ACCIDENT INVESTIGATION BOARD FINLAND

Investigation report

B3/2008L

In-flight structural failure at Taipalsaari on 15 August 2008

Translation of the original Finnish report

OH-PDY

Piper PA-28R-200 Arrow II

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SUMMARY

IN-FLIGHT STRUCTURAL FAILURE AT TAIPALSAARI ON 15 AUGUST 2008

An air accident occurred at Taipalsaari on Friday, 15 August 2008 at about 13:14 (all times are Finnish local time), when a Piper PA-28R-200 Arrow II, registration OH-PDY, crashed into Lake Saimaa near the southern tip of Peräluoto Island. The accident site is located approximately 20 km north of Lappeenranta Airport. The aircraft was owned by Malmi Air Ltd and operated by Patria Pilot Training Ltd, a company based at Helsinki-Malmi Airport.

The aircraft had flown an instrument training flight from Helsinki-Malmi Airport to Kuopio in accordance with the training syllabus. The flight from Kuopio to Lappeenranta was to be a progress check flight arranged by the flight school. As the aircraft was approaching Lappeenranta Terminal Control Area (TMA), the pilot requested to leave the cruising altitude of 8000 ft (ca. 2400 m) in order to fly some manoeuvres included in the progress check flight's programme. The topic was upset recovery training. Air traffic control approved this with 3000 ft (900 m) as the lower limit for the exercise.

At about 13:13, some eyewitnesses heard an unusual noise from an aircraft engine, which ended with a loud noise caused by an impact with the water. The aircraft was destroyed at impact. All occupants of the aircraft – a flight instructor and two student pilots – were killed instantly.

A person who had seen the aircraft crash into the water reported the accident to the Emergency Response Centre of South-East Finland at about 13:17. The wreckage and the occupants of the aircraft were quickly located. After the crash some eyewitnesses saw loose aircraft parts fall from a cloud and plunged into the lake. When the wreckage was recovered, it was confirmed that approximately half of both wings and the right stabilator were missing.

Samples taken from the wing spars that were still attached to the fuselage and the stabilator as well as the balance weight arm that was torn off of the stabilator spar were examined at the Technical Research Centre of Finland (VTT). The Centre was requested to examine the fracture mechanisms and, particularly, any signs of material fatigue as well as the directions of the forces which caused the fracture. No signs of metal fatigue or material defects were found in the samples.

Clear indications of upward deflection of the wing were found in the left wing spar. However, the right wing spar showed no clear signs pointing to the direction from which the loads that caused the fracture came. It is likely that the stabilator broke off when the detached wing hit it.

The aircraft was not equipped with flight recorders. The fixed GPS navigation system did not have a track logging feature. However, the flight and its final stages were recorded by radar. Radar returns were analysed with the assistance of radar experts and a speed and altitude diagram was drawn for the 120 final seconds of the flight. The last reliable radar contact from the aircraft came 10 seconds before the collision with the water. On the basis of the analysis and by using speed and altitude data for the flight path, the investigation commission performed a mathematical analysis on how the wings broke off. The calculations showed that when the wings broke the airspeed must have been at least 155 kt and the load factor approximately 7 g.

The accident was caused by the flight instructor flying the aircraft into an attitude from which a safe recovery permitted no mistakes. The instructor may thus have overestimated his own ability to respond to the student's mistakes as well as the student's ability to execute the recovery. The aircraft reached a high airspeed and the flight control inputs used in the recovery resulted in acceleration that was great enough to break the wings off.

A crucial factor contributing to the accident was that only once before had the instructor flown upset recoveries with a student on the aircraft type in question. The student pilot on the accident flight had never before trained upset recovery on this aircraft type.

The most important contributing factors included:

Deficiencies in standardisation training contributed to the fact that flight instructors followed dissimilar procedures. Some flight manoeuvres were also possibly conducted in a high-risk manner.

The instructions on progress check flight 4 (VTL4) were not explicit with regard to upset recovery training.

The flight instructor may not have wanted to intervene in the student pilot's performance at an early stage, since the student was on a check flight.

The flight instructor did not perceive an earlier occurrence on the VTL4 flight as an incident, and consequently did not change the procedure he used.

The student's earlier experience of upset recovery had been gained on aerobatic aircraft. The instructor's experience as an instrument flight instructor and check pilot on this aircraft type was limited.

A large number of students and lack of resources created schedule constraints in the flight training organisation. As a result, pre and debriefings with students were often insufficient.

The investigation commission made five safety recommendations. One of them was addressed to EASA, two to the Finnish Civil Aviation Authority and two to flight training organisations

The investigation commission recommends that EASA study the possibility of drawing up a proposal for a standard which would suggest that all GPS devices intended for use in aviation have a function that records the parameters of the route flown. Moreover, the memory of such devices should not require a power source to retain the stored data.

The investigation commission advises the Finnish Civil Aviation Authority to require that the Student Pilot in Command (SPIC) training system include a sufficient number of dual instruction flights on an aeroplane in order to improve students' instrument flying skills. The second recommendation advises CAA Finland, when accepting training syllabi, to require that progress check flights be flown with a flight examiner who has not participated in the flight training of the student pilot in question.

The investigation commission recommends that Patria Pilot Training Ltd draw up detailed flight training instructions for progress check flights, and advises all flight training organisations in general to prepare unambiguous training instructions and organise regular training sessions with mandatory attendance for all instructors listed in the organisation's instructor records. The topics and participants of each training session should be documented in the training records.

TABLE OF CONTENTS

ABBREVIATIONS

ATPL	Airline Transport Pilot Licence
BKN	Broken (cloud)
CPL	Commercial Pilot Licence
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
FEW	Few
FI(A)FCL	Flight Instructor (Aircraft) Flight Crew Licence
GAFOR	General Aviation Forecast
hPa	Hectopascal
JAR	Joint Aviation Regulations
kt	Knot(s)
MHz	Megahertz
MSL	Mean sea level
MSSR	Monopulse Secondary Surveillance Radar
NTSB	National Transportation Safety Board
OPS	Operations
OVC	Overcast
PPL	Private Pilot Licence
QNH	Altimeter setting
SAR	Search and Rescue
SCT	Scattered
SEP	Single engine piston
SPIC	Student Pilot In Command
TRG	Training
VFR	Visual Flight Rules
VHF	Very high frequency
VMC	Visual meteorological conditions
VOLMET	Meteorological information for aircraft in flight
VOR	VHF omnidirectional radio range
VRB	Variable
VTL4	Progress Check Flight 4

SYNOPSIS

An air accident occurred at Taipalsaari on Friday, 15 August 2008 at approximately 13:14 (all times are Finnish local time) when a Piper PA-28R-200 Arrow II, registration OH-PDY, crashed into Lake Saimaa near the southern tip of Peräluoto Island. The accident site is located approximately 20 km north of Lappeenranta Airport. The aircraft was owned by Malmi Air Ltd and operated by Patria Pilot Training Ltd, a company based at Helsinki-Malmi Airport. The aircraft was destroyed upon impact and all occupants, the flight instructor and two student pilots, were killed instantly.

They had flown an instrument training flight from Helsinki-Malmi to Kuopio in accordance with the training syllabus. The flight from Kuopio to Lappeenranta was an internal progress flight test arranged by the flight school. As the aircraft was approaching Lappeenranta Terminal Control Area, the pilot requested to leave the cruising altitude of 8000 ft (ca. 2400 m) in order to fly some manoeuvres included in the progress check flight's programme. The topic was upset recovery practice. Air traffic control gave 3000 ft (900 m) as the lower limit for their exercise.

A person who witnessed the aircraft crash into the water reported the accident to the Emergency Response Centre of South-East Finland at about 13:17. The wreckage and the occupants in the aircraft were quickly located. After the crash some eyewitnesses saw loose aircraft parts fall from a cloud and plunge into the lake. When the wreckage was recovered, it was confirmed that approximately half of both wings and the right stabilator were missing.

AIB Finland investigators left for the site at 16:30 on the day of the accident. Later that day the deceased were taken to Lappeenranta Central Hospital for pathological examination. On 17 Aug 2008 the wreckage was lifted and the following day it was transported to Helsinki-Vantaa Airport for detailed examination. Eleven persons from the Army Academy's executive assistance detail combed the nearby islands for the missing aircraft parts.

On 19 Aug 2008, Accident Investigation Board Finland (AIB) appointed investigation commission B3/2008L for this accident. Investigator Esko Lähteenmäki was named investigator-in- charge, accompanied by Air Accident Investigator Tii-Maria Siitonen and Investigators Ismo Aaltonen and Hans Tefke as members of the commission.

Mr Heikki Aalto, Senior Teacher of aeronautical engineering at Tampere University of Applied Sciences and Major (Eng) Riku Lahtinen, Chief of Aircraft Maintenance at Karelia Air Command were invited as experts to investigate the structural failure of the aircraft. Mr Markku Roschier, Master of Science, was invited to investigate organisational questions and Mr Jaakko Kulomäki, Master of Psychology at the National Defence University, to examine flight crew actions. Rescue operations were analysed by Mr Kari Ylönen, Master of Social Sciences. At his own request, Markku Roschier was relieved of his duties as an expert to the investigation commission on 9 Sept 2009.

Pursuant to ICAO Annex 13, the US National Transportation Safety Board (NTSB) designated Accident Investigator David Bowling to assist the investigation commission.

On 14 Oct 2009 the draft final report was sent for comments to CAA Finland and Patria Pilot Training Ltd as well as to Finavia, the Finnish Air Force Headquarters, the ERC of South-East Finland and the technician who had maintained the aircraft. Comments were received by 16 Nov 2009. CAA Finland's comments are appended to this report.

The report was sent for comments to NTSB and EASA on 18 Jun 2010.

The investigation was completed on 3 Dec 2009 and the recommendations were reviewed on May 2011. The investigation report was translated into English.

The material used in the investigation is stored at the Accident Investigation Board Finland.

1 FACTUAL INFORMATION

1.1 History of the accident flight

On the morning of the accident the flight instructor had his own multi-engine check flight. At approximately 04:30 in the morning he left his home for Helsinki-Malmi Airport to prepare for his flight. His check flight began at 07:00 and ended at 08:42. The student pilot who was scheduled to be the pilot flying on the accident flight had been preparing for the flight past midnight and had got up at approximately 06:00 in the morning.

The flight instructor and the student pilots departed Helsinki-Malmi at 09:42 on an instrument training flight for Kuopio Airport. The flight was included in the flight training syllabus. Student pilot A was the pilot flying and student pilot B sat in the rear seat. They landed in Kuopio at 11:24 and refuelled the aircraft. The student pilots switched positions and roles. The sortie from Kuopio to Lappeenranta was a progress check flight 4 (VTL4) for student pilot B. This sortie includes, among other things, upset recovery from unusual attitudes as well as different instrument approaches. Upset recovery training was planned to be flown in the Lappeenranta Terminal Area (TMA) before the instrument approaches.

The accident flight began at Kuopio Airport at 11:57. The cross-country leg towards Lappeenranta was flown at 8000 ft (2400 m). Student pilot B contacted Lappeenranta ATC at 13:07 and requested a clearance to the TMA. The air traffic controller cleared them to Lappeenranta TMA with 3000 ft (900 m) as the lower limit. After this, the flight crew made no further contact with the ATC. Judging by radar returns, they continued for the most part parallel with their track prior to entering the TMA. From the radar returns of the final stages of the flight it was possible to discern a rapid increase in airspeed and a dramatic loss of altitude. The aircraft’s ATC transponder provided altitude information as far down as 3400 ft. From the radar information it was possible to estimate that the wings broke off at 5000-4500 ft during recovery from a dive. Parts that separated in flight were also visible on the radar. As a result of the structural failure, the aircraft crashed into the lake at a steep angle.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	2	1	
Serious			
Minor/None			

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

Approximately 90 l of Avgas and about 10 l of engine and hydraulic oil leaked into the lake.

1.5 Personnel information

Flight instructor:	Age 27
Licences:	JAR Commercial Pilot Licence, valid until 30 Sept 2010. Medical certificate: Class 1, valid until 13 Nov 2008. Medical certificate: Class 2, valid until 13 Nov 2012.
Ratings:	All required ratings were valid.
Training:	On 2 Oct 2003 the flight instructor graduated from Pilot Factory's ATPL course. He continued his education on the same flight school's flight instructor course, beginning as a trainee flight instructor on 7 Feb 2006. He completed Boeing 757 type-rating training in Nov-Dec 2006, at which time he quit working as a flight instructor at Patria Pilot Training. He completed instrument flight instructor training from 17 Sept - 31 Oct 2007, after which he worked as a part-time flight instructor in addition to his duties as an airline pilot.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours and landings
All types	4 h 58 min 2 landings	77 h 55 min 45 landings	99 h 53 min 81 landings	2,074 h 12 min 3,211 landings
Type in question	3 h 16 min 1 landing	43 h 41 min 35 landings	71 h 3 min 49 landings	168 h 16 min 144 landings

Co-pilot, Boeing 757	854 h
Flight instructor, multi-engine aircraft	13 h
Flight instructor, VFR operations	610 h
Flight instructor, IMC operations (SPIC)	167 h
Flight instructor, basic instrument training	7.5 h

Student pilot in front seat (B): Age 23

Licences: JAR Private Pilot Licence (PPL) issued on 4 Sept 2007, valid until 4 Sept 2012.

Medical certificate: Class 1, valid until 27 Oct 2008.

Medical certificate: Class 2, valid until 27 Oct 2012.

Ratings: All required ratings were valid.

Training: He had started training on the CPL course on 28 Nov 2006.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours and landings
All types	1 h 17 min 0 landings	17 h 13 min 14 landings	39 h 52 min 41 landings	128 h 00 min 263 landings
Type in question	1 h 17 min 0 landings	17 h 13 min 14 landings	30 h 26 min 30 landings	30 h 26 min 30 landings

Of his total flying experience, 42 h 38 min were instrument hours.

