aerodynamic centre, which is essential to model. It would be extremely inaccurate for a propeller aircraft had it only been done by using photographs of the airplane. This kind of flight test-based location automatically incorporates the propeller's typical effects on stability.

It was established on test flights that the equilibrium calculated at the rearmost permissible CG of 0.610 m is already mildly statically unstable. At such a CG the aircraft tends to raise or lower its nose independently as a result of even a small initial disturbance.

As per the flight test report the static stability of the OH-XDZ decreased somewhat at high engine power and improved at low engine power in comparison to a moderate power setting. This is expected behaviour for an aircraft fitted with a tractor type propeller. Nonetheless, the flight test did not include situations involving flight at a high weight and borderline airspeed V_{ne} with the engine at idle because such situations are abnormal.

At CGs associated with the skydivers' jump phases the aircraft has been at least mildly statically unstable, at which time the equilibrium is easily disturbed and controlling the aircraft becomes more difficult. However, according to the aeromechanical calculation model, because of the wing's own pitching moment, a great downforce is required from the tailplane at high airspeeds to maintain equilibrium irrespective of aircraft loading. The wing's own pitching moment is an essential factor when flying at a high airspeed and it requires a negative tail lift, even if the CG were at the permissible aft limit.

When it comes to turboprop engines the negative propulsive force of the propeller at idle is typically considerable. At least at moderate and high airspeeds the propeller will rotate at a rate which corresponds to the highest RPM, which the propeller governor will keep constant. At such time the propeller acts as a windmill which turns the engine's turbine, through transmission, at a very high speed. In other words, it imparts some power from the airflow to the engine. In addition to the 'reverse thrust' the loss of positive propulsion clearly accentuates the aircraft's drag, at which time the combined effect in the longitudinal force is great.

As engine power is being reduced the change from the propeller's positive propulsive force to a negative one also means that the airflow decreases within the zone of the propeller blast. At such time the velocity of the airflow and the effective kinetic pressure on the tail of an aircraft such as the OH-XDZ diminish, which directly reduces the absolute value of the tailplane's lift coefficient.

The effects of engine power changes particularly on the OH-XDZ at 200 KCAS, i.e. approximately 450 km/h TAS, were estimated on a numeric airflow calculation model which included a model of the aircraft's fuselage and an actuator plate approximating the aforementioned propeller. According to calculations the kinetic pressure felt on the tailplane could diminish by 7 % when the power setting is reduced from a fairly high cruising speed to flight idle. These calculations are briefly explained in an annex included in Patria's report, in Appendix 5.

In addition to pitching moment effects the power reduction transforms the propeller's positive propulsive effect into a negative effect, which may shift the occupants of the aircraft forward as the airspeed decreases.

Because of the aforementioned factors the immediate effect of the longitudinal change is an angular acceleration, resisted by the aircraft's own inertial moment. In the calculated example the 20°/s2 angular acceleration, per se, would generate a negative acceleration of -2.0 g within 0.75 sec. In reality, the aircraft's natural aerodynamic damping, dependent on angular velocity, resists the incipient change in pitch angle, even if the static stability in relation to the interference in the angle of attitude were negative. Also the pilot's possible corrective action, i.e. tailplane deflection upwards, counters the nose-down movement. In the analysed situation the damping, dependent on angular acceleration, and the effect of instability largely neutralise each other. If there is any lag in the pilot's reactions as regards counter-steering, an angular movement will develop.

1.16.5 Determining the propeller's blade angles

The propeller blade angles were determined in order to establish the events that resulted in the failure of the wing strut. Of special interest was the question of whether the propeller had been in the beta range.

In the collision with the ground the propeller separated from the engine. All of the blades were bent and one blade (blade no.1) was broken off at its root. The turning mechanism of blade no. 3 was broken and it rotated freely. In accordance with blade angle measurements the angle of blade no.1 was 14.3 deg, blade no. 2 was 8.9 deg and blade no. 3 was 36.5 deg.

On the right side at the front of the engine there was a governor which was badly broken in the crash. Some of the lever tie-rods were crushed and pressed against the side of the governor. The beta light microswitch's actuating cam was in the "beta light on" position. The beta light turns on when propeller blade angles are at 8 degrees (Figure 4). The microswitch and the mechanism of its actuating cam had broken off from the governor housing.

The positions of the rods were compared with those on a fully functioning engine. Judging by their positions the governor had been in the beta range.

Figure 19. The photo on the left shows governor rod comparisons – a functioning engine above and a photo displaying the OH-XDZ's rod arrangement below. The photo on the right shows the guide which is operated by the engine's fuel control lever.

When propeller blade angles are being adjusted in turboprop engines, one must also adjust the fuel control lever. The guide which was controlled by this lever had been crushed in the crash, or deformed as a result of the fire, to such an extent that the roller could no longer move to the beta range; it remained in the normal operating range of the propeller.

The measured blade angles were remarkably dissimilar. Two blades were clearly in the flight position. Blade no. 3 had 'brushed' the ground first and, therefore, it was somewhat bent forward. This indicated that the blade angle was on the 'pull' side, rather than at a negative angle.

Judging on the basis of the comparison the governor lever tie-rod and the beta light actuating cam were in the beta range. Also the valves at both ends of the lever were close to corresponding values. These positions may not necessarily correspond to the situation that preceded the crash because the actuating mechanism of the beta switch had broken off the governor housing. Also, when the propeller separated from the engine the beta disc at the rear of the propeller hub had probably pushed the propeller control levers. The beta disc relays blade angle information to the governor.

The investigation found topics which speak both for and against the propeller having been in the beta range. The indications from the propeller marks were considered to be the strongest because the blades hit the ground before the engine or the governor. According to the propeller analysis the propeller was not in the beta range when it made contact with the ground. This is also supported by the position of the fuel control levers.

In the investigation of the wreckage no other pre-existing technical fault, apart from the right wing strut's fatigue failure which was later established in material testing, could be found.

1.17 Organisational and management information

Finnish Aeronautical Association

This is included in the Finnish version only.

Finland's Sport Aviators

Finland's Sport Aviators (association) and three individuals, together, owned OH-XDZ, the accident airplane. The association was responsible for the use of the airplane in many skydiving clubs' skydiving operations. The domicile of the association, founded in 2004, is Loppi. In addition to skydiving the association runs sport aviation, paragliding and aeromodelling activities. Of its total 700 or so members 12 are mainly involved in paragliding and 70 fly ultralight aircraft. The rest of them are skydivers. The members pay an annual membership fee as well as a fee per jump. You have to be a member of the club to be allowed to skydive from the airplane.

Finland's Sport Aviators had arranged the financing for the airplane construction, and the association was responsible for the airplane's total maintenance. Membership fees and jump fees were used to finance the airplane and its maintenance.

Tampere Skydiving Club

This is included in the Finnish version only.

1.18 Additional information

1.18.1 Constructing the aircraft, and the certification for the flight test phase

Background information regarding the construction

Up until the turn of the millennium skydivers would typically skydive from light aircraft owned by skydiving clubs which could carry them at most to the altitude of 3 000 m. Since skydiving as a sport has evolved, the new disciplines require a jump altitude of 4 000. It took too long to climb this high on light aircraft. Skydiving communities did not have enough cost-effective aircraft that could climb to a 4 000 m jump altitude.

The use of experimental aircraft is generally cost-effective because they have less stringent requirements than type certificated aircraft. Compared to experimental aircraft, sufficiently large and effective type certificated aircraft are expensive to own and operate. According to regulations the builder or owner of an experimental aircraft is permitted to carry out maintenance. Due to the less stringent requirements the operating costs of such aircraft are lower than those of type certificated aircraft. All skydiving airplanes previously used in Finland were type certificated.

Build approval process

Pursuant to Aviation Regulation *AIR M5-2 Experimental aircraft construction* a Permit to build was to have been obtained from the Civil Aviation Authority (nowadays: Finnish Transport Safety Agency).

On 6 Apr 2005 the builders applied for a Permit to build a Comp Air 8 aircraft. According to the application the airplane was to be constructed from a kit. Appended to the application was a 3D structural drawing, including the most important dimensions.

The supplementary information noted that the aircraft kit has the FAA's "*major portion" determination*[16], dated 26 Aug 1999, and it was included as an attachment to the application. The supplementary information also reported that over 200 Comp Air 8 aircraft had been delivered and that 30-40 Comp Air 8 versions were built/flying. The supplementary information also noted that a jump door, associated equipment included, was planned to be built on the right side of the fuselage. The 3D drawing attached to the Permit to build application did not include the winglets which the builders had designed. Nor did the application make it clear that the airplane was to be built with the version of the Comp Air wing which included the 12 inch winglets. No weight and balance estimates nor construction drawings, strength calculations, stability reports or performance estimates were appended to the Permit to build application. The number of occupants was given as 1+(8…10).

The Permit to build application detailed the training and aircraft construction experience of the builders and the build supervisor. The supervisor had consented to act as the build supervisor for this aircraft. As background information the builders reported having visited Brazil for the purpose of getting familiar with a Comp Air 8 aircraft, which was being used in skydiving operations, and that they had visited the manufacturer's plant and the company that overhauled the engine.

The favourable recommendation of the Experimental Commission of the Finnish Aeronautical Association was dated 1 May 2005.

The CAA's flight safety administration issued the Permit to build on 13 May 2005 under the record number 23/62/05. The permit was valid until 31 May 2010, presupposing that the work was carried out in accordance with the drawings and instructions of Aerocomp Inc.

[16] The kit manufacturer had demonstrated to the FAA that the Comp Air 8 aircraft meets the requirements of FAR 21.191(g).

The permit designated a supervisor for the build and emphasised that, in general, the aviation regulations were to be followed. No special requirements were set for the build in the permit.

The construction

The aircraft's construction began on 14 Dec 2005. The builders worked in compliance with the aircraft kit manufacturer's instructions. The progress phases of the build were recorded in the construction log which the builders signed. They asked for some clarifications from the kit manufacturer. The reinforcement fibres and fabrics as well as the fillers to be used in the build were included in the aircraft kit. The aircraft kit manufacturer stipulated that Derakane 411-350 resin be used. During the construction the builders took samples from resin batches which the supervisor inspected. These inspections were recorded in the construction log.

A jump door was fabricated on the right side of the fuselage. A foot board was installed below the door, and a handgrip above the door track. The cockpit door was put on the left side of the fuselage, and the right side door was covered.

The builders designed the interior of the airplane together with experienced skydivers. All materials used in the interior design were made of fireproof material. It took them approximately 9 000 hours to complete the construction. The airplane was weighed for the first time on 8 Oct 2008. The first test run of the engine occurred on 22 Oct 2008.

According to Aviation Regulation AIR M5-2 any modifications during construction which significantly deviate from the information presented in the permit or the permit application (e.g. those affecting the strength, performance and/or flight characteristics of the aircraft) must be approved by using a process identical to the permit application. No permit was applied for regarding the construction of winglets in writing.

Supervising the construction

According to Aviation Regulation AIR M5-2 a supervisor must be designated for a construction. The supervisor's task is to see to it that aviation regulations and the terms of the permit are followed in the construction. When necessary, the supervisor must also take appropriate action as regards any observed anomalies. The supervisor also attests to the construction log.

