Federal Department of Environment, Transport Energy and Communications **No. u1829**

Investigation Report of the Aircraft Accident Investigation Bureau

concerning the accident

to the aircraft Cessna CE 560 Citation V, HB-VLV

operated by Eagle Air Ltd. Aircharter + Taxi

on 20 December 2001

at Zurich-Kloten Airport

This report has been prepared solely for the purpose of accident/incident prevention. The legal assessment of accident/incident causes and circumstances is no concern of the incident investigation (art. 24 of the Federal Aviation Law).

The valid formulation of this report is the German version.

Bundeshaus Nord, CH-3003 Berne

Contents

In accordance with the Convention on International Civil Aviation (ICAO Annex 13), the sole objective of the investigation of an aircraft accident is to prevent future accidents. It is not the purpose of this investigation to apportion blame or liability.

Investigation report

Operator:	Eagle Air Ltd. Aircharter + Taxi Belp, Berne-Belp Airport, CH-3123 Belp	
Aircraft type and version:	Cessna CE 560 Citation V	
Nationality:	Swiss	
Registration:	HB-VLV	
Owner:	Eagle Air Ltd. Aircharter + Taxi Belp, Berne-Belp Airport, CH-3123 Belp	
Accident location:	Zurich-Kloten Airport	
	Coordinates of initial contact with the ground:	
	Swiss coordinates:	683 150 / 258 650
	Latitude:	N 47° 28’ 24’’
	Longitude:	E 008° 32’ 28’’
	Elevation:	425 m AMSL
		1395 ft AMSL
	Coordinates of final position of wreck:	
	Swiss coordinates:	683 100 / 259 200
	Latitude:	N 47° 28’ 41’’
	Longitude:	E 008° 32’ 27’’
	Elevation:	425 m AMSL
		1395 ft AMSL
Date and time:	20 December 2001 at 21:07 UTC	

Synopsis

Brief description

On 20 December 2001 at 21:06 UTC the aircraft Cessna CE 560 Citation V registered as HB-VLV of Eagle Air Ltd., under flight number EAB 220, took off from runway 34 of Zurich Kloten airport on a ferry flight to Berne-Belp. Fog patches had formed at the airport. The air temperature was –9 °C. Shortly after take-off, the aircraft lost height, crashed near the runway, caught fire and skidded on the frozen ground to the nearby runway 14. Both pilots were killed in the accident. The aircraft was destroyed.

Investigation

The Aircraft Accident Investigation Bureau (AAIB) formed an investigation team to investigate an aircraft accident of a catastrophic nature to large aircraft.

Since the copilot involved worked part-time for the AAIB, the investigation of human and certain operational aspects was handed over to the German Federal Bureau of Aircraft Accident Investigations in Braunschweig, (BFU-D). This guaranteed an impartial investigation and analysis. The BFU-D text items are identified as quotations within a frame.

According to Annex 13 of the Convention on International Civil Aviation (ICAO Annex 13), the states of manufacture of the aircraft have the option of assigning accredited representatives to the investigation. This possibility was not taken up.

The accident is attributable to the fact that the crew of HB-VLV did not continue their climb after take-off. As a result the aircraft came in a descent and collided with the terrain.

The investigation determined the following causal factor for the accident:

- With a high degree of probability the crew lost spatial orientation after take-off, leading to an unintentional loss of altitude.

The following factors contributed to the accident:

- The copilot’s basic training in instrument flying did not include night instrument take-offs.
- The crew’s method of working was adversely affected by great time pressure.
- Executing the take-off as a rolling take-off was not adapted to the prevailing meteorological conditions.
- There was no system in the aircraft which triggers an alarm in the event of a loss of altitude after take-off (GPWS).
- The instrumentation on the copilot’s side of the aircraft involved in the accident was not optimal.

1 Factual information

1.1 Pre-flight history and history of the flight

1.1.1 Pre-flight history

1.1.1.1 Aircraft

Aircraft HB-VLV made the following flights prior to the accident:

Date	Flight number	Flight from	Take-off time (UTC)	Flight to	Landing time (UTC)
18.12.01	EAB 218	Berne-Belp	18:05	Zurich	18:24
18.12.01	EAB 218	Zurich	19:53	East Midlands	21:28
19.12.01	EAB 219	East Midlands	12:05	Biggin Hill	12:34
20.12.01	EAB 220	Biggin Hill	13:05	East Midlands	13:41
20.12.01	EAB 220	East Midlands	17:56	Zurich	19:31

Since no technical logbook was present during the investigation, no statements could be made concerning any technical complaints during these flights.

1.1.1.2 Flight crew

1.1.1.2.1 Commander

On 18 December 2001 at approx. 15:00 UTC, the commander took off together with another co-pilot in the Cessna Citation II HB-VKP of the company Eagle Air Ltd. from Stockholm (S) and flew to Biggin Hill (UK). The commander had no flights scheduled for 19 December.

After a rest period of 35 hours and 50 minutes, the commander came on duty at 11:50 UTC on 20 December at Biggin Hill (UK). Together with the copilot, he took over HB-VLV for a ferry flight to East Midlands (UK). There he awaited his passengers for flight EAB 220 to Zurich.

1.1.1.2.2 Copilot

On 18 December 2001, the copilot flew with HB-VLV from Berne-Belp to Zurich and from there to East Midlands (UK). The commander on these flights was the Chief Executive Officer (CEO) of Eagle Air Ltd.

On 19 December the two pilots flew from East Midlands (UK) to Biggin Hill (UK), where the copilot completed his flying duty at 13:10 UTC after a flight duty time of 3 hours and 10 minutes. The CEO changed aircraft at Biggin Hill (UK) and flew back to Berne-Belp via Geneva with another copilot in HB-VKP.

After a rest period of 22 hours and 40 minutes, the copilot came on duty at 11:50 UTC on 20 December with the commander of the flight involved in the accident at Biggin Hill (UK) for a ferry flight to East Midlands (UK).

1.1.2 History of the flight

1.1.2.1 Flight from East Midlands to Zurich

On 20 December 2001, after a ferry flight from Biggin Hill (UK) to East Midlands, Eagle Air Ltd. HB-VLV took off at 17:56 UTC under flight number EAB 220 on a commercial flight to Zurich with eight passengers on board. All eight passengers worked for the company which had chartered this flight. According to the flight plan, a minimum block fuel of 3778 lbs would have been necessary. The Cessna CE 560 Citation V was refuelled with 2280 litres of kerosene resulting in an actual block fuel of 5600 lbs. The increased fuel reserve was intended to save the crew time in Zurich, since it made re-fuelling for the subsequent ferry flight to Berne-Belp superfluous (through tankage). This action (economical tankage) would avoid having to buy fuel which was subject to customs duty in Switzerland.

According to the load sheet, a fuel quantity of 5400 lbs was calculated for the take-off. Since the aircraft now exceeded the maximum permitted take-off mass, the crew made a fictitious last minute change (LMC) by reducing the number of passengers on the load sheet from eight to seven. Nevertheless, as the investigation showed, all eight passengers were on board for the flight. Even if this reduction had actually been implemented, the maximum permitted take-off mass would still have been exceeded.

The landing in Zurich took place at 19:31 UTC on runway 14. The aircraft taxied to the general aviation centre (GAC) Sector 1, where the passengers disembarked. There were various reasons to ferry HB-VLV to Berne-Belp on the same evening.

The flight plan to Berne-Belp originally was filed for a departure time of 19:30 UTC. The minimum block fuel was 2002 lbs. The actual block fuel on board was 3100 lbs.

There is no information of the extent to which an external inspection was carried out on the aircraft. It is unclear whether the crew had obtained the latest weather information.

Departure was delayed because of the difficult weather conditions and regulations on the use of runways.

1.1.2.2 Flight from Zurich to Berne-Belp

At 19:43:49 UTC the crew of EAB 220 called clearance delivery (CLD) for the first time and asked if their flight plan to Berne-Belp was available. The answer was in the affirmative and the CLD air traffic controller informed the crew that they would need authorisation for the landing in Berne-Belp.

Once it had been clarified that this authorisation had been obtained, EAB 220 called back a little later. CLD informed the pilots that their departure was planned from runway 34. However, they would have to expect a delay at that time, as arrivals and departures were being handled in batches. EAB 220 was scheduled in the next batch for take-off. CLD intimated to the crew an approximate departure time of 20:30 UTC.

When the crew called back at 20:13:49 UTC to ask for any news, CLD informed them that departure would now take place in about 45 minutes.

Since visual conditions were deteriorating due to the thickening fog, air traffic control had to increase the separation between arriving aircraft. As a result, flight EAB 220's estimated departure time was delayed to about 21:00 UTC.

At 20:24:38 UTC CLD transmitted to the crew a departure clearance. Flight EAB 220 was assigned the standard instrument departure (SID) "WILLISAU 3N" and transponder code 1403. In addition, a departure time of 21:07 UTC was estimated.

The CEO of Eagle Air Ltd. had applied in Berne-Belp for a special authorisation for a late landing after 21:00 UTC and obtained a slot until 21:30 UTC at the latest. Since the departure of HB-VLV in Zurich was being further and further delayed, the crew found themselves under increasing time pressure. The crew were in contact with the CEO several times; at the time, the latter was performing the function of the dispatcher. In order to ensure the arrival of HB-VLV in Berne-Belp by 21:30 UTC at the latest, he also telephoned the duty manager in Zurich control tower and urged him several times for an earlier departure time.

After a frequency change to apron control, the apron controller cleared EAB 220 to start its engines at 20:43:50 UTC. Approximately at the same time, an airport manager observed that HB-VLV's right-hand engine was running, although only one pilot was present in the cockpit. He was sitting in the right-hand seat. The other crew member, probably the commander, was using a scraper to remove ice deposits from the left wing. The eye witness later observed how this crew member occupied the left-hand position in the cockpit, shortly before taxiing.

Since the pilots were eager to leave their stand in the General Aviation Centre (GAC) Sector 1 as quickly as possible, they were cleared to taxi as far as the holding point for runway 28 just 2 minutes later.

There they had to wait for a taxiing Saab 2000 to pass in the opposite direction. EAB 220 was then instructed by the apron controller to continue taxiing to the holding point for runway 34 via taxiways ALPHA, INNER and ECHO.

One minute after taxi clearance had been given, the crew of EAB 220 again asked for the wording of this clearance: "*Swiss Eagle 220, sorry for that, can you say the clearance again*?" It must remain open whether HB-VLV had missed the intersection in the direction of the INNER taxiway. It is clear, however, that the apron controller had to intervene shortly afterwards with a correction: "*220, continue on taxiway INNER, INNER, and then ECHO to Holding Point 34, Echo 9*".

At 20:56:50 UTC flight EAB 220 made contact with Aerodrome Control (ADC) and stated that the aircraft was on Echo 9 just before the start of runway 34. The air traffic controller (ATCO) requested the crew to wait short of runway 34, since approaches were still taking place in the opposite direction on runway 16. At 21:04:51 UTC ADC cleared the aircraft to line up on runway 34.

The crew[1] taxied onto runway 34 and – after they had received take-off clearance at 21:05:54 UTC – initiated a rolling take-off by setting take-off power. At this time, meteorological visibility was 100 m with partial fog.

Since the left-hand engine was run up within six seconds to 102 percent of take-off power and the right-hand engine to 58 percent, for a few seconds during the acceleration phase the aircraft veered on the runway to such an extent that it's heading changed 10 degrees to the right. The crew were only able to bring the aircraft back into alignment with the runway by making a major nose-wheel control correction

[1] Various indications led to the conclusion that from this point onwards the commander was very probably pilot non flying and the copilot pilot flying (cf. sections 1.11.2.3 and 2.2.1). Because of a defect in the cockpit voice recorder (CVR), none of the pilots' conversations were recorded.

and by distinctly reducing the thrust of the left-hand engine. Afterwards the two engines were brought synchronously to take-off power and the take-off continued.

Flight EAB 220 lifted off from runway 34 at 21:06:40 UTC. Shortly after take-off, the commander of EAB 220 acknowledged the request to change frequency to departure control. At about the same time various members of the airport fire-fighting services, who were inside and in front of the fire-fighting unit satellite “North” between runways 34 and 32, heard noises and saw visual indications of a low-flying aircraft. Immediately afterwards the noise of a crash and the flash of a fire were noted.

At 21:07 UTC the aircraft impacted onto the frozen ground 400 m to the south-east of the end of runway 34 and skidded in a northerly direction, leaving a trail of debris. The main body of the wreck finally came to rest 500 m beyond the site of initial impact on runway 14/32. The rescue services reached the burning wreck after a few minutes.

DFDR data revealed that the autopilot was disengaged during the whole flight.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	2	---	---
Serious	---	---	---
Minor/none	---	---	

1.3 Damage to the aircraft

As a result of the force of the initial impact, the subsequent tumbling impacts and the intense fire which broke out after initial contact with the ground, the cockpit, front and central parts of the fuselage and large parts of both wings were badly damaged. The only parts not consumed by the fire were the rear of the fuselage which was torn off during the initial impact, with the horizontal and vertical stabilizers, and the two engines.

1.4 Other damage

There was minor material damage and damage to land on the aerodrome. The site of the crash has since been reinstated.

1.5 Personnel information

1.5.1 Commander

Person	†Stauffer Laurent Werner, male, Swiss citizen, born 1966
Flight duty times	Flight duty time on 19.12.01: 0:00 h
	Rest time: 35:50 h
	Start of duty with Eagle Air Ltd. on the day of the accident: 11:50 UTC
	Flight duty time at the time of the accident: 9:17 h

Licence	Airline Transport Pilot Licence ATPL (A), issued by the Federal Office for Civil Aviation, valid till 30.06.2006
Ratings	Radiotelephony International RTI (VFR/IFR)
	Night flying NIT (A)
Ratings to be extended	SE piston
	Type rating C500/550/560 PIC
	Type rating SAAB 2000 PIC
	Flight instructor trainee FI/T (A)
Instrument ratings	SE piston, CAT I, valid till 29.06.2002
	C500/550/560 PIC, CAT I, valid till 25.06.2002
	SAAB 2000 PIC, CAT I, valid till 04.03.2002
National ratings/licences	Aerobatics extension ACR (A)
	Glider GLI
Last check	Skill test on 26.06.2001
Last line check	According to upgrading report (FOCA Form 31.36) at Eagle Air Ltd. on 10.07.2001
Medical certificate	Last periodic examination on 30.06.2001
	Commencement of validity 30.06.2001

Flying experience	4761:18	h total
on powered aircraft:	4738:18	h
on gliders	23:00	h
as pilot in command	2432:23	h
on type involved in the accident	250:42	h
during the last 90 days	118:04	h
on the day before the accident	0:00	h
on the day of the accident	3:16	h
Commencement of pilot training	1988	

1.5.1.1 Professional training and social background

Nach einer Ausbildung zum Mechaniker übte der Kommandant zunächst eine selbständige Tätigkeit aus, bevor er in die Fliegerei wechselte.

Der Kommandant war verheiratet und Vater eines kleinen Kindes. Aufgrund der Berufstätigkeit beider Elternteile kam es zu familiären Belastungen, da er sehr häufig nicht zuhause war und die Kinderbetreuung einseitig zu Lasten seiner Ehefrau ging.

After training as a mechanic, the commander initially worked as a freelance before he changed over to aviation.

The commander was married and the father of a small child. Family stress arose because of the professional activity of both parents, as he was very frequently not at home and child care devolved onto his wife.

1.5.1.2 Pilot training and activity

Der Kommandant finanzierte seine Pilotenausbildung bis zu Erlangung der CPL und der Fluglehrerberechtigung für Motorflugzeuge selbst.

Nach erfolgreicher Aufnahme und dem Erwerb der ATPL beim Crossair Trainingscenter (April bis Juni 1995) flog er als Linienpilot auf der Saab 2000 bei der Firma Crossair AG. Nach drei Jahren wurde er zum Kommandanten befördert.

Er verliess das Unternehmen nach einem von ihm verursachten fliegerischen Zwischenfall: Bei einem Anflug auf Nizza hielt er sich nicht an die Verfahrensrichtlinien des Unternehmens, was zu einer unnötigen Gefährdung des Flugzeugs und der Passagiere führte. Als disziplinarische Massnahme wurde er in den Rang eines Copiloten zurückgestuft.

Am 31.08.2000 verliess er das Unternehmen nach insgesamt fünf Jahren Zugehörigkeit. Der Kommandant arbeitete für einige Monate auf Saab 2000 bei der Firma Europe Air Charter in Luxembourg. Bald darauf wurde er bei dem Flugbetriebsunternehmen Eagle Air Ltd. als Kommandant eingestellt.

The commander financed his own pilot training up to obtaining the CPL and flight instructor's licence for powered aircraft.

After successful admission and the acquisition of the ATPL at the Crossair Training Centre (April to June 1995), he flew as an airline pilot on the Saab 2000 with Crossair Ltd. He was promoted to commander after three years.

He left the company after a flying incident of his own making: during an approach to Nice airport he did not comply with company procedures, leading to unnecessary risk to the aircraft and passengers. As a disciplinary measure he was demoted to the rank of copilot.

On 31.08.2000, he left the company after a total of five years' employment. The commander worked for some months on the Saab 2000 with the Europe Air Charter company in Luxembourg. Soon afterwards he was employed as a commander by the operator Eagle Air Ltd.

1.5.1.3 Conversion to Cessna Citation Series 500/550/560

Die Umschulung des Kommandanten auf die Cessna Citation erfolgte bei FlightSafety International in den USA. Während der Umschulung zeigte er keine praktisch-fliegerischen Schwächen, wurde aber für seine ungenügende Umsetzung des crew resource management (CRM) kritisiert.

The commander's conversion to the Cessna Citation took place at FlightSafety International in the USA. During conversion he exhibited no practical flying weaknesses, but was criticised for his inadequate implementation of crew resource management (CRM)[2].

1.5.1.4 Personality aspects

Der Kommandant wurde als eine lebensbejahende Persönlichkeit beschrieben, der wahrzunehmende Aufgaben vorsichtig-gewissenhaft mit Ruhe und Disziplin ausführte. Er besass eine überdurchschnittliche Intelligenz und ein sehr ausgeprägtes Denkvermögen. Unter erhöhtem Anforderungsdruck zeigte er im Leistungsvermögen deutliche Schwankungen. Im Auftreten gab er sich sehr selbstsicher mit einer Tendenz zur Arroganz, er konnte aber auch sehr einfühlsam und natürlich auftreten.

Seine bei Crossair gewonnene Erfahrung im Linienflugbetrieb ermöglichte ihm einen professionellen Arbeitsstil, der ihn, zusammen mit seiner angenehm sympathischen Art, bei den Copiloten des Flugbetriebsunternehmens beliebt machte. Er war für sie jederzeit ansprechbar und zeigte sich offen gegenüber Vorschlägen und Kritik. Seine ausgesprochene Gutmütigkeit führte dazu, dass er seinen Copiloten gelegentlich Freiheiten einräumte, die nicht immer den schriftlich festgehaltenen Verfahrensvorgaben des Flugbetriebs entsprachen. Obwohl seine Einstellung als teamorientiert beschrieben wird, zeigte er sporadische Schwächen im praktischen Führungsverhalten; unter bestimmten Bedingungen konnte er sehr selbstzentriert auftreten - er versuchte dann, alle anfallenden Aufgaben eigenständig auszuführen.

The commander was described as an optimistic personality who carried out tasks to be performed in a cautious and conscientious way, calmly and in a disciplined manner. He was of above-average intelligence and possessed very pronounced reasoning power. When subject to heavy demands, he exhibited distinct fluctuations in capability. His manner was very self-assured, with a tendency to arrogance, but he could also appear very empathetic and natural.

The experience he had gained with Crossair in airline flying gave him a professional style of working, which, together with his pleasant, sympathetic nature, made him very popular with the operator's copilots. He was always approachable for them at all times and was open to proposals and criticism. As he was very good-natured, this occasionally led to him allowing his copilots freedoms which did not always correspond to the operator's procedures laid down in writing. Although his attitude is described as team-orientated, he exhibited sporadic weaknesses in practical management behaviour; under some conditions he could appear very self-centred – at which times he tried to perform all tasks which came up independently.

1.5.2 Copilot

Person	†Brunner Marc, male, Swiss citizen, born 1964
Flight duty times	Start of duty on 19.12.01: 10:00 UTC End of duty on 19.12.01: 13:10 UTC

[2] CRM is a management philosophy originating with the commander, according to which all crew members are required to co-operate on a common solution to a problem and optimised decision-making. Behaviour contrary to this management philosophy, for example, would be if the commander, in a situation in which accepting support would be appropriate, acts as a "single combatant" and does not include other crew members in the decision-making process.

	Flight duty time on 19.12.01: 3:10 h Rest time: 22:40 h Start of duty with Eagle Air Ltd. on the day of the accident: 11:50 UTC Flight duty time at the time of the accident: 9:17 h
Licence	Commercial Pilot Licence CPL (A), issued by the Federal Office for Civil Aviation, valid till 05.05.2005
Ratings	Radiotelephony International RTI (VFR/IFR) Night flying NIT (A)
Ratings to be extended	SE piston ME piston Type rating C500/550/560 COPI Flight instructor trainee FI/T (A)
Instrument ratings	SE piston, CAT I, valid till 07.10.2002 ME piston, CAT I, valid till 07.10.2002 C500/550/560 COPI, CAT I, valid till 07.10.2002
National ratings/licences	Mountain landings MOU (A)
Last proficiency check	TR (A) proficiency check on 06.09.2001 CR/TR (A) proficiency check IFR/VFR SPA/MEP on 29.09.2001
Last line check	No information, line checks were not recorded in writing
Medical certificate	Last periodic examination on 31.10.2001 Commencement of validity 18.11.2001

Flying experience	1110:20	h total
on powered aircraft:	1110:20	h
as pilot in command	580:36	h
on type involved in the accident	401:50	h
during the last 90 days	39:40	h
on the day before the accident	00:40	h
on the day of the accident	3:16	h
Commencement of pilot training	1994	

1.5.2.1 Professional training and social background

Der Copilot fühlte sich schon als Jugendlicher von der Fliegerei angezogen und bewarb sich gegen Ende seiner Schulzeit für die Fliegerische Vorschulung, für die er abgelehnt wurde. Nach einer Lehre zum Automechaniker und nach bestandener Matura absolvierte er ein Jurastudium, welches er erfolgreich abschloss.

Der Copilot war verheiratet, seine Ehefrau unterstützte seine fliegerischen Ambitionen.

Even in his youth, the copilot was attracted to flying and applied for preliminary pilot training towards the end of his schooling; he was rejected. After a car mechanic's apprenticeship and after passing his school-leaving examination (baccalaureate), he successfully concluded legal studies.

The copilot was married; his wife supported his ambitions to be a pilot.

1.5.2.2 Pilot training and activity

Der Copilot begann seine fliegerische Ausbildung ab Herbst 1994 auf einem Flugfeld in der Nähe des Wohnortes. Der Führerausweis für Privatpiloten wurde ihm am 16. August 1995 erteilt. In einer intensiven Weiterbildung erlangte er 1998 den Berufspilotenausweis (CPL) und die Instrumentenflugberechtigung (IR) auf mehrmotorigen Flugzeugen.