Student pilot in back seat (A): Age 31

Licences: JAR Private Pilot Licence (PPL) issued on 6 Sept 2007, valid until 6 Sept 2012.

Medical certificate: Class 1, valid until 9 Oct 2008.

Medical certificate: Class 2, valid until 9 Oct 2012.

Ratings: All required ratings were valid.

Training: He had started training on the ATPL course on 28 Nov 2006.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours and landings
All types	1 h 59 min 1 landing	17 h 13 min 14 landings	38 h 32 min 77 landings	124 h 39 min 240 landings
Type in question	1 h 59 min 1 landing	17 h 13 min 14 landings	31 h 51 min 25 landings	31 h 51 min 25 landings

Of his total flying experience, 41 h 38 min were instrument hours.

1.6 Aircraft information

Figure 1. OH-PDY in the summer of 2007. Photo: Marko Koponen

1.6.1 Basic aircraft information

The aircraft was a single-engine, all-metal, low-wing, four-seat aircraft equipped with retractable landing gear.

Aircraft:

Type:	Piper PA-28R-200 Arrow II
Registration:	OH-PDY; previously entered as PA-2 in the Military Aircraft Register
Owner:	Malmi Air Oy
Operator:	Patria Pilot Training Ltd
Category:	Normal
Manufacturer:	Piper Aircraft Corporation, USA
Serial number and year:	28R-7435013, 1973
Airworthiness valid until:	31 May 2009
Maximum takeoff weight:	1,204 kg/2,650 lb
Total hours:	11,984 h

Engine:

Type:	Lycoming IO-360-C1C
Serial number:	L-23115-51A
Year of manufacture:	1980
Manufacturer:	Avco Lycoming, USA
Total running time:	2,867 h
Running time:	1,074 h after complete overhaul
Fuel:	Avgas 100LL

Propeller:

Type:	Hartzell HC-C2YK-1BF
Serial number:	CH 25208 ‘E’
Year of manufacture:	Not known
Manufacturer:	Hartzell Propeller Inc.
Total running time:	3,778 h
Running time:	292 h after complete overhaul.

1.6.2 Maintenance history

The aircraft had previously been used by the Finnish Air Force, registered as PA-2. It had been bought new and taken into use on 21 May 1974. The aircraft was removed from the military aircraft register in 2004, at which time it had been flown 11,693 hours.

The aircraft was sold to a private owner in 2004. Thereafter, an extensive structural and system inspection was completed as per a maintenance plan approved by CAA Finland. The work was done by a JAR-145 approved maintenance organisation. The aircraft was found to meet the requirements of the type certificate, whereafter it was inspected and issued a certificate of airworthiness on 9 May 2005 and, subsequently, entered into the civil aircraft register.

A maintenance organisation, which held a national permit, had conducted the annual inspection and 100 h scheduled maintenance at 11,820 total hours on 19 May 2008. The last date of the scheduled inspection was 20 May 2008. Two discrepancies were discovered in the inspection, for which ’A’ remarks (i.e. to be repaired before the next flight) were written. These were marked as completed prior to the next flight.

On 9 Aug 2008, an aircraft technician conducted the last maintenance (50 h) at Helsinki-Malmi Airport. Total hours at that time were 11,966. Related airworthiness directives and service bulletins were marked as completed. The maintenance for time limited components was, for the most part, marked as completed.

Instruments, gyro units and engine accessories were maintained in accordance with the requirements of IFR operations. However, no entry on the radar transponder's Mode C test was found. The gyro unit, turn coordinator and the attitude indicator had been functionally tested at the JAR-145 repair shop on 30 April 2008. They were installed on the aircraft during its annual inspection on 19 May 2008. The maintenance test flight was flown on 19 May 2008, at which time there were no complaints.

The latest records of mass and balance and compensation of the magnetic compass were not entered into the airframe logbook. A valid aircraft weight and balance report was attached to the journey logbook. During the flying season several such complaints had been entered into section XI of the journey logbook, which lacked comments, mentions of corrective action completed or transfers to the Hold Item list. The detected and reported complaints (10) mainly concerned communication and electrical equipment. While the aircraft was fit to fly, its airworthiness, according to aviation regulations, would have required entries of corrective action or a mention of the detected complaints being transferred to the Hold Item list, as well as comments on their effects on flight operations.

1.6.3 Weight and balance information

No Operational Flight Plan, including weight and balance calculations, for this flight was ever found. According to the last weight and balance report, the basic weight of the aircraft was 783.50 kg. Takeoff weight was calculated at 1121.50 kg. The combined weight of the flight instructor and the student pilot on the front seat was 155 kg; the passenger weighed 70 kg; the estimated weight of baggage was 15 kg; and fuel weighed 98 kg. The aircraft's maximum weight was 1204 kg. The aircraft's centre of gravity was in the middle of the permissible range. The weight of the aircraft at the time of the accident was 1090 kg. This was calculated by deducting 31.50 kg, i.e. the weight of the fuel that was used during the flight prior to the accident. The aircraft was correctly loaded at the time of the accident.

1.7 Meteorological information

The Finnish Meteorological Institute created an estimate of meteorological conditions at Taipalsaari at the time of the accident.

Lappeenranta METAR at 13:20 (seven minutes after the accident): Wind 230°/15 kt, visibility over 10 km, clouds 1/8 stratocumulus at 3900 ft and 6/8 stratocumulus at 5500 ft, temperature 20°C, QNH 1011 hPa.

TAF 12:00-21:00: Wind 220°/15 kt, visibility over 10 km, broken clouds at 3000 ft, temporary changes expected from 12:00-15:00: scattered clouds and cumulonimbus at 3000 ft.

That day there were many cumulus, cumulonimbus and towering cumulus clouds in the area. The first cloud layer was scattered cloud at 2000-3000 ft and a second layer of broken cloud was at 3000-6000 ft. Weather at the site of the accident was probably dry. Weak local showers were occurring in the northern areas of Lake Saimaa.

Surface temperature was approximately 18°C, zero level being between 8000-10000 ft. Weak or moderate icing was possible in cloud above the zero level. Turbulence was either nonexistent or weak. Visibility was over 10 km.

From the perspective of aviation, no significant weather phenomena occurred, nor did the meteorological conditions have any effect on the accident.

1.8 Aids to navigation and radars

The aircraft was equipped with a fixed GPS. The aircraft’s transponder worked normally. Both military and civilian radars tracked the progress of the flight.

1.9 Communications

The aircraft’s VHF radiocommunications worked normally. In addition, Lappeenranta ATC’s radiocommunications, telephones and recording systems worked normally.

1.10 Aerodrome information

The flight departed from Kuopio with the intention of landing at Lappeenranta. Lappeenranta ATC provides procedural control-based air traffic service in the control zone (CTR) and the terminal area (TMA).

1.11 Flight recorders

The aircraft had no flight recorders. The fixed GPS device did not have a track logging feature.

1.12 Wreckage and impact information

1.12.1 On-site wreckage distribution

The crash site is on the Ilkonselkä open lake area of Lake Saimaa, near Peräluoto Island.

Judging by eyewitness accounts and the structural damage, the aircraft collided with the water at a high airspeed and at a steep angle, with the engine still running. After the airframe had crashed into the lake, aircraft parts fell from the cloud.

The aircraft was completely destroyed upon impact. No debris distribution diagram was drawn. Rather, wreckage distribution was recorded on video. Smashed wreckage lay on the bottom of the lake, albeit in one piece for the most part. Scores of smaller aircraft parts that separated at impact as well as paper documents were scattered around the fuselage.

The largest solid pieces that were found were the propeller, engine cradle, firewall and the instrument panel, which was embedded into it, remains of both inboard wing sections, the fin and rudder, the left stabilator as well as an aircraft skin panel that was torn loose at the bottom of the rear fuselage.

The water depth at the site is approximately 5.5 metres. Engine and hydraulic oil as well as fuel were spread around the accident area. Furthermore, loose items from the aircraft as well as some of the occupants' personal belongings were floating at the site. Two of the deceased were found on the surface and the third one under the wreckage. The body was brought to the surface before the wreckage was recovered. The rescue department cordoned off the area with oil containment booms.

The recovery of the wreckage was planned on the basis of the divers' videos. The remains of the wreckage were lifted onto a pallet, mainly in one go, for preliminary investigation and transportation. The divers then collected the small parts and other loose material. The biggest missing parts were the outboard sections of both wings, including the ailerons, as well as the right stabilator and its trim tab. Detailed investigation of the wreckage was done at Helsinki-Vantaa Airport.

Figure 2. Recovering the wreckage at the accident site

1.12.2 Wreckage investigation

Fuselage and cockpit

The fuselage and the cockpit were destroyed beyond all recognition. The broken seats were strewn about, having torn loose from their mounting brackets. The front seat belts as well as the right rear seat belt had stretched and the belt buckles were broken by the force of the impact. All of the seat belts were still connected to their mounting brackets. It was impossible to make any reliable observations on the engine controls and switch positions.

All of the instruments were broken. A laboratory inspection of them was deemed unnecessary because they would not have shown the values of the moment when the wings broke off. The gyro vacuum pump was disassembled and inspected. Both the pump and its drive axle were intact. The attitude indicator was not inspected because it was broken. It had been functionally tested in April 2008 at which time it operated normally.

Wings

The inboard wing sections were still connected to what was left of the fuselage. Both wing spars had broken off at approximately 215 cm from the side of the fuselage. The parts that were still connected to the spars included the remains of the fuel tanks, the main landing gear, parts of the trailing edge flaps and small pieces of skin panel. The rest of the wings (approximately 225 cm in length) were missing.

Tail surfaces

The rudder and the vertical stabiliser were intact as was the left stabilator. The right stabilator and its trim flap were missing. The Piper Arrow has a combined elevator/stabilator, a so-called full-flying tail.

Flight controls

All flight controls were badly damaged due to the in-flight structural failure and the collision with the water. The right and left side rudder pedals were broken. The rudder control cables were intact and still attached to the pedal assembly and linkage bellcrank.

The stabilator control cables were attached to the bottom of the control column and to the brackets on the stabilator balance arm. One of the brackets had torn loose. One cable had broken because of high tension. The balance, including the balance arm, was torn off the stabilator spar. The left side of the stabilator was still attached to its hinge supports and moved freely.

The stabilator trim cables were broken. The stabilator screw actuator at the tail was intact and the trim control arm was attached to the trim tab. Judging by the number of wraps visible on the trim screw, the aircraft was trimmed nose heavy (corresponding to a cruise descent).

Both handles on the left control wheel and the right handle of the right control wheel were broken. The handles had been bent forward before they broke. Both universal joints on the control wheel tubes were broken. Aileron control cables were still attached to roller chain turnbuckles and bellcranks. Airframe structures had sheared the aileron balance cable. Both of the aileron control rodends were broken from the aileron side. The aileron bellcrank housings were not connected to the wing structure. The left aileron bellcrank housing had spun around in the air stream, thereby twisting the control cables.

The flap lever was in the down position but the lever lock teeth were broken. The flap control cable was attached to the lever and to the torque tube chain. Although the flap control rods were broken, their ball ends were still attached to the flap bracket attachments and torque tube cranks. The inboard flap parts were attached to the bracket/rod attachments and wing structures. Wing flap tip sections were found crushed near the wreckage.

Electrical system

The battery and battery box came loose and the battery was split. When the fuselage disintegrated, the mid-airframe wiring was damaged. Switches and equipment on the instrument panel were partly loose and crushed.

Hydraulic system

The aircraft's power pack came loose and broke off at impact. Similarly, hydraulic lines and hydraulic assemblies were crushed.

Figure 3. Wreckage found at the site of impact

Powerplant

When the aircraft collided with the water the oil sump, induction manifolds and exhaust pipes broke. Baffle plates were partly loosened. The bottom spark plugs were broken and the ignition wires were either cut or loosened. The starter ring gear was broken and the starter was missing. The alternator was hanging loose on its wiring and there was an impact mark on its side. The crankshaft seized up when the propeller was spun. Equipment in the accessory section was in place and looked intact. It was not considered necessary to disassemble the engine.

The tubular muffler pipes were deformed and flattened in the crash. There were cracks on the mufflers which showed that they had been welded some time in the past. The length of one weld was approximately 10 cm; it was almost completely torn. Fracture surface analysis showed that the repaired area had been ground down to such an extent that the weld seam had become thin. Judging by the fracture surface the weld was probably tight. Other weld repairs had been done outside the heater shroud. No discoloration caused by an exhaust leak was found on the inner surface of the heat exchanger.

Propeller

The propeller was attached to the crankshaft flange. One blade was bent backwards and there was a deep dent in the middle of its leading edge. The blade had struck the alternator. The other blade was slightly bent backwards. The linkage inside the hub was broken. The spinner and its back plate were crushed. It was not considered necessary to disassemble the propeller.