The person who acted as the supervisor for the construction of the OH-XDZ had been an aircraft mechanic and a sports aviator. He was also familiar with composite repairs. The supervisor made altogether eight inspection reports. He inspected all hidden structures before they were covered. The supervisor was also present at the build when the work phase was exceptionally demanding. The supervisor's final inspection occurred on 9 Nov 2008. The inspection report does not make any mention of the winglets.

Aircraft inspection

According to Aviation Regulation AIR M5-2 the aircraft must be inspected before it is taken into use. Following this, a temporary Permit to fly will be issued for the purpose of test flights. On 12 Nov 2008 two experienced aircraft inspectors carried out the inspection and in their inspection report they recommended that a test flying permit be issued.

Temporary Permit to fly

According to Aviation Regulation AIR M5-2 the temporary Permit to fly includes the necessary limitations for test flying activity. If the permit runs out before the test flights have been concluded, the aircraft must be inspected before the validity of the permit can be extended.

A temporary Permit to fly was issued to the OH-XDZ. The permit was valid until 30 Nov 2009, and it specified the personnel who would be permitted to carry out test flights for the purpose of testing flight characteristics.

1.18.2 Flight test programme and the flight manual

Test flights

According to Aviation Regulation AIR M5-2 the test flights must demonstrate that the aircraft has no hazardous operating characteristics or design features. The aircraft must be controllable throughout its normal range of speeds, in the full range of the centre of gravity and throughout all the manoeuvres to be executed. In order to receive a limited certificate of airworthiness the aircraft's flight test programme must have been completed and the total flight time must be at least:

- 25 hours for aircraft with no engines, or for certificated engine and propeller combinations when installed, or
- 45 hours on all other aircraft.

The flight test programme commenced on 15 Jan 2009. According to the flight test plan the intention was to fly at least 22 test flights for the purpose of testing the flight characteristics. The scope of the planned programme was 3 hours of ground runs and 45 hours of test flights. The total weight of the aircraft and the position of its CG were altered between test flights by attaching water tanks to the cabin floor. The CG was also changed in flight by having a person in full parachuting gear move about in the cabin compartment. The planned aft CG limit on test flights, as per the programme, was 0.720 m. On the basis of flight test documentation the demonstrated aft CG limit was 0.661 m. According to the records made on the test flight when the longitudinal static stability was neutral, the stall characteristics remained normal.

As the flight test programme progressed, the builders consulted the aviation authority regarding the possibility of proceeding to test skydives. Nevertheless, the authority recommended that the flight characteristics be evaluated by a more experienced test pilot prior to the test skydiving phase. The builders invited an experienced test pilot to fly the required flight characteristics evaluation flights. A representative of the aviation authority considered this test pilot as suitable to carry out the abovementioned flights.

Determining the airspeed limitations

In the kit manufacturer's flight manual (Walter Turbine Powered Comp Air 7 Comp Air 7SXL Comp Air 8 Comp Air 10 Pilots Operating Handbook, POHCA7810-1.0) the airspeed limitations were given in calibrated airspeeds. The flight manual gave 227 mph, i.e. 197.3 kt, as the maximum permissible calibrated airspeed (V_{ne}) for the CA8 type.

In the beginning of the OH-XDZ's flight test phase the builders flew test data points in the airspeed range of 60-170 kt so as to determine the position error in the pitot system. On the basis of the results the airspeed indicator's calibration graph was drawn in the OH-XDZ's flight manual.

The calibration graph extended to the airspeed of 170 kt. As per the graph, the position error was positive at high airspeeds; in other words the indicated airspeed was higher than the calibrated airspeed. The system had no position error at 100 kt, and at airspeeds lower than this the indicated airspeed was lower than the calibrated airspeed.

In the later phases of the flight test programme the builders flew at 201 kt IAS as the OH-XDZ's top speed. Presuming that the airspeed calibration graph is linear, this corresponds to 194.5 KCAS.

The builders determined the airspeed limits for the OH-XDZ in indicated airspeed so as to add some safety margin, and because they did not perceive any need for higher airspeeds in the airplane's normal operations. For the same reason the airspeed limitations with the flaps extended and the maximum speed for normal operations were also further reduced from the ones given by the kit manufacturer.

There are no limitations in the OH-XDZ's flight manual or the flight manual provided by the kit manufacturer as regards rapid changes in engine power setting or warnings related to the changes' effects, for example, on longitudinal stability.

The effect of weight and balance to aircraft performance and flight characteristics

In order to evaluate the flight characteristics of the OH-XDZ an experienced test pilot completed two test flights on 20 April 2009. The first flight was flown with the CG forward (0.339 m). Nothing out of the ordinary was noticed. On the second flight water tanks were loaded onto the aircraft to move the CG towards the aft limit of its envelope. At takeoff this CG position corresponded to a situation in which the airplane would have 10 skydivers (0.515 m). While aloft, the CG was moved further back (0.610 m); according to the flight test report this resembles a situation on a jump run where some of the skydivers are standing outside on the foot board, about to exit the airplane. The experienced test pilot's key observations from different CG positions are presented in the following table.

CG at	Longitudinal stability	Observations
0.339 m	Static stability clearly positive. Airspeed stability slightly positive. Dynamic stability calm. Stable when flight controls free.	No short-period motion detected; the fugoid dampens slowly. High engine power worsens and low engine power improves longitudinal stability.
0.515 m	Static stability slightly positive. Airspeed stability almost neutral. No AOA fluctuation or fugoid motion. Neutral when flight controls free.	No stick force needed for 15 kt airspeed changes at climb and cruise power. After deflection the aircraft remained in the new flight condition. High engine power worsens and low engine power improves longitudinal stability.
0.610 m	Static stability slightly negative in all configurations and at all power settings. Airspeed stability almost neutral or slightly negative. No dynamic stability because of negative static longitudinal stability. Shows some divergence when flight controls free.	No stick force needed for 15 kt airspeed changes at climb and cruise power. Longitudinal control in flight demands more attention. After deflection the airspeed decayed or accelerated without dampening, albeit very slowly. High engine power worsens and low engine power improves longitudinal stability.

The summary of the test report states that, during loading, the pilot must see to it that the CG remains in the permissible range when the CG is close to its backward aft limit. While the test pilot thought that the backward aft CG limit (0.610) was permissible, it should only be allowed in a situation where the skydivers were jumping out of the airplane, and with flaps retracted and engine power at idle. In this configuration and with this power setting, according to the test pilot, the airplane was not unstable.

The flight test programme was completed on 4 Aug 2009. In all, 68 test flights were flown during, 15 of which were skydiving test flights. Altogether 121 landings were made, and the total flight time was 52 h 45 min. During the flight test phase 134 skydives were made.

On the basis of the flight test material made available to the investigation group, or the experienced test pilot’s interview, no such things were found with aircraft performance, its flight characteristics or usability for skydiving activity which would compromise flight safety.

Flight manual

Aviation Regulation AIR M5-2 requires that a journal be kept on flight test results so as to be able to demonstrate that all flight test requirements are completed, and that sufficient basic information and limitations can be prepared for the flight manual. The journal must be signed by the test pilots and attested to by the build supervisor. The build supervisor's approval concerns the structure of the aircraft and any possible modifications. The flight test report is to be presented to the aircraft inspector for the purpose of obtaining a limited certificate of airworthiness.

According to Aviation Regulation M5-1 an experimental aircraft is not required to have an aviation authority-approved flight manual. Instead of a proper flight manual the aircraft must have a Finnish language flight manual which provides sufficient information necessary for the safe operation of the aircraft, its operational parameters and limitations, any possible special characteristics, and pre-flight inspection instructions. Before the Permit to fly can be issued, according to the Regulation the aircraft inspector must verify that the manual's type information and operational parameters and limitations match up with the aircraft and the flight test journal. According to the markings in the OH-XDZ's manual an inspector from the Finnish Aeronautical Association inspected the aircraft's manual which the builders had drafted; the manual was approved on 6 Aug 2009.

According to the manual the manoeuvring limit load factors for the OH-XDZ with flaps up were n_z = +3.8…-1.9 and with flaps down n_z = +2.9...-1.2. All aerobatic manoeuvres, including spins, were prohibited.

Stall speed with one pilot and a full fuel load, i.e. at the total weight of 1 700 kg, was 52 kt with the flaps retracted and 47 kt with the flaps extended to 38˚. With the maximum load, i.e. at 2 500 kg, the stall speed was 59 kt with the flaps up and 53 kt with the flaps extended to 38˚.

Judging by the flight test journal and the flight manual the airplane's stall characteristics were correct and safe in the entire CG envelope. The aircraft was fitted with a stall warning device which gave off an aural warning to the pilot's headset when the angle of attack approached the stall(ing) angle of attack. According to the flight test journal the stall warning was set to sound at an angle of attack that in straight and level flight corresponded to approximately 5 kt below the speed of stall. The airplane had no tendency to depart while stalling, and it would immediately recover when the pull on the stick was decreased.

1.18.3 Permit to Fly

According to Aviation Regulation AIR M5-2, at the completion of the flight test programme the aircraft must be re-inspected for the purpose of obtaining a limited certificate of airworthiness. The certificate of limited airworthiness is issued for a fixed period, and in order for the airplane to receive a revalidation for the certificate it must be inspected.

The aircraft inspectors that carried out the first inspection re-inspected the airplane after the flight test programme on 6 Aug 2009, at the total flight time of 52 h and 116 flights. On the basis of the inspection they recommended that a limited certificate of airworthiness be issued. On 12 Aug 2009 the CAA issued a Permit to fly which was valid until 31 Aug 2012.

A recommendation of airworthiness review certificate (previously known as periodic inspection) was given to the aircraft on 27 Aug 2012, which recommended that the aviation authority issue an airworthiness review certificate, valid until 31 Aug 2015. This certificate was issued on 30 Aug 2012. Following a review of the Aviation Act, as well as authorities merging and changing their names, the Finnish Transport Safety Agency's Permit to fly issued to the aircraft in question was dated 3 Nov 2011.

1.18.4 Type rating training required for Comp Air 8

After the initial phase of operations the need arose to train more pilots to carry out skydiving flights on the OH-XDZ. The CA8 was a new, single-engine turboprop (SET) type in Finland, for which no Finnish FI(A) flight instructors were type-rated.

The builders of the airplane had valid national CA8-type ratings within their licence categories, which originally was based on an SET-category rating completed in Germany. A flight examiner in Finland had, on special authorisation, carried out their skill tests for the purpose of extending the validity of their type ratings. While the builders did not have the required FI(A) instructor rating, they had extensive flight instructor experience in FI(UP) and FI(GP) sports aviation. At the time of application both of them had flown approximately 2 000 total hours.

The builders applied for special permission from the Finnish Transport Safety Agency to provide type rating training to one FI(A) flight instructor-rated person who, pursuant to JAR-FCL 1.261, would then apply for type rating training course certification and train new pilots for the CA8. The flight instructor in question had a commercial CPL(A) licence, FI(A) instructor rating, IR(A) instrument rating and he also possessed a TR(A) BE300/1900/IR type-rating. In the application his total flight experience amounted to 973 h and his flight instructor experience was 425 h.