Der Copilot erlangte in der Folge weitere Berechtigungen und bestand auch die theoretische Prüfung für Linienpiloten (ATPL). Im Frühjahr 1999 wurde ihm eine fliegerische Teilzeitbeschäftigung bei der Firma Eagle Air Ltd. angeboten, für welche der Copilot ab dem 25. Mai 1999 die Umschulung auf Cessna Citation begann.

Für den Copiloten war die Fliegerei nicht die hauptberufliche Tätigkeit. Er nutzte alle Gelegenheiten zum Fliegen, die sich ihm boten, aber hauptberuflich leitete er als Anwalt eine eigene Kanzlei und war nebenberuflich auch für das BFU und das Bundesamt für Zivilluftfahrt als Sachverständiger tätig. Aufgrund der nebenberuflich ausgeübten Pilotentätigkeit entsprach sein fliegerischer Trainingsstand nicht dem eines hauptberuflich tätigen Piloten.

The copilot began his pilot training in autumn 1994 on an airfield near his place of residence. His private pilot's licence was granted on 16 August 1995. In intensive further training, he acquired a commercial pilot licence (CPL) and instrument flight rating (IR) on multi-engined aircraft in 1998.

The copilot subsequently acquired further ratings and also passed the theoretical examination for the airline transport pilot licence (ATPL). In spring 1999 he was offered a part-time pilot's position with Eagle Air Ltd., for which the copilot began conversion to the Cessna Citation from 25 May 1999.

Flying was not the copilot's principal professional activity. He made use of all opportunities to fly which were offered to him, but in the main he managed his own lawyer's practice and was also employed on a freelance basis as an expert by the AAIB and the Federal Office for Civil Aviation. In view of his freelance pilot's activities, his level of training as a pilot did not correspond to that of a full-time professional pilot.

1.5.2.3 Conversion to Cessna Citation Series 500/550/560

Die Umschulung auf die Cessna Citation erfolgte bei FlightSafety International in Frankreich. Während der Umschulung zeigte der überwiegend in der Fliegerei nach Sichtflugregeln (VFR) gross gewordene Copilot Schwächen in den praktisch-fliegerischen Fertigkeiten bei alleiniger Referenz auf die Instrumente (IFR). Bedingt durch die Komplexität des Flugzeuges Citation bestand er die abschliessende Flugprüfung im Simulator nicht.

In der Schweiz wurde nochmals eine Ausbildung begonnen, die zu angemessenen Lernfortschritten führte. Sie wurde mit einem erfolgreichen und als „durchschnittlich“ beurteilten Prüfungsflug abgeschlossen. Einzelne Schwachstellen des Prüflings wurden im Instrumentenüberblick (scanning) und in der Führung des Flugzeugs um die Querachse (pitch) gesehen.

Conversion to the Cessna Citation took place at FlightSafety International in France. During the conversion, the copilot, predominantly experienced in flying according to visual flight rules (VFR), exhibited weaknesses in practical/flying skills with exclusive reference to instruments (IFR). Because of the complexity of the Citation aircraft he did not pass the subsequent flying test in the simulator.

Training was begun again in Switzerland; this led to moderate progress in learning. It was concluded with a successful test flight which was deemed to be “average”. Individual weak points in the test were observed in instrument scanning and in management of the aircraft’s pitch.

1.5.2.4 Personality aspects

Der Copilot wurde als „starke Persönlichkeit“ beschrieben, der sich Herausforderungen stellte und diese selbstbewusst und dynamisch anpackte. Er wollte vieles gerne selbst machen. Seine ausgeprägte Intelligenz und sein schnelles Auffassungsvermögen verhalfen ihm zu vielen positiven beruflichen Erfahrungen. Er arbeitete konzentriert und zuverlässig, war aber auch ablenkbar. In einem Team war er es gewöhnt zu führen. Sein Auftreten war ohne Überheblichkeit. Kritik an seiner Person konnte er nur schwer annehmen.

The copilot was described as a “strong personality”, who welcomed challenges and tackled them assuredly and dynamically. He certainly wished to do many things for himself. His pronounced intelligence and quick learning ability helped him with many positive professional experiences. He worked reliably and with concentration, but could also be distracted. Within a team, he was used to leading it. His conduct was free from arrogance. It was difficult for him to accept personal criticism.

1.5.3 Air traffic controller A

Function	Duty Manager (DM) and Ground Controller (GRO)
Person	Swiss citizen, born 1947
Licence	for air traffic controllers, issued by the Federal Office for Civil Aviation on 20 September 1971, last renewal dated 19 September 2001, valid until 19 September 2002.

1.5.4 Air traffic controller B

Function	Clearance Delivery (CLD)
Person	Danish citizen, born 1963
Licence	for air traffic controllers, issued by the Federal Office for Civil Aviation on 15 October 2000, last renewal dated 10 August 2001, valid until 10 August 2002.

1.5.5 Air traffic controller C

Functions	Aerodrome Controller (ADC)
Person	Swiss citizen, born 1970
Licence	for air traffic controllers, issued by the Federal Office for Civil Aviation on 15 November 1996, last renewal dated 12 March 2001, valid until 12 March 2002.

1.6 Aircraft information

1.6.1 Aircraft HB-VLV

1.6.1.1 General

Aircraft type	Cessna CE 560 Citation V
Manufacturer	Cessna Aircraft Company, Wichita, Kansas, USA
Registration	HB-VLV
Serial number	560-0077
Year of construction	1990
Maximum take-off mass	16300 lbs (7393 kg)
Owner	Eagle Air Ltd. Belp, Berne-Belp Airport CH-3123 Belp
Operator	Eagle Air Ltd. Belp, Berne-Belp Airport CH-3123 Belp
Registration certificate	Dated 9 April 1997, issued by the Federal Office for Civil Aviation
Airworthiness certificate	No. 1 dated 29 April 1997, issued by the Federal Office for Civil Aviation
Scope of the aviation certificate in non-commercial use	Dated 29 October 1998 / No. 2, issued by the Federal Office for Civil Aviation VFR by day VFR by night IFR CAT I B-RNAV (RNP 5) NAT MNPS Special Routes
Scope of the aviation certificate in commercial use	Dated 08 August 2000 / No. 2, issued by the Federal Office for Civil Aviation: VFR by day VFR by night IFR CAT I B-RNAV (RNP 5)

Minimum crew	Two pilots
Airframe flying hours	3559 h
Airframe, number of cycles (landings)	3528
Engines	2 engines, Pratt & Whitney Canada Inc. model JT15D-5A
Date of last Phase B check (150 h interval)	12 September 2001
Flying hours at last Phase B check	3448 h
Flying hours since last Phase B check	111 h
Wing span	15.91 m
Length	14.39 m
Height	4.57 m
Thrust per engine	2900 lbs

1.6.1.2 Engine number 1 (left)

Serial number	PCE 108160
Operating time since manufacture	3559 h
Flying cycles since manufacture	3528
Operating time since installation in HB-VLV	3559 h
Flying cycles since installation in HB-VLV	3528

1.6.1.3 Engine number 2 (right)

Serial number	PCE 108157
Operating time since manufacture	3315 h
Flying cycles since manufacture	3339
Operating time since last overhaul	1516 h
Flying cycles since last overhaul	1465

1.6.1.4 Navigation equipment and instruments

The following systems were available to the pilots for navigation:

- Single FMS (B-RNAV) Honeywell GNS-X C129/GNS-XLS CDU
- Dual VOR/ILS Collins VIR-32
- Dual DME Collins DME-42
- Dual ADF Collins ADF-462
- Dual transponder Collins TDR-90
- Single ADS (air data system) Honeywell AZ-241
- Single stormscope system

- Single radio altimeter Collins ALT-55B
- Single weather radar system Honeywell WU-650
- Single flight director computer Honeywell FZ-500
- Dual compass system Honeywell C-14D
- Single autopilot Honeywell PC-500

Selected instruments and equipment which might have affected the accident during take-off were investigated (see section 1.6.11).

1.6.1.5 Communications equipment

The following systems were available to the pilots for communication:

- Flight interphone system
- Passenger address system
- Dual Collins VHF COM system
- Single HF COM system

The crew also had at their disposal a mobile telephone which was used for communication with their company. This telephone was not permanently installed in the aircraft.

1.6.2 Mass and centre of gravity

1.6.2.1 Mass and centre of gravity of flight EAB 220 from East Midlands to Zurich

A last minute change (LMC) was found on the load sheet for flight EAB 220 from East Midlands (UK) to Zurich. This contained a correction of the number of passengers from eight to seven. According to the representative of the company which chartered this flight, however, all eight passengers were on board.

According to the actual load calculation below, with eight passengers HB-VLV was loaded as follows:

Basic operating mass	9895 lbs	
Basic operating mass arm	302.44 in	
Basic operating mass moment	2990704 in•lbs	
Pax mass	1464 lbs	
Pax mass arm	240.25 in	
Pax moment	351726 in•lbs	
Baggage mass	167 lbs	
Baggage arm	348 in	
Baggage moment	58116 in•lbs	
Dry operating mass	11526 lbs	max. 12200 lbs
T/O fuel mass	5400 lbs	
T/O mass	16926 lbs	max. 16300 lbs
T/O MAC	19.83 %	
T/O arm	297.61 in	

Before the LMC the mass was 626 lbs over the maximum permitted take-off mass.

After the LMC the mass was still 443 lbs over the maximum permitted take-off mass.

The centre of gravity in both cases was outside the envelope published in the flight manual.

1.6.2.2 Mass and centre of gravity of the accident flight

The entries in the load sheet for the aircraft, drawn up for the Zurich – Berne-Belp flight, were used as a basis for determining the mass and centre of gravity at the time of the accident. These data were confirmed by the documents found at the site of the accident.

Basic operating mass	9895 lbs	
Basic operating mass arm	302.44 in	
Basic operating mass moment	2990704 in•lbs	
Pax mass	0 lbs	
Pax mass arm	0 in	
Pax moment	0 in•lbs	
Baggage mass	26 lbs	
Baggage arm	348 in	
Baggage moment	9048 in•lbs	
Dry operating mass	9921 lbs	max. 12200 lbs
T/O fuel mass	3100 lbs	
T/O mass	13021 lbs	max. 16300 lbs
T/O MAC	25.19 %	
T/O arm	301.96 in	

The mass and centre of gravity were within the envelope published in the flight manual. At the time of the accident some 3000 lbs of fuel was on board.

1.6.3 Aircraft control systems

1.6.3.1 Primary aircraft control systems

1.6.3.1.1 Elevators and rudder

A comprehensive examination of the remains of the elevator and rudder systems, as well as analysis of the DFDR data of the aircraft involved in the accident, did not give any indication of any defect in these systems immediately before the crash.

1.6.3.1.2 Ailerons

The fragments of the aileron skin, made from carbon composite material, found at the site of the initial impact, as well as the type of fractures at the aileron connecting fixtures, suspension parts and rivets, gave cause for more detailed clarifications.

Examination of these fragments revealed no indications of material fatigue or anomalies related to the materials. All material fractures were evaluated as fractures resulting from forced rupture.

Corresponding analysis of the DFDR likewise gave no indication that there was any defect in this aircraft's control system before the crash.

1.6.3.2 Secondary aircraft control systems

The DFDR data for the secondary aircraft control systems did not allow any conclusions regarding malfunctions to be drawn.

1.6.3.2.1 Flap position

The flap positions recorded in the digital flight data recorder between take-off and impact were:

- take-off 15° extended
- 14 seconds after lift-off commencement of retraction
- 24 seconds after lift-off retracted

These flap position recordings during the flight involved in the accident matched those for the preceding flights in terms of positions and sequence of movements.

It was possible to determine the position of the two flap actuators at the time of the impact, these were in the "flaps up" position. The mechanical indication of the flap position in the cockpit corresponded to the 0° flap position.

The flap lever was at the 15° position. It was very probably moved to this position on impact.

1.6.3.2.2 Elevator trim

Trim about the pitch axis was effected by a trim tab on each elevator. Elevator trim tab adjustment could be performed manually or electrically. Manually, trim was adjusted via a trim wheel on the left-hand side of the central pedestal. Electrically, trim was adjusted by actuating the two trim switches on the control wheels; the commander's switches had priority.

The nose up and nose down trim setting could be read off from a mechanically driven trim indicator next to the trim wheel. The trim adjustment range for take-off was specially identified by a white marker on the central pedestal with a caption TO (take-off) and one marker respectively for ferry flights and fully loaded flights.

The cockpit elevator trim control wheel and the trim position indicator were destroyed on impact.

The positions of the elevator trim tabs on the left and right elevators were in the 2° tab up position. Because of the extensive damage, no conclusions could be drawn about the position of the trim tabs at the time of the accident.

1.6.3.2.3 Rudder trim

The cockpit rudder trim control wheel and the trim position indicator were destroyed on impact.

The position of the rudder trim tab on the rudder was in the 0° position. Because of the extensive damage, no conclusions could be drawn about the position of this trim tab at the time of the accident.

1.6.3.2.4 Aileron trim

The cockpit aileron trim control wheel and the trim position indicator were destroyed.

The position of the aileron trim tab on the right aileron was in the 5° up position. Because of the extensive damage, no conclusions could be drawn about the position of this trim tab at the time of the accident.

1.6.4 Landing gear

The landing gear lever in the cockpit was in the gear down position. The two main landing gear cylinders and the nose gear cylinder were in the gear up position.

Investigation of the fracture and the deformation of the nose gear lock mechanism revealed that the nose gear was retracted at the time of initial contact with the ground.

1.6.5 Speed brake

The actuator of the left speed brake was in the retracted position. The position of the right actuator could not be determined because of the extensive damage.

It can be assumed with a high degree of probability that the speed brake was retracted at the time of the initial impact.

1.6.6 Engines

1.6.6.1 Visual inspection

The engines were subjected to an inspection and no pre-existing defects were found.

Points worthy of note:

- The actuators on both thrust reversers were found in the locked/stowed position.
- The fan on the right engine was badly damaged. This indicates that it was rotating at high speed on impact.
- The damage to the left engine also indicates that it was running at high power at the time of the accident.

These findings correspond to the DFDR recordings.

1.6.6.2 Engine acceleration

The DFDR analysis of the aircraft’s take-off phase showed that the aircraft veered approximately 10° to the right as the two engines were accelerated to take-off power. It was possible to bring the aircraft back into alignment with the runway by an immediate counter-measure. Further investigations showed that similar corrections had been necessary during earlier take-offs in order to maintain the correct take-off direction. This unusual take-off behaviour resulted from the different acceleration time of the two engines when the power lever was set to the take-off power position.

Analysis of all the flights recorded in the DFDR indicated that the ground idle of the high-pressure rotors (N2) of the two engines differed by 7-8%. In the case of the accident flight, the speed of the left engine at ground idle was 49% N2 and that of the right engine was 41% N2. It must be noted that the engine with the higher idle speed reaches a higher thrust value earlier during the engine acceleration phase if the power levers are operated at the same time. If the power lever is moved forward quickly, the difference in thrust during engine acceleration may be considerable.

The following reference values were found in the manufacturer's documentation:

Source	Speed (N2)	Tolerance
Engine manufacturer's maintenance manual	gnd idle NORM: min 46.0 %	Not mentioned
	gnd idle HIGH: min 52.0 %	Not mentioned
Aircraft manufacturer's maintenance manual	gnd idle NORM: min 46.0 %	+0.5 %/-0 %
	gnd idle HIGH: min 52.0 %	±0.5 %
Airplane flight manual	gnd idle NORM: min 46.0 %	+1.0 %/-0 %
	gnd idle HIGH: min 52.0 %	±0.5 %

1.6.7 Instruments

1.6.7.1 General

The first aircraft of the type Citation were built in the 1970s. A further development, the Model 550 Citation II, was built from 1977 onward. The derived version of the Model 550, known as the S550 or SII, formed the basis for the Model 560 Citation V.

In this aircraft series the cockpit instrumentation was designed primarily for the pilot on the left-hand side. Equivalent equipment for both pilots was available as an option for the Models S550 and 560. This option was not installed in the airplane involved in the accident.

According to the manufacturer a single-pilot version of the Models S550 and 560 was never offered due to the higher gross weight.

1.6.7.2 Artificial horizons

The most significant difference in instrumentation between the two sides of the cockpit concerns the most important instrument for IFR operations. The commander's and copilot's artificial horizons were of different types and from different manufacturers.

In HB-VLV, the commander had a Honeywell ED-600 electronic attitude director indicator (EADI) on his side to represent the aircraft's attitude.

An AIM electro-mechanical attitude indicator was installed on the copilot's side.

The commander's EADI measured 103 x 93 mm, whilst the copilot's attitude indicator measured 79 x 63 mm. The considerable difference between the two horizons is shown in Annex 5.1.

In addition to attitude, the commander's EADI was able to display further information such as the flight director, for example. This feature was not provided on the copilot's attitude indicator. Moreover, the reading accuracy for pitch was distinctly lower for this instrument.

In the event of a power failure, a warning flag appears on the copilot's attitude indicator.

The copilot's attitude indicator was examined for serviceability at the time of the crash. Traces of the impact were found on the display scale. The investigation found that this instrument's gyro had functioned.

1.6.7.3 Standby horizon

The electro-mechanical standby horizon P/N 5040041902 was installed immediately adjacent to the copilot's attitude indicator. This independent device was used as a reference attitude display in the event of a deviation between the two pilot's artificial horizons.

In the event of a power failure, a warning flag appears on the standby horizon.

The standby horizon was examined for serviceability at the time of the crash. The investigation found that this instrument's gyro had functioned. It was not possible to obtain any information about the attitude displayed during the accident.

1.6.7.4 Horizontal situation indicator

The copilot's horizontal situation indicator (HSI) was of the Honeywell RD-450 type. This display, unlike the commander's electronic horizontal situation indicator (EHSI) was also an electro-mechanical instrument.

The copilot could pre-select a course for navigation via a course select knob. A course deviation was indicated by a needle on a scale.

The display also offered the option of setting a heading as a reference for the pilot.

If VHF navigation is set to an ILS frequency, the glide path display on the right-hand side of the instrument is activated.

In the event of malfunction of the corresponding parameter, warning flags (HDG, NAV and VERT) appear.

1.6.7.5 VHF navigation system

The VHF navigation system receives signals from VHF omni-directional radio-range (VOR), localizer, glide slope and marker transmitters.

The bearing and deviation signals generated in the corresponding receivers were displayed on the commander's EADI (electronic attitude director indicator) and the EHSI (electronic horizontal situation indicator) and on his radio magnetic indicator (RMI). On the copilot's side the signals were displayed on the HSI and RMI. Separate receivers were provided for reception of VOR and ILS signals. The following description is limited to the VOR function.

HB-VLV was fitted with a dual VOR system. Each of the two systems consisted of a VOR receiver, a VHF NAV controller and a VOR/LOC antenna.

The purpose of a VOR system is to determine an aircraft's bearing in relation to a ground station with known geographical coordinates. If a VOR course is then set, the system is able to calculate and display the course deviation.

The VOR frequency is selected on the corresponding VHF NAV controller (#1 or #2). A second VOR frequency could be pre-selected and called up by pushing a button. The VOR system works in the 108.00 – 117.95 MHz frequency range, with 50 kHz channel spacing. In the 108 – 111 MHz frequency range, only the even tenths of a megahertz are specified as VOR frequencies. The frequencies could also be set via the navigation management system's control display unit (CDU).

A specific Morse code is modulated on the VOR transmitter to identify the VOR ground stations. This Morse code can be monitored via the audio system.

1.6.7.6 Distance measuring equipment

HB-VLV was equipped with two DME (distance measuring equipment), type Collins DME-42. These DME systems consisted of a DME interrogator unit, a VHF NAV controller and an L-band antenna (962 - 1213 MHz).

The purpose of a DME system is to determine the distance from the aircraft to a ground station. DME ground stations are generally co-located with VOR ground stations. The frequency is selected via a common VHF NAV controller.

These DME were associated with the respective VHF NAV controller. The corresponding DME distance could be read off on the DME indicators in the cockpit.

1.6.7.7 Navigation management system

The aircraft involved in the accident was equipped with a Honeywell GNS-X navigation management system. At the end of 1998 this system was converted to a GNS-X C129 with a GNS-XLS CDU. Among other things, this system supported the following functions:

- determination of position using various sensors (GPS, DME/DME, VOR/DME)
- calculation of flight parameters (ground speed, track angle, drift angle, desired track, crosstrack distance, distance to waypoint, bearing to waypoint, estimated time of arrival, wind speed and direction)
- generation of a route on the basis of manually entered waypoints and with the assistance of the navigation database
- calling up a pre-programmed company route, a standard instrument departure route (SID) or a standard arrival route (STAR)
- support for fuel planning
- output of navigation data to the commander's EADI and EHSI

Manual entry of waypoints along a route, calling up a company route or modifying a route is performed via the control display unit (CDU). The resulting flight plan plus the relevant navigation parameters are then displayed on this unit.

The navigation management unit (NMU) obtains the data allocated to the navigation fix designators (lat/long, variation, etc.) in the navigation database, which is updated every 28 days.

If a flight plan is drawn up during flight preparation, once ATC clearance has been issued a standard instrument departure route (SID) can be inserted. The SID are stored in the navigation database and cannot be modified by the pilots. SID are constructed in the navigation management unit by means of a set of so-called 'procedural legs'.

During cruising, the navigation management system navigates along a defined flight plan, i.e. from waypoint to waypoint. By means of the direct to (DTO) function, any waypoint along the flight plan can be selected directly from the present position.

The data generated by the navigation management system are displayed on the commander's EHSI by means of a corresponding setting on the display controller.

Among other things, the system allows pilots to set the frequencies of the VHF and VOR/DME systems with the aid of the CDU.

The navigation management system is constantly checked by a monitoring system in the NMU and system errors are displayed to the crew.

1.6.8 Ground Proximity Warning System

No ground proximity warning system (GPWS) was installed in the aircraft involved in the accident.

A GPWS generates visual and acoustic warnings if the aircraft approaches dangerously close to the ground. The GPWS also generates acoustic height information to inform pilots of an approach to the ground.

The ground proximity warning computer (GPWC) monitors and processes certain signals from the aircraft and triggers a warning if the aircraft violates one of the following warning envelopes:

- mode 1 excessive descent rate
- mode 2 excessive terrain closure rate
- mode 3 altitude loss after take-off
- mode 4 unsafe terrain clearance
- mode 5 inadvertent descent below glideslope
- mode 6 altitude awareness call outs (radar altitude)

For each mode there are defined acoustic (synthetic voice) warnings. If multiple acoustic warnings are triggered at the same time, they have different degrees of urgency.

1.6.9 Maintenance of the aircraft

Since 1986 Eagle Air Ltd.'s aircraft fleet maintenance had been carried out by the company Airbase Ltd. at Belp airport. Airbase Ltd. was in possession of a JAR 145 licence and was authorised to carry out this work. There was no written maintenance contract between the two companies.

The technical documentation for the aircraft was held by the company Airbase Ltd. The times for the periodic maintenance work were scheduled by Eagle Air Ltd. The documentation for the work to be performed was drawn up by Airbase Ltd. in accordance with the Cessna 560 maintenance manual, interval and phase cross-reference for inspection time limits.