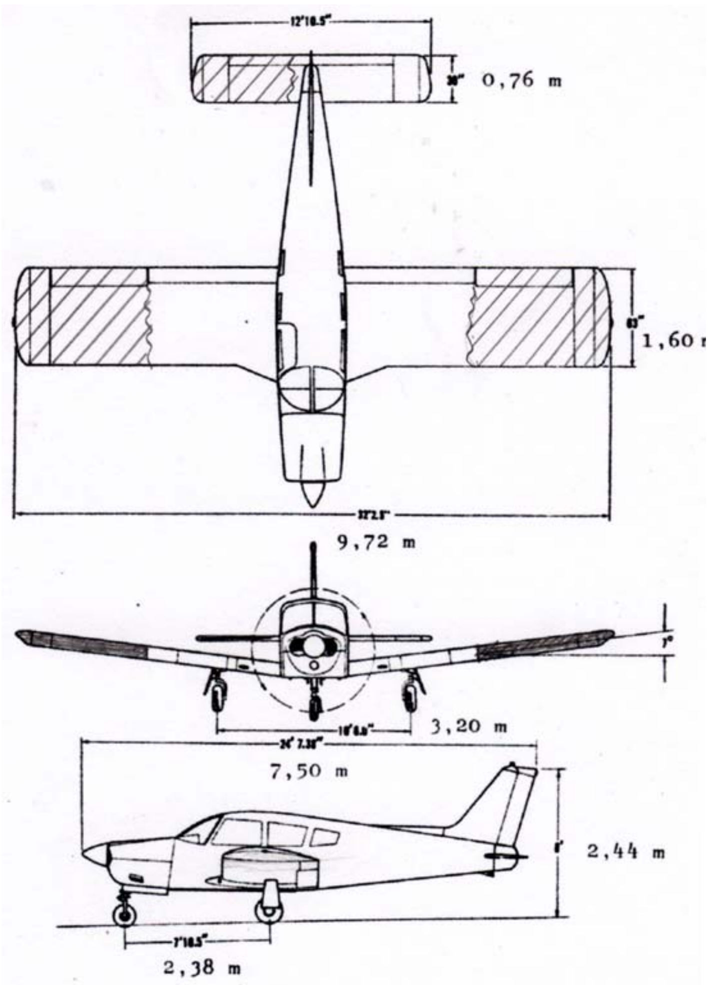

Figure 4. Stripes denote sections of structure that separated in flight

Parts discovered in searches

An approximately 0.5 m^2 sized piece of skin panel from the lower surface of the left wing as well as the right aileron were found in the searches. The skin panel piece had torn off at the location where the wing broke off. The piece was badly dented and it had numerous cracks.

The aileron was slightly bent along its length. Its outboard piano hinge and outermost rib as well as the balance attached to the rib were missing. The inboard hinge was attached and had come off the wing when the rivets broke.

Figure 5. Parts that fell off the aircraft in flight and were discovered in searches.

1.13 Medical and toxicological information

Forensic autopsies, including microscopic and forensic chemical determinations, were performed on all of the casualties at the Central Hospital of Etelä-Karjala.

Blunt head and thoracic trauma were the primary and immediate causes of death for all of the casualties. Toxicological investigation did not discover any signs of alcohol, medications or drugs. The front seat occupants' blood tests showed 1% carbon monoxide. As per the forensic autopsy report: "this blood content is considered to be low and it has no effect on a person's performance. The raise in carboxyhemoglobin caused by one cigarette is higher than the blood concentration now discovered."

1.14 Fire

There was no fire.

1.15 Rescue operations and survival aspects

1.15.1 Rescue operations

The ERC of South-East Finland received its first emergency call at 13:17 from an eyewitness on Lake Saimaa. The eyewitness reported having seen a small aircraft crash into the water north of Päiviönsaari Island in the Taipalsaari municipality. Soon after the first phone call another eyewitness called the ERC of South-East Finland from Suur-Riehkiö Island. He reported having seen loose parts falling from the sky after the crash. The ERC operator who answered the first call selected *medium-large air accident* as the accident type. At 13:21 the operator called units from the Etelä-Karjala Rescue Department's Taipalsaari fire brigade and Lappeenranta rescue station as well as three ambulances to the site. The on-call chief fire officer (LP3) of Lappeenranta was the incident commander.

Immediately after answering the first emergency call the ERC operator alerted Area Control Centre, South Finland (EFES) at 13:22. The operator inadvertently gave EFES the wrong area code for the ERC of South-East Finland. At 13:23 the first eyewitness called the ERC again, reporting that remains of an aircraft and one deceased person were floating at the site of the crash.

A third eyewitness called Lappeenranta ATC at 13:25 and inquired whether an aircraft was missing. He said that he had been north of reporting point SAIMA (one of the reporting points in the Lappeenranta CTR). At first he had heard varying sounds of an aircraft engine followed by a bang and then silence. In the course of this call EFES also called Lappeenranta ATC, reporting the air accident on Lake Saimaa. Lappeenranta ATC called the aircraft by radio but did not receive an answer. The last contact between the aircraft and Lappeenranta ATC occurred at approximately 13:09.

A Border Guard helicopter, flying in Northern Karelia and monitoring the authorities' VIRVE telecommunications network, overheard the discussion regarding the air accident's rescue operation. At 13:34 the helicopter offered executive assistance to the operation. Within about an hour it arrived at the scene and photographed the accident site from the air.

EFES repeatedly tried to call the ERC of South-East Finland. However, due to the previously given erroneous area code, they did not get trough. Finally, EFES asked the ERC of Pirkanmaa to relay them to the ERC of South-East Finland. The switchboard of the ERC of South-East Finland was busy and, consequently, the ERC of Pirkanmaa was put on hold for 4:32 minutes.

At 13:43 the first eyewitness called the ERC for the third time and reported that a boat from a nearby camping site was in the process of recovering two bodies that were floating in the water. Moreover, he provided more detailed information of the location. The campsite boat as well as other civilian boats which arrived at the scene picked up items floating on the surface. They were later handed over to Lappeenranta Police.

Almost all units that were called out to the site arrived at the same boat launching ramp at the end of Virransalmentie road. The first ones to arrive were the three ambulances from Lappeenranta, followed by the Taipalsaari contract fire brigade unit with their boat. Rescue personnel and another boat arrived from the Lappeenranta rescue station. The first ones to arrive at the accident site, at 13:54, were fire-fighters from the Taipalsaari fire brigade and ambulance drivers. The on-call chief fire officer (LP3) set up a command post at the boat launching ramp while the station manager (LP4), together with divers, proceeded to the target. Some Taipalsaari fire-fighters went to Mäntysaari Island, north of the accident site, to fetch a larger boat. They arrived at the scene a little later.

While on his way to the site, LP4 was initially informed by Lappeenranta ATC that there were two people on board. At 13:54 EFES called LP3 and reported, among other things, that the flight plan listed three persons on board the aircraft. Since the site of the crash had already been found, LP3 assumed incident command during the phone call. The divers that arrived on the second boat found the wreckage at the depth of 5.5 m and recovered the third casualty from under the wreckage. After he was lifted to the surface, LP4 informed LP3 that there was no longer any need for rescue operations. LP3 contacted the police field commander and it was decided that the police would assume the command and responsibility for communications at 14:17. CSI agents began to investigate the site at 15:20.

1.15.2 Survival aspects

Judging by the technical investigation of the wreckage and forensic determinations the pilots' seat belts were fastened. Aircraft structures were completely destroyed when the aircraft collided with the water at a high airspeed. It is estimated that the airspeed at which the aircraft collided with the water was approximately 240 kt (445 km/h). Calculations also found that the rate of acceleration, determined by any realistic stopping distance values, reached at least 1,000 g.

The persons on board the aircraft were killed instantly.

1.16 Tests and research

1.16.1 Wing spar and stabilator fracture surface analyses

The samples taken from the wing spars still attached to the fuselage and the balance weight arm which had torn off from the stabilator spar were examined at the Technical Research Centre of Finland (VTT). The Centre was requested to examine the fracture mechanisms, particularly any signs of material fatigue and the directions of forces that caused the fracture.

The samples were visually inspected and their fracture surfaces were inspected with a stereo microscope. Several samples were taken from the fracture surfaces of all of the pieces, which were subsequently analysed by a scanning electron microscope.

The sample from the right wing was mainly bent forwards. In addition to the forward bend, minor deformations had occurred in the wing spar. Some of them were so local that they were probably caused by the collision with the water. Apart from said deformations, the machined wing spar was intact. A crack had occurred next to the end of the aluminium spar along the approximately 1.3 mm thick sheet aluminium alloy spar. Next to the crack, the thickness of the inboard spar root plate is approximately 2.6 mm. In the middle of the fractured root plate there was a secondary crack that ran through a rivet hole, pointing upwards at an oblique angle. The area above this crack was bent backwards. The length of the section where the inboard spar is riveted to the outboard spar is 205 mm.

Signs of some upward deflection were present on the upper and lower edges of the left wing spar. In addition, the lower edge was bent forwards. The area between the machined spar's holes had buckled in a manner which points to shear stress caused by an upwards bend. The fracture had occurred on the machined spar as well as the 1.3 mm thick sheet aluminium alloy spar. The edges of cracks that were on the machined spar were bent upwards and contained secondary fractures.

The right side of the stabilator was torn off. The U-shaped rear spar was bent backwards for approximately 15 cm and the forward box spar's fracture surface edges were bent forwards. The cracked plate was deflected upwards and contained secondary fractures.

As a result of the impact with water, the stabilator balance arm was torn off of the stabilator's box structure. A stabilator cable attach fitting on the balance arm was cracked; the fracture roughly followed the weld seam.

No signs of metal fatigue or material defects were found when fracture surfaces were examined visually or by stereo microscope. Neither did the fracture surfaces display any signs of altering or inconsistent fracture mechanisms. Most of the fracture surfaces, especially those on the thinnest components, were at a 45º angle from the surface of the plate. This is typical of a shear fracture. Some fracture surfaces showed marks caused by post-fracture blows or abrasion. An example of such post-fracture damage is the fracture surface on the bottom of the inboard left spar root.

In order to select material for fracture surface analysis with the scanning electron microscope, five samples were taken of fracture surfaces from the right wing spar, six samples from the left wing spar and four samples from the stabilator's fracture surfaces. In addition, one sample was taken from the stabilator balance arm's cracked aft flange, another piece that contained a fracture surface that spanned three rivets on the arm's forward flange as well as a piece that contained the control cable's cracked attach fitting. Selection criteria aimed at samples which would most likely contain fatigue cracking areas, such as fracture surfaces limited to the outer edges of wing spars as well as the edges of spar holes. Samples analysed with the scanning electron microscope only included fracture surfaces that were typical of a ductile fracture. No signs of other fracture mechanisms, manufacturing flaws or material defects were found. The rivets' fracture surfaces appeared typical of ductile fracture. Rivet material shear rotation roughly corresponded to the angle at which the flange rotated to the right in relation to the box spar.

Such shear rotation occurs in a situation in which an aircraft collides with water when banked to the right.

Figure 6. Parts inspected by VTT. Top: part of the stabilator. Middle: part of the left wing spar. Bottom: part of the right wing spar (all of the parts' fracture surfaces were at the left end).

1.16.2 Radar information analysis

Determination of the flight path

Radars recorded the flight and its final phases. Since there were no flight recorders in the aircraft, the flight path and, especially, its final phases were recreated by recorded radar information. The aircraft was performing upset recovery at the time when its wings disintegrated. A more detailed analysis of the flight path is in chapter 2.2.

The last confirmed radar return from the aircraft came approximately 10 seconds before the aircraft collided with the water. Radar experts helped analyse the radar information and this information was used to create an airspeeds/altitude diagram for the final two minutes of the flight. The time interval focused on was 13:12:00 – 13:14:00. After this point in time, radar returns came from the then separated aircraft parts in the accident area. Ground speeds were calculated on the basis of radar plots.

The investigation commission recreated the flight on a Beechcraft Bonanza flight training device. The recreated flight could establish the initial adverse condition the flight instructor had flown on the progress check flight 4 in July, the use of flight controls and the acceleration of airspeed. The flight parameters of the initial adverse condition were obtained by interviewing a student pilot who had earlier been on the same flight. A more detailed description of the flight, including events, is in chapter 1.18.2. As the Beechcraft Bonanza is slightly heavier than the Piper Arrow, this was taken into account in the evaluation of the simulation.

1.16.3 Structural failure of the aircraft

Initial flight parameters at the end phase of the accident flight

The initial aerodynamic reference values were taken from the following sources: the Piper Cherokee Arrow Pilot´s Operating Manual; a copy of the Finnish Air Force's Piper Arrow Flight Manual, 15 Feb 1974, p. 4; *Airplane Aerodynamics and Flight Mechanics,* pp. 181–182, by Seppo Laine, Jaakko Hoffren and Kari Renko.

Wing geometry: rectangular planform wing; span 9.72 m; chord 1.60 m; area 170 sq ft (15.79 m^2).

Drag polar in clean configuration: zero-lift drag coefficient C_{do}=0.0254. The zero-lift drag coefficient was calculated by using the information in Seppo Laine, *et al*. The drag coefficient which is dependent on lift, i.e. the induced drag coefficient K, was evaluated by using the aspect ratio A=5.98 and the Oswald efficiency factor e=0.85. Hence, the induced drag coefficient K=0.0626.

Thus the drag polar is $C_D = C_{do} + K{*}C_L^2 = 0.0254 + 0.0626{*}\ C_L^2$.

Unless otherwise specified, true airspeed was used in the calculations.

The meteorological information at mean sea level deviated so little from standard atmosphere values that the calculation used ISO Standard Atmosphere values for densities. The wind data used was 22 kt at 260 degrees.

Maximum engine power at mean sea level is 200 hp. The propeller's propulsive efficiency used was 0.85. The calculated maximum speed in steady level flight at 5000 ft at full power was 149 kt.

Wing ultimate load as per static fatigue testing

The most important physical quantities from the standpoint of structural disintegration are time, airspeed and change in altitude during the final seconds. Using the aforementioned quantities it is possible to calculate the manoeuvring load factors for the aircraft structures. The investigation commission did not conduct a wing break test. Rather, calculations were based on the aircraft manufacturer's wing strength data. The factors that would come into play as regards the wings breaking off were mathematically evaluated by using airspeed values obtained in flight path determination. The investigation also used information from investigations conducted on similar incidents involving wings breaking off of aircraft in the United Kingdom in 2000 and in the United States in 2007.