It was the opinion of the aviation authority that this training method guaranteed that the flight safety level mentioned in JAR-FCL 1.045 would be met, if not exceeded, if the type rating instructor was a FI(A)-type rated instructor. On 9 May 2012 the authority granted permission to the builders to provide CA8-type rating training to the flight instructor in question. This was a special permission issued for the purpose of training one person in accordance with JAR-FCL and the Aviation Act.

Once the flight instructor had received the type rating on the CA8, Finland's Sport Aviators applied for permission to organise a CA8-type rating training course for three pilots. On 3 Jun 2013 the authority granted this permission. The training was carried out at Jämijärvi from 15-17 Jun 2013. Two pilots participated on the course; one of them was the pilot of the accident flight. The curriculum encompassed 17 hours of theoretical instruction and at least 5 hours of flight training. The training flights were designed to cover the CA8's type-specific characteristics and the special features of skydiving operations.

Judging by the training documentation and the flight logbook the minimum training requirements were met. The documentation shows that the schedule was extremely tight. The trainees successfully passed the theoretical knowledge examinations.

Skill test

The pilot of the accident flight passed his skill test[17] for CA8 type rating at Utti on 28 Jun 2013. The same flight examiner also received the skill tests from all other pilots trained on the OH-XDZ.

Even though the OH-XDZ was purpose-built for skydiving the examiner, according to his account, did not test the applicants' skills in areas related to skydiving. For example, during the skill test the flight examiner did not query issues such as the impact of skydivers' seating and weight distribution to the CG; nor did the examiner ask the applicants to make any weight and balance calculations associated with skydiving operations.

Following the skill tests they talked about the wisdom of having new pilots fly skydiving flights under the watchful eye of experienced pilots at first in order to achieve sufficient competence. According to the airplane's journey logbook such two-crew member flights were flown for approximately 17 hours before the pilot flew his first solo skydiving flight.

Aviation Regulation OPS M6-1 requires 100 total flight hours from the PIC in skydiving operations, of which at least 75 hours of flight time must be on aircraft of the same category. In addition the PIC must be rated for carrying passengers. The PIC must be familiar with skydiving as well as the characteristics of the aircraft being used on the skydiving flights.

The pilot of the accident flight had the flight experience required by the abovementioned Regulation. The Regulation does not specify what sufficient type experience in the airplane's characteristics on skydiving flights means. For example, Aviation Regulations PEL M2-6 and M2-7 which relate to aerotowing or float-plane ratings describe the theoretical and practical skill requirements in much more detail. In order to receive the aforementioned ratings a pilot must also pass a separate skill test that measures the applicant's proficiency with regard to the activity in question.

[17] According to Aviation Regulation TRG M1-6 (*Regulations relating to flight examinations in sport aviation*) which concerns flight crew licensing in sport aviation the purpose of a skill check is to examine the theoretical and practical proficiency of the applicant. In order to do so a flight test or a skill check includes an actual flight as well as a written and/or oral examination, aimed to ensure that the applicant has a satisfactory level of knowledge and skills. The purpose of the flight examiner's oral examination is to ensure that the applicants are able to apply the information, regulations, methods and skills in situations that they may encounter in flight activities, within the scope of the licence, rating or permission in question.

1.18.5 Skydiving operations

Aerial work and the commercial aspect of this activity

National regulations and statutes apply to aerial work in Finland. The European Union is presently working on a directive involving aerial work.

Pursuant to the Aviation Act[18] aerial work means using an aircraft for special tasks. Skydiving flights, under the Aviation Act, constitute aerial work. In general, a certificate issued by the Finnish Transport Safety Agency is required for aerial work. However, pursuant to the Act, an aerial work certificate is not required for glider towing, parachuting flights, forest fire patrol flights or search and rescue flights when they are occasionally performed at the request of an authority. According to the Government Bill's[19] detailed justifications parachuting activity was considered to be a relatively limited form of aerial work, and already subject to sufficient regulation by the aviation authority; it was not seen to include any such risks that warranted it becoming subject to licensing.

The Finnish Transport Safety Agency may also permit aerial work operations other than the abovementioned without a certificate, if obtaining a certificate is not deemed necessary to ensure safety. The Finnish Transport Safety Agency shall issue more detailed regulations on the requirements for obtaining an aerial work certificate, as necessary for the safe conduct of aerial work operations.

Aviation Regulation *OPS M1-23 Aerial Work* lays down provisions on aircraft and pilots even for those which do not require an aerial work certificate. According to the Regulation even in these cases the aircraft must have an airworthiness certificate which can only be issued to a certificated aircraft. The pilot must hold a commercial licence. However, under this Regulation this section does not apply to the categories mentioned in the Aviation Act that do not require an aerial work certificate.

The commercial aspect of parachuting has been addressed in the detailed justifications[20] of the Government Bill for a new aviation act. According to the Bill any internal flight activities conducted by a sport aviation association would not classify as commercial aviation. These would entail, for example, skydiving operations in which one member of the club carries another member on an aircraft for a skydive, for which service said skydiver reimburses his club by paying a fee.

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[18] 1194/2009. The Act lays down provisions on aerial work in Chapter 8, Section 67 presents the definition of aerial work and Section 77 lays down the provisions for an aerial work certificate.

[19] Section 77 of the Aviation Act presently in force is essentially analogous to Section 76 of the previous Aviation Act (1242/2005), for which the Government Bill's (HE 139/2005) detailed justifications expressed the safety aspect.

[20] The detailed justifications Section 68 of the Government Bill (HE 139/2005) for the previous Aviation Act (1242/2005).

The position of the Finnish Transport Safety Agency continues to be that a sport aviation club's aircraft used for skydiving operations does not need to be type certificated, nor does the pilot need a commercial licence.

Skydiving operations on the OH-XDZ

According to the owners, the flight instructor and type-trained pilots the goal was to save time and fuel by carrying a full load to the desired altitude and the jump run accurately and by following a pre-planned flight path, and to rapidly return to landing for the next load. So as to avoid any unnecessary engine start cycles, using the airplane in daily skydiving operations required information on several consecutive loads. In practice, the airplane would fly several consecutive flights, always close to its maximum takeoff weight.

According to the flight manual the skydivers were to sit in an aft-facing position. In accordance with the flight manual's *Section 7.2 Loading*, skydivers in the cabin had to be positioned as far forward as possible at takeoff and landing. The pilots said that compliance with these instructions was being monitored. The investigation group found video material from previous flights in which at least one of the rearmost skydivers was on his knees during takeoff, facing forward.

According to the flight manual it takes 13 minutes to climb to FL 195 (5 950 m) at the total weight of 1 800 kg. The time to climb to 4 200 m, which was the case on the accident flight, was approximately 10 minutes. The airspeed used during the climb on skydiving flights was approximately 90-95 kt. A skydiving flight which included the takeoff, a climb to 4 200 m, skydivers exiting as well as the descent and landing normally took 15 minutes at the most. By using the GPS device which was included in the instruments of the airplane, pilots, wind conditions pending, would home in as rapidly and fuel-economically as possible on the pre-agreed jump line.

A distance display was installed above the jump door from which the skydivers could monitor the distance to the planned exit point of the first jumper. The plan was to stay on the jump line for no more than one minute or so with ten jumpers. At two nautical miles from the exit point the skydivers began to prepare for the jump. The rearmost two skydivers, or those closest to the jump door, got on their knees to crack open the jump door for the purpose of catching site of the jump run.

When the skydivers opened the door the pilot reduced power to idle. According to the flight manual engine power on the jump run was to be (Torque) 0-15 %, and airspeed 65-70 kt. The flaps were to remain retracted, i.e. in position 0. At these settings the airplane would descend 100-200 m during the jump run.

The low airspeed on the jump run reduces flight control effectiveness, and controlling the aircraft requires large flight control input. In order to keep the tail-heavy aircraft stable and in a shallow glide on the jump run the pilot, in extreme situations, must set the elevator trim tab to its forward position and also keep pushing the control stick. The pilot can feel the CG shift caused by skydivers moving about in the cabin.

According to the flight manual the pilot gives an OK for the skydivers to jump, at which time the skydiver next to the door opens the door and makes certain that the door is fully open, and that it stays open on its locking magnets. Special supports on the sides and above the jump door make it easier for the skydivers to climb out on the jump run. The flight manual prohibits hanging from the wing strut. However, it is permissible to hold onto it which prevents the airflow from pushing the skydiver backwards. In accordance with the information received pilots would have intervened had the skydivers not followed these instructions. The investigation group found video material from previous flights in which a skydiver is hanging from the wing strut in violation of the instructions.

If the skydivers felt that the jump run was incorrect they would ask the pilot to fly a new jump run. At this time the door would be closed and the pilot would gradually increase power. According to interviews a sufficient power increase was approximately 30-40 %. When the airspeed had increased to 90-100 kt the pilot would home in on a new jump run by making a shallow turn. First the pilot would turn approximately 180 degrees and then he would keep climbing back to the correct jump altitude. No instructions existed as regards ordering the skydivers back to their normal seating positions from the jump door prior to homing in on the new jump run.

The pilot of the accident flight had not previously had to home in on a new jump run on the CA8 aircraft with a full load. With the smaller skydiving aircraft (C206) the pilot had plenty of experience in homing in on new jump runs. These situations were normally caused by air traffic control constraints. The pilot had flown many skydiving flights at Pirkkala airport where separation between skydiving operations and other traffic is commonplace.

When flying at the maximum weight the pilots were instructed to reduce altitude at idle power, at about 130 kt airspeed. According to the pilots who had flown on the OH-XDZ the airplane accelerated quite rapidly in a glide if any engine power above idle was used. None of them had any experience regarding flight control effectiveness or flight control forces at airspeeds exceeding 155 kt at the maximum weight.

The builders of the airplane had given the following oral instruction with regard to skydiving operations with the OH-XDZ: the pilot should not fly with other aircraft types during the same day. The reasoning for this was that the procedures, handling and characteristics of smaller piston-engine airplanes considerably deviated from the CA8. They wanted the pilot's full attention only on one aircraft type during one day.

Use of oxygen and hypoxia

According to Aviation Regulation OPS M2-1, flight crew members engaged in performing duties essential to the safe operation of an aeroplane in flight should use supplemental oxygen continuously for any period in excess of 30 minutes when the pressure in compartments occupied by them will be between 700 hPa and 620 hPa (altitude 3 000 - 4 000 m in the Standard Atmosphere), and for any period that the atmospheric pressure in compartments occupied by them will be less than 620 hPa (altitude > 4 000 m in the Standard Atmosphere).

In accordance with the operational instructions for skydivers, published by the Finnish Aeronautical Association, oxygen masks in non-pressurised aircraft must be made available to skydivers when flying at altitudes exceeding 4 000 m, however, their use is only mandatory at altitudes exceeding 6 000 m.

On skydiving flights on the OH-XDZ the goal was to make it possible for all jumpers to exit, at the least, at 4 000 m. During the jump run the aircraft would lose approximately 100-200 m in altitude, therefore, the altitude at the beginning of the jump run was typically 4 200 - 4 300 m.