The work performed by Airbase Ltd. was notified by means of performance confirmations to the aircraft manufacturer for updating the CESCOM (Cessna computerized maintenance). Among other things, this maintenance management system recorded the performance of periodic checks on the system components, as well as deadline monitoring and feedback of service bulletins (SB) und service letters (SL) to be executed.

Job cards on engine change, adjustments, test flights and implementation of airworthiness instructions were not available. Likewise findings on the occasion of checks and their rectification were not logged.

No technical log book was found either in the wreck or in the technical documentation.

According to information from Eagle Air Ltd., pilot complaints were reported either verbally or in writing to Airbase Ltd. Eagle Air Ltd. reported that a hold item list was kept for minor defects.

According to information from Airbase Ltd., they had no knowledge either of the existence of a hold item list or of the receipt of written fault notifications. In each case, faults or defects to be eliminated were reported only verbally.

Airbase Ltd. was not able to document which repairs it had carried out for Eagle Air Ltd during the time it was responsible for maintenance.

Furthermore, it could not be ascertained when the navigation database was last updated or whether it was valid at the time of the accident.

1.6.10 Modifications to the aircraft

1.6.10.1 Angle of attack system

As of 1 February 1999, service bulletin (SB) 560-34-70 (Teledyne A-O-A Computer Mod.), declared as mandatory by the FAA and the FOCA, was due for implementation.

According to a maintenance transaction report, the SB was implemented on the occasion of the major service in December 1999, i.e. 10 months after the due date. No FOCA consent to a deferral was available.

This AD was missing from the aircraft's FOCA airworthiness directives list (FOCA Form 52.081).

All documentation was missing, apart from the FAA 8130-3 certificates for the two newly installed computers P/N SLZ8066. Among other things, implementation of the SB also included modification of the aircraft wiring.

It is not known whether and how the flight calibration check required in the SB for this modification was carried out.

1.6.10.2 Avionics

The following two modifications to the avionics were made:

- modification to the navigation system GNS-X to a GNS-X C129/GNS-XLS CDU
- modification of the VHF-COM from 25 kHz to 8.33 kHz channel spacing

These modifications are documented.

As a basis for the airplane flight manual (AFM) supplement for the modification of the navigation system, the maintenance company used the AFM supplement for Beech model E90 approved by the Federal Aviation Administration (FAA) on 10 October 1997. The maintenance company amended this to an AFM supplement for Cessna Citation C560, which was approved on 30 October 1998 by the Federal Office for Civil Aviation.

1.6.10.3 Engine nacelle inlet

The two engine inlets were replaced with new design nacelle inlets by a maintenance company in Germany on the basis of SB 560-54-01.

This modification is documented.

1.6.11 Findings after the accident

1.6.11.1 General

The following control units and displays were of significance for the investigation. Other parts of the cockpit equipment were also investigated; they subsequently proved irrelevant to the investigation.

1.6.11.2 Display controller

Location	Control unit / display	Position
Pilot panel RH	BRG ○	FMS1
	ADI DIM	Unascertainable
	DH TST	Unascertainable
	HSI DIM	Unascertainable
	WX DIM	Unascertainable
	BRG ◇	ADF2

1.6.11.3 Horizontal situation indicator copilot

Location	Control unit / display	Position
Copilot panel LH	Compass display	Approx. 350°
	Course selector	335°
	Course deviation indicator	Centred
	Heading selector	Approx. 334°
	Glideslope pointer	1 ¼ dot under reference line, and wedged with the VERT flag

1.6.11.4 VHF navigation – NAV controller left (#1)

Location	Control unit / display	Position
Centre panel	Equipment switch	Between ON and HOLD
	Frequency selector switch	Unascertainable
	Frequency changer	Switch broken off

1.6.11.5 VHF navigation – NAV controller right (#2)

Location	Control unit / display	Position
Centre panel	Equipment switch	HOLD
	Frequency selector switch	Unascertainable
	Frequency changer	Switch broken off

1.6.11.6 DME indicator

Location	Control unit / display	Position
Centre panel	PWR button	Depressed and latched
	Distance indicator	Unascertainable

1.6.11.7 Radio magnetic indicator copilot (#2)

Location	Control unit / display	Position
Copilot panel LH	Compass display	350° (fixed)
	Single pointer	Rotating freely
	Double pointer	Rotating freely
	VOR/ADF selector	Unascertainable

1.6.11.8 Radio magnetic indicator commander (#1)

Location	Control unit / display	Position
Pilot panel RH	Compass display	349° (fixed)
	Single pointer	148° (fixed)
	Double pointer	148° (fixed)
	VOR/ADF selector	Unascertainable

1.6.11.9 Exterior lights

Location	Control unit / display	Position
Pilot panel LH	Recognition lights	RECOG - ON
	Anti-collision lights	ANTI COLL - ON
	Navigation lights	NAV - ON

1.6.11.10 Navigation management system

The front panel of the control display unit (CDU) exhibited slight traces of fire. The housing had been compressed. The connector housing on the rear was highly corroded; the connector pins were in good condition. The antenna cable had been torn off. The antenna connector was in good condition. The voltage transformer on the rear was highly corroded.

1.7 Meteorological information

1.7.1 Summary

Behind a cold front which was moving over Switzerland from the north-west, clouding at Zurich airport was clearing rapidly in the early evening. By 20:50 UTC the air temperature had dropped to -9 °C and from 19:20 UTC fog patches had formed in the area of the airport; however, by the time of the accident it had not combined to form a homogenous layer of fog.

1.7.2 General weather situation

The centre of an extended high-pressure area was located just west of Ireland. A low-pressure area covered extensive parts of Scandinavia. Between these two pressure systems cool air flowed towards the Alps from the north-west. Over the course of the day, a weakened cold front within this north-west current crossed Switzerland and in the evening was located over the Alps.

1.7.3 Weather conditions at Zurich airport

1.7.3.1 During the day

In the early morning the precipitation zone of the weakened cold front reached the airport area from the north-west. From 04:50 UTC light snowfall was observed. Apart from a brief pause, the snowfall persisted until 12:20 UTC. In this precipitation period meteorological visibility fluctuated between 1800 m and 4000 m.

In the afternoon the sky remained very cloudy, but there was no further precipitation. Between 18:00 UTC and 19:00 UTC the cloud cleared rapidly; at 18:50 UTC only 1-2 octas stratus was observed.

Given the light cloud cover, the air temperature fell from –5 °C to –9 °C between 18:50 UTC and 20:50 UTC. Fog patches were reported from 19:20 UTC onward. Meteorological visibility was 1800 m at 18:50 UTC, 250 m at 19:50 and 150 m at 20:50 UTC. However, by the time of the accident fog patches had not combined to form a homogenous layer of fog.

1.7.3.2 Weather at 19:50 UTC

Wind measurement point runway 14/16	VRB, 2 kt
Wind measurement point runway 34	350°, 2 kt
Meteorological visibility:	250 m
Weather phenomena:	Fog patches
Runway visual range runway 14A	Over 1500 m
Runway visual range runway 16A	Fluctuating between 800 m and 300 m
Runway visual range runway 28A	Fluctuating between 1500 m and 400 m, trend decreasing
Precipitation	No precipitation
Cloud	1/8, base 250 ft AAL
Air temperature measurement point runway 14/16	-8 °C
Dew point measurement point runway 14/16	-8 °C
Atmospheric pressure, QNH	1025 hPa
Atmospheric pressure, QFE runway 28	974 hPa
Runway condition	Over 50% of runway surfaces wet, depth not operationally significant or not measurable. Effect on braking: no reliable indication possible

1.7.3.3 Weather at 20:20 UTC

Wind measurement point runway 14/16	290°, 2 kt
Wind measurement point runway 34	340°, 2 kt
Meteorological visibility:	200 m
Weather phenomena:	Partial fog
Runway visual range runway 14A	Fluctuating between 1500 m and 325 m, trend decreasing
Runway visual range runway 16A	Fluctuating between 600 m and 250 m, trend increasing
Runway visual range runway 28A	550 m
Precipitation	No precipitation
Cloud	2/8, base 150 ft/AAL
Air temperature measurement point runway 14/16	-8 °C
Dew point measurement point runway 14/16	-8 °C
Atmospheric pressure, QNH	1025 hPa
Atmospheric pressure, QFE runway 28	974 hPa
Runway condition	Over 50% of runway surfaces wet, depth not operationally significant or not measurable. Effect on braking: no reliable indication possible

1.7.3.4 Weather at 20:50 UTC

Wind measurement point runway 14/16	300°, 2 kt
Wind measurement point runway 34	260°, 1 kt
Meteorological visibility:	150 m
Weather phenomena:	Partial fog
Runway visual range runway 14A	Fluctuating between 400 m and 250 m, trend reducing
Runway visual range runway 16A	Fluctuating between 900 m and 400 m
Runway visual range runway 28A	Over 1500 m, trend decreasing
Precipitation	No precipitation
Cloud	Vertical visibility 80 ft
Air temperature measurement point runway 14/16	-9 °C
Dew point measurement point runway 14/16	-9 °C

Atmospheric pressure, QNH	1025 hPa
Atmospheric pressure, QFE runway 28	974 hPa
Runway condition	Over 50% of runway surfaces wet, depth not operationally significant or not measurable. Effect on braking: no reliable indication possible

1.7.3.5 Weather at the time of the accident (21:07 UTC)

Wind measurement point runway 14/16	320°, 1 kt
Wind measurement point runway 34	330°, 3 kt
Meteorological visibility	100 m
Weather phenomena	Partial fog
Air temperature measurement point runway 14/16	-9 °C
Relative humidity	95 %
Ground temperature	-7.3 °C
Concrete temperature	-7.3 °C
Atmospheric pressure, QNH	1025.4 hPa
Atmospheric pressure, QFE runway 28	974 hPa
Ground condition at observation station	Powder snow, completely covering the ground, depth of snow 1 cm

1.7.3.6 Ice formation on the aircraft before take-off in Zurich

1.7.3.6.1 Water content of the air at the time of the accident

The air contained approximately 2 g water per kg air.

(atmospheric pressure: 974 hPa, dew point -9 °C)

1.7.3.6.2 Fog formation at the airport

- Fog patches were reported for the first time at 19:20 UTC
- Partial fog was reported at 20:20 UTC and at 20:50 UTC
- The fog patches were thicker at the north of the airport than in the area of the GAC (General Aviation Centre)
- Up to the time of the accident, fog coverage over the area of the airport was incomplete

1.7.3.6.3 Aggregate condition of the fog

Between 18:50 UTC and 20:50 UTC the air temperature fell rapidly from -5 °C to -9 °C under a practically clear sky. Over this period the dew point fell from -6 °C to -9 °C, and in the process approximately 0.5 g of water vapour per kg air condensed or sublimated.

The fog patches which formed were so-called ‘young clouds’. At temperatures between -6 °C and -9 °C droplets of water which are still predominantly supercooled are present in young clouds. At the time of the accident the fog therefore probably still consisted predominantly of supercooled water droplets.

Pilots’ statements such as “*Halo around RWY lights*” (SR 460, take-off at 23:15 UTC), however, allow the conclusion that a considerable number of ice crystals were already present at this time (23:15 UTC).

1.7.3.6.4 Effects on the aircraft

Apart from the impact of supercooled fog droplets which would freeze relatively rapidly on the surface of the aircraft, under these conditions (an almost clear sky, rapidly falling temperature) the formation of hoar frost due to sublimation is also possible, especially in the case of aircraft whose surface temperature is already significantly below zero degrees C.

In the area of the GAC (General Aviation Centre) the fog was less dense, so radiation from the airframe would have been greater than in the fog patches.

GAC Sector 1 is surrounded on virtually all sides by buildings, from which a degree of heat is radiated. Cooling is therefore somewhat reduced in this area.

1.7.3.6.5 Pilot reports regarding ice formation on the aircraft before the landing at 19:30 UTC

During their approach, two incoming aircraft reported “*a little ice*” (LX 497, landing on runway 16 at 20:51 UTC) and “*some frost*” (LX 3629, landing on runway 16 at 21:01 UTC).

1.7.3.6.6 Pilots’ statements

Pilots’ statements differ depending on the surface temperature of the aircraft, the parking position and the time the aircraft spent in the airport area.

ARRIVAL:

- SR 809 (landing on runway 16, 21:06 UTC): “*no ice on ground*”, despite a long taxiing time.
- LX 3549 (landing on runway 16, 20:41 UTC): “*light frost during ground time*”

DEPARTURE:

- LX 914 (departure from runway 28, 20:28 UTC): “*Frost on wings, de-icing not necessary*”
- LX 3038 (departure from runway 28, 20:50 UTC): “*no ice on wing, melted due to warm fuel*”
- LX 3878 (departure 21:02 UTC): “*no de-icing on ground*”

Later departures:

- SR 606 (departure from runway 34, 23:09 UTC): “*long period outside, wings covered in frost, de-iced twice*”
- SR 436 (departure from runway 34, 23:11 UTC): “*some frost on wing, de-iced twice*” (on ground since approx. 19:15 UTC)
- SR 810 (departure from runway 34, 23:13 UTC): “*Frost, de-iced twice*”

- SR 460 (departure from runway 34, 23:15 UTC): "*light frost on wing, de-iced*"
- SR 710 (departure from runway 34, 23:17 UTC): "*Frost to ice, de-iced twice, ice on fan blades*"

1.7.3.7 METAR aerodrome weather reports

The following METAR was valid at the time of the accident:

202050Z 30002KT 0150 R14/0250V0400D R16/0400V0900N R28/P1500N PRFG VV000 M09/M09 Q1025 8829//99 NOSIG=

1.7.4 Broadcast weather information

1.7.4.1 ATIS

The flight crew of HB-VLV were in possession of ATIS information X-RAY

INFO X-RAY

LANDING RUNWAY 14 ILS APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 1950 UTC 20.12.2001
350 DEG 2 KT
VIS 250 M
R14/P1500 R16/0300 R28/0400
FOG PATCHES
FEW 250 FT
-08/-08
QNH 1025 TWO FIVE
TREND BECOMING VIS 200 M
TRANSITION LEVEL 50
TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION, NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT.
RUNWAY REPORT No. 091 1825
ALL RUNWAYS,
FULL LENGTH 30 M WET, DEICED
APRON AND TAXIWAYS PATCHES OF WET SNOW, TAXI WITH CAUTION

Then subsequent ATIS reports followed:

INFO YANKEE

LANDING RUNWAY 14 ILS APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2020 UTC 20.12.2001
340 DEG 2 KT
VIS 200 M
R14/0325 R16/0250 R28/0550
PARTIAL FOG
SCT 150 FT
-08/-08
QNH 1025 TWO FIVE
TREND BECOMING BKN 200 FT
TRANSITION LEVEL 50
TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION, NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT
RUNWAY REPORT No. 091 1825
ALL RUNWAYS

FULL LENGTH 30 M WET, DEICED
APRON AND TAXIWAYS PATCHES OF WET SNOW, TAXI WITH CAUTION

INFO ZULU

LANDING RUNWAY 16 ILS APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2020 UTC 20.12.2001
340 DEG 2 KT
VIS 200 M
R14/0325 R16/0250 R28/0550
PARTIAL FOG
SCT 150 FT
-08/-08
QNH 1025 TWO FIVE
TREND BECOMING BKN 200 FT
TRANSITION LEVEL 50
TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION, NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT
RUNWAY REPORT No. 091 1825
ALL RUNWAYS
FULL LENGTH 30 M WET, DEICED
APRON AND TAXIWAYS PATCHES OF WET SNOW, TAXI WITH CAUTION

INFO ALPHA

LANDING RUNWAY 16 ILS APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2020 UTC 20.12.2001
340 DEG 2 KT
VIS 200 M
R14/0325 R16/0250 R28/0550
PARTIAL FOG
SCT 150 FT
-08/-08
QNH 1025 TWO FIVE
TREND BECOMING BKN 200 FT
TRANSITION LEVEL 50
TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION, NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT
RUNWAY REPORT No. 091 1825
ALL RUNWAYS
FULL LENGTH 30 M WET, DEICED
APRON AND TAXIWAYS PATCHES OF WET SNOW, TAXI WITH CAUTION

At the time of the accident the following ATIS information was being transmitted:

INFO BRAVO

LANDING RUNWAY 16 ILS APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2050 UTC 20.12.2001
260 DEG 1 KT
VIS 150 M
R14/0250 R16/0400 R28/P1500
PARTIAL FOG
VER VIS 80 FT
-09/-09
QNH 1025 TWO FIVE

NOSIG
TRANSITION LEVEL 50
TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION,
NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT
RUNWAY REPORT No. 091 1825
ALL RUNWAYS
FULL LENGTH 30 M WET, DEICED
APRON AND TAXIWAYS PATCHES OF WET SNOW, TAXI WITH CAUTION

Then followed the ATIS report:

INFO CHARLIE

LANDING RUNWAY 16 ILS APPROACH, DEPARTURE RUNWAY 34
QAM LSZH 2120 UTC 20.12.2001
330 DEG 3 KT
VIS 100 M
R14/P1500 R16/0300 R28/0275
PARTIAL FOG
VER VIS 70 FT
-09/-09
QNH 1025 TWO FIVE
NOSIG
TRANSITION LEVEL 50
TAXIWAY HOTEL 1 AND TAXIWAY KILO CLOSED, VACATE RUNWAY WITH CAUTION,
NEW TAXI PROCEDURE VIA TAXIWAY DELTA AND FOXTROT
RUNWAY REPORT No. 091 1825
ALL RUNWAYS
FULL LENGTH 30 M WET, DEICED
APRON AND TAXIWAYS PATCHES OF WET SNOW, TAXI WITH CAUTION

1.7.5 Runway visual range and meteorological visibility

1.7.5.1 Runway visual range

According to ICAO document 4444, runway visual range (RVR) is defined as follows: "*The range over which the pilot of an aircraft on the centre line of a runway can see the runway surface markings or the lights delineating the runway or identifying its centre line*". This means that runway visual range is essentially the maximum distance in the direction of the runway at which the runway lights can still be identified. It is measured using transmissometers (TMM). Values in the range from 50 m to approximately 800 m can be measured using short-base TMM (15 m measurement distance), and RVR values between approximately 100 m and 2000 m can be measured using long-base TMM (50 m measurement distance), though in this case measurement accuracy is reduced for the low range of measurement. For runways with ILS approaches, both short-base and long-base TMM are necessary. Both types are therefore installed on runways 14 and 16 of Zurich airport. At the time of the accident, only long-base TMM were installed on runway 28.

RVR values from 50 m to 1500 m are quoted in the weather reports. If the runway visual range is less than 50 m, M0050 is reported and if it is more than 1500 m this is indicated by P1500. Thus in VOLMET (METAR) and ATIS (QAM) RVR values over 1500 m are not reported.

1.7.5.2 Meteorological visibility

Meteorological visibility (now termed ground visibility) is defined as the maximum distance at which an object of appropriate size can still be identified. Meteorological visibility is determined only in the horizontal plane. If visibility is not the same in all directions, the lowest visibility is reported. Switzerland and other countries make the following exception in this respect: if visibility is not the same in all directions, the prevailing visibility is reported. Prevailing visibility is understood as the value which is achieved or exceeded in half the circumference around the observation site; the half circumference may be formed by distinct and separate sectors.

1.7.5.3 Relationship between meteorological visibility and runway visual range

A light source can be detected at a greater distance than an unilluminated object. At night-time, therefore, the RVR value is 3 to 4 times higher than meteorological visibility. During the day, the sun has a glaring effect in fog, i.e. the meteorological visibility is only about half that of the RVR value.

1.7.5.4 Locations of transmissometers at Zurich Airport

Three transmissometer installations are positioned along runway 16/34 at a distance of 110 m from the runway centre line, in the following locations:

- TMM 16A: approx. 420 m from start of runway 16
- TMM 16B: approx. 1480 m from start of runway 16
- TMM 34C: approx. 550 m from start of runway 34

The measured RVR values are relayed every ten seconds to skyguide's InfoNet and displayed accordingly within fractions of a second on the workstation displays.

1.7.5.5 Chronological evolution of runway visual range along runway 16/34 on the evening of the accident

The following table shows the one-minute average of runway visual range for selected periods:

TIME (UTC)	TMM 16A	TMM 16B	TMM 34C
19:30:08	2000	1600	2000
19:35:08	0900	0800	2000
19:40:06	0300	0750	2000
19:45:06	0500	0600	2000
19:50:06	0750	0800	2000
19:55:07	0375	0600	2000
20:00:07	0400	0250	1800
20:05:07	0400	0250	1900
20:10:08	0275	0350	2000
20:15:08	1600	1900	1300
20:20:07	2000	2000	0900
20:25:08	2000	2000	0900
20:30:08	0750	1400	0750
20:35:08	0900	2000	1000
20:40:08	0700	2000	0400
20:45:08	0400	2000	0375
20:50:07	0550	2000	0400

TIME (UTC)	TMM 16A	TMM 16B	TMM 34C
20:55:07	0325	1700	0500
20:56:07	0400	0650	0750
20:57:07	0450	0350	1500
20:58:07	0400	0300	0400
20:59:07	0350	0275	0325
21:00:06	0375	0300	0300
21:01:06	0400	0800	0325
21:02:06	0325	0700	0350
21:03:06	0275	1200	0375
21:04:06	0275	1100	0350
21:04:47	0300	1300	0325
21:04:57	0300	1300	0325
21:05:07	0300	1600	0325
21:05:17	0300	1600	0350
21:05:27	0350	1600	0350
21:05:37	0350	1700	0350
21:05:47	0350	1700	0400
21:05:57	0400	1700	0400
21:06:07	0400	1800	0400
21:06:17	0400	1800	0450
21:06:27	0400	1800	0450
21:06:37	0400	1900	0450
21:06:47	0400	1900	0450
21:06:57	0400	1900	0450
21:07:07	0400	1900	0450
21:07:17	0400	1900	0400
21:07:27	0375	1900	0400
21:07:37	0375	1900	0400
21:07:47	0375	1900	0400
21:07:57	0400	1900	0400
21:08:07	0400	2000	0400

(2000 = 2000 m or over 2000 m)

1.8 Aids to navigation

1.8.1 General limitations

As part of the relocation of VOR/DME KLO due to construction of the midfield terminal, two coverage diagrams were prepared for the new location of the VOR. Analysis of these two diagrams indicated that the signal is subject to partial interference below 12 000 ft.

Approach and departure paths are not affected by these topography-related coverage deficiencies, as test flights proved. There is no knowledge of any incidents or reports to air traffic control which might relate to VOR KLO irregularities.

On the basis of these facts, it was decided at a meeting with the IFR procedure group (IPG) Zurich in 1999 to publicise the above-mentioned limitation; this was accepted by the FOCA. A detailed report was produced at the time by skyguide.

1.8.2 Navigation aids for standard instrument departure “WILLISAU 3N”

The localizer of the runway 16 instrument landing system, DVOR/DME Kloten (KLO), DVOR/DME Trasadingen (TRA) and DVOR/DME Willisau (WIL) are used as navigation aids. All are equipped with distance measuring equipment (DME).