In the aircraft manufacturer's wing static strength test, the wing broke at 163.7% from the design limit load. According to this information the corresponding brake-off load factor n_{break} on the accident flight was 6.86 g. Stall speed at the altitude of 5000 ft at load factor 6.86 g was 155 kt.

The formulae used in obtaining the aforementioned results are stored at AIB Finland as reference material to this investigation report.

1.16.4 Freedom of movement of the control column

If an aircraft's control column (wheel type) moves slightly upwards when it is pulled all the way back, there is a risk of its becoming jammed if the control input force is not parallel with the control wheel tube. This happens when the control wheel's tube gets stuck on the spacer stop in the instrument panel. When the control column is lowered, the wheel is freed. The phenomenon resembles the situation when one attempts to close a desk drawer that is skewed.

The Civil Aviation Authority published the information letter TM 15/69, 17 July 1969 on the risk of jamming and then re-published it as the advisory circular OPS T1-10 on 25 June 1979.

Another factor limiting the movement of a wheel type column is when the control wheel tube's universal joint bolts get hooked onto the electrical wires behind the instrument panel. In such cases jamming was caused by the combined effect of bolts that were too long and a poorly tied electrical harness.

Since the instrument panel and the control columns were badly damaged it was impossible to inspect the functioning of the control columns. The electrical wiring harness behind the instrument panel was also deformed by the impact, making it impossible to reliably determine its condition before the accident.

The investigation commission inspected the functioning and condition of another Piper PA 28R-200 aircraft, OH-PKN, which had been used by the Finnish Air Force. It had logged almost as many flight hours as the accident aircraft. The inspection revealed that when the control wheel was pulled all the way back the distance from the back surface of the column to the instrument panel spacer stop was 25.5 cm. When the column was pushed all the way forward, the distance was 6.5 cm. Approximately 1.52 cm before the wheel was pulled all the way back, it rose discernibly. At this point, if the wheel was pushed in such a manner that the force was not parallel with the control wheel tube, jamming could be felt. This phenomenon disappeared immediately when the direction of the control input force was changed so as to make it parallel with the control wheel tube.

The aircraft that was inspected had a properly tied electrical wiring harness behind the instrument panel. Furthermore, since the flexible joint bolts did not protrude too much past the nuts, there was no risk of the control wheel jamming in the aircraft in question. The accident aircraft's flexible joint bolts were also correct in size.

1.17 Organisational and management information

1.17.1 General

The company started flight training operations as Pilot Factory Oy in 1989. In 2003 there was a change in the company's ownership. Patria Oyj bought its first 50% of the company in 2003, followed by the remaining 50% in 2004. It was placed into the Patria Aviation Business Unit and renamed Patria Pilot Training Ltd. Helsinki-Malmi Airport has been the main flight operations location during its existence. The principal owners of Patria Oyj are the State of Finland and the multinational European Aeronautic Defence and Space Company EADS. Patria Oyj is also a strategic business partner of the Finnish Defence Forces.

Patria Pilot Training Ltd has a flight training organisation certificate, FIN/FTO/2003. At first, the flight school leased its aircraft, but in 2008 it bought the fleet. The fleet (eight AS202 Bravo and one PA-34 Seneca) comprised the basic resources for flight training. The PA-28 Arrow aircraft are primarily reserved for instrument training. The company's regular personnel provided basic flight training. However, the company relied, for the most part, on part-time instructors for advanced flight training.

In addition to the flight school's own fleet, the FTO certificate's aircraft register included nine single-engine aircraft and one seaplane as well as three twin-engine aircraft. The register also listed other aircraft used in type-rating training. The certificate listed seven approved flight training devices, one of which was reserved for type-rating training. There were six approved flight simulators for type-rating training. In addition, Tallinn, Estonia, was certified for theoretical instruction and Sofia, Bulgaria, was certified for flight training.

The company's flight training syllabi covered the range from Private Pilot Licence (PPL) to Airline Transport Pilot Licence (ATPL). Moreover, the company's courses covered flight instructor training for the aforementioned licences. The company had type-rating courses for the DHC6 Twin Otter and Saab SF340 as well as theoretical and synthetic flight instruction courses for Boeing B757 and MD80 aircraft.

1.17.2 Flight training organisation

The company's Managing Director did not partake in the company's daily operations, nor was he listed in the company's manuals. The company had a separate Accountable Manager whose task it was to demonstrate to the aviation authority that sufficient funds were in place for the purpose of providing training in accordance with approved standards. In practice, the Accountable Manager had to wield the powers of the Managing Director. In addition to the Accountable Manager, the volume of operations required that the organisation had the following CAA Finland-certified postholders: Head of Training, Chief Flying Instructor, Chief Ground Instructor and Quality Manager. In addition, there were three other chief flying instructors who were responsible for type rating training for the MD80, B757 and SF340 aircraft as well as two chief ground instructors (in Tallinn, Estonia and Kauhava, Finland). Additionally, the company had a Maintenance Manager and a Chief Simulator Instructor.

While the organisation chart in the company's Operations Manual (OM) was otherwise correct, the postholders' names were not up-to-date.

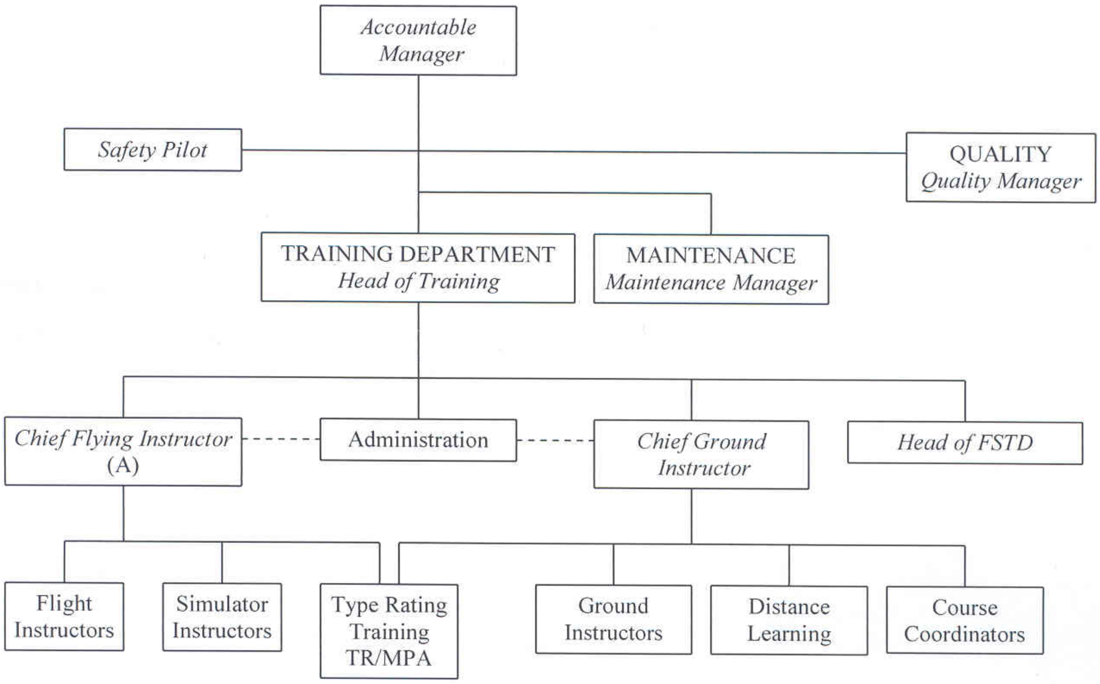

Figure 7. Patria Pilot Training organisation

The company's Accountable Manager changed in the beginning of 2008. The Chief Flying Instructor changed in February 2008. The next postholder change occurred in July 2008 when the Quality Manager and two new Chief Ground Instructors began their duties. The Maintenance Manager was appointed in February 2008 and the head of Patria Aviation's training department was changed in March 2008.

In 2008, the company was running seven separate ATPL courses, all in different stages of progress, as well as one PPL course commissioned by an outside source. In all, there were approximately 100 students on these courses. Seven regular flight instructors and 37 part-time flight instructors were available for flight training. The regular personnel were responsible for approximately half of the theoretical knowledge training. The ATPL syllabus comprised 917 lessons. One lesson lasted 50 minutes. The minimum number of flying hours was 195.

1.17.3 Airline Transport Licence Course syllabus

The commercial pilot training course at Patria Pilot Training Ltd was an integrated ATPL course training system. Student pilots would first complete a Private Pilot Licence (PPL), followed by a Commercial Pilot Licence (CPL), Instrument Rating (IR) and Multi-engine rating (ME). Theoretical knowledge training for an ATPL licence was an integrated continuum. On completion of the course, pilots are issued a Commercial Pilot Licence, including ratings.

Instrument flight training is organised so that, after obtaining the PPL licence, student pilots fly approximately 27 hours with a flight training device simulating the twin-engine Piper Seneca. Additionally, the student pilot was to log 42.5 hours as Student pilot-in-command (SPIC) on a single-engine aircraft. The function of the flight instructor on SPIC flights is to evaluate and monitor the student pilot's independent action. The flight instructor is nonetheless the pilot-in-command.

The definitions of the flight school as well as those of the JAR Requirements regarding flight time as the student pilot-in-command and the duties of the flight instructor on such flights are as follows:

> *It is flight time during which the flight instructor shall only observe the student acting as pilot-in-command and shall not influence or control the flight of the aircraft* (Patria Training Manual).
>
> *The flight instructor shall act as a safety pilot monitoring the airspace and shall not control the flight of the aircraft, unless necessary for flight safety concerns* (Patria Operations Manual).
>
> *SPIC time shall be credited as pilot-in-command time, unless the flight instructor had to influence or control any part of the flight. A ground de-briefing by the flight instructor does not affect the crediting as pilot-in-command time* (JAR-FCL 1).

Apart from basic instrument training, on the integrated ATPL course the student pilot will fly all instrument flights as student pilot-in-command so as to accrue the necessary minimum hours as pilot-in-command. If the flight instructor has to influence or control the flight, the flight must be logged as a dual instruction flight and the SPIC flight must be re-flown.

The company has adopted an operating model that allows student pilots to establish pairs after the PPL phase. These pairs have flown SPIC flights together. In this way it has been possible to accelerate their progress on the course. It is easier for a pair to agree on the flight schedule with the flight instructor. While the first student acts as student pilot-in-command, the other, as per the company's OM, is a *passenger and observer of the training flight*. This definition is inconsistent. No person can simultaneously act as a passenger and observer in an aircraft. Pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008, *Emergency abnormal situations must not be simulated when passengers or cargo are being carried*.

At the end of the single-engine instrument training phase the student pilot flies a progress check flight 4 (VTL4) prior to commencing multi-engine flight training. The VTL4 is the training organisation's internal check flight and it is flown in accordance with a distinct check flight list. Flight instructors do not have training instructions for the progress check flights. Rather, only the titles of the items to be checked are listed on the check flight's evaluation form. Upset recovery, during which this accident occurred, is one such title. Patria's training and operations manuals do not describe the initial adverse condition (airspeed, attitude and power setting). Flight instructors that fly progress check flights do not have any specific proficiency requirements.

1.17.4 Aircraft maintenance

National regulations were followed in aircraft maintenance. The overarching policy in the company's maintenance activities was that aircraft maintenance was to be carried out in a PART145 organisation that was designated by the flight school. User agreements were signed on aircraft. Subsequently, as per the OM, Patria Pilot Training Ltd was responsible for aircraft maintenance, airworthiness and operations. However, the user agreement obligated the owner to remain responsible for aircraft maintenance arrangements, in derogation of the arrangement described in the user agreement. In practice, a maintenance certifying technician would carry out the maintenance within his privileges.

1.17.5 Quality System

The company's Quality System Manual (QSM) was approved by CAA Finland. Its latest revision was dated April 2006. The QSM described the normal Quality System used in aviation in which the Quality Manager is responsible for the functioning of the Quality System. He had the right to designate external auditors. The material delivered to the investigation commission did not contain a list of auditors or their audit scopes, as required by JAR-FCL. The QSM included the necessary forms as well as the annual plan. Findings made by the company's quality management organisation were recorded as occurrences, divided into three categories: *major*, *minor* or *comment*. Postholders were required to carry out quality audits in their respective fields. According to the QSM, Management Evaluations which are intended to assess the functioning and results of the Quality System are to be held once every six months. One Management Evaluation had been held before the accident. Additionally, the QSM mentions that the Quality Group should convene twice a year. The material delivered to the investigation commission did not contain any documents of such meetings. The company reported having organised one meeting on quality processes in the spring of 2008.

The internal audit document for 2006 stated that the 12 month timeline had not been observed as regards Quality Audits or Quality Inspections. Quality Audits were not documented in accordance with the QSM; nor had they been able to follow the Audit Plan for 2006. Seven out of seventeen areas were audited as late as the spring of 2007. Even after that, a significant number of quality inspections were missing.

The Audit Plan for 2007 was carried out within the schedule. Four of the belated seven audits from 2006 were recorded as 2007 audits.

The 2008 Audit Plan was implemented within schedule. According to the material delivered to the investigation commission, the first nonconformities from June's audit findings were recorded as late as September.

1.17.6 Management

Managing a flight school requires the kind of organisation defined in JAR-FCL 1. The Head of Training bears total responsibility for coordinating flight training, synthetic flight training and theoretical knowledge training as well as monitoring the progress of individual student pilots. The Chief Flying Instructor is responsible for supervising the work of flight instructors and simulator instructors as well as standardising all flight training and synthetic flight training.

The Operations Manual (OM) delineates the Maintenance Manager's tasks and duties. He is responsible for keeping flight operation postholders informed of maintenance arrangements as well as the maintenance and flight hour situation of the fleet.