The cabin of an aircraft like the CA8 is non-pressurised. The OH-XDZ had an oxygen bottle and two nasal cannulae (nasal prongs). Even though the aircraft climbed to over 4 000 m on almost every skydiving flight, the pilots would generally not use supplemental oxygen.

When climbing on non-pressurised aircraft above 3 000 m, the decreasing partial pressure of oxygen in the ambient air can negatively impact the performance of the pilot and the skydivers. The decreasing partial pressure of oxygen causes hypoxia[21]. Its effects depend on the altitude and time of exposure. At altitudes above 4 000 m the probability of exposure to hypoxia increases dramatically. If the visit to the altitude is only fleeting, the effect of hypoxia is probably negligible.

According to weather soundings on the day of the accident there was 620 hPa air pressure at approximately 4 100 m AGL. The aircraft spent approximately 1.5 minutes above this altitude on the accident flight.

1.18.6 Later psychosocial support

This is included in the Finnish version only.

1.18.7 Lessons learned from psychosocial support

This is included in the Finnish version only.

[21] Hypoxia deprives the central nervous system of oxygen. Hypoxia can cause light-headedness, a feeling of wellness, poor judgement and can strengthen disorientation. The effects depend on the individual and they can be exacerbated by, among other things, smoking, overweight, fatigue, task-induced stress or tension.

1.18.8 The action of State leadership

This is included in the Finnish version only.

1.18.9 Disaster Victim Identification

This is included in the Finnish version only.

1.18.10 Other safety investigations associated with skydiving operations and Comp Air type aircraft

This is included in the Finnish version only.

1.18.11 International comparison of skydiving operations

The SIAF conducted a survey in 28 European countries regarding the use of experimental aircraft and seat belts in skydiving operations. Twelve countries responded to the survey.

Four countries do not place any restrictions on the occupancy of experimental aircraft. In seven countries the maximum occupancy is four, and in one country it is two.

Nine countries prohibit skydiving flights in experimental aircraft. While three countries do not ban it, they have never had experimental aircraft in skydiving operations.

In seven countries skydivers must wear seat belts at takeoff and landing. Five countries do not mandate the use of seat belts.

1.19 Useful or effective investigation techniques

Flight path modelling

For the purpose of analysing the flight path the positional and altitude information as well as eyewitness video material which was made available to the investigation was modelled into a flight path and flight attitude parameter database. The material was converted for the CAE Flightscape Insight™ flight data analysis software. No flight data recordings or GPS device recordings were available to the investigation. The animation made it possible to evaluate the flight path in 3D, and to analyse the flight condition at different points in time.

It was possible to compile the data, which were irregular, recoded at different intervals and also contained inaccuracies, into correct and consistent information by converting the material, which contained sporadic observations, through mathematical modelling into a continuous stream of information. Several irregular sources could be flexibly combined while continuing to filter the data. Weak individual data points were eliminated and the information was migrated into uniform WGS-84 coordinates. The data were processed and the necessary computations were carried out in a Cran R programming environment. A Forevid program was used as a tool in the video analysis.

Regarding altitude, it was possible to model the final phase of the flight more accurately than the early part of it by using the very frequent recording intervals of Altitrack and CYPRES recordings. Correspondingly, the increasingly infrequent radar plots made it more difficult to precisely determine the aircraft's flight path and airspeed.

Observations were taken from the compiled data at one second intervals. In order to assess the airplane's attitude the existing information was used to compute bearing, pitch and bank angles. Lacking more precise attitude information, the angle of attack and the sideslip angle were not modelled. Acceleration in relation to three axes was calculated in the aircraft's own coordinates, which was based on the aforementioned attitude information. Such an analysis of the prevailing g-forces better corresponded with the loads on aircraft structures and persons. Nevertheless, the data are only approximate.

Heading information is based on calculating the change between the positions of consecutive observations. Other flight attitude information was based on computing the changes that occurred in relation to the aircraft's three axes. Forces of acceleration were calculated on the basis of airspeed and time, and they were rectified along the aircraft's own coordinates.

Flight attitude information calculated in this manner can only be descriptive when the aircraft is in a normal flight condition, i.e. before it ends up in a flight condition resembling an inverted spin following the moment of the occurrence. In addition to using the compiled data the aircraft's attitude during the descent that followed the moment of the occurrence was modelled by means of eyewitness video and observations. The flight that preceded the accident flight was modelled as reference material.

2 ANALYSIS

2.1 Accident analysis

The analysis used the AcciMap Approach[22], and the text in this chapter is based on the attached AcciMap graph which the investigation group prepared.

Background for the construction of the OH-XDZ

In the early 2000s Finland's skydiving community had hopes of using a cost-effective aircraft type which was well-suited for skydiving operations. The previously used aircraft were type certificated. The skydiving disciplines evolved towards higher jump altitudes; now the desire was to jump from 4 000 m rather than the previously used 3 000 m. In all the annual number of skydives was approximately 45 000. The aim was to carry out the skydiving flights as rapidly as possible, yet in a cost-effective manner. It was felt that it took too long to climb to 4 000 m with the piston engine aircraft being used at the time.

The builders of the OH-XDZ travelled to the United States to visit Aerocomp Inc., the manufacturing plant of the Comp Air airplane's aircraft kit as well as the production facilities of the company which delivered suitable turboprop engines for the aircraft. In addition, the builders went to Brazil to familiarise themselves with a Comp Air airplane which was being used in skydiving operations. The builders prepared thoroughly for the project.

The builders decided to construct an experimental Comp Air 8 airplane from an aircraft kit. They had a background in aviation as well as previous experience in building sport aviation aircraft. The aircraft would be in constant and heavy use. The builders estimated that the Comp Air airplane would be well suited for such use. The dimensions of the cabin and its carrying capacity allowed for a load of ten skydivers, which facilitated cost-effective operations. Unlike in many foreign countries, Finnish aviation regulations do not limit the number of occupants carried by experimental aircraft.

[22] The AcciMap Approach is used in analysing contributing factors, finding the most important conclusions as well as for preparing and focusing on the most effective safety recommendations.
The accident is depicted as a chain of events on the bottom of the AcciMap graph. Identified decision-makers and other levels that guide action are marked on the left edge. The different elements of the chain of events are shown as a bottom-to-top sequence. The lower part of the graph portrays an assessment of the individual accident which is being studied, from which the process leads to wider positions and implications, for example, at the national or international level. The report follows the AcciMap graph and provides more detailed background for individual text boxes and their interrelationships. The analysis of the authorities' action, as laid down by the safety Investigation Act, is done separately, as required. Source: J.Rasmussen and I.Svedung, 2000, Proactive Risk Management in a Dynamic Society, Swedish Rescue Services Agency, Karlstad, Sweden.

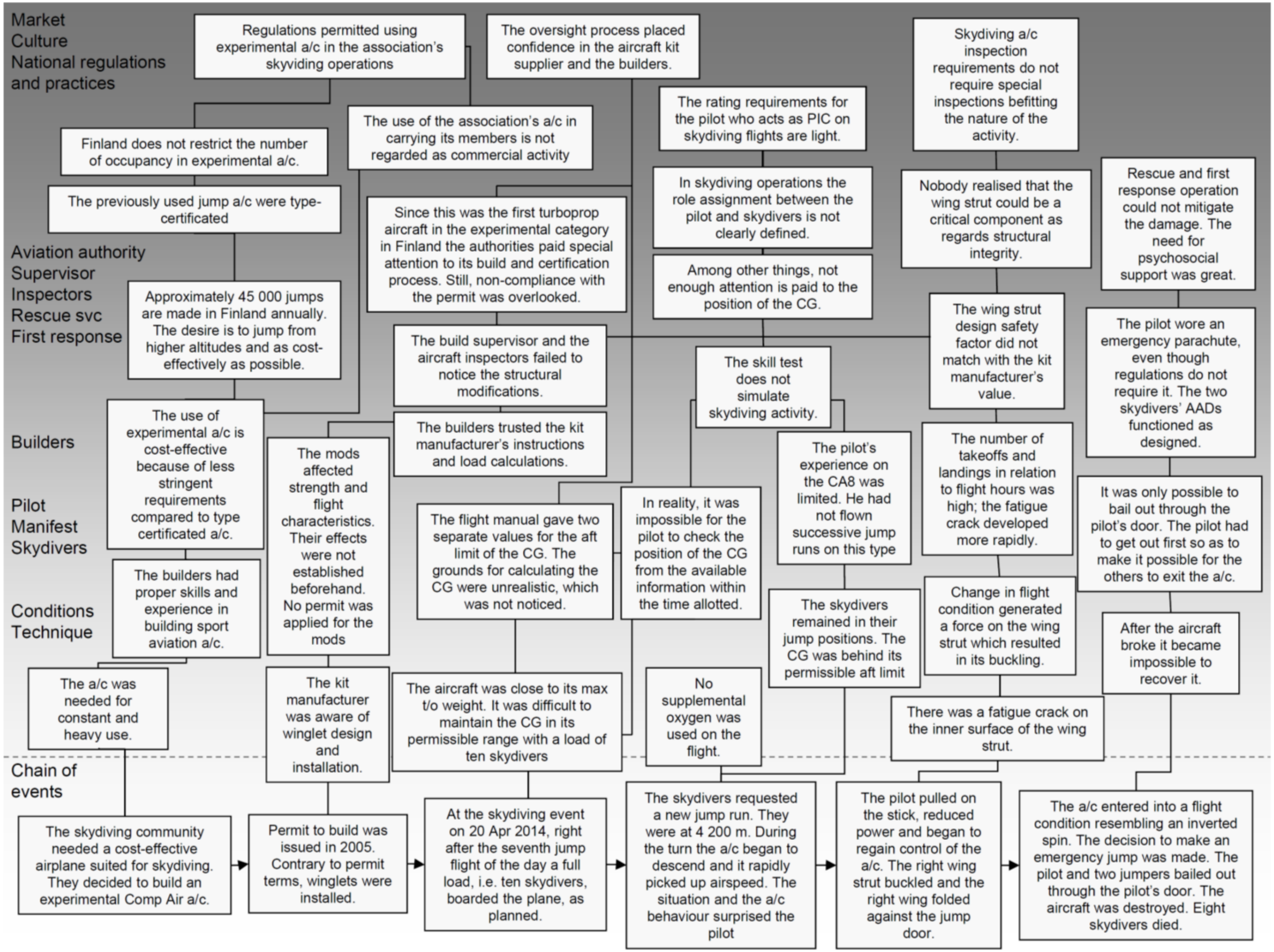

Figure 20. The AcciMap graph

The aircraft was owned and operated by an association. The aviation authorities interpreted an association's use of aircraft to carry its members only as not constituting commercial activity. Hence, the pilot only needed a private pilot's licence.

The rules made it possible to use an experimental aircraft in the association's skydiving operations.

The build process for the OH-XDZ

The builders applied for a Permit to build a Comp Air 8 airplane from an aircraft kit. Aerocomp Inc., the manufacturer of the kit, was an American company which had sold over 200 kits that included different versions of the Comp Air airplane. The permit application did not mention that the airplane was to be built with the version of the Comp Air airplane's wing that was fitted with 12 inch winglets. A 3D attachment was appended to the application; it did not include the winglets, which the builders themselves had designed. The Experimental Commission of the Finnish Aeronautical Association gave a favourable recommendation, and the aviation authority issued the Permit to build on 13 May 2005. The permit required that the work was to be carried out in accordance with the drawings and instructions of Aerocomp Inc.