Navigation aid	LLZ 16 ZRH
Geographical location:	47° 26’ 36.52” N, 008° 33’ 29.27” E
Elevation	1400 ft AMSL
Frequencies	LLZ 110.50 MHz, DME channel 42 X
Period of operation	24 hours

Navigation aid	DVOR/DME KLO
Geographical location	47° 27’ 25.73” N, 008° 32’ 44.14” E
Elevation	1410 ft AMSL
Designated operational coverage (DOC)	50 NM/25 000 ft
Frequencies	DVOR 114.85 MHz, DME channel 95 Y
Operating time	24 hours

Navigation aid	DVOR/DME TRA
Geographical location	47° 41’ 22.16” N, 008° 26’ 13.15” E
Elevation	1850 ft AMSL
Designated operational coverage (DOC)	100 NM/50 000 ft
Frequencies	DVOR 114.30 MHz, DME channel 90 X
Operating time	24 hours

Navigation aid	DVOR/DME WIL
Geographical location	47° 10’ 41.88” N, 007° 54’ 21.30” E
Elevation	2417 ft AMSL
Designated operational coverage (DOC)	50 NM/25 000 ft
Frequencies	DVOR 116.90 MHz, DME channel 116 X
Operating time	24 hours

The transmitter installations of stations LLZ 16 ZRH, DVOR/DME KLO, DVOR/DME TRA and DVOR/DME WIL were in normal operation on 20 December 2001 from 20:45 to 21:15 UTC and were available to the operational services without restriction.

1.8.3 Other navigation aids

Equipment	Type and manufacturer	Date of commissioning
LOC ILS 14 ZRH	LOC 411 by Thales ATM	1999
GP ILS 14 ZRH	GS 412 by Thales ATM	1999
DME ILS 14 ZRH	FSD 40 by Thales ATM	1999

1.9 Communications

1.9.1 Air traffic control units involved

1.9.1.1 General

Air traffic control unit	Abbreviation	Frequency
Clearance delivery	CLD	121.800 MHz
Ground control	GRO	121.900 MHz
Aerodrome control (tower)	ADC	118.100 MHz
Approach control west	APW	118.000 MHz
Aerodrome vehicle (mobile radio)		164.475 MHz

1.9.1.2 Assignment of personnel in aerodrome control

Skyguide's sector allocation plan provided for four working positions in aerodrome control at the time of the accident. In fact, three working positions were occupied.

The duty manager had taken over the ground control (GRO) function because of an absence due to sickness.

1.9.2 Recordings of conversations

The following data were continuously recorded in the TWR by a digital storage system and saved on digital data storage (DDS):

- all VHF radio channels in use; in addition, a recording device for short-term recordings is installed at the ADC workstation
- all wired links between the workstations
- all telephone conversations at the workstations
- radiotelephone links for communication with police and rescue services

Comprehensibility was good and the recording was complete.

The conversations at the control tower were not recorded by an area microphone.

1.9.3 Communications equipment

The system management (SYMA) log book indicated no failures or defects of the communications equipment in the control tower at the time of the accident. The same applies to all internal air traffic control connections (intercom, telephone).

1.10 Aerodrome information

1.10.1 General

Zurich Airport is located in north-east Switzerland. In 2001, the skyguide air navigation services company handled a total traffic volume of about 297,000 IFR (instrument flight rules) arrivals and departures.

At the time of the accident an extensive construction programme was in progress, centred on the dock midfield located within the triangle of runways.

The dimensions of the Zurich airport runways are as follows:

Runway	Dimensions	Elevation of the runway thresholds:
16/34	3700 x 60 m	1390/1386 ft AMSL
14/32	3300 x 60 m	1402/1402 ft AMSL
10/28	2500 x 60 m	1391/1416 ft AMSL

The reference elevation of the airport is 1416 ft AMSL and the reference temperature is specified as 24.0 °C.

1.10.2 Runway equipment

The airport is characterised by a system of three runways, two of which (16 and 28) intersect at the airport reference point. The approach corridors of two other runways (14 and 16) intersect approximately 850 metres north-west of the threshold of runway 14. Runways 16 and 14 are equipped with a CAT III instrument landing system (ILS) and are therefore suitable for precision approaches. Runway 28 allows non-precision approaches on the basis of VOR/DME KLO.

Runway 34 is equipped with a lighting system which complies with ICAO standards for continuous operation under all weather conditions. A distinction is made between lighting systems with high (LIH – light intensity high) and low (LIL – light intensity low) intensity.

The high-intensity runway centreline lights and the high-intensity lights at the edges of the runway (edge lights) are important for take-offs in poor visibility. The intensity of this lighting system can be set to 1%, 3%, 10%, 30% and 100%.

The runway centre line lighting system is laid in the ground and heated. The lamps are installed at 15 m intervals. They are white up to 900 m before the end of the runway. Between 900 m and 300 m before the end of the runway they are alternately white and red, and over the last 300 m they are exclusively red. The light beam is adjusted vertically to 3°.

The runway edge lights are positioned at 30 m intervals on both sides of the runway and are approximately 1 m beyond the useable runway surface. The lights are white and over the last 600 m before the end of the runway they are amber.

1.10.3 Operating concept

At the time of the accident, the noise abatement procedures for Zurich Airport played a critical role in determining the take-off and landing runways, above all for take-offs before 07:00 and after 21:00 local time (LT). The relationship between local Swiss time in winter and UTC is as follows: LT = UTC+1h. Additionally, on 19 October 2001 the operating concept concerning landings before 06:00 LT and after 22:00 LT had been changed. The reason for this was the forward drawn measures relating to a bilateral agreement between Switzerland and Germany, which was undergoing the ratification procedure in the autumn of 2001.

Thus the following operating concept applied to Zurich Airport as regards the use of runways:

Time (LT) / wind conditions	**Runway directions specified for use**	**Restrictions / comments**
05:30 – 06:00	Landing: standard VOR/DME approach on runway 28 Take-off: none	Minimum values according to AIP. If the minimum values were not met, runway 16 or 14 could be used for landing.
06:00 – 07:00	Landing: runway 16 for all aircraft Take-off: runway 34 for jet aircraft runway 28 for propeller aircraft	Between 06:30 and 07:00 four jet aircraft take-offs were permitted from runway 28.
07:00 – 22:00	Landing: runway 14 for all aircraft	
07:00 – 21:00	Take-off: runway 28 for all aircraft	Take-off from runway 16 possible if take-off from runway 28 is not possible because of performance limitations
07:00 – 08:30 09:45 – 13:00 18:30 – 21:00	Take-off: runway 16 allowed for all aircraft	Option to increase capacity
After 21:00	Take-off: runway 34 for jet aircraft Take-off: runway 28 for propeller aircraft only	
After 22:00	Landing: standard VOR/DME approach on runway 28 For heavy category and B757 aircraft, runway 16 may be used	Minimum values according to AIP. If the minimum values were not met, runway 16 or 14 could be used for landing.
West wind conditions	Take-off: runway 32 Landing: runway 28	
“Bise” wind conditions	Take-off: runway 10 Landing: runway 14	Take-off from runway 16 possible if take-off from runway 10 is not possible because of performance limitations

1.10.4 Rescue and fire-fighting services

Zurich Airport is equipped with Category 9 fire-fighting resources. The concept guarantees intervention within two to maximum three minutes at any point within the airport area. For this purpose the fire-fighting services maintain two main stations – “Base” and satellite “North” – which are both equipped with fire-fighting appliances in compliance with ICAO recommendations. In addition, there is also the satellite “A” location (at the western end of Fingerdock A), which has a universal extinguisher vehicle.

The airport’s professional fire-fighting services are on permanent stand-by during flight operations at the airport. If an incident occurs, the units are in constant contact with the control tower and the police using appropriate means of communication.

1.11 Flight recorders

1.11.1 Digital flight data recorder DFDR

1.11.1.1 Technical description

The Fairchild flight data recorder system Model F1000 consists of a digital flight data recorder (DFDR) and a triaxial accelerometer.

The data of various aircraft systems and sensors are polled according to a pre-set programme and then forwarded sequentially to the digital flight data recorder. All data, analogue or digital, are converted in the DFDR to a uniform format and stored digitally in a prescribed sequence. For subsequent analysis, the data must be reconverted by an external computer into engineering units (heading in degrees, altitude in feet, etc.).

The DFDR was installed in the rear of the aircraft. It stored the data in a memory unit which was housed in an impact-proof and fire-proof capsule in order to be able to withstand even the impact of a crash. The memory unit can record 64 data units or words for about 50 hours. When the memory is full, the oldest data are automatically overwritten.

The triaxial accelerometer was located in the centre of the fuselage. It recorded the accelerations along the three axes of the aircraft.

Several potentiometers were used as sensors for control movements. In addition, position switches were present to record “discrete conditions” (e.g. gear down).

The digital flight data recorder began to work when one of the engines was running and the parking brake was released.

1.11.1.2 Maintenance and monitoring

The DFDR was checked according to the maintenance manual job card during the last Phase B check on 12 September 2001.

1.11.1.3 Findings

The DFDR Fairchild Model F1000, P/N S703-1000-00, S/N 00548 was recovered from the wreck during the night of the accident. The recorder exhibited minor external damage.

1.11.2 Cockpit voice recorder

1.11.2.1 Technical description

The Sundstrand cockpit voice recorder (CVR) system consisted of a cockpit voice recorder Model AV557C, a microphone monitor and a cockpit area mike (CAM). The CVR was installed in the rear of the aircraft. The microphone monitor was installed in the cockpit in the right meter panel. The CAM was installed in the overhead panel.

The recording device installed was an analogue CVR. This device contains a magnetic tape loop with a recording time of 30 minutes. The tape is divided into four tracks (channels): P1, P2, PA and CAM. Three magnetic heads are arranged sequentially: the erase head, the recording head and the playback head. Before recording, the tape is erased by a conventional erase head. The playback head after the recording head is used for test purposes. The magnetic tape is housed in a shock-proof and fire-proof cassette.

Channels P1 and P2 record the pilot's and copilot's respective conversations using the boom microphone (or handmike). The CAM channel records cockpit conversations and noises. The PA channel is used to record announcements over the public address system.

When the aircraft is parked after a flight, the pilot has the option of erasing the entire tape (bulk erase). This erasure takes place by overlaying a 400 Hz signal using a magnetic coil which covers the entire tape. This makes the recording unusable. The tape is erased when the erase button on the CVR microphone monitor is kept depressed for at least 2 seconds. The 400 Hz signal, together with the old recordings, is again erased before a fresh recording is made.

If the test button on the CVR microphone monitor is depressed, a 600 Hz signal is recorded sequentially on each of the four tracks. A display instrument is actuated via the playback head; this is deflected four times. The 600 Hz signal can also be monitored via the headphone connection on the microphone monitor.

1.11.2.2 Maintenance

The cockpit voice recorder was repaired in February 2000 by an external maintenance company and re-installed in HB-VLV on 24 February 2000. According to the job cards available, after installation the cockpit voice recorder was subjected to several operational checks, performed by Airbase personnel, the last of these was on 12 September 2001. The checks prescribed in each case were confirmed by a signature as having been carried out. No complaints had been noted.

1.11.2.3 Operational check by flight crew

According to Eagle Air Ltd. company check list C560 HB-VLV dated July 1997 the CVR had to be checked before each flight.

Since the last CVR recording of the flight on 12 April 2000, no Eagle Air Ltd. pilot had complained about the CVR system for some 20 months.

1.11.2.4 Findings

The CVR Sundstrand Model AV557C, P/N 980-6005-077, S/N 11747 was recovered from the wreck during the night of the accident. The recorder exhibited minor external damage.

No recordings of the accident flight existed on the CVR. The cockpit conversations recorded on the magnetic tape related to a flight which took place on 12 April 2000. Accordingly, the last recording was made on this date which means some 20 months before the flight involved in the accident.

When the device was opened, the following findings were made:

- the magnetic tape was torn into three parts. The investigation found that this damage was caused by the accident.
- The drive belt from the motor to the tape transport roller had skipped off the drive roller. Thus no new recordings were possible. This damage was not caused by the accident.

1.12 Wreckage and impact information

1.12.1 The impact

Immediately before initial contact with the ground the aircraft was flying on a heading of 350° and its speed over the ground was approx. 200 kts. As a result of forensic investigations of debris from the rear fuselage structure, which contacted with the ground first, it is concluded that the aircraft was in a recovery manoeuvre. The final DFDR recordings confirm the initiation of this recovery manoeuvre. The forensic investigations also showed that at initial impact the aircraft had an attitude of 1-5° nose-up (ANU) and approximately 5° right wing down.

After the first contact with the ground, the aircraft began to tumble about the yaw and pitch axis. In the process it hit the frozen ground several times. During these impacts the tail section, the engines and wings were separated from the fuselage.

The length of the debris field from the site of first impact to where the fuselage of the aircraft came to rest on runway 14 was about 500 m. The width of the debris field extended some 80 m.

According to the investigation of parts of the wreck, the landing gear and flaps of the aircraft were retracted on impact. These findings were confirmed by the DFDR data.

1.12.2 Debris field

Initial contact with the ground occurred to the north of the satellite “North” fire-fighting services on a nature trail. No impact crater was formed because of the hard, frozen ground.

The level debris field extended from the point of initial ground contact to the centre of runway 14/32. Parts of the wreckage were spread over a long area of approximately 40 000 m^2.

The debris field was sub-divided into sectors for documentation purposes. The positions of the larger pieces of wreckage were logged and individual parts of the wreckage were photographed.

1.13 Medical and pathological information

1.13.1 Commander

1.13.1.1 History and medical findings

According to information from the responsible medical examiner, no illnesses relevant to the accident existed.

1.13.1.2 Medical forensic findings

The report of the competent institute for legal medicine comes to the following conclusion:

The injuries were so serious, with crushing of all internal organs, multiple bone fractures and partial surface burns that instantaneous death occurred as a result of the accident. No evidence of pre-existing illnesses could be found.

Likewise all toxicological investigations on common substances (alcohol, various drugs, carbon monoxide and sedatives) in both the blood and urine proved negative. Moreover, no fumes could be found in the lungs.

The pilot (clearly identified by DNA as surname forename) died instantaneously at the time of the accident as a result of the injuries suffered.

1.13.2 Copilot

1.13.2.1 History and medical findings

According to information from the responsible medical examiner, no illnesses relevant to the accident existed.

He occasionally wore spectacles, but met the necessary medical requirements for flying even without spectacles, so no entry on the licence was necessary.

1.13.2.2 Medical forensic findings

The report of the competent institute for legal medicine comes to the following conclusion:

The injuries were so serious, with crushing of all internal organs, multiple bone fractures and partial surface burns that instantaneous death occurred as a result of the accident. No evidence of pre-existing illnesses could be found.

Likewise all toxicological investigations on common substances (alcohol, various drugs, carbon monoxide and sedatives) in both the blood and urine proved negative. Moreover, no fumes could be found in the lungs.

The copilot (clearly identified by DNA as surname forename) died instantaneously at the time of the accident as a result of the injuries suffered.

1.14 Fire

The disintegrating aircraft caught fire about 15 m after initial impact. The front section of the fuselage came to rest on runway 14/32 still burning.

There are no technical or forensic indications that fire broke out on the aircraft before its initial contact with the ground.

At the time of the accident there were approx. 3000 lbs or 1700 litres of fuel on board.

1.15 Survival aspects

1.15.1 Possibilities of surviving the accident

The crash occurred at high speed on frozen ground. The resulting forces acting on the crew were not survivable.

1.15.2 Alarm and rescue

Flight EAB 220 took off at 21:06 UTC from runway 34 and was requested a little later by the aerodrome controller (ADC) to change to the approach control west (APW) frequency, 118.000 MHz.

Shortly afterwards the aerodrome controller noticed that EAB 220's radar echo disappeared from the bright display. After calling the aircraft three times and unsuccessfully enquiring with APW as to the whereabouts of flight EAB 220, the aerodrome controller raised a major alarm at 21:08 UTC.

Shortly after EAB 220's take-off, members of the satellite "North" fire-fighting unit noted unusual noises of a low-flying aircraft, followed by the sound of an impact and the flash of a fire. After the major alarm was raised, the airport fire-fighting services were called out. In addition, the local fire-fighting services in Opfikon and Kloten were called out.

The first intervention was by the satellite "North" fire-fighting unit, subsequently supported by the "Base" fire-fighting unit and the rescue unit. Oil barriers had to be laid out. After the fire had been successfully extinguished, it was ascertained that both occupants were dead.

The fire-fighting services continued their work until 03:00 UTC on the following day. Recovery work continued from daybreak.

1.16 Test and research

1.16.1 Forensic investigations

Forensic investigations were carried out on 72 parts of the aircraft's mechanical, electro-mechanical and avionics systems.

1.16.2 Stall due to ice

Analysis of the recording from comparable flights and the flight involved in the accident revealed no substantial differences concerning control deflections, increase in speed, vertical acceleration and attitude during the initial climb. On the basis of the DFDR recordings it was possible to exclude a stall during the accident flight.

The extent to which icing can alter the aerodynamic behaviour of the aircraft in such a way that identical control movements produce different trajectories was also investigated (see section 1.19).

1.16.3 Investigation of the GNS-XLS control display unit

Enquiries with the manufacturer of the GNS-XLS control display unit revealed that though this unit is able to store data on selected frequencies or the entered flight plan, these data are lost if power fails.

However, selected frequencies were stored in the NAV controller and in the COM controller respectively. This takes place regardless of whether these are entered on the control display unit (CDU) of the navigation management system or on the corresponding controller.

1.16.4 Investigation of the VHF NAV and VHF COM controllers

Investigation of the non volatile memories of the VHF COM controller produced the following results:

- VHF COM #1: the last selected frequency was 128.525 MHz (ATIS in Zurich)
- VHF COM #2: the last selected frequency was 118.000 MHz (approach control Zurich)

Investigation of VHF NAV controllers #1 and #2 produced no conclusive result, so it was not possible to determine the last tuned NAV frequencies.

1.17 Organizational and management information

1.17.1 The operator

1.17.1.1 General

Die Firma Eagle Air Ltd. Air Charter + Taxi war ein kleines Flugbetriebsunternehmen, das von seinem Gründer geleitet wurde. Neben seiner Position als Geschäftsführer stand er auch den Bereichen Technik, Administration und Flugbetrieb vor und flog ebenfalls als Kommandant im Unternehmen. Die Position des Chefpiloten hatte er einer anderen Person zugewiesen.

Der große Kostendruck in der gesamten Branche der Bedarfsluftfahrtunternehmen galt auch für die Eagle Air Ltd., die einem starken Konkurrenzdruck ausgesetzt war.

Eagle Air Ltd. Air Charter + Taxi was a small aviation company managed by its founder. In addition to his position as CEO, he also headed the engineering and maintenance, administration and flight operations departments and also flew as a commander within the company. He had assigned the position of chief pilot to another person.

The high cost pressure in the entire air charter industry also affected Eagle Air Ltd, which was exposed to strong competitive pressure.

1.17.1.2 Operating licence based on the Flight Operations Manual according to VBR I

In 1987, Eagle Air Ltd. first acquired an operating licence for commercial transport of persons and goods. This licence was first renewed in 1992.

A further renewal of the general operating licence, issued on 22 December 1997, was based in accordance with art. 27 LFG and art. 103 LFV on an audit dated 9 December 1997.

1.17.1.3 Air Operators Certificate according to JAR-OPS 1

Eagle Air Ltd. was not certified according to JAR OPS 1.

In 2002 the company Eagle Air Ltd. became Swiss Eagle AG and continued to operate according to VBR I on the basis of an operating licence dated 23 October 2002.

The operating licence according to JAR-OPS 1 was issued on 7 May 2004.

1.17.1.4 Company structure

Die Strahlflugzeugflotte der Firma Eagle Air Ltd. bestand aus einer Cessna CE 550 Citation II und einer Cessna CE 560 Citation V.

Das Flugbetriebsunternehmen beschäftigte drei fest angestellte Flugzeugführer sowie zwei Piloten auf halben Stellen. Die anderen für das Unternehmen arbeitenden Flugzeugführer waren freiberufliche Mitarbeiter.

Eagle Air Ltd. war zum Zeitpunkt des Unfalls nicht nach JAR-OPS 1 zertifiziert.

Eagle Air Ltd.'s jet aircraft fleet consisted of one Cessna CE 550 Citation II and one Cessna CE 560 Citation V.

The operator employed three full-time aviators plus two pilots who worked 50% positions. The other aviators working for the company were freelancers.

At the time of the accident Eagle Air Ltd. was not certificated to JAR-OPS 1.

1.17.1.5 Selection procedure for aviators

Bei der Rekrutierung neuer Flugzeugführer wurde auf standardisierte Auswahlverfahren zur Überprüfung der fachlichen und persönlichen Eignung verzichtet. Der Entscheid zur Übernahme eines Bewerbers in die Position eines Flugzeugführers wurde vom Geschäftsführer auf der Grundlage eines Gesprächs zwischen ihm und dem Piloten gefällt.

When new aviators were recruited, no use was made of standardised selection procedures for verifying professional and personal suitability. The decision to accept an applicant as an aviator was taken by the CEO on the basis of an interview with the prospective pilot.

1.17.1.6 Working climate

Das Arbeitsklima war laut Aussagen von Flugzeugführern des Unternehmens durch den autoritären Führungsstil des Geschäftsführers geprägt, der engen telefonischen Kontakt zu seinen Flugzeugführern während deren Einsätze hielt. Es war nicht ungewöhnlich, dass er ihnen auch während der Flugeinsätze konkrete Handlungsanweisungen vorgab.

Unregelmässige Flugeinsätze und hohe Arbeitsbelastungsspitzen gehören in diesem Geschäft zum Alltag und zehren an den Kräften der beanspruchten Piloten. Dieses galt auch für die Piloten der Eagle Air Ltd. und insbesondere den hier betroffenen Kommandanten.

Die Copiloten flogen nicht gerne mit dem Geschäftsführer, der selbst als Kommandant auf seinen Flugzeugen agierte, da er von ihnen aufgrund seiner dominanten und nicht teamorientierten Verhaltensweise als anstrengend erlebt wurde. Sein Führungsverhalten stand im Kontrast zur CRM-Philosophie. Mit den Leistungen der für sein Unternehmen fliegenden Copiloten war er häufig nicht zufrieden, was er ihnen auch vermittelte.

According to statements by company pilots, the working climate was characterised by the CEO's authoritative style of management, who maintained close telephone contact with his pilots during their duties. It was not unusual for him to lay down specific instructions for their actions even during flying duties.

In this sector, irregular flying missions and high workload peaks are part of everyday life and undermine the reserves of pilots subject to these demands. This also applied to the pilots of Eagle Air Ltd. and in particular to the commander involved.

The copilots did not like to fly with the CEO, who also flew as commander on his aircraft, as he was considered to be tough going because of his dominant and non team-oriented behaviour. His management behaviour was in contrast to the CRM philosophy. He was frequently dissatisfied with the performance of the copilots flying for his company and told them so.

1.17.1.7 Operating procedures - FOM

The FOM (flight operations manual) lays down the relevant fundamentals for flying operations at the time of the accident as follows (quoted *verbatim*):

"FOM 4.03.02 – 200 Use of navigation and anti-collision lights

(...)

The rotating beacon is always on in accordance with the checklist. Strobe lights shall be switched on when taxiing on the runway and shall be switched off when leaving the runway (exception in cloud for preventing vertigo)

FOM 5.02.02 – 200 Copilot piloting the aircraft

In order to maintain and improve his skill in handling the aircraft and to train himself for a future position as PIC, the copilot shall, in addition to taking part in the PIC's meteorological and route briefing etc., carry out part of the flying.