According to the OM, company management should convene once a week. However, there is no obligation to keep minutes of these meetings. Relevant information is promulgated via Information Leaflets. As per the OM, instructors' proficiency is monitored and maintained by arranging instructor meetings at least once a week. Additionally, annual instructor seminars are arranged, in which procedures are standardised and analysed.

During the actual investigation the commission did not received any documentation on flight instructors' weekly meetings or annual flight instructor seminars. When the draft report was sent for comments, the company delivered the minutes of four instructor meetings from the summer of 2008. Four to seven flight instructors attended the instructor meetings, led by the Chief Flying Instructor,

Documents from the weekly meetings, arranged regularly in 2007, were delivered to the investigation commission. During the first quarter of 2008 there was a five week hiatus in the meetings. The company's 2007 Chief Flying Instructor did not attend these meetings during the summer of 2007; the rest of the time he attended them less regularly than the other postholders. Maintenance personnel did not attend the meetings at all.

According to the minutes of the weekly meetings in 2007 and 2008, topics ranged from instructor resources to course progress, the use and technical condition of the aircraft fleet as well as the introduction of PA-28 Arrow aircraft. While the shortage of instructors was noted, they had not come up with a plan to solve the problem. Entries related to the instructor shortage were repeatedly consistent. Although the delay in course completion was noted, meeting minutes do not clarify who was responsible for rectifying the matter. The meetings also monitored the development of the company's financial situation.

The Operations Manual details standardisation requirements and methods. These comprise instructor training, supervising the work of instructors, standardisation training for the Head of Training as well as study guides and information leaflets. With regard to the flight instructor on the accident flight, his only record of standardisation training was from April 2007. According to the company's comments, the check flight on the morning of the accident flight was standardisation training for the flight instructor, led by the Head of Training.

1.17.7 Training oversight audits conducted by CAA Finland

CAA Finland supervises licensed flight schools by conducting a number of training oversight audits which are considered appropriate. Findings are recorded as nonconformities to which the company in question must propose corrective action within the allotted time. When CAA Finland considers the corrective action to be sufficient, the nonconformity in question can be regarded as rectified. In conjunction with major nonconformities, CAA Finland can restrict or revoke the licence.

The oversight audit of March 2005 involved the management, instructor staff, management and supervision of activities, as well as the premises used in flight operations and the Quality System. The audit resulted in eight nonconformities upon which it can be noted that there were shortcomings within the management and the monitoring of quality arrangements. The shortcomings proved that the Quality Manager and the Accountable Manager were remiss in their duties concerning the supervision of activities.

In the audit of December 2005 the auditors analysed the entire Quality System. No nonconformities were apparently recorded. The material delivered to the investigation commission did not include the actual audit report.

In April 2006, the audit focused on the management and instructor staff, archives, instructions, training records, management and supervision of activities as well as training devices and the Quality System. Four training record nonconformities were written down. It can be noted that the Head of Training was incapable of monitoring or managing the implementation of courses. Nine Quality System nonconformities were recorded. The audit protocol contains the following general statement: *The Quality Manager/auditor should not be too closely involved in the operation of the training system, lest the objectivity of the audit be jeopardised.* Furthermore, it was noted that that internal audits did not detect clear and significant nonconformities such as the authorities were able to observe.

The material delivered to the investigation commission did not include documents on CAA Finland’s possible oversight audit in 2007. Rather, the company’s documents reveal that CAA Finland’s audit report of April 2007 was never sent to the company.

After the accident, the oversight audit of 2008 was carried out at two separate instances in October and November 2008. The audit focused on the management and instructor staff, training records, training record cross-checking, harmonisation of activities, management and supervision, certified aircraft, the Operations Manual, the Training Manual and the Quality System.

Two major nonconformities were recorded; they concerned aircraft insurance and the management of technical faults. Additionally, five findings on training were made; they were consolidated into two nonconformities (harmonisation of flight instructors’ activities and training records). Eight Quality System findings were recorded; they were consolidated into a single nonconformity as follows*: the Quality System has been slapdash and, often, ineffective. The aforementioned major nonconformities serve as proof of this*.

As regards the Quality System, the Quality Manager's full time duties elsewhere prevented continuous supervision at Helsinki-Malmi Airport, and the role of his deputy was not entirely independent. When it comes to auditing, the comments focused on the absence of audits in 2007 and on the fact that only the regular audits had been completed. Nonconformities were inadequately recorded and it was not possible to clearly verify their follow-up and monitoring. Moreover, nonconformities were not assessed with regard to their significance, nor was the timetable of their completion established. The final finding concerned Management Evaluation approvals, i.e. the fact that they had not been signed by the Accountable Manager.

1.17.8 The introduction of PART 66 licences in Finland

Pursuant to the, still in force, Commission Regulation (EC) published on 20 Nov 2003, the national authority began to issue PART 66 aircraft maintenance licences (AML) to maintenance personnel in accordance with its conversion provisions. As per CAA Finland's advisory circular, the licences and national privileges that were issued as per national Aviation Regulations will expire on 1 June 2011, at the latest.

When the proficiency of the technician that maintained the aircraft was being assessed, an extract of his licence was ordered from CAA Finland. At this point it became apparent that his national AML had been technically revoked. He was not aware of this and still possessed the licence. At the same time he had been issued a PART 66 B1/B2 licence with privileges concerning the B2 category. In conjunction with the conversion process, CAA Finland did not request the return of the previous AMLs or personally inform anyone of the fact that their licences had been revoked. CAA Finland did publish an advisory circular on the conversion process. A circular, however, does not carry the status of an Aviation Regulation.

The advisory circular ambiguously described the process of how previous national licences are technically revoked in the conversion process. The circular does not explain how the new PART 66 AML privileges affect release rights.

The investigation commission considers it plausible that several aircraft flying in Finland have maintenance certificates issued on the basis of incomplete licence privileges. Such aircraft are not airworthy.

1.17.9 Results of the investigation commission' survey among the students

During the course of the investigation the commission conducted a 38 point survey on the students of ATPL courses 20, 21 and 22. The casualties of this accident were students on ATPL course 22. The survey polled questions related to theoretical knowledge training and flight training, the functioning of the organisation as well as other training related issues. Forty-one questionnaires were sent to the students and the commission received 29 replies.

The investigation commission drew attention to some of the most discernible issues. Approximately 60% of the respondents felt that the level of preparation for flights varied significantly between different flight instructors. Approximately 65% of the respondents also thought that there were considerable differences in the content of their instruction. Approximately 65% of the respondents said that they had inadequately prepared for and flown flights because of there being a rush.

If the flight instructor has to influence any part of a SPIC flight, it then becomes a dual instruction flight. Nevertheless, over half of the respondents said that a flight instructor had controlled a part of a SPIC flight without it having been recorded as a dual instruction flight.

All of the respondents criticised delays in course completion. Whereas the company markets an approximately 18 month ATPL course, JAR-FCL gives 18 months as the minimum period for the course, extending up to 36 months. The students had overly optimistic impressions regarding the course schedule.

1.18 Other information

1.18.1 Unusual attitude and upset recovery training

Unusual attitude denotes an attitude at which the pilot loses control of the aircraft unless he carries out corrective action. The purpose of upset recovery training is to learn to identify an unusual attitude and recover the aircraft to level flight. Such exercises are done at various stages of flight training. The practice begins with the flight instructor flying the aircraft into an unusual attitude, for example by banking the aircraft or by raising or lowering the nose. Then, the flight instructor will release the flight controls and ask the student pilot to recover the aircraft to level flight. This is repeated on different power settings as well as in VMC and simulated IMC conditions. In simulated IMC conditions the student pilot's field of vision is restricted to the instrument panel.

According to the company's flight training system, student pilots practice upset recovery on SPIC flights with the aerobatically rated Bravo aircraft before their progress check flight 4 (VTL4). On VTL4 flights they fly upset recoveries on PA-28 Arrow aircraft for the first time.

1.18.2 The flight instructor's experience of Progress Check Flight 4 and the previous Progress Check Flight 4 in July

The Chief Flying Instructor flew the majority of the students' VTL4 flights. Due to holiday schedule arrangements, he assigned three flight instructors for these flights. One of them was the instructor on the accident flight. The material delivered to the investigation commission did not contain any mention of their familiarisation with VTL4 flights. The Chief Flying Instructor was under the impression that the instructor on the accident flight had previously flown numerous VTL4 flights. The company's Operations Manual listed the following proficiency requirements for flight instructors up until the student pilot's IR

(SEP) check flight: valid instrument rating, valid instrument instructor rating, company-provided orientation to flight instruction and refresher studies of instrument procedures. The flight instructor received his IRI rating in December 2007. Apart from the report of the check flight that was flown on the morning of the accident flight, the material delivered to the investigation commission did not contain any records of standardisation training during the time his IRI rating was valid.

The instructor on the accident flight had only flown two VTL4 flights, both on the Piper Arrow. Only one of these flights had included upset recovery training. Prior to that flight he did not brief upset recovery technique with the student pilot. At the end of the manoeuvres in the practice area the flight instructor suddenly placed the aircraft into a demanding, unusual attitude at cruise speed by applying full left rudder and by banking the aircraft 90 degrees to the left. According to the student pilot, this resulted in a rapid, steep dive with the airspeed pushing the ‘red limit’, i.e. the maximum permissible speed. The student pilot managed to recover the aircraft to level flight. During debriefing the flight instructor noted that airspeed had momentarily been extremely high. On this flight, too, there was another student in the rear seat. The student pilot was given the lowest passing grade on upset recovery. The check flight report mentions a considerable loss of altitude during recovery. Nevertheless, since the student pilot passed the check flight, the Head of Training did not take any action on this remark. Neither the flight instructor nor the student pilot filed a flight safety occurrence report.

1.18.3 Search for the parts that separated in flight

Approximately one minute after the fuselage crashed into the lake, some eyewitnesses saw aircraft parts falling from the cloud into Lake Saimaa. These parts were also visible on the radar. One eyewitness saw three large parts falling into the water approximately one kilometre from where he was at the time. Eyewitness observations generated one search area and the radar returns another one. The total area that was searched was approximately two square kilometres.

Radar returns made it possible to determine the area in which the aircraft disintegrated. Radars also displayed separated parts drifting with the prevailing wind, i.e. at approximately 260 degrees. The area where the eyewitness thought the parts fell called for a wind direction of approximately 310 degrees. The day after the accident a terrain search was conducted on close-by islands and rocks. No aircraft parts were discovered.

From 17 Aug - 3 Sept 2008 both water areas were searched by using side scan sonar. A GPS device was used for running systematic search patterns. The rocky bottom made it difficult to interpret the acoustic reflections. Points of interest were denoted by GPS coordinates on the search map. These targets were later checked by video on a remotely operated submersible vehicle (ROV) from 1 – 4 Sept 2008.

Since interpreting the reflections of the side scan sonar proved challenging, searches were started with a Pulse 12 metal detector on 18 Sept 2008. The detector was towed by a boat so that it was close to the lake’s bottom. All the same, because of ferrous rocks in the search area the device was not effective and its use was abandoned on 19 Sept 2008.

The search in Lake Saimaa was continued with a large ROV on 29 Sept 2008. The device had three video cameras as well as effective floodlights and sonar. The transect width was approximately 7 m. The boat the ROV was steered from had a map-based GPS positioning system. With the ROV operating in the front sector of the boat on its 30 m tether, it was impossible to form a seamless search pattern because the ROV itself did not have a positioning system. Searches found the aircraft's journey logbook and Jeppesen binder. Since the search areas had already been partly combed over several times the search with this apparatus was called off on 8 Oct 2008.

The Finnish Maritime Administration's Inland Waterways Production Unit started a search with two boats on 11 Nov 2008. One boat conducted a multibeam sounding over the entire search area in order to create a high-resolution depth model. Target locating was based on a synchronised interpretation of the depth model and side scan sonar data. Possible targets were marked with buoys which were then inspected by the ROV, steered from the other boat. During six days of searching, 68 targets were inspected. On 14 Nov 2008 two separated aircraft parts were discovered. The parts, an approximately 0.5 m^2 piece of skin panel from the lower surface of the left wing as well as the right aileron, were on the sonar scan line at approximately 1300 m and 1600 m, respectively, from the aircraft's debris line. Subfreezing temperatures and snowfall made any further searches impossible so the searches were ended on 19 Nov 2008.

When the Inland Waterways Production Unit of the Finnish Maritime Administration started the search, the resolution of the search apparatus was assessed by dropping an aircraft wing resembling the one being searched for as well as an aluminium sheet the size of the stabilator into the lake. The parts were barely discernible in the images.

1.18.4 Prior similar accidents

Several accidents have occurred in the United States where the PA-28 series rectangular wings have broken off in flight. The latest such occurrences happened 31 May 2006 in Utah, 26 Oct 2007 in New Jersey and 15 Nov 2007 in Texas. In the first two of these accidents the pilot apparently lost control of the aircraft as a result of spatial disorientation and the aircraft apparently overloaded during a recovery attempt.

In the last mentioned incident a flight instructor was flying manoeuvres in a PA-28R-200 Arrow at a high airspeed. He was flying aerobatics with two student pilots.

All of the separated parts in these three incidents were found during the investigations. The wings had broken off at the very same place as in this incident and the stabilator mounting had failed in flight before the plane crashed into the ground.

In an accident that happened on 3 Dec 2000 in the United Kingdom, the left wing of a PA-28-200 Arrow II aircraft broke off at the same place as in the accident now being investigated. Stabilator tips as well as the fin and rudder separated in flight after the wing broke off. According to the British Air Accident Investigation Branch (AAIB), the aircraft had first rapidly pitched upwards followed by a violent roll to the left, thereby becoming almost inverted. The left wing had probably snapped off during the pilot's corrective action. Even though the manoeuvring was probably done at a permissible airspeed (112 kt), the violent manoeuvre as well as the nearly simultaneous and sudden motion around the longitudinal and lateral axes overloaded the structure. According to calculations that were done during the investigation, the wing's tensile strength surpassed its design limit.