The aircraft build began on 14 Dec 2005 and it was completed in approximately three years. The progress phases of the build were recorded in a construction log. The supervisor designated for the build made altogether eight inspection reports. Among other things, he inspected all hidden structures before they were covered.

If any modification is made during construction which significantly deviates from the permit, it must be approved using a process identical to the permit application. No permit was applied for the installation of wing extensions and winglets. The supervisor's inspection reports do not make any mention of the modifications associated with the wing. The effects of the modifications to structural integrity or flight characteristics were not established prior to commencing the construction. The calculations presented to the builders at the kit manufacturer's plant probably did not correspond to the aircraft's real structural integrity, especially as regards the safety factors related to the load resistance of the wing strut. The manufacturer did not give the calculations and, therefore, the builders could not verify the correctness of the limitations in the flight manual; nor were they able to determine the wing modifications' effects to loading charts themselves.

In other respects the build and its supervision, apart from the wing modifications, were completed in a diligent and proper manner.

The aircraft was initially inspected on 12 Nov 2008. Two experienced aircraft inspectors carried out the inspection and in their report they recommended that a test flying permit be issued. The inspectors made no mention of the winglets in their report. On 19 Dec 2008 the OH-XDZ was issued a temporary Permit to fly which authorised the test flights.

The aviation authority wanted to make certain that the airplane's flight characteristics were safe before proceeding to test skydives. After having consulted the authorities the builders requested that, as part of the flight test programme, the flight characteristics be evaluated by an experienced test pilot. The flight test programme complied with the aviation regulations.

Following the test flights an aircraft inspection as per aviation regulations was carried out on the OH-XDZ. The inspectors recommended that a limited certificate of airworthiness be issued to the aircraft. On 12 Aug 2009 the CAA issued a Permit to fly.

Since the OH-XDZ was the first turboprop aircraft in the experimental category in Finland the authorities paid special attention to its construction and certification process. The build proceeded in accordance with the aviation regulations in other respects except for the deviation from the permit as regards failing to notice the winglets. Confidence was placed in the aircraft kit supplier and the builders.

Loading on the accident flight

During the skydiving event on 20 Apr 2014 the OH-XDZ landed and taxied to the loading point after the seventh skydiving flight of the day. According to the plan a full load, i.e. ten skydivers, boarded the plane. For the pilot this was his sixth and second consecutive flight on this airplane. In the morning he had flown skydiving flights on a Cessna 206. It is typical for experienced towing and skydiving pilots to fly several consecutive flights. Judging by the meals he had and the amount of sleep the previous night his alertness level was normal.

The load organiser who boarded the airplane gave the pilot the load list, which included every jumper's name and exit weight. According to the list the total weight was 929 kg. The investigation group calculated that the total weight of the aircraft at takeoff was 2 531 kg, which is nine kilogrammes below the maximum allowable takeoff weight.

As per normal routine the skydivers got into their planned positions in the planned order of exit. It took less than three minutes for the airplane to be ready for departure. The engine was kept running during the boarding. The skydivers' positions are not fitted with seat belts, nor are the seating positions prescribed the flight manual's loading chart marked on the floor. Nonetheless, as per aviation regulations it is permissible to carry up to ten skydivers in an aircraft without seat belts, on the PIC's consent and on the skydivers' own responsibility.

Seat belts can improve flight safety in skydiving aircraft such as the OH-XDZ in at least two ways. The skydivers' seating positions are specific if they are strapped into seat belts. This makes it more straightforward to calculate and maintain the CG within its permissible range. Furthermore, during takeoff, the initial climb or any abnormal situations skydivers restrained by seat belts are better protected themselves and from bumping into each other should the aircraft veer off the runway or make a forced landing following engine failure at low altitude. In cases such as these the injuries to persons are most probably less serious compared to unrestrained skydivers. The PIC can give them permission to open their seat belts once the aircraft reaches an altitude from which an emergency jump is possible. When it comes to this particular accident, seat belts would not have made any difference.

During the rapid boarding the pilot of the OH-XDZ could not reliably determine the CG of the aircraft. The loading calculations presented in the flight manual were based on unrealistic seating positions. The accepted practice was to rely on the notion that carrying ten skydivers was OK, both for the maximum weight and the CG. The errors contained in the spreadsheet program used during the CA8 type rating training had left the pilot with a wrong impression regarding the CG's location on skydiving flights.

It was difficult to maintain the CG in its permissible range with a load of ten skydivers. According to loading tests carried out during the investigation the CG of the airplane was probably outside its flight manual-specified aft limit at takeoff. Evidently, such a CG was not atypical in the OH-XDZ's skydiving operations.

On the OH-XDZ the routine practice was to climb to an altitude which was a couple of hundred metres above the jump altitude at the beginning of the jump run. The accident flight climbed to 4 200 m on a wide left turn. According to aviation regulations all flight crew members in non-pressurised cockpits should use supplemental oxygen continuously when pressure is below 620 hPa which, in the accident day's conditions, translated to altitudes above 4 100 m.

Supplemental oxygen was available in the cockpit but the pilots did not normally use it on jump runs flown at 4 000 m. The effects of hypoxia caused by the reduced partial pressure of oxygen depend on the altitude and time of exposure. While the effect of hypoxia as a factor degrading the performance of the pilot in this accident cannot completely be excluded, it is unlikely because of the altitude which was used and the fleeting period of exposure. Nevertheless, from the standpoint of safety it is important to follow all regulations to the letter regarding the use of supplemental oxygen.

Calculating the centre of gravity as per the flight manual

During the flight test phase of the OH-XDZ in the spring of 2009, before test skydives were carried out, an experience test pilot evaluated the airplane's flight characteristics on two flights by using different CG positions. On the basis of these flights the permissible CG range was included in the flight manual. Two separate values were given for the permissible aft limit of the CG: the frontward aft limit was to be used during takeoff and landing, and the backward aft limit was only to be used on the jump line with the engine on idle and flaps retracted. The flight manual did not prescribe limitations to the aft limit of the CG for other phases of flight.

The flight manual's instructions for calculating the CG were based on skydiver seating positions which, according to the investigation, were unrealistic. Judging by the reconstruction carried out during the investigation not every jumper was able to sit in the position specified by the flight manual. In reality, the CG was to the rear of the one calculated by the loading chart. The investigation also discovered an incorrect statement in the flight manual as regards a 6-way group exit.

The flight manual of the OH-XDZ was also inspected during the inspection for a limited certificate of airworthiness. No shortcomings were found in the manual. Nor were any irregularities or faults discovered in the CA8's type rating training or its skill test when it comes to calculating the CG or its position in group exit situations.

The instructions for calculating the CG, and the manner or presentation, are vague and prone to risk. In this regard, verifying the essential information of an aircraft which was purpose-built for skydiving operations was inadequate.

Acting as PIC in the OH-XDZ's skydiving operations

The manner of loading, the pilot's chances of monitoring the skydivers' positioning in the different phases of flight as well as the instructions given for this in the flight manual were inadequate. The shortcomings indicate that not enough attention was paid to CG management. This was probably so because the personnel participating in skydiving operations did not sufficiently understand the importance of the CG to the controllability of the airplane or to flight safety.

The indistinct relationship between the roles of the pilot and the skydivers decreases control over the factors affecting the safety of flight. In skydiving operations the tasks on the OH-XDZ were not clearly defined in all respects, or the assigned division of tasks was not followed. Practices may have changed in accordance with the manning on board or on the ground. In that case it is possible that critical situations or procedures regarding safety were not under anyone's control, or that they were assigned to a person who did not have the proper capabilities for the tasks. In aviation the PIC is responsible for factors affecting the safety of flight.

In light of the nature of skydiving operations, the rating requirements for the pilot who acts as PIC on skydiving flights are light. Skydiving operations can occur at a much higher tempo compared to regular sport aviation, and demand considerable attention. Scheduling pressures can be high and on jump days the pilot's workload can be strenuous. Skydivers expect the pilot to operate in the most efficient manner as regards jump activity, which only adds to the demands of the task. At times, skydivers' goals can be incompatible with the factors affecting the safe conduct of flight.

By its nature, skydiving activity is equivalent to carrying passengers. It can be regarded as more demanding than, for example, aerotowing and seaplane activities, for which specific rating requirements exist. The competence for seaplane rating is demonstrated through a skill test which takes into account the requirements of said activity. When it comes to ultralight aircraft, seaplane and aerotowing ratings can only be obtained through successfully completed skill tests.

During the skill test for a CA8 type rating the accident flight's pilot was not tested for situations associated with skydiving operations. Even if the particular aircraft is specifically built for skydiving operations, regulations do not require any such examining on a type rating skill test. The flight examiner had, justifiably so, recommended that the pilots who had successfully passed the skill test fly skydiving flights on the OH-XDZ under the watchful eye of experienced pilots at first. This was also done.

In order to spot erroneous calculation practices or programs taught during training, flight examiners should check during skill tests that pilots are able to correctly determine the CG of the aircraft with typical loads.

Aviation regulations do not precisely stipulate any requirements for PICs in skydiving operations. At present, in addition to the total flight time requirements, they only state that the PIC must be familiar with skydiving and the particular characteristics of the aircraft to be used on skydiving operations. The regulations do not include any detailed theoretical knowledge or flight training requirements critical to skydiving. These include, for example, the significance of being the PIC as regards responsibilities and duties, loading the aircraft, general instructions and limitations in skydiving operations, standard procedures and phrases as well as other cooperation with skydivers, including ground personnel. Finland does not require skydiving pilot rating or such skill tests which would verify the proficiency of the pilot in skydiving operations, or any possible abnormal situations or emergencies on the type in question.

The jump run and the turn for a new jump run

When the aircraft was approaching the jump run the two rearmost skydivers began to prepare for catching site of the jump run, and moved towards the jump door to open it. Probably, some other jumpers at the rear of the cabin began to prepare for the jump and, by moving in the cabin, shifted the CG towards the tail.

The backward aft limit of the CG was allowed in the OH-XDZ's flight manual on the jump run. According to loading reconstructions carried out during the investigation the CG of the airplane was probably outside its flight manual-specified aft limit on the jump run. According to the records made on the test flights made for the purpose of establishing flight characteristics the longitudinal static stability was mildly negative, which demanded more attention to longitudinal control from the pilot.

When the skydivers cracked the jump door open, trying to catch sight of the jump run, the pilot reduced power to idle to bleed off airspeed in order to adjust it so it would be suitable for jumping. The skydivers gave the pilot instructions as regards getting onto the correct jump run. On the basis of radar return comparisons the airplane was a bit more to the east when it came over the airfield, compared to previous flights. Since the skydivers noticed that they had overshot the jump line they closed the jump door and asked the pilot to fly another run.

The pilot did not tell the jumpers who had already started their jump preparations and moved rearwards in the cabin as much as possible, to move back to their loading chart-prescribed positions. When the aircraft moved away from the jump run its CG remained behind its backward aft limit which was only permissible for use on the jump run. Limiting the flight manual-permitted rearmost CG only to the jump run would have required that the skydivers return to their places. In this situation the CG of the aircraft remained so far towards the aft that when the aircraft began to home in on a new jump run, its static stability was at least mildly unstable.