The PIC shall:

- *Perform the take-off and landing himself until passing 200 hrs as PIC.*
- *Perform the take-off and landing personally whenever the following conditions exist: Close to minimum runway length, or crosswind close maximum authorized component or major deficiencies in the aircraft or ground instatllations or any other unfavourable conditions.*

As a rule, the copilot shall be given the opportunity ti fly at the controls from the righthand seat normally up to 50% but at least 25% of the total flight time.

When the copilot is flying the aircraft, the PIC shall perform the copilot's normal duties and not interfere with the flying pilot's disposition and flying, unless these are considered to be contrary to safety regulations and standards.

The handing-over of the controls shall be done with clear confirmation by calling: ***your control / my control.***

FOM 5.03.01 – 5.3 Use of checklist and (...)

The company has established a checklist system to ensure that aircraft are operated correctly and in accordance with the AFM in the different stages of the flight. The PIC shall ensure that the checklist routine is faithfully barried out on all occasions when it is required to be used.
(...)

FOM 11.02.01 – 11.2 Weather Minima for take-off

The weather Minima for take-off of the relevant country must be strictly observed. If there exist no higher local or Jeppesen weather Minima, the following Minima are valid for the Company.

Vertical visibility 0 ft.

Horizontal visibility

Runway lighting	*Aircraft category*		
	A	*B*	*C*
NIL (day only)	*500 m*	*600 m*	*600 m*
RWY Edge lights	*400 m*	*400 m*	*400 m*
RWY Edge lights or centerline lights	*250 m*	*300 m*	*300 m*
RWY Edge and centerline ligths	*150 m*	*150 m*	*150 m*

FOM 15.01.02. – 220 Removal of snow and ice on the ground from the aircraft

Removal of snow and ice on the ground has to be made in accordance with PIC's instructions. Whenever necessary, ground staff shall be advised on aircraft de-icing procedures and a close supervision shall be maintained.

If the aircraft has been sprayed with de-icing to remove snow and ice, the PIC delegated crew member shall instruct the ground crew to arrange that no water enters or is left in static ports or other air intakes where it can easily freeze

Before embarking, the PIC shall make a general inspection of the aircraft and coordinate with the supervisor that the aircraft is not released for taxying before all frost, snow or ice on any part of the aircraft, which may adversely affect its performance or operation, has been removed.

As a guiding rule, take-off with even the smallest amount of ice or frost on any part of the aircraft must not be attempted.

Dry snow shall not be left to blow off during the take-off run.

After snow removal, the tail section and the wings of the aircraft must remain completely clean while the forward section of the fuselage may not get more that 0,5 cm of fresh snow before take-off.

If these conditions cannot be met, snow/ice removal and anti-icing spraying has to be done in the hangar.

After completion of de-icing it is important that take-off is made as soon as possible, therefore, the PIC shall arrange with the control tower, crew and ground personnel that everything is prepared beforehand to reduce the time from starting engines to actual take-off."

1.17.1.8 Internal company instruction concerning de-icing

The CEO expressed himself as follows in this regard:

"*Every aircraft has an appropriate de-icing agent, a five-litre aerosol, plus a 60 cm wide scraper which extends to about 2.50 m in length. Ice on the wing and tail should be sprayed with the agent. It is possible to reach all points with the scraper. All aircraft* *are also equipped with a step. Many places have no facilities. If the aircraft has flown previously, this equipment is generally adequate. At Berne airport and only when the ice is thick, for example when it rains overnight, is the [name of the handling company] de-icing vehicle called in, or wherever the aircraft is parked it should be placed in a hangar to thaw out*."

1.17.1.9 Operating procedures, Cessna CE 560 Citation V

1.17.1.9.1 Anti-collision lights

Eagle Air Ltd.'s company check list C560 HB-VLV is based on the valid airplane flight manual (AFM).

In the company's documents there are no SOP (standard operating procedures) for the Cessna CE 560 in which the individual points of the work checklist are described in greater detail.

One point relevant to the accident is found in the line up checklist:

The checklist item concerning anti-collision and landing lights states "On/as required".

In the AFM, in Section III – Operating Procedures, Normal Procedures, the Before Take-off Check specifies "anti-collision lights and recognition lights – ON" with the following note:

"***NOTE***

Do not operate the anti-collision lights in conditions of fog, clouds or haze as the reflection of the light beam can cause disorientation or vertigo"

1.17.1.9.2 Engine RPM

The idling speeds of the high-pressure compressor (N2) and the corresponding tolerances are found in the AFM in Section III – Operating Procedures, Normal Procedures.

RPM (N2)	Tolerance
gnd idle NORM: min 46.0 %	+1.0 %/-0 %
gnd idle HIGH: min 52.0 %	±0.5 %

In the Eagle Air Ltd. company check list C560 these speed values differ as follows:

RPM (N2)	Tolerance
gnd idle NORM: min 49 % - 50 %	No information
gnd idle HIGH: min 52 % - 53 %	No information

Furthermore, it can be stated that engine start procedures relating to checking the idle speeds differ from the AFM.

1.17.1.9.3 Take-off procedure Cessna 560

The take-off procedure is not described in greater detail in the AFM. In the pilot training manual of the Flight Safety International training organisation the take-off procedure is described as follows:

Sample Pretake-off Briefing:

Figures GEN-1 (Anhang 5.2) *and GEN-2 show accepted Citation V take-off profiles*

Accomplish the following briefing prior to requesting take-off clearance:

1. *"This will be a (static or rolling) take-off with flaps set at (state flap position)." (mention anti-ice if required.)*
2. *"I will advance the throttles, and you set take-off power."*
3. *"Call Airspeed alive, '70 kts', 'V_1', 'rotate', 'V_2' and 'positive rate'."*
4. *"Monitor all engine instruments and the annunciator panel during take-off. At the '70 kts' call, cross-check both airspeed indicators."*
5. *"In the event of a serious malfunction prior to V_1, call 'abort'." (Captain may reserve authority to call abort)*
6. *"If a malfunction occurs at or after V_1, we will continue the take-off. Advise me of the malfunction, and we will handle it as an in-flight emergency. Plan to fly (state intentions)"*
7. *"Departure instructions are (state intentions). The navaids are set to…"*
8. *"Any questions?"*

Normal Take-off:

At V_R, the pilot will rotate the aircraft to a 10° noseup attitude on the ADI and, when a positive rate of climb is indicated, retract the gear. As the airspeed increases through a minimum of V_2 + 10 kts (V_{FS}), retract the flaps. Continue to accelerate to normal climb speed, and complete the After Take-off-Climb checklist.

1.17.1.9.4 Ground de-ice/anti-ice operations

De-icing of the aircraft is recommended in Section IV of the AFM – Advisory Information as follows:

"During cold weather operations, flight crews are responsible for ensuring the airplane is free of ice contaminants.

Ground icing may occur whenever there is high humidity with temperatures of +10 °C or colder. Type I deice, and Type II or Type IV anti-ice fluids may be used sequentially to ensure compliance with FAA regulations (clean wing concept) requiring critical component airframe deicing and anti-icing.

NOTE

It is recommended that flight crews refamiliarize themselves seasonally with the following publications for expanded deice and anti-ice procedures:

- *Cessna Maintenance Manual Chapter 12.*
- *FAA Advisory Circular AC 120-58 (large aircraft), dated September 30, 1992 or later.*

- *FAA Advisory Circular AC 135-17 (small aircraft), dated December 14, 1994 or later.*
- *Cessna Citation Service Letter SL560-30-08, dated May 29, 1998, or later.*

DEICING/ANTI-ICING PROCEDURES (TYPE I, TYPE II, AND TYPE IV FLUIDS)

ONE STEP DEICING – Type I fluid is used to remove ice, slush and snow from the airplane prior to departure, and to provide minimal anti-icing protection, as provided in the Type I holdover timetable (refer to applicable service letter).

TWO STEP DEICE/ANTI-ICE – May be used to ensure the airplane remains clean after deicing. Type II or Type IV fluid is used to provide longer term anti-icing protection, as provided in the Type II or Type IV holdover timetable (refer to applicable service letter).

CAUTION

TYPE I, TYPE II, AND TYPE IV FLUIDS ARE NOT COMPATIBLE AND MAY NOT BE MIXED. ADDITIONALLY, MOST MANUFACTURERS PROHIBIT MIXING OF BRANDS WITHIN A TYPE.

Line personnel should be supervised by the PIC or SIC to ensure proper application of deice or anti-ice, fluids. Refer to figures 7-5 and 7-6.

NOTE

The first area to be deiced/anti-iced should be easily visible from the cabin/cockpit and should be used to provide a conservative estimate for unseen areas of the airplane before initiating take-off roll.

Holdover timetables (refer to applicable service letter) are only estimates and vary depending on many factors which include temperature, precipitation type, wind and airplane skin temperature. Holdover times are based on mixture ratio. Times start when the last application begins.

Guidelines for holdover times anticipated by SAE Type I, Type II, or Type IV, and ISO Type I, Type II, or Type IV fluid mixtures are a function of weather conditions and outside air temperature (OAT).

CAUTION

- *AIRPLANE OPERATORS ARE SOLELY RESPONSIBLE FOR ENSURING HOLDOVER TIMETABLES CONTAIN CURRENT DATA.*
- *TABLES ARE FOR USE IN DEPARTURE PLANNING ONLY AND THEY SHOULD BE USED IN CONJUNCTION WITH PRETAKE-OFF CONTAMINATION CHECK PROCEDURES.*

NOTE

- *Tables do not apply to other than SAE or ISO Type I, Type II or Type IV FPD fluids.*
- *The responsibility for the application of this data remains with the user.*
- *The freezing point of Type I, Type II, and Type IV fluid mixture must be at least 10 °C (18 °F) below the current OAT.*

SPRAYING TECHNIQUE – TYPE I FLUID

Type I fluid should be sprayed on the airplane (with engines off) in a manner which minimizes heat loss to the air. If possible, fluid should be sprayed in a solid cone pattern of large coarse droplets at a temperature of 160 ° to 180 °F. The fluid should be sprayed as close as possible to the airplane surfaces, but not closer than 10 feet if a high pressure nozzle is used. Refer to Figures 7-5 and 7-6 for essential areas to be deiced and anti-iced.

SPRAYING TECHNIQUE – TYPE II FLUID

Application techniques for Type II fluid are the same as for Type I, except that since the airplane is already clean, the application should last only long enough to properly coat the airplane surfaces. Refer to Figure 7-5 and 7-6 for essential areas to be deiced/anti-iced.

Type II, fluid should be applied cold to a "clean" airplane. It is, however, sometimes heated and sprayed as a deicing fluid. For this case, it should be considered a Type I fluid, as the heat may change the characteristics of the thickening agents in the fluid. Type II fluid, therefore, applied in this manner, will not be as effective as if it were applied cold.

SPRAYING TECHNIQUE – TYPE IV FLUID

Application techniques for Type IV fluid are the same as for Type I, except that since the airplane is already clean, the application should last only long enough to properly coat the airplane surfaces. Refer to Figure 7-5 and 7-6 for essential areas to be deiced/anti-iced.

Type IV, fluid should be applied cold to a "clean" airplane. It is, however, sometimes heated and sprayed as a deicing fluid. For this case, it should be considered a Type I fluid, as the heat may change the characteristics of the thickening agents in the fluid. Type IV fluid, therefore, applied in this manner, will not be as effective as if it were applied cold.

NOTE

- *Holdover time starts when last application has begun.*
- *Some Type IV fluids could form a thick or high-strength gell during "dry-out" and when rehydrated form a slippery film.*
- *Some Type IV fluids exhibit poor aerodynamic elimination (flow-off) qualities at colder temperatures.*
- *Heated areas of aircraft (i.e.; heated leading edge) should be avoided due to the fact that fluid may "dry-out" into hard globular nodules.*
- *Type IV fluid should not be used undiluted below -24 °C (-11 °F).*

PRETAKE-OFF CONTAMINATION CHECK – GROUND ICING CONDITIONS

When ground icing conditions are present, a pretake-off contamination check should be conducted by the PIC/SIC within 5 minutes prior to take-off, preferably just prior to taxiing onto the active runway. Critical areas of the airplane such as empennage, wing, windshield and control surfaces should be checked to ensure they are free of ice, slush and snow or that the deice/anti-ice fluids are still protecting the airplane. Refer to Figure 7-5 and 7-6 for essential areas to be deiced/anti-iced."

1.17.2 The maintenance company

The first licence for aircraft maintenance operations was issued to the Airbase Ltd. company by the FOCA on 11 January 1990.

The application for JAR-145 certification was submitted by a new director as the accountable manager on 9 July 1992.

This director took over Airbase Ltd., Belp, on 17 November 1994.

The first recommendation to issue a maintenance operations licence according to VLU/JAR-145 (JAA Form six Part 4) was issued by the FOCA on 2 December 1994.

From 1995 the maintenance company was audited several times with regard to fulfilment of VLU/JAR-145. The recommendations to renew the maintenance operations licence according to JAR-145 (JAA Form six Part 4) were issued respectively on 6 January 1998 with 9 complaints and on 10 February 2000 with 23 complaints.

No licensed technical specialist was employed by the company Airbase Ltd. Belp to work on electrical and electronic equipment. In each case licensed personnel from a third-party company were called in to carry out this work.

The following documentation for work performed on HB-VLV could not be provided by the operator or Airbase Ltd. Belp by the time of completion of the investigation:

- job cards, calibration and test records for the angle of attack modification according to service bulletin (SB) 560-34-70 (see also section 1.6.10.1).
- airworthiness certificate (Form one) for the installed remote vertical gyro. Airbase Ltd. provided a respective copy in association with their comment, dated December 13th 2004, on the draft of this investigation report
- job cards and the required ground run records for carrying out an engine change. Airbase Ltd. provided a respective copy in association with their comment, dated December 13th 2004, on the draft of this investigation report
- job cards and documentation for all repairs carried out.

1.17.3 The supervisory authority

1.17.3.1 General

The laws and ordinances on aviation in Switzerland are based on the recommendations of the International Civil Aviation Organisation (ICAO). For commercial aviation operators, the requirements and rules of the Joint Aviation Authorities (JAA), which are embedded in the Swiss legislation, also apply.

According to the Federal Aviation Law (*Luftfahrtgesetz*), the Federal Council exercises supervision over aviation throughout the Swiss Confederation. Direct supervision of civil aviation is the responsibility of the Federal Office for Civil Aviation (FOCA), which is an office of the Federal Department of Environment, Transport, Energy and Communications (DETEC).

1.17.3.2 Structure

At the time of the accident, the Federal Office for Civil Aviation (FOCA) had approximately 150 employees. At the beginning of 2001, a reorganisation project was implemented which resulted in the Office having a process-oriented structure. Thus the FOCA units can be classified into three divisions: the first consisted of operational business, conducted by seven process teams. The second area constituted the centres of competency, which to a certain extent were subordinated to the processes. The employees in these units were fundamentally integrated into the processes where they applied the specialist knowledge of their centre of competency in the production of the respective products. The third area was the management of the Office, with the supporting units, which performed functions across the divisions and ensured the operation of the organisation.

In relation to the accident, the following processes are of importance:

- Process Infrastructure Planning (IP) – with the Aviation Infrastructure Plan (*Sachplan Infrastruktur der Luftfahrt* - SIL) this process provided the central planning framework for the development of the civil aviation infrastructure in Switzerland. The concepts and planning fundamentals also included the radio navigation plan and the radio frequencies plan, as well as economic development of the airspace structure. IP was additionally responsible for air traffic control procedures and hence also for supervision of the Swiss air navigation services company skyguide, for fixing aviation charges and for aviation information relevant to safety.
- Process Air Transport Companies (*Luftverkehrsbetriebe* - LV) – this process was responsible for licensing and operational supervision of air transport companies. This also included the technical monitoring of aircraft and the SAFA ramp checks, within the framework of which foreign aircraft and crews are randomly checked on Swiss aerodromes. A corresponding organisation for Swiss aircraft was planned at the time of the accident but had not yet been introduced.
- Process Aerotechnical Organisations (Flugtechnische Betriebe - FT) – the FT process is responsible for licensing and continuous supervision (including periodic audits) of some 100 aircraft maintenance companies, more than 20 manufacturing companies and training companies for aircraft maintenance personnel. The FT process also deals with licences in the maintenance sector. The regulations and procedures are based on the European standards of the Joint Aviation Authorities (JAR 145, JAR 21, JAR 147, JAR 66) and national decrees (VUP).

1.17.3.3 The introduction of JAR-OPS 1 in Switzerland

On the occasion of a conference on 29 April 1997 the FOCA explained to representatives of the Swiss aviation companies the introduction of JAR-OPS 1, which was to be implemented by 1 April 1998 at the latest.

Capacity bottlenecks in the FOCA were found to exist during this introduction. Consequently, the introduction of JAR-OPS 1 concentrated primarily on the larger aviation companies. Some applications from smaller companies were deferred.

The transitional regulations were defined in article 9 of VJAR-OPS 1 as follows (quote):

1. *Für die Besatzungszeiten gelten bis zur Inkraftsetzung der entsprechenden Bestimmungen von JAR-OPS 1 (Subpart Q) durch das Bundesamt die Vorschriften der Verordnung vom 23. November 1973 über die Betriebsregeln im gewerbsmässigen Luftverkehr (Ziff. 4.7).*

   Until implementation of JAR-OPS 1 (Subpart Q) by the FOCA, regulations for flight duty times in accordance with the ordinance on operating procedures in commercial aviation (Ziff 4.7), dated 23rd November 1973, remain effective.

2. *Das Bundesamt setzt jedem Flugbetriebsunternehmen eine Frist, in der es den Betrieb und das Betriebsreglement den Bestimmungen dieser Verordnung und JAR-OPS 1 anzupassen hat.*

   The FOCA sets each operator a timeframe during which the operation and the operations manual have to be adapted to the regulations of this ordinance and of JAR-OPS 1.

3. *Bis zur Genehmigung des angepassten Betriebsreglementes bleibt das bestehende Recht anwendbar.*

   Existing regulations remain effective until approval of the adapted operations manual.

Diese Verordnung tritt am 1. November 1997 in Kraft.

This ordinance becomes effective on 1st November 1997.

unquote

The FOCA supervised the operator Eagle Air Ltd. in accordance with the ordinance on operating procedures in commercial aviation (Verordnung über die Betriebsregeln im gwerbsmässigen Luftverkehr – VBR I).

1.17.3.4 Introduction of JAR-OPS at Eagle Air Ltd.

See section 1.17.1.3

1.17.4 Air traffic control

1.17.4.1 Aerodrome control

Aircraft which take off, land or cross runways are controlled by skyguide’s aerodrome control, located in the control tower. For this purpose, depending on the traffic volume, skyguide operates the four units ADC 1, ADC 2, GRO and clearance delivery (CLD) at up to four different workstations. A duty manager (DM) is responsible for supervising duty operations in the control tower and in the approach and departure unit.

1.17.4.2 Assignment of personnel

At the time of the accident, skyguide’s sector allocation plan envisaged 4 working positions at the console in the control tower. In fact, 3 working positions were occupied.

One controller had not turned up for duty because of illness. The duty manager (DM) therefore had to implement the personnel plan with one less controller. This meant that at the time of the accident he additionally had to cover the function of ground control (GRO).

1.17.4.3 All weather operations and low visibility procedures

In accordance with skyguide instructions, under certain weather conditions, several procedures became effective within the framework of all weather operations.

Among other things the following definitions applied:

“All Weather Operations (AWO)

Any taxi, take-off, or landing operation in conditions where visual reference is limited by weather conditions.

Low Visibility Procedures (LVP)

Specific procedures applied at an aerodrome for the purpose of ensuring safe operations during Category II and III approaches and landings, and Low Visibility Take-Offs.

Low Visibility Take-Offs (LVTO)

A take-off on a runway where the RVR is 375 m or less at any position of the departure runway.

Low Visibility Operations (LVO)

Flight operations, which take place during take-offs conducted on a runway where the RVR is 375 m or less, as well as approaches and landings in Category II and III weather conditions."

The implementation of operations under low visibility conditions (LVO) took place in several phases.

In the preparation phase, which begins in the event of runway visual ranges (RVR) in the touch down zone (TDZ) of 750 m or less, various precautions have to be taken. Pilots were not informed about this phase.

The beginning of the application phase differed for take-offs and landings:

- landing: an RVR value of 550 m or less in the TDZ area
- take-off: an RVR value of 375 m or less along the runway

In above cases crews must be informed via ATIS or by radio: "*Low visibility procedures in operation*". In addition, the RVR values for the touch down zone and stop-end have to be transmitted.

Additionally in the application phase, various measures were taken which are listed in annex 5.3.

1.17.4.4 Transmission of RVR values

The ADC controller did not transmit any RVR values to flight EAB 220 as part of the take-off clearance.

1.17.5 Flughafen Zürich AG - Unique

1.17.5.1 General

Flughafen Zürich AG (Unique) is the Confederation's licensee and operates Zurich Airport. In this capacity, it performs the following operations-related tasks in particular: apron control, apron service, duty office, security zone protection and cantonal reporting centre for obstacle limitation, security, plus fire-fighting and safety, maintenance services including winter service, environmental protection and aircraft noise management.

With regard to skyguide, the duty officer was the Unique contact concerning deviations from the runway utilisation concept.

1.17.5.2 Apron Control

Flughafen Zürich AG (Unique) is responsible for controlling aircraft and vehicles on the ground on the apron, on the taxiways south of runway 28 and east of runway 16, on some sections of taxiways north of runway 28 in the area of the new Dock E and in the area of taxiways "Romeo" and "Romeo 8" as well as the "Whiskey" stands.

1.17.6 Restrictions at Berne-Belp airport

Berne-Belp airport was open from Monday to Friday for non-scheduled flights as follows:

Monday to Friday: 07:00 – 22:00 LT, from 20:00 LT for landings only.

20 December 2001 was a Thursday. On the basis of a special authorisation, which the CEO of Eagle Air Ltd. had obtained from the airport's management, HB-VLV was permitted to land in Berne-Belp up to 22:30 LT (21:30 UTC) latest.

1.18 Additional information

1.18.1 Take-offs under instrument meteorological conditions

1.18.1.1 General

Since 1982 the ICAO manual of all-weather operations has recommended technical and operational guidelines which are of significance for operations under instrument meteorological conditions. The basics relating to low visibility procedures (LVP) also affect aviation companies such as Eagle Air Ltd. in connection with low visibility take-off (LVTO).

In chapter 4 of the manual, Basic Requirements for the Aeroplane and Flight Crew, the operator should comply with the following operational points summarised in brief, especially for LVTO:

- Theoretical and practical training to the crew members as appropriate to their duties.
- Standard and abnormal situations during take-off in reduced visibility.
- Recurrent crew training in association with proficiency checks.

Among other things, the following facts are relevant to this accident:

- As soon as the runway visual range (RVR) falls below 400 m, in accordance with AIP Switzerland LVP should also be applied for take-offs for flight operations in Zurich.
- There were no procedures for LVP in the Eagle Air Ltd. operating procedures.
- The commander of the flight involved in the accident completed LVP training whilst with his previous employer. He had practical experience of LVP operations.
- The copilot did not have any LVP training.