The abovementioned investigations found no pre-existing fatigue cracks or other technical faults in the aircraft. The fractures that resulted in structural failure were caused by overloading the aircraft.

1.19 Investigation methods

The stages of the flight were simulated by a 2D spreadsheet-based flight mechanics model and a 3D JSBSim flight dynamics model. The latter is used as the flight mechanics model in some flight simulators. A vehicle configuration file corresponding to the Piper Arrow was used as the program's script file for simulation purposes.

2 ANALYSIS

2.1 Fracture surface analysis

The fracture surface analysis conducted at the Technical Research Centre of Finland (VTT) found only ductile fractures. There were no signs of other fracture mechanisms, fatigue crack growth, pre-existing damage, material or manufacturing flaws. Judging by this, it is apparent that all fractures on the parts that were inspected were caused during the course of the accident when sudden structural loads caused stresses that exceeded the strength of the materials.

Wing failure

The wings broke off during a violent, sudden recovery. They broke off almost simultaneously because if one wing had broken off before the other asymmetric lift would have caused acceleration around the longitudinal axis. Inertial forces caused by instantaneous tangential acceleration would reduce the bending moment of the wing. An increasing rotational speed would decrease the angle of attack of the still attached wing and, consequently, its lift and bending moment. This is why the remaining wing would not break off. G-forces must have increased rapidly during the recovery so as to make it possible for both wings to brake off nearly simultaneously.

The fact that both wings fractured and ultimately broke off required a load which clearly exceeded the ultimate design load.

2.2 Analysis of the flight path

2.2.1 Validity and precision criteria of the initial parameters

Experts were only able to provide rough estimates on how precise the radar information was. This made it difficult to arrange the observations in order of reliability. When assessing the reliability of the observations, attention was focused on the manner by which unconnected measurements either corroborated or contradicted with observations made at the same point in time.

Radars measure the position and altitude of a target. Ground speed can be calculated on the basis of this information. The analysis used information from four radars. The altitude information of one primary radar and two secondary surveillance radars (SSR) was used in the analysis. The aircraft’s radar transponder provides altitude information to the SSR. These two, independent, measurements provided nearly identical data with regard to changes in the aircraft’s altitude. This being the case, altitude information can be regarded as reliable. The long interval between radar returns (4-10 s), range and altitude degrade the preciseness of the flight path’s determination. Therefore, possible deviations cannot be included in flight path simulation.

The damaged aircraft’s nose-dive was also observed by eyewitnesses.

2.2.2 The flight path before and after the aircraft's structural failure

The two final minutes of the aircraft's flight path were analysed in more detail. In the beginning of the observation period the aircraft was flying at 7000 ft. All radars painted a more or less uniform picture, within tolerances, of the aircraft's flight path and manoeuvring from 13:12:00 to 13:13:20. The aircraft was in a shallow descent, possibly manoeuvring.

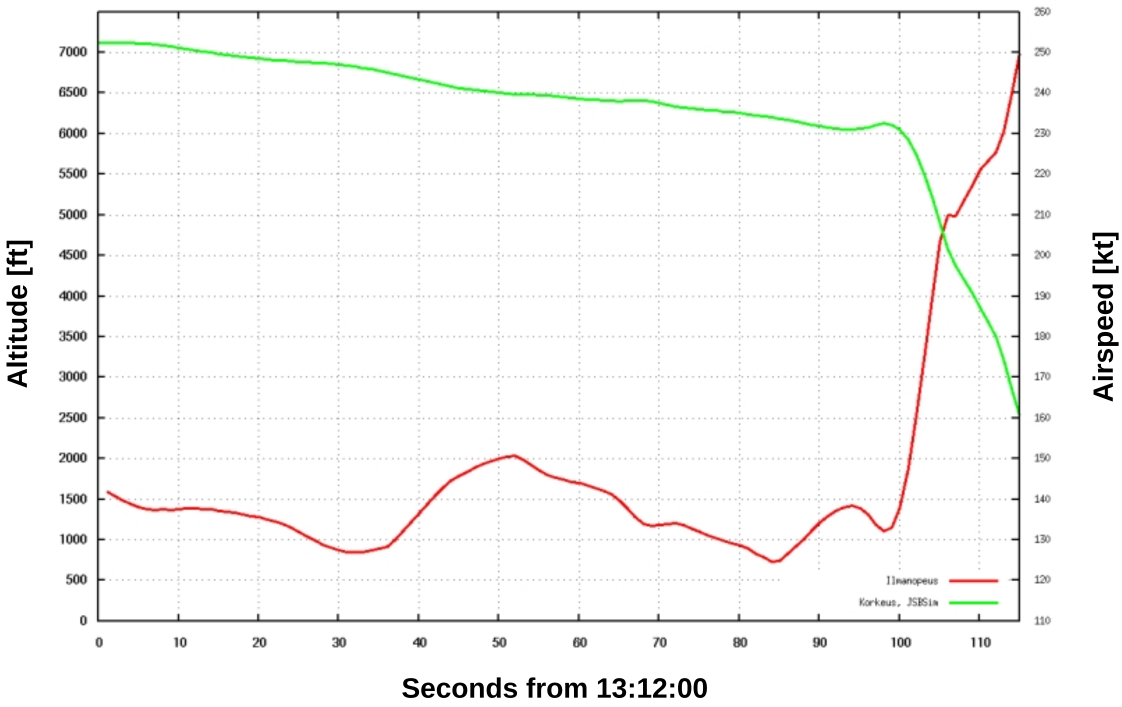

Figure 8. Change in airspeed and altitude as per radar returns.

After this interval the number and reliability of radar returns gradually declined along with the decreasing altitude. SSR data were used as the aircraft's altitude information. The point in time when the wings broke off, as well as the probable left spiral dive that followed, was determined by radar contacts

The investigation commission believes that the initial adverse condition was set off by banking the aircraft approximately 90 degrees to the left at 125-135 kt and by applying left rudder. This corresponds to the upset recovery procedure the flight instructor had a student pilot perform on his previous VTL4 flight. During the previous instance the aircraft approached its maximum permissible airspeed. Judging by radar returns, the aircraft went into a dive and its heading changed approximately 160 degrees to the left during the recovery. The wings broke off during the recovery at 5000-4500 ft; the airspeed was over 200 kt. The aircraft went into a left spiral dive which continued until the collision with the water. Airspeed was approximately 240 kt (ca. 445 km/h) at impact.

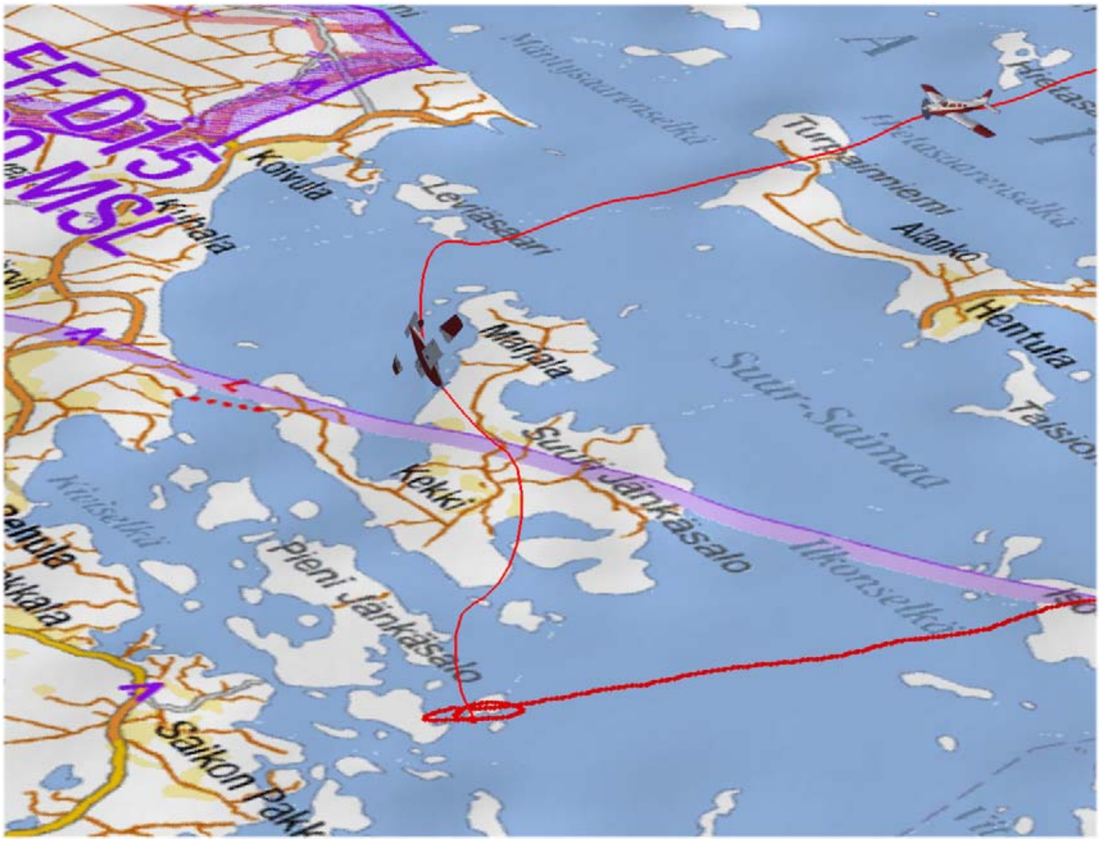

Figure 9. Flight path simulation of the final two minutes (the lower line represents the flight's 2D projection over the surface of the lake)

2.2.3 Possible causes of the incorrect recovery

A strong pull on the control column caused the wings to break off. Flight controls are quite stiff at high airspeed and, therefore, it is possible that the student pilot and the flight instructor simultaneously pulled each one on his own column. Since the aircraft in question did not have an accelerometer, it was impossible for the student or the instructor to estimate how many G's they were pulling. According to Patria's comments, the company does not use aircraft accelerometers in flight training with aerobatic aircraft. Rather, recovery is performed by the pilot's perception as well as by using information from airspeed and attitude indicators, the altimeter and the directional gyro. The investigation commission has estimated the following three most probable factors which may have caused the need for a rapid, strong pull on the control column:

- The aircraft was approaching maximum permissible airspeed and they attempted to slow the aircraft down by means of a strong pull. Exceeding the maximum permissible airspeed is generally considered to be dangerous and, therefore, they may have performed a rapid, strong control input to reduce airspeed;
- They used a strong pull during upset recovery to prevent flying into a cloud;
- Stick forces grow along with airspeed. If both pilots pull on the control column during recovery from a dive, control feel is lost.

2.2.4 Analysis of the flight characteristics of the damaged aircraft

The wings broke off almost simultaneously, albeit asymmetrically. Whereas the right wing separated at the end of the machined aluminium spar, a piece broke away from the underside of the left wing's machined spar. Wing skin panels fractured in the occurrence and, subsequently, at random. After the wings broke off they were probably asymmetrical. Roll control was lost. Add the separation of the stabilator half to this equation and a loss of control must have immediately ensued.

2.3 The flight training system and Progress Check Flight 4 (VTL 4)

Patria Pilot Training Ltd uses an integrated ATPL course training system. This system only encompasses one check flight instead of several check flights included in traditional flight training systems. This makes it more difficult to monitor the progress of a student and training goals because no external intermediate checks are conducted. The company uses internal progress check flights (VTL1, 2, 3 and 4) at the end of each syllabus. If PPL and CPL check flights are deemed necessary, it is possible to fly them. The four training syllabi include altogether twelve blocks, at the end of each the flight instructor assesses the student pilot's aptitude to move on to the next one. It is the Chief Flying Instructor who promotes student pilots to the next block.

After practicing with a flight training device, all single-engine instrument training flights are flown as SPIC flights. On these flights the flight instructor should not instruct the student. Should the flight instructor need to influence or control the flight, it must be logged as a dual instruction flight. Nevertheless, since the student pilots do not have instrument experience on real aircraft, the need for instruction at times is obvious. Moreover, there is a great need for a thorough pre-flight briefing. According to the survey given to the student pilots, approximately 60% felt that pre-flight briefings were inadequate. The threshold for logging SPIC flights as dual instruction flights is high because increasing the number of training flights impacts course schedules as well as the availability of flight instructors and aircraft.

A VTL4 flight is the flight that concludes the single-engine instrument training block. One of the topics to be checked is upset recovery. Patria has not regulated the initial adverse condition with regard to attitude or airspeed. Unambiguous instructions are needed so as to make the practice uniform and safe for all students. Only in this way could the results of check flights be comparable.

Aviation best practices also expect that internal progress check flights be flown with flight instructors that have not participated in a student pilot's instruction. The flight instructor on the accident flight had flown quite a few instrument flights with the student pilot in question.

The student pilot on the accident flight had practiced upset recovery on Bravo aircraft. However, on the VTL4 flight he flew the recovery for the first time on a Piper Arrow. Whereas the Bravo is an aerobatic aircraft, the Piper Arrow is a normal category aircraft which does not have an accelerometer. Compared to the Bravo, the Piper Arrow easily accelerates to a high airspeed in a descent. Therefore, a flight instructor should not place the aircraft in such an initial adverse condition from which the aircraft would accelerate to a high airspeed or require high G-forces during recovery. As the initial adverse condition is being planned, the flight instructor must take into consideration the aircraft's characteristics and limitations as well as the student pilot's reaction time at the start of the recovery and his possible erroneous flight control inputs during recovery.