While the pilot had amassed over 1 000 total flight hours, his experience on the CA8 was limited. He was familiar with homing in on new jump runs except on this type. As demonstrated in flight tests the static stability at this CG was neutral or mildly negative. With a CG such as this the aircraft tends to raise or lower its nose independently as the result of even a small disturbance. Barring any additional and sudden interference, the aircraft is still fully controllable through active and correctly-timed counter steering. When it comes to airspeed stability the aircraft was neutral or mildly negative at this CG, according to the flight test report. In practice, this means, among other things, that the pilot does not receive normal and correct feedback from the changing longitudinal control forces as regards increasing or decreasing airspeed.

At the onset of the turn the pilot increased engine power. The increase on the effective turboprop aircraft was probably too large. On the basis of flight test reports a power increase on this type decreases longitudinal stability. The CA8 was much more powerful and more sensitive in longitudinal control than the Cessna 206, with which the pilot had flown earlier in the morning. Because of their great dissimilarity the builders had stated that one should not fly with the CA8 and other smaller skydiving aircraft during the same day.

During the turn the airplane began to descend and its airspeed increased rapidly, which the pilot did not immediately realise. The situation and the behaviour of the airplane surprised the pilot.

Most probably the reasons for the problems in maintaining and adjusting the pitch angle during the turn resulted from the controllability of an aircraft which was flying near its maximum weight and was mildly neutral in longitudinal stability. The pilot used the visual horizon as a point of reference. It is possible that the problems encountered during the turn were partly caused by the pilot’s incorrect observation of the actual visual horizon. In the west-northwestern sector, where the pilot was focusing his gaze, there were large areas nearby where the sky was clear. Further away, at 3 500 m there was a continuous layer of cloud and the pilot may have inadvertently interpreted this to be the horizon.

The downward acceleration experienced during the final stage of the turn was most probably caused by a combination of the effects of the CG to longitudinal stability, the large power increase and a momentary lapse in controlling the airplane because of an incorrect observation of the visual horizon. The stall angle was probably not exceeded on the jump run or during the turn.

Change in flight condition following the turn

The pilot straightened out. The airspeed had accelerated and within a distance of 1 400 m the aircraft had descended in all approximately 350 m. According to the pilot's observations the airspeed peaked at 185 kt IAS. In accordance with the information collected from compiled radar data and the parachutes' AADs as well as one jumper's recording altimeter the maximum permissible airspeed of the CA8 type (V_{ne} = 197 KCAS) was probably not exceeded in the descent that followed the turn. However, the maximum permissible airspeed (V_{ne} = 199 KIAS) according to the OH-XDZ's flight manual was probably exceeded for a few seconds. Up until the moment when the wing strut buckled the airspeed was probably in excess of the CA8-type's design manoeuvring speed V_a and the maximum speed for normal operations V_{no}.

The pilot attempted to reduce airspeed by converting the glide into a climb by pulling on the control stick. He said that the longitudinal stick forces were relatively high while straightening out from the glide. It is possible that the increased control force was caused by the elevator's growing hinge moment associated with the high airspeed. It is also possible that when the aircraft turned away from the jump run the pitch trim remained close to its forward position, i.e. on the 'push' side. None of the pilots who had flown the OH-XDZ had any experience in the required flight control forces at such high airspeeds and at high loads.

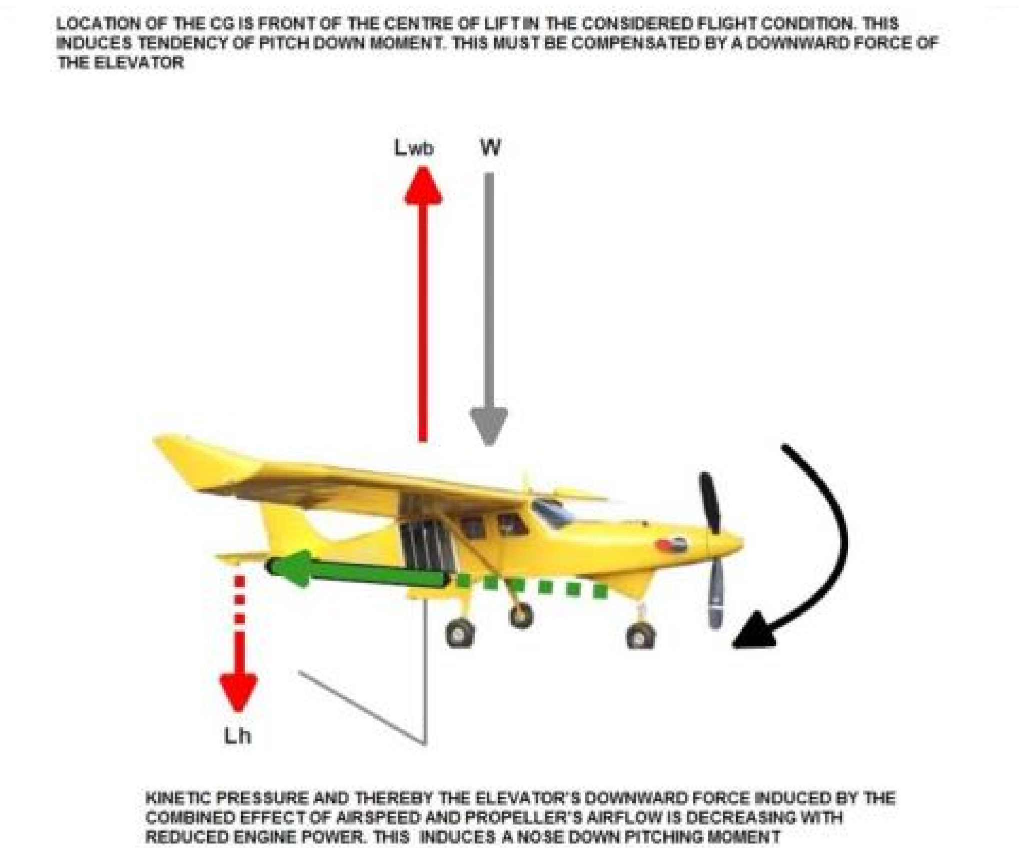

Figure 21. Change in longitudinal equilibrium during engine power reduction.

Two forces and one pitching moment are normally evaluated when determining an aircraft's equilibrium in relation to its centre of gravity. The combined lift of the wing and fuselage, and its pitching moment, has an effect on the aerodynamic centre of the wing-fuselage. At a high airspeed the nose-down moment requires an offsetting tail-down force so as to balance the situation. For the sake of simplification the flight condition illustrated in figure 21 is presented in such a manner that the effects of the wing-fuselage lift and the pitching moment are combined into a single force affecting the centre of lift.

Having noticed that the airspeed had accelerated close to the maximum permissible speed the pilot managed to convert the glide into, at least, a gradual climb. Then he rapidly pulled the power lever to idle so as to reduce the airspeed.

When it comes to turboprop engines the negative propulsive force of the propeller at flight idle is typically considerable, at which time the combined effect in the longitudinal force is great. Simultaneously the airflow in the zone of the propeller wash slows down. Then the velocity of the airflow and the effective kinetic pressure felt on the tailplane on an aircraft such as the OH-XDZ diminish, which directly reduces the offsetting force of the horizontal stabiliser.

Should the balancing force of the tailplane, as a result of power reduction, reduce by 7 %, it could be a significant initial disturbance to unbalance the delicate equilibrium of the aircraft in a statically unstable situation. The reduction of kinetic pressure experienced on the tailplane, per se, would only aggravate the instability.

The OH-XDZ's flight manual did not set any limitations for engine power use at different airspeeds. The pilot was unaware how a rapid power reduction on this aircraft affects the pitching moment when flying close to the maximum permissible airspeed. It is likely that the pilot instinctively reduced the engine power when he noticed that the aircraft had accelerated close to the maximum permissible airspeed, and when the instability associated with the CG made it difficult to control the aircraft.

At a high airspeed a rapidly forming change in the angle of attitude, even a small one, caused by a disturbance in the pitching moment, results in large changes in g-forces. The aircraft's static instability boosts the inadvertent changes in the angle of attitude; neither the aircraft's natural dynamic damping nor counter steering will effectively prevent them. It is also possible that the sudden deceleration shifted the skydivers forward as, preparing for the jump, they had moved from their seats. This, for its part, contributed to the emergence of the nose-down moment.

Buckling of the wing strut

The negative change in the angle of attack which resulted from a disturbance in the pitching moment at a high airspeed may have exposed the right wing strut to a critically high negative g-force within one second. The right wing's wing strut buckled upwards (1) and the right wing folded down against the jump door (2) (figure 22). The aircraft lost its controllability instantaneously and began to rotate around its vertical axis in a flight condition resembling an inverted spin.

The investigation found no indications of technical fault in the flight control or propeller systems.

Judging by the location where the fillet between the right wing and the fuselage was found it was determined that it came loose at altitude. The fracture marks on the fillet indicated that the right wing had folded downwards around its root mountings. The root spar of the wing broke when the wing folded. Fuel streamed from between the wing and the fuselage during the nosedive. The eyewitnesses said that the aircraft left a vapour trail. They made their observations after the wing had already folded.

The folding of the right wing was caused by the buckling of the wing strut due to a downward force.

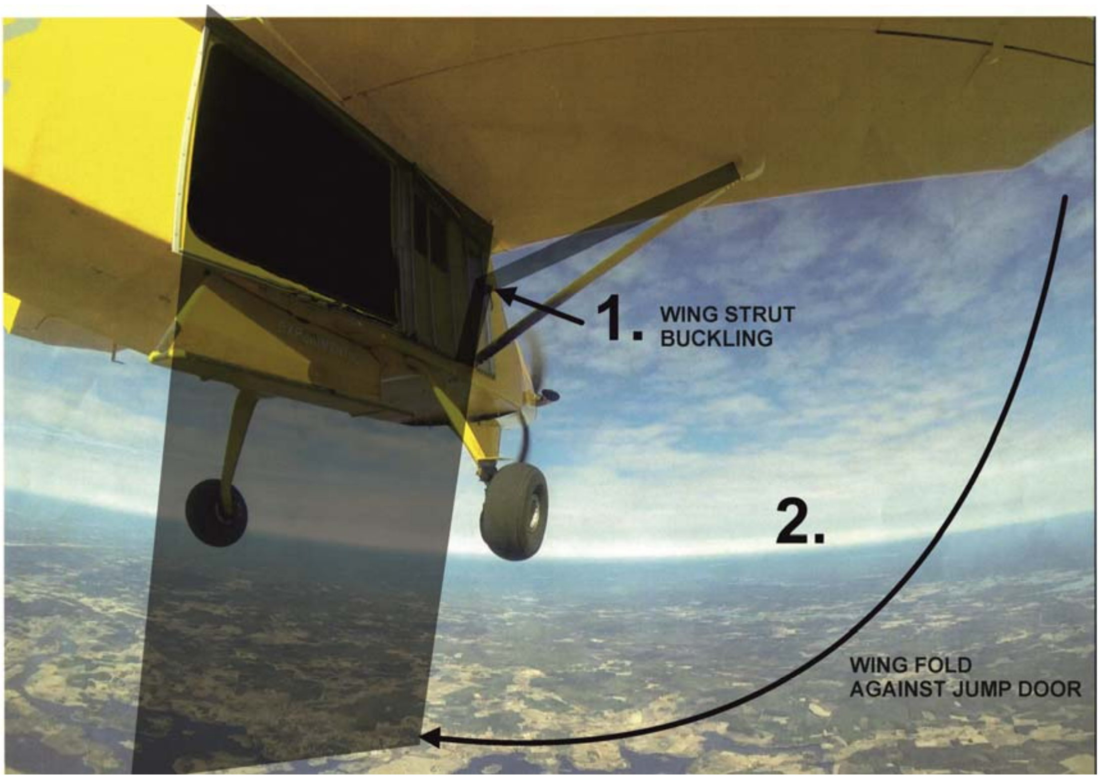

Figure 22. The wing's folding against the jump door.