1.18.1.2 Instrument take-offs in IFR basic training

1.18.1.2.1 General

The investigation revealed that at the time of the accident IFR basic training did not go into detail about the characteristics of an instrument take-off. The objective of such training is to prepare for making a low visibility take-off.

The only evidence in relation to training for instrument take-offs is chapter 4 of the IFR Flight Instruction Programme prescribed by the FOCA.

1.18.1.2.2 Commander

As the FOCA documents show, the commander completed his IFR basic training according to the IFR Flight Instruction Programme on 4 August 1994.

The commander's training record shows five night instrument take-offs.

1.18.1.2.3 Copilot

As the FOCA documents show, the copilot completed his IFR basic training according to the IFR Flight Instruction Programme on 21 April 1998.

During his IFR basic training, the copilot did not make any night instrument take-offs.

1.18.2 Instrument flight rules procedures in Zurich

1.18.2.1 General

The procedures for instrument flight rules in force at the time of the accident were published in the Jeppesen route manual, based on the Swiss AIP aviation manual.

1.18.2.2 Minimum visual ranges for take-offs under instrument meteorological conditions

The required minimum visual ranges for take-offs from runway 34 under instrument meteorological conditions were published as follows in the Jeppesen route manual used by the crew:

Runway lighting	Aircraft category		
	A	B	C
NIL (day only)	500 m	600 m	600 m
Runway lights (RL) or centreline lights (CL)	250 m	300 m	300 m
Runway lights (RL) and centreline lights (CL)	200 m	200 m	200 m
Runway lights (RL), centreline lights (CL) and multiple RVR values required	150 m	150 m	150 m
Approved operators	125 m	125 m	125 m

The aircraft involved in the accident was classified category B.

1.18.2.3 Standard instrument departure "Willisau 3N"

The standard instrument departure "Willisau 3N" for runway 34 was described in the Jeppesen route manual (annex 5.4):

"WIL 3N ❷

On 335° track (use ILS 16 for track guidance) to KLO 4 DME or 3500', whichever is later, turn left (max IAS 210 kts), 245° track, intercept TRA R-192 to BREGO Intersection, intercept WIL R-055 inbound to WIL VOR-DME. Initial climb clearance 5000'

Cross BREGO Intersection at or above 6000', ZH551 Intersection and WIL VOR-DME at or above 7000'

❷ Between 22:00 and 07:00 LT, if 3500' is not reached at KLO 4 DME advise ATC, 336° track (Rwy 32) or 335° track (Rwy 34) to KLO 9 DME, turn left, intercept TRA R-192."

1.18.2.4 Noise abatement procedure

The noise abatement procedure (NAP) was described in general in the Jeppesen route manual as follows:

"DEPARTURES

(...)

Deviation from SIDs as depicted on Zurich SID charts is only possible at altitudes above 5000' (above FL80 between 2201-0600LT for departures in direction of Albix Int or Gersa Int) with ATC approval. As far as possible a rolling take-off is executed. Engine power shall be increased only after entering take-off runway. After lift-off climb with maximum climb gradient considering flight safety.

FAN-JET ENGINED AIRCRAFT

Take-off to 2900'	*Take-off power.* *Take-off flaps* *Climb at V2+10 Kt (or as limited by body angle)*
At 2900'	*Reduce thrust to not less than climb power*
2900' – 4900'	*Climb at V2+10 (or as limited by body angle)*
At 4500'	*Normal speed and en-route climb configuration*

(...)"

1.19 New methods of investigation

1.19.1 Use of a numeric simualtion

Icing on wings and control surfaces which could have had an effect on the trajectory was considered as a possible cause of the accident in view of the following factors:

- meteorological conditions at the time of the accident
- pilots' statements about icing conditions on the evening of the accident
- a witness statement from an airport manager, who observed a crew member of HB-VLV removing ice immediately before taxiing
- at least one accident involving the same aircraft type due to icing is documented

DFDR data evaluation did not allow any conclusion whether possible icing on wings or horizontal stabilizer had an impact on the aerodynamical characteristics.

The aircraft manufacturer could not provide a simulation programme for the Cessna CE 560 Citation V which might have made it possible to perform calculations of the flight path in the event of icing on wings or control surfaces.

The extent to which icing can alter aerodynamical characteristics of a Cessna CE 560 in such a way that identical control movements produce different trajectories was investigated with the help of an aerodynamical model. This model enabled a numerical simulation of the take-off phase taking into account the influence of various factors.

The aircraft manufacturer provided aerodynamical data and parameters. Those data were integrated into an existing simulation model. DFDR data from earlier flights of HB-VLV were used to prove plausibility of the simulation results of the accident flight.

The investigation proved that the flight path of the Cessna CE 560 after take-off was consistent with the control deflections. Therefore, an influence on the aerodynamical characteristics of the aircraft as a result of icing on wings and horizontal stabilizer can be excluded with a high degree of probability.

2 Analysis

2.1 Technical aspects

2.1.1 Aircraft control - flaps

The DFDR recordings show that the flaps were retracted 14 seconds after take-off at 524 ft above ground level (AGL).

At the same time the elevator trim tabs began to move in the nose down direction. The trim tab movement lasted for 8.5 seconds. In 42 previous take-offs the average duration of trim operation by the crew, when retracting the flaps from 15° to 0°, was 2.55 seconds.

In the range of flap movement between 15° and 25° electrical elevator trim is actuated automatically to equalise the control forces which are generated. This trim tab adjustment amounts to about 1° to 1.5°.

It was investigated whether, during the flight involved in the accident, the automatic elevator trim had been actuated because of a malfunction during flap retraction from 15° to 0°. The results of the investigation were as follows:

- The flaps had been retracted after the landing in Zurich from 40° to 0° and subsequently extended again to 15°. This position remained unchanged until take-off.
- Analysis of the DFDR recordings for the five preceding flights showed that the automatic elevator trim was working normally for flap extension and retraction between 15° and 25°.
- It was possible to recover the mechanism with the micro switches for actuating automatic elevator trim in a relatively good condition. The investigation determined that the position of the micro switches was set correctly.

No indications could be found that the relatively long trim time during the climb is attributable to a fault (see also section 2.2.3.1).

2.1.2 Cockpit Voice Recorder

It could not be ascertained why the CVR defect was neither detected nor complaint by pilots or the maintenance provider for about 20 months.

2.1.3 Airworthiness

There is no indication that aircraft HB-VLV was not in an airworthy condition at the time of the accident.

2.2 Human, operational and organizational aspects

2.2.1 Working basis

Since the cockpit voice recorder did not record the conversations during the flight involved in the accident, there is no clear evidence of the work distribution between the commander and copilot, or rather the pilot flying (PF) and the pilot non flying (PNF). On the basis of detailed examination and comparison of the take-off characteristics of previous flights made by the commander and the copilot, it can be assumed with a high degree of probability that on the flight involved in the accident the commander was PNF and the copilot was PF.

This assumption is based on the following facts:

- According to statements by employees of the operator, it was customary to allow the copilot to fly the aircraft as PF on ferry flights.
- The flight from Biggin Hill (UK) to East Midlands (UK) was a ferry flight and according to records in the personal log book it was made with the copilot as PF.
- The flight from East Midlands (UK) to Zurich was a passenger flight and was made with the commander as PF.
- The flight from Zurich involved in the accident was a ferry flight.
- According to statements by employees of the operator the commander was known to allow copilots to take off fairly often.
- On the accident flight, the commander conducted radio communications with ATC; this is typically one of the PNF's duties.
- The manner in which engine power was set on take-off corresponded to the power setting during the take-off from Biggin Hill (UK), during which the copilot was PF. It differed clearly from the power setting of the flight from East Midlands (UK) to Zurich where the PIC was PF.
- The manner in which the elevator control was applied during the take-off of the accident flight corresponded to that of the take-off from Biggin Hill (UK), during which the copilot was PF. It differed recognisable from the flight control handling of the flight from East Midlands (UK) to Zurich where the PIC was PF.

2.2.2 The "SHEL" model

The origin of aircraft accidents can often be explained by the complex interaction of human, technical, operational and environmental factors. In terms of the analysis, therefore, a systematic approach was chosen which not only describes the obvious errors but also analyses the fundamental situation and ascertains the deeper-lying causes of primary errors.

In order to make relationships clearer and clarify the flight crew's behaviour and decision-making processes, the "SHEL" model recommended by the International Civil Aviation Organisation in "Human Factor Digest No. 7" was applied. This tool is a model for considering the interaction of people with other people and technical equipment in a specific working environment. The four letters "S-H-E-L" are an abbreviation of the four components of the model:

S – software	Non-material part of the system which consists mainly of procedures, checklists, rules and regulations.
H – hardware	Technical systems such as the aircraft, equipment, etc.
E – environment	The environment includes all external factors such as the weather, other aircraft, air traffic control, operators and the supervisory authority.

L – liveware	The human being, with his variations and limits is placed at the centre of the model. Several L elements may interact with each other (commander, copilot, etc.)

For the investigation of the present aircraft accident, the commander and copilot were taken as the central starting points for the liveware (L) element. The type of interaction of the two flight crew members constituted another important subject of investigation (L-L). Furthermore, the relationships between the flight crew and the aircraft (L-H) and the interface between flight crew and procedures (L-S) were considered. As a final point, the effect of the environment on the flight crew procedures was examined (L-E). This environment, in addition to the weather and air traffic control, also included the operator and the supervisory authority.

2.2.3 Commander (L)

2.2.3.1 Behaviour during the flight involved in the accident

Der Kommandant dürfte sehr motiviert gewesen sein, den Rückflug nach Bern-Belp noch an diesem Abend durchzuführen. Ein Motiv lag vermutlich in dem vom Geschäftsführer über das Mobiltelefon übermittelte „Wunsch" zur Rückverbringung des Flugzeugs zum Heimatflughafen, was als eine Vorgabe zu verstehen war. Des Weiteren war es ihm auch ein Bedürfnis möglichst bald wieder bei seiner Familie zu sein, um mit ihr den bevorstehenden arbeitsfreien Tag verbringen zu können. Nicht zuletzt war ihm dieses Bedürfnis wichtig, weil er durch seine fliegerische Tätigkeit allzu oft von seiner Familie getrennt war.

Wie aus der Sprechfunkaufzeichnung, dem charakteristischen Setzen der Leistungshebel und dem Steuerungsverhalten um die Querachse zu erkennen ist, überliess der Kommandant die Steuerung des Flugzeuges seinem Copiloten.

Der Kommandant war ein gutmütiger Mensch, der zuvor gezeigt hatte, dass er Copiloten Optionen ermöglichte, die nicht immer den Verfahrensvorschriften entsprachen. Da er über eine entsprechende fliegerische Erfahrung verfügte, dürfte er davon ausgegangen sein, Derartiges verantworten zu können.

Diese Vorgehensweise war in dem Luftfahrtunternehmen üblich, da Copiloten vorzugsweise bei Leerflügen als pilot flying (PF) agieren sollten. Daher ist es wahrscheinlich, dass auch das Setzen der Triebwerksleistung für den Start durch den Copiloten als PF erfolgte. Ob der Kommandant eingriff, als die Triebwerke ungleichmässig beschleunigten und das Flugzeug nach rechts auszubrechen drohte, muss offen bleiben.

In einer Höhe von 300 bis 400 Fuss über Grund begann der das Flugzeug steuernde Copilot den Neigungswinkel (pitch) des Flugzeugs zu reduzieren. Rund drei Sekunden später wurden die Landeklappen eingefahren. Aufgrund der vom Kommandanten praktizierten crew co-ordination kann davon ausgegangen werden, dass er dieses als PNF ausführte. Das sich danach deutlich verstärkende Absinken des pitch wurde von ihm während der darauf folgenden 13 Sekunden nicht registriert, da er nunmehr vermutlich mit der Ausführung einer anderen Tätigkeit beschäftigt war. Wahrscheinlich galt seine Aufmerksamkeit dem Einstellen der Frequenz am Funkgerät, da er Funkkontakt mit einer anderen Flugsicherungsstelle aufnehmen sollte.

Ermüdungserscheinungen als Folge der vorausgegangenen Flüge könnten ihn bei dieser Tätigkeit beeinträchtigt haben, so dass er der Überwachung der Tätigkeiten des Copiloten und dem Mitverfolgen der Fluglage auf seinem künstlichen Horizont (monitoring), dem in dieser Flugphase wichtigstem Fluginstrument, nicht genügend Aufmerksamkeit widmete.

Eventuell könnte er auch durch ein anderes Ereignis wie ein im Cockpit auftretendes Signal – zum Beispiel dem Klingeln eines Mobiltelefons - abgelenkt worden sein.

The commander was probably highly motivated to make the return flight to Berne-Belp that evening. One motive was presumably the CEO's "wish", communicated via the mobile telephone, to return the aircraft to its home airport, which was meant to be understood as an instruction. Furthermore, he also needed to get back to his family as soon as possible in order to spend the following day off with them. This need was important to him, because his flying frequently kept him away from his family.

As is apparent from the radio communications recording, the characteristic setting of the power lever and the control behaviour around the pitch axis, the commander handed over control of the aircraft to his copilot.

The commander was a good-natured person who had previously shown that he gave copilots options which did not always correspond to procedures. Since he had appropriate flying experience, he may have assumed that he could take responsibility for such actions.

This behaviour was customary in the aviation company, since copilots should preferably act as pilot flying (PF) on ferry flights. It is therefore probable that the copilot, as PF, also set the engine power for take-off. It must remain open whether the commander intervened when the engines accelerated unevenly and the aircraft began to veer to the right.

At a height of 300 to 400 feet above ground level, the copilot controlling the aircraft began to reduce the pitch of the aircraft. The flaps were retracted some three seconds later. On the basis of the crew co-ordination practised by the commander, it can be assumed that he did this as PNF. He did not register the subsequent marked reduction in pitch over the next 13 seconds, presumably because he was busy with other activities. He was probably giving his attention tuning the radio, as he had to establish radio contact with a different air traffic control unit.

When carrying out this activity, he may have been affected by fatigue as a result of the preceding flights, and so did not pay sufficient attention to monitoring the copilot's activities including observing the attitude on his artificial horizon, the most important flight instrument in this phase.

He may possibly also have been distracted by another event such as signal inside the cockpit – e.g. the ringing of a mobile telephone.

2.2.3.2 Psychological aspects

Aus den vorliegenden Informationen ergibt sich kein Hinweis darauf, dass sich der Kommandant zum Zeitpunkt des Unfalls in einer außergewöhnlichen psychischen Belastungssituation befand, die ihn in kognitiver und/oder emotionaler Weise so stark beeinträchtigte, dass er nicht zum Führen eines Flugzeugs in der Lage gewesen wäre.

From the information available there is no indication that at the time of the accident the commander was in an unusual situation of mental stress which affected him to such a cognitive and/or emotional extent that he would not have been able to control an aircraft.

2.2.3.3 Physiological aspects

Nach allen verfügbaren Informationen war der Kommandant zum Zeitpunkt des Unfalls gesundheitlich nicht beeinträchtigt. Es gab keinen Hinweis auf das schleichende oder akute Auftreten einer die Flugtauglichkeit massiv beeinträchtigenden physiologischen Störung (incapacitation).

According to all the information available, the commander had no health problems at the time of the accident. There was no indication of the gradual or acute onset of any physiological incapacitation which would have had a massive adverse effect on flying ability.

2.2.4 Copilot (L)

2.2.4.1 Behaviour during the flight involved in the accident

Der Copilot dürfte motiviert gewesen sein, den Rückflug nach Bern-Belp noch an diesem Abend durchzuführen. Gründe dafür dürften neben dem vom Geschäftsführer geäusserte „Wunsch" zur Rückkehr des Flugzeugs nach Bern-Belp insbesondere die eigenen Terminverpflichtungen am nächsten Tag gewesen sein.

Diese Ausgangsmotivation, verbunden mit der Möglichkeit, das Flugzeug selbst steuern zu können sowie die vorhandene Bereitschaft zur Rückkehr nach Bern-Belp seitens des Kommandanten dürften zur Durchführung dieses Fluges geführt haben.

Kurz nach dem Abheben von der Startbahn und dem Einfliegen in die unerwartete Nebelwand (IMC) sowie dem Einfahren des Fahrwerks und der Landeklappen musste das manuell gesteuerte Flugzeug vom PF in einer stabilen Fluglage gehalten werden.

Die vom DFDR kurz nach dem Einfahren der Landeklappen aufgezeichnete und für diese Flugphase ungewöhnliche Flugzeugbewegung (kontinuierlicher Übergang von maximal +10 Grad vor der maximal erreichten Flughöhe zwischen 500 und 600 Fuss über Grund in einen Neigungswinkel von –12 Grad), dürfte von dem PF nicht bewusst herbeigeführt worden sein. Dieser aussergewöhnliche Regelungsvorgang um die Querachse muss auf die Steuereingabe durch den PF zurückgeführt werden. Der Copilot hatte die Konsequenzen dieser Systemeingabe nicht sofort erkannt, da er keine rechtzeitige Gegenkorrektur ausführte. Seine Aufmerksamkeit konnte dabei durch langsam wirksam werdende Ermüdungserscheinungen als Folge der vorausgegangenen Flüge kurzzeitig reduziert gewesen sein, so dass er den künstlichen Horizont als sein primäres Fluginstrument nicht genügend beachtete. Wahrscheinlicher dürfte aber eine kurzzeitige Ablenkung seiner Aufmerksamkeit durch einen äusseren Reiz gewesen sein, wie zum Beispiel ein im Cockpit auftretendes Signal oder eine Handlung des Kommandanten. Dabei konnte es sich auch um das Greifen nach einem Gegenstand gehandelt haben.

Durch das Anheben der Flugzeugnase bei Dunkelheit und Nebel gingen die Sichtreferenzen zur Pistenbefeuerung verloren. Dadurch liess sich die Fluglage des Flugzeugs nicht mehr mittels Orientierung am natürlichen Horizont erkennen. Der auf der Seite des Copiloten eingebaute künstliche Horizont mochte aufgrund seiner Baugrösse und der geringen Ablesegenauigkeit für den mit diesen Flugbedingungen vergleichsweise unerfahrenen Copiloten keine ausreichend schnelle Orientierung über die aktuelle Fluglage ermöglicht haben. Im Folgenden könnte der Copilot durch eine schnelle Drehung des Kopfes den Blick auf den ergonomisch besser ablesbaren linken künstlichen Horizont des Kommandanten gerichtet haben, um eine korrekte und präzise Lageorientierung zu finden, was ihm aber nicht mehr rechtzeitig gelang.

Einen Start unter vergleichbaren Wetterbedingungen, wie denen am Unfallabend, dürfte er mit hoher Wahrscheinlichkeit zuvor selbst niemals durchgeführt haben.

The copilot was probably motivated to make the return flight to Berne-Belp that evening. The reasons for this, apart from the CEO's "wish" to have the aircraft returned to Berne-Belp, may have included the copilot's own obligations the next day.

This initial motivation, combined with the possibility of being able to fly the aircraft himself and the commander's own readiness to return to Berne-Belp, may have led to the flight being made.

Shortly after lifting off from the runway, flying into the unexpected wall of fog (IMC) and retracting the gear and flaps, the manually controlled aircraft had to be maintained by the PF in a stable attitude.

The aircraft's change in pitch (continuous transition from max. +10 degrees before the maximum altitude achieved of between 500 and 600 feet above ground level to a pitch angle of –12 degrees) recorded by the DFDR shortly after retraction of the flaps, which was unusual for this phase of the flight, must have been carried out inadvertently by the PF. This unusual control procedure about the pitch axis has to be attributed to control input by the PF. The copilot had not immediately realised the consequences of this system input, as he did not make any timely correction in the opposite direction. His attention may have been reduced briefly as a result of slow-acting phenomena of fatigue as a result of the previous flights, so that he did not pay sufficient attention to the artificial horizon as his primary flight instrument. More probably, however, his attention may have been diverted by an external stimulus, such as, for example, a signal occurring inside the cockpit or an action by the commander. He may also have been reaching for an object.

The visual references to the runway lighting were lost as a result of the aircraft's nose being raised in the darkness and fog. Consequently, it was not possible to determine the attitude of the aircraft by orientation using the natural horizon. The artificial horizon installed on the copilot's side might not have allowed the copilot, with comparatively little experience of these flying conditions, to orientate himself in sufficient time as to the current attitude, because of its size and low reading accuracy. The copilot could have turned to look at the commander's artificial horizon, which was more ergonomic and easier to read, by quickly turning his head in order to acquire correct and accurate positional orientation, but he did not manage to do this in time.

He had very probably never before taken off under weather conditions comparable with those on the evening the accident occurred.

2.2.4.2 Psychological aspects

Aus den vorliegenden Informationen ergibt sich kein Hinweis darauf, dass sich der Copilot zum Zeitpunkt des Unfalls in einer aussergewöhnlichen psychischen Belastungssituation befand, die ihn in kognitiver und/oder emotionaler Weise derartig beeinträchtigte, dass er nicht zum Führen eines Flugzeuges in der Lage gewesen wäre.

From the information available there is no indication that at the time of the accident the copilot was in an unusual situation of mental stress which affected him to such a cognitive and/or emotional extent that he would not have been able to control an aircraft.

2.2.4.3 Physiological aspects

Nach den zur Verfügung stehenden Unterlagen war der Copilot zum Zeitpunkt des Unfalls gesundheitlich nicht beeinträchtigt. Neben den in Kapitel 2.2.8.3 angeführten Beeinträchtigungen gab es keinen Hinweis auf die Flugfähigkeit beeinträchtigende innere Auslöser im Sinne einer schleichenden oder akuten incapacitation.

According to the information available, the copilot had no health problems at the time of the accident. Apart from the adverse effects listed in section 2.2.8.3, there was no indication of any inner trigger which might have adversely affected his flying capabilities, such as gradual or acute incapacitation.

2.2.5 Interaction between commander and copilot (L-L)

Beide Flugzeugführer kamen gut miteinander aus, obwohl sie sich vom Typ her deutlich unterschieden. Der Kommandant war ein schlanker, eher feinfühliger Mensch und der Copilot ein kräftig-athletischer, eher dynamischer Mensch. Beide waren hochmotiviert, auch unter erschwerten Bedingungen diesen letzten Flug des Tages durchzuführen.

Beide Flugzeugführer hatten sich für die Durchführung des Fluges entschieden, obwohl sie zusammen in der Lage gewesen wären, dem beharrlichen Drängen des Geschäftsführers zu widerstehen. Sie befanden sich nun unter dem enormen Zeitdruck, den Zielflughafen noch vor dessen nicht mehr fernen Schliessungszeit erreichen zu müssen. Die Verzögerungen vor dem Start infolge ungünstiger meteorologischer Bedingungen am Boden sowie des Zusammenstellens von Abfluggruppen aufgrund der nächtlichen Einschränkungen in der Nutzung des Pistensystems erhöhten den auf ihnen lastenden Zeitdruck weiter. Als sie endlich die Startfreigabe erhielten, führten sie einen eiligen Start durch, um noch rechtzeitig in Bern-Belp landen zu können.