The abovementioned difference in aircraft characteristics was noticed during the flight instructor's previous VTL4 flight in July. During this flight, the aircraft lost a lot of altitude during recovery and accelerated close to its maximum permissible airspeed. Since no flight safety occurrence report was made, the training organisation was incapable of intervening with the flight instructor's risky practice. Neither did the flight instructor choose to change his routine for the following VTL4 flight, the accident flight.

2.4 Maintenance activity analysis

The maintenance arrangements in the aircraft's user agreement contradicted the Operations Manual as well as the user agreement presented to CAA Finland. When the aircraft was introduced to flight training, neither the owner's maintenance arrangements nor the associated maintenance certifying technician's proficiency were confirmed or quality assessed. The investigation revealed that the Maintenance Manager did not supervise aircraft maintenance, such as spare parts' airworthiness and storage, the suitability and/or calibration of the aircraft technician's tools or reference material used in maintenance.

The investigation commission believes that the maintenance certifying technician should not have signed off the last 100 h maintenance because this particular maintenance included areas which his PART 66 licence privileges did not cover. The technician, however, was under the assumption that he issued the maintenance certificate under the privileges of his national licence. Additionally, the investigation commission believes that had he issued the maintenance certificate pursuant to the B1/B2 licence, he should have had to pass a personal proficiency examination on topics including practical experience, reference materials and tools. According to the investigation commission, a properly functioning Quality System would have revealed the shortcomings as regards reference material, monitoring of tools and spare part storage. The Quality System may also have revealed the limitations, among other things, in the technician's licence privileges.

2.5 Muffler change

When the technician performed the 100 h maintenance in the summer of 2008, he discovered that the muffler shroud end plates had worn a hole on the surface of the muffler. He decided to change the mufflers. In his storage he had refurbished mufflers which had been repaired because of shroud end plate wear. He installed these on the aircraft. At this time he also notified the owner of the aircraft that the aircraft should get new mufflers and that the refurbished ones could only be used for 50 flight hours. The technician said that he decided to install the weld-repaired mufflers because the aircraft needed to return quickly to the flight line.

According to the technician, the refurbished mufflers had been welded by a person who had an aviation welding certification. Nevertheless, since no proper airworthiness document had been written as regards the welding, the technician did not record the muffler change into the aircraft's documents. In aviation, these kinds of parts are not airworthy, nor is it permissible to install them on aircraft.

At the time of the accident the persons occupying the front seats had 1% blood carbon monoxide. Yet, the rear seat occupant's blood had no carbon monoxide. Since the occupants in this aircraft type are seated close together, breathing the same air, it is unlikely that the carbon monoxide originated from a leak in the muffler.

The forensic autopsy report stated that the rise in carboxyhemoglobin caused by one cigarette is higher than 1%. The student pilot who was the pilot flying was known to be a smoker. However, neither the flight instructor nor the other student smoked. The carboxyhemoglobin concentration that was discovered is considered to be low and has no effect on a person's performance.

2.6 Possible jamming of the control column

The advisory circular OPS T1-10, regarding the jamming of the control column, concerns Piper PA-28R-200 aircraft. Another factor that limits the movement of the Piper PA-28R-200's wheel type column is when the control wheel tube's flexible joint bolts get hooked onto electrical wires behind the instrument panel. Both of these factors which limit the control of the aircraft only appear when the column is pulled all the way back. In reality, such situations may arise during stall recovery training, for example. This kind of a situation entails a low airspeed.

According to radar information, the aircraft's airspeed during the final two minutes exceeded 120 kt. The flight programme did not call for stall recovery training. The investigation commission does not consider it likely that the control column would have jammed on the accident flight.

2.7 Analysis of the organisation and Quality System

The investigation commission believes that when a company uses an integrated training system, it must be able to properly monitor and evaluate training and, when required, deal with observed shortcomings. Judging by CAA Finland's oversight inspections in 2005-2006 as well as in 2008, the company's internal quality monitoring did not comply with the manner presented in the Quality Manual. Moreover, the company's Quality System reports imply that internal quality monitoring was not carried out. It is the opinion of the investigation commission that the management was not able to markedly improve the functioning of the Quality System during the observation period (1/2006-8/2008). Due to missing internal audits, it has been possible for dissimilar practices to evolve within the company.

Corporate culture revolves around a company's regular personnel. In this instance, the flight instructors providing PPL training comprised an important core team. There was particular need for standardisation training for the instructors that provided advanced training as, after all, they were part-time instructors coming from different training backgrounds. The company's new management began to actively standardise flight training by publishing an instrument training manual in the spring of 2008. The manual explained instrument approach procedures.

In its marketing practices the company aimed to set itself apart from other Finnish flight academies as a cost-effective and expeditious training institution. In 2008, the student-to-instructor and student-to-aircraft ratio was quite high. Courses were not completed within the advertised 18 month schedule. Furthermore, the company was under contract to provide PPL training to another flight school. This being the case, the training organisation was pushed to its limits.

Judging from interviews it is evident that, prior to 2008, the Chief Flying Instructor played a passive role in the flight training organisation. In 2007, the flight instructor on the accident flight operated as acting Chief Flying Instructor. Still, the company was unable to provide any documentation with regard to making this temporary post official. According to the Operations Manual the Head of Training is the deputy of the Chief Flying Instructor. Since the temporary arrangement was implemented in the summer, the most active training period, the investigation commission regards this as relevant with regard to the operating and training culture.

2.8 Rescue operations

Taipalsaari belongs to the Emergency Response Centre (ERC) of South-East Finland's area of responsibility as well as to the Etelä-Karjala Rescue Department. The ERC received word of the accident within a few minutes of the occurrence, after an eyewitness on the lake got his mobile telephone from his cottage. The site of the accident was sufficiently accurately known from the start, which made it possible for the emergency responders to go immediately to the right location. The correct number of occupants in the aircraft was given to the rescue personnel at 13:54. The ERC received some duplicate reports of the accident. The ERC did not alert the authorities' telecommunications network (VIRVE) caller groups nor, because of being busy, could it respond to the initial queries from units called out to the site. The units took off on the basis of text messages sent to mobile phones and VIRVE handhelds.

Even though it is normally the ERC supervisor's duty to alert Area Control Centre, South Finland (EFES), the ERC operator who answered the first emergency call did this. The operator gave the wrong area code for the ERC of South-East Finland. After repeated call attempts to the wrong number EFES finally asked the ERC of Pirkanmaa to contact the ERC of South-East Finland. At the time the ERC of South-East Finland was busy and the ERC of Pirkanmaa was put on hold for 4:32 minutes.

The first boats belonging to bystanders from nearby islands arrived at the accident site within 10 minutes from the occurrence.

Rescue operations had no effect on the aircraft occupants' survival. All three persons in the aircraft were killed instantly when the aircraft collided with the water at high speed.

2.9 Human factor analysis as per the Reason model

The model of accident causation developed by James Reason was used as the base of this analysis. A theoretical model (Fig. 10) describing the onset of an accident in conjunction with upset recovery was built on the accident causation model. The model includes a hazard and an accident as well as defences, or barriers, between them which should prevent hazards from becoming accidents. In addition, the model encompasses unsafe acts of human involvement, local workplace factors and organisational factors which, by affecting the defences, contribute to the accident.

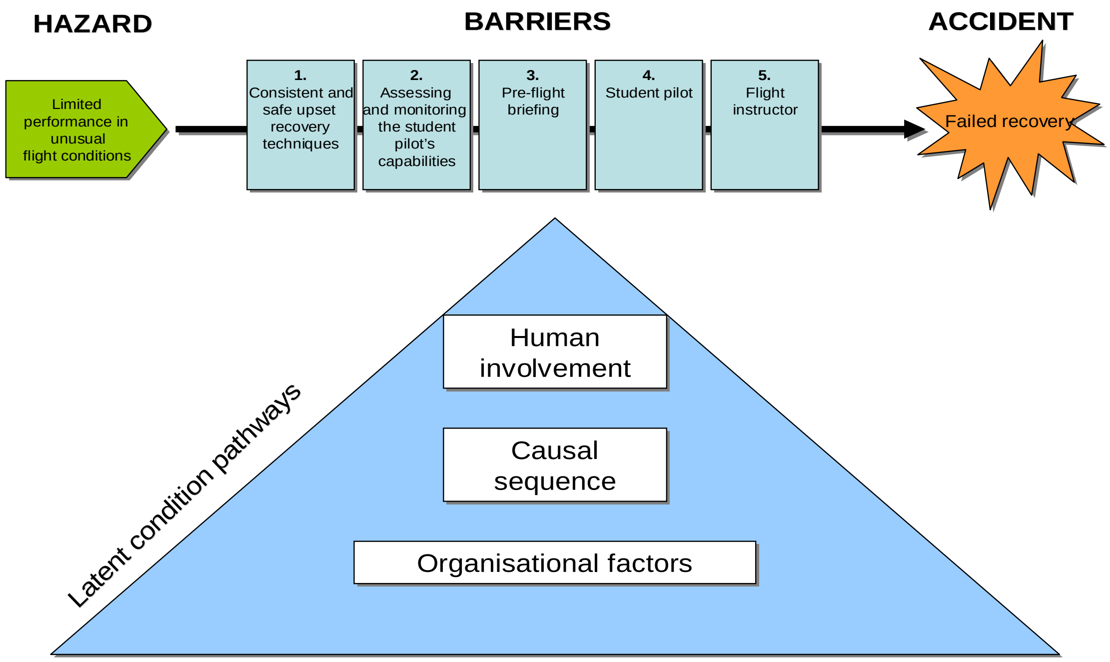

Figure 10. An Accident Causal Chain in upset recovery

2.9.1 Hazards and accidents

In this case the student pilot's limited ability to recover the aircraft from unusual attitudes establishes the hazard. Limited capacity can be caused by inadequate knowledge or skills, scant experience or situation-specific factors that limit pilot performance, such as fatigue, stress or illness. The situation becomes dangerous when the demands surpass the limits of pilot performance (Fig. 11). Inexperienced pilots meet their performance limits in less demanding situations than experienced pilots.

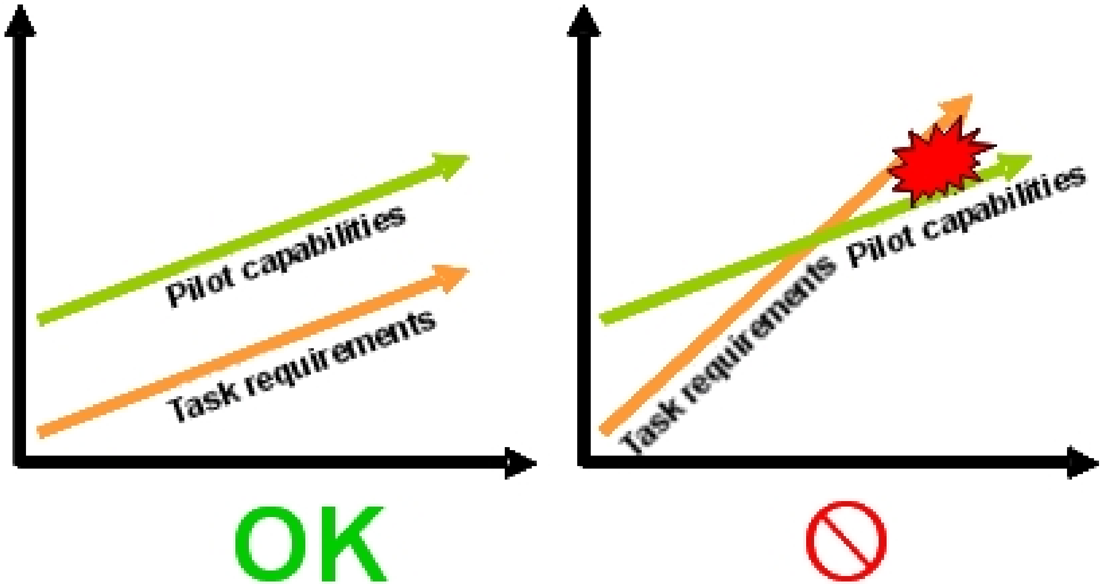

Figure 11. Pilot capabilities and task requirements. Safe and unsafe situations.

According to this model a hazard results in an accident if no defence mechanism prevents one from happening. In this case the student pilot's limited capabilities lead to an incorrect upset recovery technique for the situation. The erroneous technique, in turn, results in structural overloading.

2.9.2 Defences

The hazard created by a student pilot's limited capabilities is ever-present in all flight instruction. When it comes to safe operations, it is important that the demands of sorties not exceed the student's capabilities.

The purpose of defences is to prevent hazards from turning into accidents. In this particular case the defences should have, above all, prevented the student pilot from ending up in a situation which overwhelmed him. On the one hand, the difficulty level of flights in various phases of training and for different aircraft types should be such that all students, on the basis of prior training, can be expected to safely complete them. On the other hand, each student's capabilities to successfully complete the planned flight must be individually evaluated before the flight is flown. It is also important to make certain that flights are flown in accordance with the flight school's planned syllabus. Should the student face a situation which is too demanding for him, the function of the remaining defences is to prevent an accident from happening.

Defences on upset recovery flights:

Consistent and safe upset recovery techniques. Pre-defining the technique ensures that the demand level of upset recovery training will not exceed the generally expected proficiency level of students in a given phase of training. Standardised techniques guarantee that instructor-induced factors will not cause unexpected variation in the demand levels of sorties.

Monitoring and evaluating the student pilot's capabilities. Monitoring and evaluation make certain that individual student pilots are not required to fly sorties for which they are not personally capable.