When the g-forces on the wing strut are positive, there is an upward force on it, i.e. 'pull'. In accordance with the VTT's report the tensile strength of the wing strut profile is 268 kN, which clearly meets the design requirements.

According to calculations the safety factor reported in the OH-XDZ's Permit to build for the wing strut's real strength at -1.8 g did not materialise at the maximum weight. Pursuant to Aviation Regulation AIR M5-2 the limit loads for experimental aircraft must be, at least, within the range of +3.8…-1.5 with a safety factor of 1.5. This, according to calculations, seems to have been met with the OH-XDZ fitted with winglets. It was impossible to establish the change of the negative limit load to -1.9 from the values reported in the flight manuals of the kit manufacturer and the OH-XDZ because the kit manufacturer never provided the requested load calculations. While, according to calculations, a CA8 aircraft built as per the original kit does meet the Aviation Regulation-stipulated design criteria, it does not meet the safety factor 2, reported by the kit manufacturer.

If the wings' lift is increased, for example, as a result of modifications to the wing area or other lift-enhancing changes, the limit loads and airspeed limitations must be checked and, if necessary, re-evaluated. Compared to a normal CA8 aircraft, the winglet-fitted OH-XDZ's wings experienced higher tensile and compressive stress on the wing struts because of the wing's higher aerodynamic flexural forces. The OH-XDZ's flight manual used unchanged values.

The wing strut's fatigue cracking

The transverse fatigue crack on the right wing's wing strut had probably, for its part, degraded the structural integrity of the strut. Judging by the wing strut's fracture surface it was possible to determine the direction in which the crack propagated. On the fracture surface on the upper surface of the wing strut the buckling had occurred parallel with the tensile stress, which demonstrated that the direction of the force in the final bending was upwards in relation to the direction of flight. As a result of the change in the flight condition the wings encountered a downward force (negative g-force), at which time the wing strut was subjected to compressive stress, as a result of which it bent upwards.

The fatigue crack had begun above the bolt mountings of the wing strut profile on its inner surface and propagated transversely in both directions towards the leading edge of the profile and the corner of the mounting. At its end the fatigue crack turned lengthwise, parallel with the profile. The crack propagated from the inside of the profile and over time went towards the outer surface. It was impossible to detect in visual inspection prior to the accident. After the aircraft was destroyed it was impossible to investigate any possible damage to the wing strut's fittings or other damage to the profile.

The wing strut was bolted onto the wing at both ends (wing and fuselage). The direction of buckling was logical as regards the profile and the direction of the mountings because the flexural stiffness of an aerofoil-shaped strut, articulated at both ends, was smaller in this direction than the stiffness along its chord.

In all the OH-XDZ's journey logbook registered 809 flight hours and 3 015 landings, which translates into approximately four landings per every hour flown. Because of the short flights and repeated landings the activity was very stressful on aircraft structures. Characteristically to skydiving operations, a significant part of this airplane's flights had been flown close to its maximum takeoff weight, which only increased the structural stress. Since the exact temperature changes or vibrations on the wing strut are unknown the effects of the temperature of the engine's exhaust gas stream or vibration to the onset of the fatigue cracking on the right wing strut cannot be fully excluded.

The wing strut’s buckling resistance was exceeded during the deceleration which was caused by a relatively high negative g-force during the change in the flight condition. The investigation could not determine the exact value of the g-force.

Skydiving aircraft inspection requirements do not call for any special inspections befitting the nature of the activity. No inspections or time limitations were set for the wing strut in the aircraft’s maintenance or periodic inspection programmes. Several type certificated aircraft’s wing struts have either flight time or calendar based inspection cycles.

Apart from the right wing strut’s fatigue failure which was later established in material testing, no other pre-existing technical fault could be found in the investigation of the wreckage.

Collision with the ground

Once the right wing lost its aerodynamic lift the aircraft entered into a flight condition resembling an inverted spin. After the aircraft broke it became impossible to recover it.

The airplane lost altitude at a high rate. It collided with the ground after a nosedive which lasted approximately 55 seconds. The rate of rotation was approximately 134 degrees per second, which the skydivers felt as 2-4 g depending on their position in the cabin during the spinning. A decision to make an emergency jump was made. The folded right wing prevented egress though the jump door.

The pilot and two skydivers managed to bail out through the pilot’s door on the left side of the fuselage. The pilot had to get out first so as to make it possible for the others to exit the aircraft. The pilot was wearing an emergency parachute, even though aviation regulations do not mandate the use of one. The other pilots of the aircraft also wore emergency parachutes as routine practice. The skydivers’ AADs functioned as designed.

2.2 Analysis of the rescue operation and the action of the other authorities

This is included in the Finnish version only.

3 CONCLUSIONS

3.1 Findings

1. The pilot’s licence, required ratings and his medical certificate were valid. The pilot’s total flight experience was 1 029 h and on-type experience 43 h.

2. The aircraft was a Comp Air 8 airplane; it was a composite construction aircraft, registered in the experimental category. It was also the first turboprop aircraft in its category in Finland. It was constructed in Finland from an American aircraft kit. The aircraft was not type certificated.

3. The aircraft was airworthy and it had the required insurance. It had logged 809 h and 3 015 landings.

4. In order to jump from the airplane one had to a member of the association that owned it. The activity was the association’s internal, non-commercial activity.

5. A skydiving event lasting the entire Easter weekend was being organised at Jämijärvi aerodrome.

6. In addition to the pilot there was a full load, i.e. ten skydivers in the aircraft. They sat on the benches and the floor in an aft-facing position.

7. The aircraft’s ramp weight was 2 531 kg, i.e. nine kilogrammes below the maximum takeoff weight. The centre of gravity was probably outside the flight manual’s aft limit at takeoff and on the jump run.

8. The aircraft climbed to 4 230 m. The rearmost skydivers moved back inside the cabin and opened the jump door. They realised that they had overshot the jump run and closed the door.

9. The pilot turned left in order to home in on a new jump run. He did not tell the jumpers to move back to their loading chart-prescribed positions.

10. During the turn the aircraft began to descend and it very rapidly accelerated close to its maximum permissible calibrated airspeed, which the pilot did not immediately realise. The situation and the airplane’s behaviour surprised the pilot. He pulled on the control stick and the aircraft levelled out or went into a shallow climb. The pilot reduced engine power to idle.

11. In conjunction with the power reduction the velocity of the airflow on the horizontal stabiliser probably dropped suddenly. The ability of the stabiliser to generate lift decreased which resulted in a nose-down movement. The negative g-force generated a downward force on the wing. The decreasing angle of attack caused a downward force on the wing and, hence, a negative g-force.

12. The right wing's wing strut buckled upwards and the right wing folded down against the jump door. The aircraft lost its controllability instantaneously and began to rotate around its vertical axis in a flight condition resembling an inverted spin.

13. The decision to make an emergency jump was made in the aircraft. The wing which had folded against the jump door prevented egress through the door. The pilot and two skydivers sitting at the front of the airplane bailed out through the pilot's door.

14. The pilot's emergency parachute and the two jumpers' automatic activation devices functioned as designed.

15. The pilot and one jumper sustained serious injuries. The second jumper's injuries were minor.

16. Eight skydivers did not manage to bail out. They died in the collision with the ground.

17. The aircraft was completely destroyed in the collision with the ground and the fire that followed the crash.

18. There were several eyewitnesses to the accident, and their emergency calls rapidly launched the rescue operation. Skydivers on the ground immediately started a search to locate the ones that bailed out of the aircraft.

19. Numerous rescue and emergency medical care were dispatched to the scene. Since all of the damage occurred instantaneously with the collision with the ground, the rescue units could not mitigate the damage or injuries.

20. The HEMS helicopter was not on the automatic dispatch list. It was dispatched a little later. This caused a 22 min delay for it to arrive.

21. The need for psychosocial support was great. Afterwards there were shortcomings in the arrangements of psychosocial support.

22. The application for a Permit to build did not articulate that wing extensions at the plane of the wing and winglets would be installed on the aircraft. The builders did not apply for a change to the permit in writing. The structure of the wing strut corresponded to the original aircraft kit.

23. The kit manufacturer was aware of the design and installation of the winglets.

24. The effects of the structural modifications to the aircraft's structural strength had not been established beforehand. The kit manufacturer had shown the builders the load calculations of the original aircraft design, but they were not given to the builders.

25. According to calculations the safety factor for the wing strut's actual stress resistance did not materialise at -1.8 g at the maximum weight given in the Permit to build. The minimum requirement as per Aviation Regulations was met.

26. The build supervisor and the aircraft inspectors overlooked the structural modifications.

27. When the material of the right wing strut was analysed it became clear that there was a fatigue crack on the inner surface of the wing strut. The crack had formed over a long period of time and it was impossible to detect in visual inspections. In the investigation of the wreckage no other pre-existing technical fault could be found.

28. The stall angle and the maximum permissible calibrated airspeed were probably not exceeded.

29. National aviation regulations permit the use of experimental aircraft in skydiving operations.

30. National pilot rating requirements for skydiving operations are incompatible with the demands of the activity. There is no requirement for a separate skill test.

31. Supplemental oxygen was not used on the flight. The exposure to hypoxia at approximately 4 000 m was so fleeting that it probably did not cause any significant functional symptoms.

3.2 Probable causes and contributing factors

The cause of the accident was that the stress resistance of the right wing's wing strut was exceeded as a result of the force which was generated by a negative g-force. The force which resulted in the buckling of the wing strut was the direct result of a negative (nose-down) change in pitching moment, in conjunction with an engine power reduction intended to decrease the high airspeed.

The buckling was followed by the right wing folding against the fuselage and the jump door. The aircraft entered into a flight condition resembling an inverted spin, which was unrecoverable. It was impossible to exit through the jump door.

The contributing factors were the following:

1. There was a fatigue crack on the wing strut. Because of the damage to the aircraft it was not possible to investigate the mechanism of the fatigue crack formation. It is possible that, in addition to the stress caused to the aircraft by short flights and high takeoff weights, the temperature changes caused by the exhaust gas stream as well as vibration contributed to the fatigue cracking.