Nach dem Einflug in IMC begann der Copilot als PF bereits in sehr geringer Höhe zu beschleunigen. Während der Kommandant als PNF vermutlich mit einer anderen Tätigkeit, wie dem Wechsel der Funkfrequenz oder einer anderen Sache im Cockpit beschäftigt war, galt seine Aufmerksamkeit nicht der Überwachung des Copiloten. Der Copilot wurde von der notwendigen Beachtung seines in dieser Flugphase wichtigsten Fluginstruments, dem künstlichen Horizont, abgelenkt. Die Ursache hierfür mochte in einem externen Reiz und/oder einer internen räumlichen Desorientierung zu finden sein. Da der Copilot nicht über die hinreichende fliegerische Erfahrung verfügte, sich unter dieser anspruchsvollen Flugbedingung auf das Wichtigste, den künstlichen Horizont, zu konzentrieren und die Steuerung des Flugzeuges nicht vom Kommandanten mitverfolgt wurde, veränderte sich dessen Neigungs- und Querlage-winkel. Die nunmehr entstandene Fluglage wurde weder vom Kommandanten noch vom Copiloten so rechtzeitig am künstlichen Horizont erkannt, dass das kurz vor dem Aufprall eingeleitete Korrekturmanöver noch hätte wirksam werden können.

The pilots got on well, although they were of distinctly different types. The commander was a slim, rather sensitive person and the copilot a well-developed/athletic, rather dynamic person. Both were highly motivated to make this last flight of the day, even under difficult conditions.

Both pilots had decided to make the flight, even though together they would have been in a position to withstand the CEO's insistence. They were under enormous time pressure to reach the destination airport before its closing time, which was now rapidly approaching. The delays prior to take-off due to unfavourable meteorological conditions on the ground plus the grouping together of departures because of the night-time restrictions on use of the runway system further increased the time pressure on them. When they finally received take-off clearance, they carried out a hasty take-off in order to be able to land in Berne-Belp in good time.

After flying into IMC, the copilot as PF began to accelerate at a very low altitude. Whilst the commander as PNF was presumably occupied on another activity in the cockpit, such as changing the radio frequency or similar, his attention was not focussed on monitoring the copilot. The copilot was diverted from the essential observation of his most important flight instrument in this phase, the artificial horizon. The cause of this may have been an external stimulus and/or internal spatial disorientation. Since the copilot did not possess sufficient flying experience to concentrate on the most important thing, the artificial horizon, under these demanding flying conditions and since control of the aircraft was not being monitored by the commander, the pitch and bank angles changed. The resulting attitude was not recognised on the artificial horizon either by the commander or by the copilot in sufficient time for the correction manoeuvre initiated shortly before impact to be effective.

2.2.6 Interaction between the flight crew and the aircraft (L-H)

2.2.6.1 General

In the consideration of the interaction between the crew and the aircraft (L-H), man and machine are at the forefront. In the process, consideration was given not only to the aircraft in itself, but also to its equipment, especially the use of the navigation equipment and instruments used during the flight.

First of all it has to be stated as an important pre-condition that aircraft HB-VLV was airworthy up to the initial impact. All aircraft control and navigation equipment was functioning correctly.

2.2.6.2 Use of the flight instruments

The operator purchased HB-VLV in the USA. The instrumentation of this cockpit corresponded to the basic equipment for operating the aircraft under instrument flight rules. It was striking, however, that this was configured predominantly for the pilot flying in the left-hand seat:

- EFIS equipment on the commander's side only
- Parameters of the navigation management system (NMS) were displayed mainly on the commander's flight instruments
- The copilot's CDI indicated the course deviation from the active leg only

In principle, it is a prerequisite for optimal cooperation in the cockpit for the instrumentation to be equivalent for both pilots. Small differences in equipment can be offset by structured standard operating procedures.

Due to the equipment of the aircraft involved in the accident, optimal two-man operation was possible only with limitations. In certain situations, the workload of the copilot as PF is so high that obtaining additional flight information from the commander's instruments may cause distraction.

Since the flight parameters of the NMS were only displayed on the commander's instruments, it can be assumed that the copilot navigated at least the first part of the SID using VOR/DME.

2.2.6.3 Use of the navigation equipment

The navigation systems which were used by the pilot flying (PF), in this case the copilot, to fly the aircraft along the standard instrument departure (SID) "Willisau 3N" were investigated.

There were essentially two factors which indicated that the VOR/DME was used. First, a course of 335° was set on the PF's HSI. This corresponds to the outbound course from runway 16. Secondly, both bearing pointers on the radio magnetic indicator RMI #1 were pointing in the direction 148°. This value is within the range of the bearing from the accident location to KLO VOR.

It can therefore be assumed that the following configuration of the navigation systems was set on the flight involved in the accident:

System	Setting	Display	Purpose
VHF NAV #1 DME #1	KLO VOR	bearing/distance	turning point D4 KLO
VHF NAV #2 DME #2	KLO VOR CRS 335°	bearing/distance	track guidance to turning point D4 KLO
RMI #2	single pointer VOR double pointer VOR	bearing to KLO bearing to KLO	backup track guidance backup track guidance

With the above configuration, the crew were in fact making a compromise regarding the track guidance prescribed in the SID, as KLO VOR was situated to the west of runway 34. The resulting deviation from the nominal track, however, would still have been within the tolerances.

The following configuration of the VHF navigation systems would have been appropriate:

System	Setting	Display	Purpose
VHF NAV #1 DME #1	KLO VOR standby WIL VOR	bearing/distance	turning point D4 KLO
VHF NAV #2 DME #2	ILS 16 IZH CRS 155° standby TRA VOR KLO VOR DME hold	localizer	track guidance to turning point D4 KLO
RMI #2	single pointer VOR double pointer VOR	bearing to KLO bearing PARK	backup track guidance

2.2.6.4 Use of the artificial horizon

The copilot checked his attitude indicator after engine start-up at the latest.

On take-off the copilot rotated the aircraft to an attitude of 7-10 degrees ANU and maintained it for about 13 seconds. He must have assumed this attitude with the aid of the artificial horizon. The nose of the aircraft then began to drop until shortly before impact the aircraft had attained an attitude of about 12 degrees AND. On the basis of the DFDR data this change happened at the same time as the deflection of the elevator. Seconds before impact, the elevator control was pulled back, initiating a recovery manoeuvre.

Immediately after take-off the copilot maintained a constant heading of 334-335 degrees for approximately 10 seconds. It can be assumed that during this phase he was maintaining the aircraft in a neutral bank attitude. The aircraft then began to change course to the right. On the basis of the recorded aileron deflections, this turn was neither initiated by the copilot nor was it corrected.

The nose of the aircraft began to drop and at the same time the aircraft began to turn to the right.

Before the crash, the aircraft exhibited a turn rate to the right of approximately one degree per second. The turn was the result of the aircraft's bank angle to the right. It corresponded to the bank angle determined forensically at the point of impact.

The gyro of the artificial horizon rotated at the nominal speed. It is therefore improbable that this gyro instrument showed an incorrect attitude.

2.2.6.5 Ground proximity warning system

Aircraft of the Cessna CE 560 Citation type operated under JAR-OPS 1 must be equipped with a ground proximity warning system (GPWS). HB-VLV was being operated according to VBR I. According to VBR I installation a GPWS on the aircraft was not a mandatory requirement.

GPWS mode 3 "altitude loss after take-off" would have warned the flight crew of the loss of altitude after take-off. After the zenith of flight path, some 500 to 600 feet above ground when the aircraft started to descend, the crew would have been warned by the synthetic voice of the GPWS "don't sink, don't sink…" until the crews respective intervention. At this height a barometric altitude loss of approximately 50 feet would have been sufficient to trigger the GPWS mode 3. Out of this a successful correction of the flight path would have been possible in this phase of the descent.

2.2.7 Relationship between flight crew and procedures (L-S)

2.2.7.1 General

In the consideration of the relationship between the flight crew and procedures (L-S), the application and implementation of general flight procedures and procedures specified by the operator are at the forefront.

2.2.7.2 Operating procedures

Schriftlich definierte und offiziell nach VBR I genehmigte betriebliche Verfahrens-anweisungen (FOM) existierten bei Eagle Air Ltd. seit 1990. Darin wurde unter anderem eine Standardterminologie verwendet sowie die Anwendung von Checklisten angesprochen. Deren Nutzung wurde zwar vorgeschrieben, inhaltlich jedoch nicht weiter ausgeführt. Ein umfassendes und klar vorgegebenes Konzept für die Zusammenarbeit und Verfahrensdurchführung im Cockpit (standard operating procedures - SOP) war darin nicht zu finden und wurde den Piloten auch nicht anderweitig zur Verfügung gestellt.

So wurde zum Beispiel die Durchführung eines take-off briefing darin angesprochen. Einheitlich zu erfolgende call-outs oder Hinweise wurden für die Startphase nicht erwähnt und blieben der individuellen Entscheidung der Piloten überlassen. Für die Anflugphase wurden konkrete Verfahrensvorgaben aufgeführt.

Da den Piloten von der Unternehmensleitung keine Schulungsprogramme zu den Themenkomplexen SOP, crew co-ordination (CC) oder crew resource management (CRM) angeboten wurden - letzteres war nur für die nach JAR-OPS 1 zertifizierten Flugbetriebe vorgeschrieben - gab es keine standardisierte Arbeitsweise im Cockpit.

Flight operations manuals defined in writing and approved according to VBR I have existed at Eagle Air Ltd. since 1990. Among other things, they use standard terminology and address the use of checklists. Though their use was prescribed, no further details were given regarding their content. A comprehensive and clear concept for cooperation and implementation of procedures in the cockpit (standard operating procedures – SOP) could not be found in them; nor was it otherwise made available to pilots.

Thus for example, carrying out a take-off briefing is addressed. Call-outs or instructions to be given uniformly were not mentioned for the take-off phase and were left to the individual pilots' discretion. Concrete procedures were listed for the approach phase.

Since pilots were not offered any training programmes by company management on the complex topics of SOP, crew coordination (CC) or crew resource management (CRM) – the latter was prescribed only for operators certificated to JAR-OPS 1 – there was no standardised method of working in the cockpit.

2.2.7.3 Departure procedures

The crew had experience of instrument flight procedures in Zurich. As the DFDR data showed, the crew began to retract the flaps as early as approximately 500 ft above ground level. The speed at this time was 172 KIAS.

The noise abatement procedure (NAP) for jet aircraft of the category to which the aircraft involved in the accident belonged specified flap retraction at 4500 ft AMSL at the earliest. In view of the favourable noise characteristics of this aircraft type, it is common practice to commence aircraft acceleration earlier than specified in the NAP.

After the crew of HB-VLV had deviated from the NAP, once the flaps had been retracted the correct procedure would have been to maintain a speed of 167 KIAS up to 4500 ft AMSL. This corresponds to the speed for the start of the climb (V_{enr}), plus 5 kt for known icing conditions at a flight mass of 13000 lbs. Only then would they have been allowed to accelerate to 250 KIAS.

As was apparent from the DFDR data, the aircraft was not stabilised at 167 KIAS. The pitch angle reduced, causing a further increase in speed.

In this connection a further possibility exists to explain the unnoticed transition to a descent after take-off: as has been mentioned, the crew were under time pressure and wanted to increase the speed to 250 KIAS immediately after retracting the flaps. The PF may have been directing his attention almost exclusively to the airspeed indicator. One indication might be the relatively long trim time. In addition, the possibility of a spatial disorientation has to be considered (see also section 2.2.8.3).

2.2.7.4 Take-off under low visibility conditions

Der nach dem Aufrollen auf die Startbahn und einem fliessenden Übergang in die Startbeschleunigung erfolgende Start (rolling take-off) entsprach nicht den internationalen Vorgaben für einen Start bei geringen Sichtverhältnissen. Die meisten Luftfahrtunternehmen schreiben ihren Piloten vor, bei solchen Wetterbedingungen vor dem Anrollen auf der Piste und vor dem Setzen der Startleistung die Triebwerke im Bereich von 60% des Startschubes stabilisieren zu lassen. Die Auswirkungen eines ungleichen Beschleunigens der Triebwerke auf Startleistung, wie es beim Unfallflug geschah, können damit vermieden werden.

Da das Flugbetriebsunternehmen noch nicht nach JAR-OPS 1 zugelassen war und auch nicht nach den neuen Richtlinien verfuhr, wurden die nach JAR-OPS 1.455 den Ablauf eines Starts unter geringen Sichtbedingungen (low visibility take-off) verfahrensmässig regelnden Vorgaben nicht angewandt. Somit blieb es weiterhin dem Unternehmen überlassen, wie es Starts unter den zum Zeitpunkt des Unfalls vorherrschenden Wetterbedingungen zu regeln gedachte. Es ist aber anzumerken, dass genau diese Problematik im ICAO Dokument „Manual of All-Weather Operations" geregelt wird, unabhängig davon wie der Flugbetrieb zugelassen war (VBR I oder JAR-OPS 1).

Eine explizite Verfahrensvorgabe für eine Startdurchführung unter derartigen Bedingungen existierte im Unternehmen nicht. Die tatsächliche Gestaltung des Vorgehens im Cockpit blieb damit im Wesentlichen den persönlichen Bedürfnissen und dem Engagement der einzelnen Piloten überlassen.

Der für die verfahrensmässige Standardisierung der Piloten zuständige Chefpilot vermochte diese Umstände nicht effizient zu verändern.

The rolling take-off, after taxiing onto the runway, did not comply with the international procedures for a take-off under low visibility conditions. Under such weather conditions, most operators instruct their pilots to stabilise their engines at 60% take-off thrust before commencing the take-off roll and setting take-off power. In this way it is possible to prevent the effects of uneven engine acceleration when setting take-off power, as occurred in the accident flight.

Since the operator was not yet licensed to JAR-OPS 1 and was not implementing the procedures of the new regulations, the procedures according to JAR-OPS 1.455 governing the sequence for a low-visibility take-off were not applied. Thus it was left to the company to regulate take-offs under the weather conditions prevailing at the time of the accident as it saw fit. However, it must be noted that this topic is dealt with in the ICAO document "Manual of All-Weather Operations", regardless of how the operator was licensed (VBR I or JAR-OPS 1).

No explicit specification of procedures for a take-off under such conditions existed within the company. The actual configuration of the procedure in the cockpit remained essentially the domain of the individual pilots' needs and commitment.

The chief pilot responsible for standardising pilot procedures was not able to change these circumstances efficiently.

2.2.8 Interface between flight crew and environment (L-E)

2.2.8.1 General

In the consideration of the “flight crew – environment” interface, the weather situation, the aviation-related physiological aspects, air traffic control as well as the operator and the supervisory authority are at the forefront.

2.2.8.2 Icing on the aircraft during ground time

2.2.8.2.1 The effect of the weather

After the passage of a weakened cold front, cloud cover over Zurich Airport reduced rapidly between 18:00 UTC and 19:00 UTC. Under a practically cloudless sky the air temperature fell by 4 °C (from -5 °C to -9 °C) between 18:50 UTC and 20:50 UTC and in the process approximately 5 g of water vapour per kg air condensed or sublimated.

As a result of sublimation, hoar frost had formed on the aircraft involved in the accident when it was parked, primarily on the exposed surfaces of the airframe.

When the sky clears after the passage of a cold front, fog forms in the evening only gradually and unevenly because of the continuing turbulence in the air. On the GAC Sector 1 parking area, therefore, the fog was less dense than in the northern part of the airport, also because of its proximity to buildings which were radiating heat. Ice probably therefore formed on the airframe primarily due to sublimation rather than freezing fog.

During taxiing on taxiways A and E to the take-off point, more ice probably formed as a result of freezing fog.

No information can be provided about the thickness of the layer of ice.

2.2.8.2.2 Departure preparation

The activities prior to departure from Zurich were characterised by great time pressure. As evidenced by the witness statements of an airport manager, the crew must have decided to de-ice the aircraft during ground time in Zurich.

The fact that the crew decided on de-icing using a scraper rather than de-icing according to the manufacturer’s operating recommendations corresponded to the operator’s usual practice.

2.2.8.3 Aviation-related physiological aspects in relation to IMC flights

Es besteht beim unerwarteten Übergang von Sichtwetterbedingungen (VMC) in Instrumentenwetterbedingungen (IMC) die Möglichkeit, dass die zum Führen eines Flugzeugs wichtige räumliche Orientierung (Raumlage-Orientierung) beim Piloten gestört sein kann. Diese Orientierung ist das Ergebnis des Zusammenspiels aller hierfür in Frage kommender Sinnesorgane. Dabei können eventuell auftretende widersprüchliche Reize eine Sinnestäuschung auslösen und zu einer räumlichen Desorientierung führen. Wird diese vom Piloten nicht rechtzeitig als solche erkannt und zu spät mit entsprechenden Gegenmassnahmen begonnen, kann sie gerade bei geringer Flughöhe zu fatalen Folgen führen.

Das Syndrom der räumlichen Desorientierung ist eine Kombination von Faktoren, die sich gegenseitig beeinflussen. Dabei sind sowohl internale Bedingungen (physische, psychische und ausbildungsbewirkte) als auch externale Bedingungen (organisatorische, umwelt- und einsatzbedingte sowie technische) von Bedeutung. Mentale und physische Belastungen wie Müdigkeit, Zeitdruck, fehlende Fertigkeiten aufgrund geringer Erfahrung in Verbindung mit weiteren Belastungen wie z.B. Beschleunigungen, Instrumentenfehler, Ablenkungen und ungewohnte Wettererscheinungen während des Fluges können den Piloten überfordern und sein Erregungsniveau stark erhöhen. All diese Faktoren können sich in ihrer zeitlichen Sequenz gegenseitig verstärken und den Verlust einer momentanen räumlichen Orientierung bewirken. Der Flugzeugführer erscheint bei Eintritt einer Desorientierung in seinem Denken und Handeln konfus, fixiert oder blockiert, die Steuerungsorgane werden rau und unkoordiniert bewegt.

Die Besatzung des Unfallfluges hatte die Zusammenstosswarnlichter (anti-collision lights) nicht ausgeschaltet. Die Reflexion der Lichter im Nebel kann eine Desorientierung oder ein Vertigo beim Piloten herbeigeführt oder zumindest begünstigt haben. Eine starke Bewegung mit dem Kopf oder dem gesamten Oberkörper kann beim Piloten kurz nach der Rotationsphase und der noch andauernden Beschleunigungsphase des Flugzeugs zu einer Beeinträchtigung der Orientierungsfähigkeit geführt haben.

Eine derartig induzierte somatogravische Illusion kann dazu führen, dass das Gleichgewichtsorgan dem Piloten ein Manöver des Flugzeugs vermittelt, welches dieses real nicht ausführt. Ohne eine visuelle Referenz zum natürlichen oder künstlichen Horizont – bei Nacht oder unter IMC - kann diese Täuschung zu einem Konflikt zwischen anhaltendem Sinneseindruck und der notwendigen Lagekorrektur des Flugzeugs führen. Eine starke Bewegung des Kopfes kann dabei das Gefühl eines sich Rückwärtsneigens bewirken, also den Eindruck des Anhebens der Flugzeugnase. Die natürliche Gegenreaktion des Piloten wäre ein Nachdrücken des Steuerhorns oder eine entsprechende Betätigung der Trimmung, um das Flugzeug wieder in die als korrekt empfundene Fluglage zu drücken.

In the event of an unexpected transition from visual meteorological conditions (VMC) to instrument meteorological conditions (IMC), there is a possibility that a pilot’s spatial orientation which is important for flying an aircraft may be perturbed. This orientation is the result of the interplay of all the sensory organs involved. Contradictory stimuli which may occur can trigger sensory disorientation, leading to spatial disorientation. If this is not recognised as such in good time by the pilot and if appropriate countermeasures are begun too late, it may lead to fatal consequences, especially at low altitudes.

The syndrome of spatial disorientation is a combination of factors which interact mutually. Both internal conditions (physical, mental and training-related) and external conditions (organisational, environmental, mission-related and technical) are of significance. Mental and physical loads such as fatigue, time pressure, missing skills due to limited experience, in conjunction with other strains such as, for example, acceleration, instrument errors, distractions and unusual weather phenomena during the flight may overtax the pilot and greatly increase his level of arousal. All these factors may reinforce each other in their chronological sequence and cause momentary loss of spatial orientation. When this disorientation occurs, the pilot appears confused, fixated or blocked in his thinking and actions; the controls are moved without finesse and in an uncoordinated manner.

The crew of the aircraft involved in the accident had not switched off the anti-collision lights. The glare of the lights in the fog may have contributed to or at least fostered disorientation or vertigo in the pilot. A pronounced movement of the pilot's head or entire torso shortly after the rotation phase and the aircraft's continuing acceleration phase may have led to adverse effects on his ability to orientate himself.

Such an induced somatographic illusion may lead to the pilot's sensory organs attributing to the aircraft a manoeuvre which the latter is not actually carrying out. With no visual reference to the natural or artificial horizon – at night or under IMC – this illusion may lead to conflict between the persisting sensory impression and the necessary correction of the aircraft's attitude. In this context, a pronounced movement of the head may induce the feeling of inclining backwards, i.e. the impression that the aircraft's nose is lifting. The pilot's natural reaction would be to push the control wheel or correct the trim accordingly, in order to bring the aircraft back to the attitude which is perceived as the correct one.

2.2.8.4 Air traffic control

2.2.8.4.1 Approach and departure procedures

According to the runway utilisation concept in force, from 20:00 UTC jet aircraft must use runway 34 for take-offs. During this period, a fairly large volume of traffic still had to be handled; as was the case on the evening of the accident. This situation led air traffic control to schedule approaches and departures of jet aircraft in groups, for reasons of efficiency.

A series of approaches was followed by a series of departures, and so on. When making up the approach and departure groups, air traffic control took into account on the one hand the sequence in which departing aircraft reported that they were ready for start up. On the other hand, the scheduled take-off slot also had to be taken into consideration.

In addition, air traffic control had to evaluate the effects of delays both on the aircraft holding for approach and those ready for take-off on the ground. In the present case, the restrictions on the use of the destination airport also had to be taken into account.

Overall, traffic on this evening was handled in accordance with the usual concept.

2.2.8.4.2 Restrictions on use in Berne-Belp

At 20:34:40 UTC the operator's CEO intervened by telephone with the duty manager in Zurich control tower. He explained to the latter that in winter Berne-Belp airport closes at 21:00 UTC, but that the operator, with its home base in Berne-Belp, had obtained exceptional authorisation until 21:30 UTC, in view of the circumstances. However, it was imperative that this time be complied with. After he had complained again about the runway utilisation concept in Zurich, he urged air traffic control to do everything they could to ensure that the aircraft could be flown to Berne-Belp in good time.

The duty manager explained to the CEO that he was obliged to comply with the runway utilisation concept and that a take-off from runway 28, for example, was no longer permitted at this late hour, even for a small jet. Moreover, because of the runway utilisation concept air traffic control was obliged to make jets take off from runway 34 only and to land on runway 16 only. However, in order nonetheless to ensure efficient traffic handling, the aircraft would be arranged in groups for arrivals and departures. At that moment it was the turn of a group of approaches. An additional aggravating factor was that it was necessary to increase the intervals between the approaching aircraft due to the poor weather conditions.

After a lengthy discussion, the duty manager finally made the CEO the offer of allowing EAB 220 to take off as the first aircraft in the next group, instead of in third place, as planned. This would save about 3-4 minutes. He would also discuss with the other air traffic controllers so that the aircraft could fly the most direct route to Berne-Belp. Subject to these measures, a landing in Berne-Belp by 21:30 UTC should have been possible.