Pre-flight briefing. A pre-flight briefing guarantees that the student, upon embarking on the flight, is aware of what is expected of him and that he can express his capability shortfalls, request additional instruction or even refuse to fly certain manoeuvres, if necessary. The pre-flight briefing provides the flight instructor his last opportunity to assess whether the student's capabilities and recent flight experience measure up to the demands of the flight.

Student pilot. A student pilot, while flying a sortie, realises that his control inputs are not appropriate to the situation, to which he reacts by changing the technique or by interrupting the manoeuvre.

Flight instructor. The flight instructor realises that the student's control inputs are incorrect. He reacts to the situation by providing instruction or by taking over the controls.

The types of aircraft used in basic flight training do not normally have so-called hard barriers, i.e. technical defence mechanisms that would prevent erroneous (overloading) control inputs in recovery situations. Such defence mechanisms could include, for example, systems that automatically curtail control surface deflection at increasing airspeeds or those that automatically kick in during a descent, preventing the aircraft from reaching airspeeds that make it possible to cause structural failure by control input.

2.9.3 Factors that contributed to the functioning of the defences

According to the model, unsafe acts, local workplace factors and organisational factors affect defences. It is possible to find aspects from these three levels that blast holes in the defences, enabling hazards to exacerbate into accidents. The following elaborates the factors that impacted the functioning of the aforementioned defences in this accident.

A consistent and safe upset recovery technique

Considering the student's capabilities, the flight instructor flew the aircraft into an excessively difficult initial adverse condition.

The flight instructor's decision could have been influenced by the fact that there were no type-specific training instructions for the initial adverse condition. He probably based his choice on his experiences from earlier similar upset recovery training. He had flown most of his previous upset recovery sorties on aerobatic aircraft; a recovery from this kind of initial adverse condition is less demanding on aerobatic aircraft. He had only had students practice upset recovery on the accident aircraft type once before. He may have not been fully aware of the demand level that this kind of initial adverse condition may lead into. The situation was particularly challenging because the student pilot had never practiced upset recovery on this aircraft type before the accident flight; the flight instructor had only flown this practice once before. The flight school's training system that uses SPIC flights curtails the possibilities of practicing manoeuvres on training flights before the check flight.

Since the flight instructors' training and professional backgrounds vary, the significance of explicit training instructions and standardised practices is highlighted. When said instructions are missing, the manner in which flight instructors have their students fly manoeuvres is based on their individual experiences. This causes variation in flight techniques and demand levels.

Evaluating and monitoring the student pilot's capabilities

The flight instructor had an incorrect impression of the student pilot's capabilities. He probably thought that the student could safely recover the aircraft from the initial adverse condition he had selected. This, however, was too challenging for the student.

The situation became particularly challenging because the student pilot had never practiced upset recovery on this aircraft type before the accident flight. The flight school's training system that uses SPIC flights curtails the possibilities for teaching or practicing manoeuvres on training flights before the check flight. The scarcity of practice situations degrades instructors' possibilities of evaluating their students' real capabilities of getting through demanding tasks on check flights.

Pre-flight briefing

If a pre-flight briefing is insufficient or entirely omitted, it cannot prevent an accident. Neither does the defence function if the student does not express his capability shortfalls during the briefing. The investigation commission does not know how the accident flight's pre-flight briefing was conducted.

There being a rush in pre-flight preparations may result in hurried or inadequate pre-flight briefings. Investigation revealed that there have been such hurried situations in this flight school's training which have adversely impacted flight preparations.

If the subject matter of the pre-flight briefing for each flight is not regulated, essential information may remain untouched. The significance of explicit instructions is highlighted when flight instructors' training and professional backgrounds vary. When there are no instructions, flight instructors conduct pre-flight briefings on the basis of their individual experiences. This may result in leaving out certain key elements.

A thorough briefing is a prerequisite for a student being able to articulate his capability shortfalls. He must know precisely what he is expected to do on the upcoming flight. At times, it may feel awkward to point out one's shortcomings during a pre-flight briefing. This is especially true with check flights that measure proficiency and where another student pilot may also be present. Moreover, a fear of prolonged studies, expensive additional flight hours and failing the check flight may raise the threshold of speaking out about one's shortcomings.

Student pilot

In order to fly safely the student, already at the onset of the recovery, should realise that his skills do not suffice and he should then hand over the controls to the instructor or change his recovery technique in mid-manoeuvre so as to be more appropriate to the situation.

Because of the challenging initial adverse condition and the aircraft's flight characteristics, events followed rapidly. There was precious little time for observations and decisions. The student pilot had no direct information of the increasing G-forces during the recovery because the aircraft was not fitted with an accelerometer. It is tremendously difficult for an inexperienced pilot to manage a controlled pull without an accelerometer during recovery at excessive airspeed. The student based his assessment of the situation on other available sources such as the attitude and airspeed indicators as well as his previous experiences of corresponding situations. He had never practiced upset recovery on the accident aircraft type. Rather, he had flown most of the previous upset recoveries on aerobatic aircraft, which permit much stronger control inputs. In the rapidly progressing situation the student may have reverted to a previously adopted recovery technique.

The student's desire to succeed on a check flight may have affected him in such a manner that he tried to manage the recovery on his own until the very last moment. Furthermore, the stress of the situation as well as possible fatigue may have degraded his performance to a degree. Still, the effect of these factors on this accident was hardly crucial.

Flight instructor

In order to prevent an accident the flight instructor should have realised early enough that the student pilot's recovery technique was incorrect and have taken over the controls.

The rapid progress of events as well as the lack of an accelerometer made it difficult for the student to correctly identify the situation and react to it. The flight instructor based his assessment of the situation on other available sources of information as well as previous experiences from analogous situations. Still, the flight instructor was in a better position with regard to spatial awareness and he had also prepared for the situation.

The flight instructor had very little experience with upset recovery on the accident aircraft type. Once before he had had a student perform upset recovery, possibly from a similar initial adverse condition. At that time the recovery was successful even though airspeed had grown remarkably high. The instructor's assessment of the situation was probably affected by his previous experience of upset recovery training with the aerobatic aircraft type used in basic training. This type allowed for a safe recovery even with strong flight control inputs. It is possible that the flight instructor did not realise that the G-forces had grown dangerously high.

Since the flight in question was a check flight and the flight instructor had confidence in the student's capabilities, the threshold for taking charge of the situation may have been high. He may not have been inclined to control the student's flying at a very early stage, lest he jeopardise a successful check flight. Fatigue, albeit hardly crucial in this incident, may have also degraded the instructor's performance to a degree.

3 CONCLUSIONS

3.1 Findings

Personnel

1. The flight instructor had valid licences and the required ratings for this flight.

2. The student pilot had valid qualifications for this flight.

3. Only on one previous progress check flight (VTL4) had the flight instructor have a student pilot fly the kind of manoeuvre (upset recovery) which resulted in this accident on a Piper Arrow.

4. On the flight instructor's previous VTL4 flight, during upset recovery, airspeed had come close to the maximum permissible airspeed and high G-forces were experienced during the recovery. It is likely that the flight instructor did not change his flying style after this flight.

5. Prior to the accident, the student pilot had not flown the kind of manoeuvre (upset recovery) which resulted in the accident on a Piper Arrow.

6. The flight was a progress check flight. Therefore, the flight instructor may have tried to avoid influencing the student pilot's flying in the early stages.

7. From the standpoint of the student's capabilities, the flight instructor placed the aircraft in a too demanding initial adverse condition for upset recovery.

8. The student had previously flown upset recovery training on a Bravo type aircraft. Due to its slower acceleration and higher G-rating, it is less challenging to practice upset recovery with the aerobatic Bravo than the Piper Arrow.

Aircraft

9. The airworthiness certificate and the certificate of registration were valid.

10. Several shortcomings were discovered in maintenance activities and there were overlooked faults in the aircraft. Therefore, the aircraft was not airworthy. The aforementioned faults did not have any effect on the accident.

11. Both wings and the right horizontal stabiliser broke off in flight.

12. Both wings broke off abruptly and simultaneously.

13. No signs of pre-existing structural damage or fatigue cracks were found on the fracture surfaces of parts that separated in flight.

14. In the aircraft manufacturer's wing break test the wing broke at 163.7% from the design limit load. On the basis of this information, the corresponding manoeuvring load factor n_{break} is 6.9 g.

15. A flight mechanic's analysis makes it possible to deduce that airspeed must have been at least 155 kt. Otherwise, without an accelerated stall, it would be impossible to achieve a load factor high enough to break the wings.

16. The wings broke off when the aircraft was handled with too rapid and forceful control inputs in relation to the airspeed.

Organisation

17. The flight school's SPIC (Student Pilot in Command) flight training system does not require training and/or demonstrations of proficiency on aircraft prior to check flights.

18. The flight school's flight training system did not include dual instruction flights in the SPIC phase.

19. The flight school did not provide instructions for flight instructors pertaining to the initial adverse condition of upset recovery.

20. The investigation commission believes that the company's management was unable to clearly improve the functioning of the Quality System in 2005-2008.

21. There were shortcomings in internal audits and training standardisation. Hence, flight instructors developed dissimilar practices.

22. Due to the poor flow of information, the training organisation was incapable of intervening with the risky practice the flight instructor demonstrated on his previous VTL4 flight.

Finnish Civil Aviation Authority

23. The material delivered to the investigation commission did not include documents on the possible oversight audit done by CAA Finland in 2007. Instead, the company's documents reveal that CAA Finland's audit report from April 2007 was never sent to the company.

24. Previous national aircraft maintenance licences were technically revoked in a manner which caused uncertainty among licence holders.

25. The privileges in the new PART 66 licence did not correspond to the ones in the previous national licence.

26. The investigation commission considers it plausible that several aircraft flying in Finland have maintenance certificates issued on incomplete privileges. Such aircraft are not airworthy.

Other findings

27. No significant phenomena occurred in the flying weather, nor did the weather have any effect on the accident.

3.2 Probable cause

The cause of the accident was that the flight instructor flew the aircraft into an attitude from which it would have only been possible to recover from if no mistakes were made. The flight instructor possibly overestimated his capacity to react to the student's mistakes as well as the student's ability to successfully execute the upset recovery. Airspeed became high. The flight control inputs used in the recovery resulted in load factors sufficient to break off the wings.

A crucial factor contributing to the accident was that only once before had the instructor have a student execute upset recoveries on the aircraft type in question, and the student pilot had never trained upset recovery on this type before the accident flight.

Contributing factors were:

- Shortcomings in standardisation training which made it possible for flight instructors to employ dissimilar practices and, consequently, may have resulted in risky flight manoeuvres.
- The VTL4 check flight instructions were not unambiguous with regard to upset recovery.
- It is possible that the flight instructor did not want to influence the student's flying at a very early phase because they were on a check flight.
- The flight instructor did not perceive the previous VTL4 flight's similar manoeuvre as an incident; neither did he change his own manner of flying.
- The student pilot had previously only flown upset recovery on aerobatic aircraft. The flight instructor had only limited experience of instrument training or check flights on this aircraft type.
- Large numbers of students and a lack of resources had caused schedule constraints in the flight training organisation. Therefore, pre-flight briefings with students were often unsatisfactory.

The cause of the accident is analysed in detail in section 2.9.

4 SAFETY RECOMMENDATIONS

4.1 Safety action already implemented

Future EASA regulations (Authority and Organisation requirements in NPA 2008-22) will provide the legal grounds for the auditing of flight instructor standardisation and a quality assessment of standardised training. This auditing will take place within all flight training organisations both by the training organisation and the competent authority.

4.2 Safety recommendations

1. The flight school's SPIC (Student Pilot in Command) flight training system does not require training and/or demonstrations of proficiency on single-engine aircraft before check flights during instrument training. If, during SPIC training, the flight instructor has to influence the flight or instruct the student, the flight must be logged as a dual instruction flight and the SPIC flight must be reflown. This training system aims at cost-effectiveness and time savings.

   The investigation commission urges the Finnish Civil Aviation Authority to require that the Student Pilot in Control (SPIC) training system include a sufficient number of dual instruction flights on an aeroplane to improve students' instrument flying skills.

2. Pursuant to JAR-FCL, check flights should be flown with flight examiners who have not participated in the instruction of the examinee. While the VTL4 flight is not included in JAR-FCL regulations, the flight is used in monitoring the student pilot's capability before promoting him to the next training block.

   The investigation commission advises CAA Finland, when accepting training syllabi, to require that all progress check flights be flown with a flight examiner who has not participated in the flight training of the student pilot in question.

3. Progress check flights must be consistent for all students. This makes it possible to equally monitor and compare students' progress.

   The investigation commission recommends that Patria Pilot Training Ltd draw up detailed flight training instructions for progress check flights.

4. Flight school staff consists of persons whose professional and training backgrounds vary. While only some of the instructors are regular flight school personnel, others just drop by to fly the agreed sorties. Therefore, instructors' standardisation training is often inadequate, which causes variance in the manner manoeuvres are flown as well as in their demand levels.

The investigation commission advises that all flight training organisations prepare unambiguous training instructions and organise regular training sessions which all instructors listed in the organisation's instructor roster are required to attend. The topics and participants of each training session should be documented in the training records.

5. GPS devices designed for air navigation have been used for a long time in support of aircraft accident investigation. In accident investigation GPS recordings improve the prospects of establishing the pre-accident events and their related stages of flight, especially when an aircraft is flying outside of radar coverage. GPS devices do not replace flight recorders, nor do they meet the same technical requirements. In order to use GPS devices in support of accident investigation they must have a logging feature. Some of the GPS devices designed for aviation do not provide this feature. The latest technology also provides better access to recorded data from GPS devices damaged in accidents.

   The investigation commission recommends that EASA study the possibility of drawing up a proposal for a standard which would suggest that all GPS devices intended for use in aviation have a function that records the parameters of the route flown. Moreover, the memory of such devices should not require a power source to retain the stored data.

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