2. The nature of skydiving operations generated many takeoffs and landings in relation to flight hours. A significant part of the operations was flown close to the maximum takeoff weight. These factors increased the structural stress.

3. The pilot's limited flight experience on a powerful turboprop aircraft, his inadequate training as regards aircraft loading and its effects on the centre of gravity

and airplane behaviour, the high weight of the aircraft and the aft position of the CG in the beginning of a new jump line and, possibly, the pilot's incorrect observation of the actual visual horizon contributed to the onset of the occurrence.

During the turn to a new jump run the aircraft began to descend and very rapidly accelerated close to its maximum permissible airspeed. The pilot did not immediately realise this.

4. The structural modifications on the wing increased the loads on the aircraft and the wing struts. Their effects had not been established beforehand. The kit manufacturer was aware of the modifications. No changes to the Permit to build were applied for in writing regarding the modifications. Neither the build supervisor nor the aircraft inspectors were aware of the origin or the effects of the modifications.

4 SAFETY RECOMMENDATIONS

4.1 Safety actions already implemented

A notification pursuant to Section 25 of the Safety Investigation Act

On 23 September 2014, pursuant to Section 25 of the Safety Investigation Act, the SIAF sent a notification to the Finnish Transport Safety Agency (Trafi) and the NTSB regarding fatigue cracking discovered in the right wing strut during the investigation.

The accredited representative of the NTSB relayed the notification to the manufacturer of the aircraft kit, requesting the company to further inform the builders and owners of similar kits. The NTSB also requested information from the manufacturer regarding the foreign owners of the aircraft type. The NTSB also said that it would inform the FAA and the Experimental Aircraft Association (EAA) so that they, by means of the aircraft register, could further relay the notification to the owners of similar-type aircraft. The NTSB reported that it was trying to reach foreign owners through the ICAO and the safety investigation authorities in countries where this aircraft type is known to be in use.

Risk assessment regarding safety in recreational aviation and safety improvement project

Trafi published its risk assessment regarding safety in recreational aviation on 29 Oct 2014. The report states that the results warrant an open debate on an acceptable risk level, the designation of roles and responsibilities between the authorities and actors in recreational aviation as well as short-term and medium-term actions to improve safety in it. On 7 Nov 2014, on the basis of the risk assessment Trafi launched a risk assessment regarding safety in recreational aviation, for which a full-time project manager was appointed until the end of 2015. The goal of the project is to establish a model and procedures, including designated responsibilities, for the safety culture of Finnish recreational aviation.

According to the risk assessment the critical risks in skydiving activities are associated with loading the aircraft and the weight shift in flight activities, especially during the climb and the jump phase. Even though skydivers are generally aware of the aforementioned risks, not every one of them sufficiently realises the risks or the factors that generate them. For this reason, compliance with regulations or familiarisation with instructions may be inadequate.

No uniform skydiving instructions or guidelines exist for skydivers and pilots. Pilot training is carried out by clubs and operators. No uniform national training guidelines exist for the purpose of training pilots for skydiving operations. The assessment brought forward the need to increase mutual awareness between pilots and skydivers regarding their actions and, especially, of the critical risks and risk mitigation.

The goal of the recreational aviation safety project is for the Finnish recreational aviation community to assume the responsibility for the development of their own safety. Furthermore, the project will see to it that the recommendations of the assessment are appropriately processed and completed. The recommendations for skydiving are as follows:

- The Finnish Aeronautical Association (SIL) will study whether all skydivers should be required to have automatic activation devices.
- Increasing awareness: The SIL will consider a solution to the promulgation of information and training as best as possible to all novice licenced skydivers and experienced skydivers who either embark on or try any new skydiving disciplines which include a heightened risk of mid-air collision in freefall.
- The SIL will publish general training guidelines for pilots that fly skydiving flights. The guidelines will be of a general nature, rather than aircraft type-specific. They will pay attention to specific skydiving-related issues in pilot training (such as weight shift in the aircraft, low-speed flight and stall). The pilot training guidelines can be built around the suitable portions of the FAA's sport parachuting safety advisory circular AC 105-2E (8. Pilot responsibilities, Jump pilot training, subsections 8b–8f).
- The SIL will publish guidelines for skydivers regarding risks in skydiving flight operations. The guidelines are to underscore the seriousness of the risks when it comes to aircraft loading and moving about inside the aircraft. The guidelines should also express views on pilot-skydiver coordination.
- Aircraft used in skydiving operations must include clear markings and instructions regarding loading and moving about inside the cabin.

All of the abovementioned guidelines and instructions should be coordinated by the SIL and drafted in concert between the pilot and skydiver communities.

Developing the operational prerequisites of Finland's Aeronautical Rescue Coordination Centre

The Aeronautical Rescue Coordination Centre (ARCC) and the Emergency Response Centre Administration have prepared a procedure by which all emergency calls associated with a potential incident or air accident would automatically be relayed to the ARCC's terminal. By doing so, the ARCC would always be informed of a situation without any delay.

The ARCC and the Ministry of the Interior Department for Rescue Services have planned adding the ARCC as a user of the rescue services' PEKE command and management application. The decision-in-principle has already been taken. The Department is drafting a memorandum of understanding as regards displaying emergency departments' positional information on the ARCC's terminal.

The ARCC and the Finnish Defence Forces have agreed on a procedure by which the ARCC's urgent calls for helicopter assistance are directly relayed to the aircrew of the helicopter on duty. This would minimise the lag in dispatching helicopters.

HEMS helicopter dispatching instructions in Satakunta

In the area of the Satakunta Hospital District the dispatching instructions of HEMS helicopters have been changed. In the southern and eastern parts of the district, where HEMS units reach the target earlier than the Central Hospital's doctor ambulance unit, HEMS units are automatically dispatched to all high-risk tasks. In the northern part of the district HEMS units are automatically dispatched to tasks related to major accidents.

Major disaster plan for Pirkanmaa Hospital District and Tampere University Hospital (TAYS)

The problems that arose in conjunction with the accident at Jämijärvi prodded along the joint preparedness development project of the psychiatric department of TAYS and the major disaster working group, ongoing since March of 2014. The goal was to expand the preparedness of psychosocial support in such a manner that the entire psychiatric clinic participates in organising it, and that the service could be obtained from a single phone number.

4.2 Safety recommendations

1. The accident revealed that there are many features in building, maintaining and operating an eleven-seater experimental aircraft built for active skydiving operations, in which inadequate planning, guidelines, supervision or completion can generate uncontrollable risks. Because of seating limitations, in many European countries it is impossible to construct or use this kind of an experimental aircraft in skydiving operations.

   The Safety Investigation Authority, Finland recommends that, when required, the Finnish Transport Safety Agency limit the number of occupants in experimental aircraft and their use in skydiving operations based on risk considerations. [FI.SIA-2015-0009]

2. The application for a Permit to build did not articulate that self-designed winglets would be installed on the aircraft. The builders did not apply for a change to the permit. The build supervisor and the aircraft inspectors overlooked the structural modifications. The modifications increased the stress on the aircraft's structures.

   The Safety Investigation Authority, Finland recommends that the Finnish Transport Safety Agency ensure that the experience and training of persons that supervise and inspect experimental aircraft meet the requirements of construction and modification control. [FI.SIA-2015-0010]

3. In light of the nature of skydiving operations, the rating requirements for the pilot who acts as PIC on skydiving flights are light. Skydiving activity is comparable to carrying passengers, which requires, among other things, more attention to detail in topics associated with loading and CG management than in normal sport aviation. For instance, specified theoretical knowledge and flight training curricula exist for glider towing-ratings.

   The Safety Investigation Authority, Finland recommends that the European Aviation Safety Agency prepare specified theoretical knowledge and flight training requirements for pilots-in-command in skydiving operations. A pilot must have to complete a separate type-specific skill test in order to obtain a jump pilot rating. The training and the skill test required for a jump pilot rating must take into account aircraft-specific characteristics and their impact on safe skydiving operations. [FI.SIA-2015-0011]

   The Safety Investigation Authority, Finland recommends that the Finnish Transport Safety Agency, in conjunction with the recreational aviation safety project, ensure that the Finnish Aeronautical Association prepares generic guidelines for skydiving operations, around which associations build training programmes for jump pilots, tailored for aircraft types and individual airplanes as well as proficiency examinations that certify their theoretical knowledge and practical skills. [FI.SIA-2015-0012]

4. The need for post-disaster psychosocial support was great, but especially later there were shortcomings in the arrangements of psychosocial support. For this reason the SIAF repeats the recommendation which was originally issued by the Investigation Commission of the Kauhajoki School Shooting on 23 September 2008.

   The Ministry of Social Affairs and Health should take steps to ensure that the plans, resources, responsibilities, and competent leadership for the provision of psychosocial support in major crises are available regardless of where the accident takes place or where the people involved come from. The aim is to provide the necessary individual, communal, and practical support to those involved, when they need it. [FI.SIA-2015-0013]

4.3 Other remarks and recommendations

Guidelines to skydivers regarding skydiving flight operations

According to Trafi’s risk assessment regarding safety in recreational aviation the goal is to prepare risk guidelines for skydivers when it comes to risks in skydiving flight operations. The guidelines will take into account aircraft loading, moving about inside the aircraft as well as pilot-skydiver coordination. Additionally, as per the risk assessment the intention is to include clear markings and instructions for loading and moving about inside the cabin in aircraft used in skydiving operations.

The SIAF endorses such guidelines and markings. Since the issue is already in process through the recreational aviation safety project, the SIAF will not issue a recommendation on it.

Taking the activity into account in aircraft maintenance

Skydiving flight operations are not separately handled in statutes. Rather, they are considered to be normal flight activities. Skydiving flights put more stress on aircraft structures compared to normal flight activities.

The owners and operators of aircraft should take into account the nature of operations in their maintenance programmes and maintenance instructions.

Intersectoral cooperation

The need to develop cooperation between the authorities was discovered in conjunction with the rescue operation. The public authority network's (VIRVE) call groups jammed. There were shortcomings in coordination between helicopter SAR flights and searches on the ground. These shortcomings had no effect on the extent or nature of damages.

The accident demonstrated the great role of cooperation, management and communications in major accidents, which must be taken into account in contingency planning.

Developing the operational prerequisites of Finland's Aeronautical Rescue Coordination Centre

The investigation revealed development needs with regard to the ARCC obtaining information, maintaining a situation picture and dispatching SAR resources. Since the matters are already in process the SIAF does not issue a recommendation.

Aircraft coordinator

During major accidents it is possible to have a large number of aircraft participating in SAR activities. The Border Guard, which is the leading maritime search and rescue (SAR) authority in Finland, is prepared to manage this kind of situation according to its Maritime Search and Rescue Manual (2010) by using an Aircraft Coordinator (ACO). The ACO is a person whose duty is to coordinate and harmonise on-scene aeronautical SAR operations.

No instructions exist for using an ACO during accidents that occur in land areas. The matter was irrelevant to the accident being investigated because only two of the five dispatched helicopters participated in active SAR. Aircraft coordination may be necessary, for example, in a similar-sized accident in rough terrain.

From the standpoint of safety and effectiveness of aviation the preparedness to coordinate aircraft activities in the entire area of Finland should exist.

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