The operator’s CEO was in agreement with this procedure and gave his thanks.

2.2.8.4.3 ATC handling of flight EAB 220

When the crew obtained clearance for start up from the apron controller at 20:43:50 UTC, it was possible to establish from the subsequent radio conversations that the flight crew were gradually feeling the time pressure, as their scheduled departure time had been delayed again and again. The reasons for this were on the one hand the weather-related delays in traffic handling, and on the other hand the fact that even now a landing in Berne-Belp by 21:30 UTC was called into question.

The crew therefore pressed the apron controller, in a noticeable haste, to allow them to leave the stand quickly. One sign of the pressure which may have been affecting the pilots was the fact that the crew of EAB 220, one minute after receiving taxiing clearance, had to ask again for the precise wording of this clearance: “*Swiss Eagle 220, sorry for that, can you say the clearance again?*”

At 20:56:50 UTC flight EAB 220 made contact with Aerodrome Control (ADC) and stated that the aircraft was on Echo 9 just before the start of runway 34. The ATCO requested the crew to wait short of runway 34, since approaches were still taking place. At 21:04:51 ADC issued clearance for the aircraft to line up on runway 34.

At this point ADC asked the crew whether they were happy with the prevailing lighting or whether the light intensity was too high. The pilot’s answer could not be understood clearly. At this time meteorological visibility was 100 m with partial fog.

EAB 220 took off at 21:06 UTC from runway 34 and a little later was handed over to the Zurich arrival frequency, 118.000 MHz. The commander acknowledged this instruction. At the time the ADC ATCO could still observe the aircraft on his bright display and ascertained according to his information that it was at an altitude of 1900 ft in a climb.

Shortly afterwards the ATCO noticed that EAB 220’s radar symbol disappeared from his bright display. Since, according to the ATCO’s statement, such a situation does occasionally occur, he waited for a brief moment. However, when the radar symbol was no longer visible on his bright display, he asked his colleague at Zurich arrival whether the pilot of EAB 220 had already called on his frequency. The answer was in the negative. The ADC ATCO called the aircraft again several times and during these calls realised that there was talk of an aircraft crash on the aerodrome vehicle frequency.

Then, 90 seconds after the last radio contact, ADC raised a major alarm at 21:08:25 UTC.

2.2.8.4.4 Low visibility procedures

The duty manager in the control tower had documented the initiation of low visibility procedures (LVP) in the TWR logbook at 20:20 UTC. The extent to which the preparation phase was concluded must remain an open question. Activation of LVP did not take place.

During a call on the clearance delivery (CLD) frequency at 19:56:43 UTC, flight EAB 220 stated that it was in possession of ATIS information X (x-ray). Up to the moment when HB-VLV was instructed at 21:04:51 UTC to line up on runway 34, the crew was at no time informed by the responsible air traffic controller of the current runway visual range (RVR).

At 21:05:54 UTC flight EAB 220 received clearance to take off from runway 34. On this occasion also, no current RVR value was communicated to the crew. At 21:05:47 UTC the following RVR values for runway 34 were displayed in the control tower: touch-down-zone 400 m, mid-point 1700 m, stop-end 350 m. Given these values, according to the procedures in the ATMM, the flight crew of HB-VLV should have been informed of the stop-end value, in addition to the current value for the touch-down zone (TDZ).

2.2.8.5 The operator

Das Flugbetriebsunternehmen war als klassischer Kleinbetrieb geprägt durch seinen Gründer und Geschäftsführer, der sein Unternehmen in autoritärer Weise leitete. Die Entscheidungsgewalt lag grundsätzlich bei dieser Person. Von seinen Flugzeugführern verlangte der Geschäftsführer die Einhaltung der von ihm gemachten Vorgaben ohne Wenn und Aber. Dieser Führungsstil führte zu einer wenig vertrauensvollen Arbeitsatmosphäre zwischen Flugzeugführern und Geschäftsführer. Eine betriebsinterne Kritik- und Konfliktkultur entwickelte sich nicht.

Der große Kostendruck in der gesamten Branche galt auch für die Flugbetriebsunternehmen und hatte seine Auswirkungen auf die Durchführung des Flugbetriebs: Operative Entscheidungen mussten unter Kosten minimierenden Gesichtspunkten getroffenen werden. So wurde zum Beispiel das Enteisen des Flugzeuges per Hand mittels Sprühflasche und Eiskratzer durch die Besatzung durchgeführt, um die nicht unbeträchtlichen Kosten für eine Enteisung durch Dritte zu vermeiden.

Die Position eines Flugsicherheitsbeauftragten, der firmenintern die Funktion eines von der Flugbetriebsleitung unabhängigen Qualitätskontrolleurs wahrnimmt und für die Einhaltung der sicherheitsrelevanten Vorschriften und Verfahren zu sorgen hat, war unter den für das Unternehmen geltenden Bestimmungen nicht vorgeschrieben und gab es auch nicht.

The operator was characterised as a classic small company by its founder and CEO, who ran his company in an authoritarian manner. The decision-making power lay with this person. Of his pilots, the CEO demanded compliance with his instructions, with no ifs or buts. This style of management led to lack of trust in the working atmosphere between pilots and the CEO. A culture of criticism and conflict did not develop within the company.

The high cost pressure prevalent in the industry also affected the operator and had effects on the way operations were carried out: operational decisions had to be taken from the viewpoint of minimising costs. Thus, for example, the aircraft was de-iced by the crew by hand using an aerosol and scraper, in order to avoid the considerable costs of de-icing by a third party.

The position of a safety officer, who performs the function of a quality controller independent of the operator's management and who is required to ensure compliance with safety regulations and procedures, was not prescribed under the provisions in force for the company; nor did such a position exist.

Eagle Air Ltd. was not certified in accordance with JAR-OPS 1. This meant that the company did not have to tackle, among others, the following measures:

- Gaining approval for low visibility procedures from the supervisory authority and publication of these in the operations manual part A (OM A).
- Equipping the aircraft with a system which triggers an alarm in the event of loss of altitude after take-off (GPWS).

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- There is no indication that aircraft HB-VLV was not in an airworthy condition at the time of the accident.
- A technical log book was not found neither in the wreckage nor in the technical documentation.
- The documentation on the technical condition of the aircraft was incomplete.
- No ground proximity warning system (GPWS) was installed in the aircraft involved in the accident. GPWS mode 3 “altitude loss after take-off” would have been able to warn the flight crew of the loss of altitude after take-off in sufficient time.
- The cockpit voice recorder (CVR) did not record the conversations during the flight involved in the accident because of a fault.
- The effect of icing on the accident can be excluded.

3.1.2 Crew

- According to the available documentation the crew were in possession of valid licences.
- The investigation found no indication of a medical cause of the accident.
- The commander had no flight duty on the day before the accident.
- The commander’s rest time before the day of the accident was 35 hours and 50 minutes.
- At the time of the accident, the commander’s flight duty time was 9 hours and 17 minutes.
- The commander was employed by the operator on a full-time basis.
- On the day before the accident, the copilot worked 3 hours and 10 minutes of flight duty time.
- The copilot’s rest time before the day of the accident was 22 hours and 40 minutes.
- At the time of the accident, the copilot’s flight duty time was 9 hours and 17 minutes.
- The copilot was employed by the operator on a part-time basis.
- The copilot was not well experienced in flying under IMC.
- The analysis of the manner in which the take-off was performed and the communication between the crew and the air traffic control units allow to conclude, that the copilot was pilot flying and the commander was pilot non flying during the flight involved in the accident.

3.1.3 Progress of flight

- The flight took place under great time pressure.
- At 21:06 UTC the crew performed a take-off from runway 34 in low visibility.
- The crew taxied onto the runway, setting take-off power and initiated a rolling take-off.
- The anti-collision lights were switched on.
- Shortly after becoming airborne the crew lost all visual references.
- The speed of the aircraft increased continuously from take-off until impact.
- At the time of retracting the flaps, the trimtabs of the elevator began to move towards nose down. With 8.5 seconds this action lasted longer than during the previous flights
- After reaching a height of 500 to 600 ft above ground level, the aircraft began to loose altitude.
- A corrective manoeuvre was commenced though this was not able to prevent impact with the ground.
- The pilot non flying (PNF) did not monitor the pilot flying (PF) adequately.
- The accident was not survivable.

3.1.4 General conditions

- After the landing in Zurich, the subsequent take-off was delayed as a result of poor meteorological conditions at the airport and restrictions on the use of runways.
- The landing in Berne-Belp should have taken place by 21:30 UTC at the latest.
- The operator’s CEO urged the duty manager in Zurich control for an earlier departure time, and emphasised that the ferry flight had to be carried out by all means.
- The operator’s CEO contacted the flight crew several times by telephone.
- At the time of the accident, the operator was not licensed for operation according to JAR-OPS 1.
- The operator’s flight operations manual did not describe all procedures for crew cooperation in the cockpit.
- The operator did not have any flight crew procedures for a low visibility take-off.
- The operator’s flight operations manual specified, among other, that in the event of unfavourable conditions the take-off should be performed by the commander.
- The aircraft involved in the accident had the minimum prescribed equipment on the copilot’s side for flying according to IFR.
- The aircraft involved in the accident had modern EFIS instrumentation on the commander’s side.
- The initiation of low visibility procedures (LVP) is documented in the TWR logbook at 20:20 UTC.

- Activation by air traffic control, e.g. transmitting via ATIS or radio the information that LVP was in force, did not take place.
- At 21:05:47 UTC the following RVR values were displayed in the control tower for runway 34: touch-down-zone 400 m, mid-point 1700 m, stop-end 350 m.
- The ADC controller did not transmit any RVR values to the flight crew.

3.2 Causes

The accident is attributable to the fact that the crew of HB-VLV did not continue their climb after take-off. As a result the aircraft came in a descent and collided with the terrain.

The investigation determined the following causal factor for the accident:

- With a high degree of probability the crew lost spatial orientation after take-off, leading to an unintentional loss of altitude.

The following factors contributed to the accident:

- The copilot's basic training in instrument flying did not include night instrument take-offs.
- The crew's method of working was adversely affected by great time pressure.
- Executing the take-off as a rolling take-off was not adapted to the prevailing meteorological conditions.
- There was no system in the aircraft which triggers an alarm in the event of a loss of altitude after take-off (GPWS).
- The instrumentation on the copilot's side of the aircraft involved in the accident was not optimal.

This report has been prepared solely for the purpose of accident / incident prevention. The legal assessment of accident / incident causes and circumstances is no concern of the incident investigation (art. 24 of the Federal Aviation Law).

4 Safety recommendations and safety actions taken

4.1 Safety recommendations

4.1.1 Swiss operators' operating licence according to Joint Aviation Requirements (JAR)

4.1.1.1 Safety deficiency

On the occasion of a ferry flight from Zurich to Berne-Belp a Cessna CE 560 Citation V took off from runway 34 at night and in poor visibility. Shortly after take-off the aircraft climbed to 500-600 ft above ground level, lost height again and impacted with the ground.

With a high degree of probability the crew lost spatial orientation after take-off, leading to unintentional loss of altitude.

At the time of the accident the operator was licensed in accordance with the ordinance on operating procedures in commercial aviation (*Verordnung über die Betriebsregeln im gewerbsmässigen Luftverkehr* - VBR I). With a certification in accordance with JAR-OPS 1, the following conditions would have been met:

- Among other things, the operator would have been obliged to gain approval for a procedure for operations in low visibility (low visibility procedures) from the FOCA, the supervisory authority, and to publish it in the operations manual part A (OM A).
- The aircraft would have had to be equipped with a system which triggers an alarm in the event of loss of altitude after take-off (GPWS).

4.1.1.2 Safety recommendation No. 327

4.1.1.3 The Federal Office for Civil Aviation should arrange for all Swiss operators still licensed according to the ordinance on operating procedures in commercial aviation (*Verordnung über die Betriebsregeln im gewerbsmässigen Luftverkehr* - VBR I) to be certified according to JAR regulations without delay.

4.1.2 Cockpit instrumentation for two-man operation in instrument flying

4.1.2.1 Safety deficiency

On the occasion of a ferry flight from Zurich to Berne-Belp a Cessna CE 560 Citation V took off from runway 34 at night and in poor visibility. Shortly after take-off the aircraft lost height and impacted with the ground.

As the investigation showed, the aircraft involved in the accident did not have an optimal instrumentation for a two-man operation. The primary instrumentation on the right-hand side, for controlling the aircraft, was less suitable than the one on the left-hand side.

4.1.2.2 Safety recommendation No. 328

The Federal Office for Civil Aviation should arrange for the instrumentation of aircraft which are flown under two-man operation relying on instruments to be arranged so that an equivalent quality of control can be achieved from both positions in the cockpit.

Glossary

AAIB	Swiss Aircraft Accident Investigation Bureau	
AAL	Above Aerodrome Level	
ACR	Aerobatics extension	National rating
AD	Airworthiness Directive	
ADC	Aerodrome Control (Tower)	
ADC	Air Data Computer	
ADF	Automatic Direction Finding Equipment	
AFS	Automatic Flight System	
AGL	Above Ground Level	
AI	Attitude Indicator	
AIP	Aeronautical Information Publication	
AMSL	Above Mean Sea Level	
AND	Attitude Nose Down	
ANU	Attitude Nose Up	
AOC	Air Operators Certificate	
AP	Autopilot	
APP	Approach Control Office	
APW	Approach Control West	
ATC	Air Traffic Control	
ATCO	Air Traffic Control Officer	
ATIS	Automatic Terminal Information Service	
ATMM	Air Traffic Management Manual	
ATPL	Air Transport Pilot Licence	
ATT	Attitude	
AWO	All Weather Operations	
BFU-D	Bundesstelle für Flugunfalluntersuchungen Deutschland	German AAIB
BKN	Broken	5-7 octas cloud cover
BRG	Bearing	
B-RNAV	Basic Area Navigation	
CAM	Cockpit Area Microphone	
CAT I	Category One	
CB	Circuit Breaker	
CDI	Course Deviation Indicator	
CDU	Control Display Unit	
CDR	Commander	
CEO	Chief Executive Officer	
CESCOM	Cessna Computerized Maintenance	
CLB	Climb	
CLD	Clearance Delivery	
COM	Communication	
CPL	Commercial Pilot Licence	
CR	Class Rating	
CRM	Crew Resource Management	
CRS	Course	
CVR	Cockpit Voice Recorder	

DA	Decision Altitude	
DDS	Digital Data Storage	
DEP	Departure Control	
DFDR	Digital Flight Data Recorder	
DH	Decision Height	
DM	Duty Manager	
DME	Distance Measuring Equipment	
DOC	Designated Operational Coverage	Area in which a specific service is available, and which frequencies associated with this service are protected
DTO	Direct To ...	
DVOR	Doppler VOR	
EADI	Electronic Attitude Director Indicator	
ECP	EFIS Control Panel	
EFIS	Electronic Flight Instrument System	
EHSI	Electronic Horizontal Situation Indicator	
ELEV	Elevation	
ELT	Emergency Locator Transmitter	
FAA	Federal Aviation Administration (USA)	
FAF	Final Approach Fix	
FD	Flight Director	
FDR	Flight Data Recorder	
FEW		1-2 octas cloud cover
FI	Flight Instructor	
FIR	Flight Information Region	
FL	Flight Level	
F/O	First Officer	
FOCA	Federal Office for Civil Aviation	
FOM	Flight Operations Manual	
ft	Feet	(1 ft = 0.3048 m)
G/A	Go Around	
GAC	General Aviation Centre	
GLI	Glider	
GNS	Global Navigation System	
GPS	Global Positioning System	
GPWC	Ground Proximity Warning Computer	
GPWS	Ground Proximity Warning System	
GRO	Ground Control	
G/S	Glide Slope	
HDG	Heading	
hPa	Hecto Pascal	
HSI	Horizontal Situation Indicator	
IAS	Indicated Airspeed	
ICAO	International Civil Aviation Organization	
IFR	Instrument Flight Rules	
ILS	Instrument Landing System	

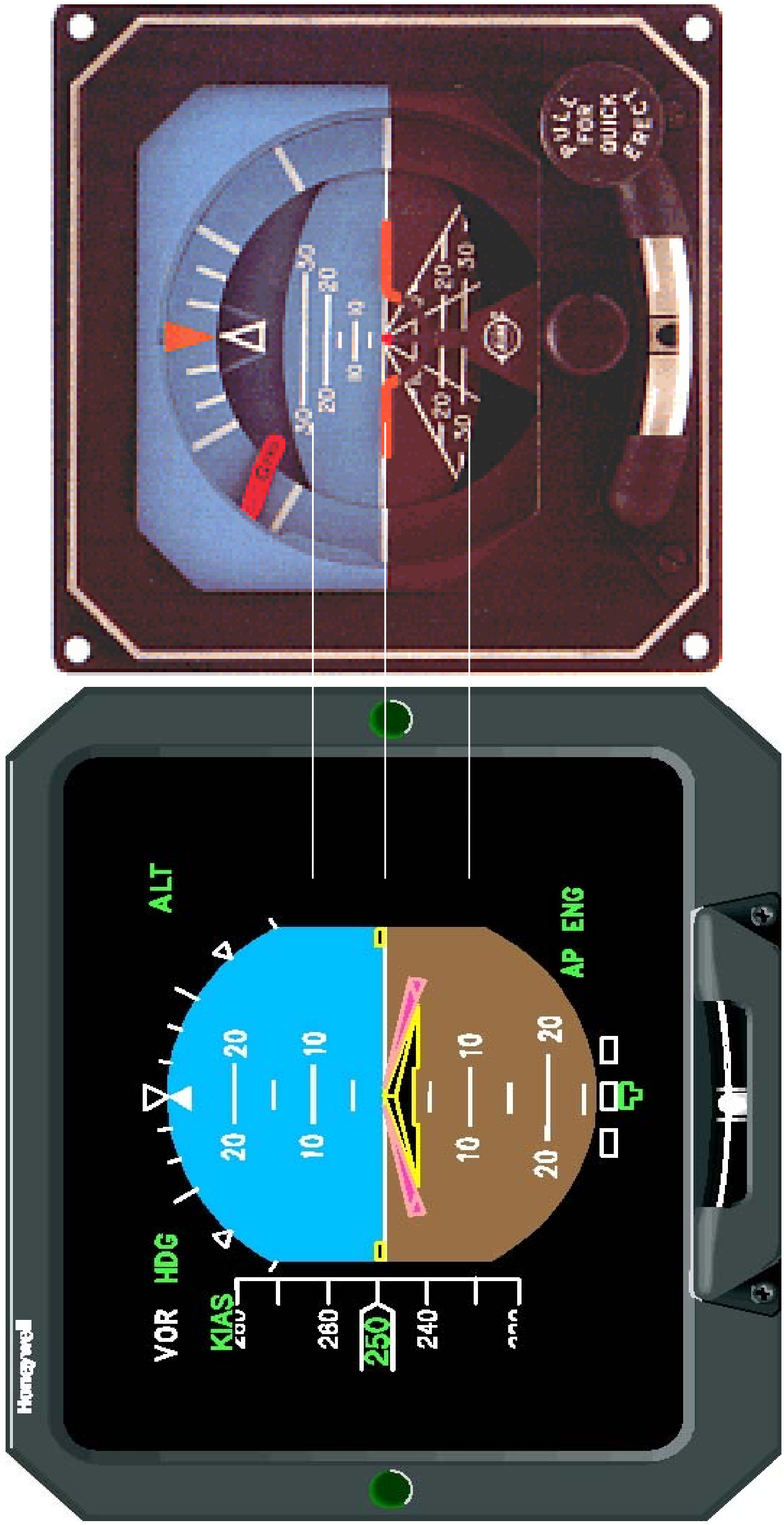
IMC	Instrument Meteorological Conditions	
IR	Instrument Rating	
ISO	International Standard Orders	
JAA	Joint Aviation Authorities	
JAR	Joint Aviation Requirements	
KIAS	Knots Indicated Airspeed	
kt	Knots	(1 kt = 1 NM/h)
LAT	Latitude	
LIH	Light Intensity High	
LIL	Light Intensity Low	
LLZ ZRH	Localizer Zurich	
LMC	Last Minute Change	
LOC	Localizer	
LONG	Longitude	
LT	Local Time	
LVP	Low Visibility Procedure	
LVO	Low Visibility Operation	
LVTO	Low Visibility Take-Off	
MAC	Mean Aerodynamic Chord	
MAG	Magnetic	
MAP	Missed Approach Point	
ME	Multi Engine	
MEP	Multi Engine Piston	
MDA	Minimum Descent Altitude	
MDH	Minimum Descent Height	
METAR	Meteorological Aerodrome Report	
MHz	Megahertz	
MNPS	Minimum Navigation Performance System	
MOC	Minimum Obstacle Clearance	
NAP	Navigation Performance	
NAT	North Atlantic	
NAV	Navigation	
NDB	Non Directional Beacon	
NDB	Navigation Data Base	
NM	Nautical Mile	(1 NM = 1.852 km)
NMS	Navigation Management System	
NMU	Navigation Management Unit	
NOAA	National Oceanic and Atmospheric Administration	
NVM	Non-Volatile Memory	
OAT	Outside Air Temperature	
OCH	Obstacle Clearance Height	
OM	Operations Manual	
OVC	Overcast	8 octas cloud cover

PANS-OPS	Procedure for Air Navigation Services – Operations	
PA	Public Address	
PF	Pilot Flying	
PIC	Pilot In Command	
PNF	Pilot Non Flying	
PWR	Power	
QAM	Local Weather Report	
QFE	Airfield related Static Pressure	Station pressure
QNH	Mean Sea Level related Static Pressure	Air pressure calibrated to sea level, calculated using the ICAO standard atmosphere
RA	Radio Altimeter	
RA	Radar Altitude	
RNAV	Area Navigation	
RNP	Required Navigation Performance	
RMI	Radio Magnetic Indicator	
ROC	Rate Of Climb	
ROD	Rate Of Descent	
RVR	Runway Visual Range	
RWY	Runway	
Rx	Receiver	
SCT	Scattered	3-4 octas cloud cover
SB	Service Bulletin	
SE	Single Engine	
SIC	Second In Command	
SID	Standard Instrument Departure	
SIGMET	Information concerning en-route weather phenomena which may affect the safety of aircraft operations	
S/N	Serial Number	
SOP	Standard Operating Procedures	
SSR	Secondary Surveillance Radar System	
SSCVR	Solid State Cockpit Voice Recorder	
STAR	Standard Instrument Arrival Route	
SWC	Significant Weather Chart	
SYMA	System Manager	
TAF	Aerodrome Forecast	
TAS	True Airspeed	
TCAS	Traffic Alert And Collision Avoidance System	
TDZ	Touch Down Zone	
TMM	Transmissometer	
T/O	Take-Off	
TR	Type Rating	
TRK	Track	
TST	Test	
TWR	Tower	

UTC	Universal Time Coordinated
VERT	Vertical
VERT SPD	Vertical Speed
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional Radio Range
WO	Work order
WX	Weather
XPDR	Transponder
ZUE VOR	Zurich East VOR

5 Annexes

5.1 Comparison EADI and AI, scale 1:1



AI – *AIM Horizon*

EADI – *Honeywell ED600*

5.2 Cessna CE 560 Citation V – normal take-off profile

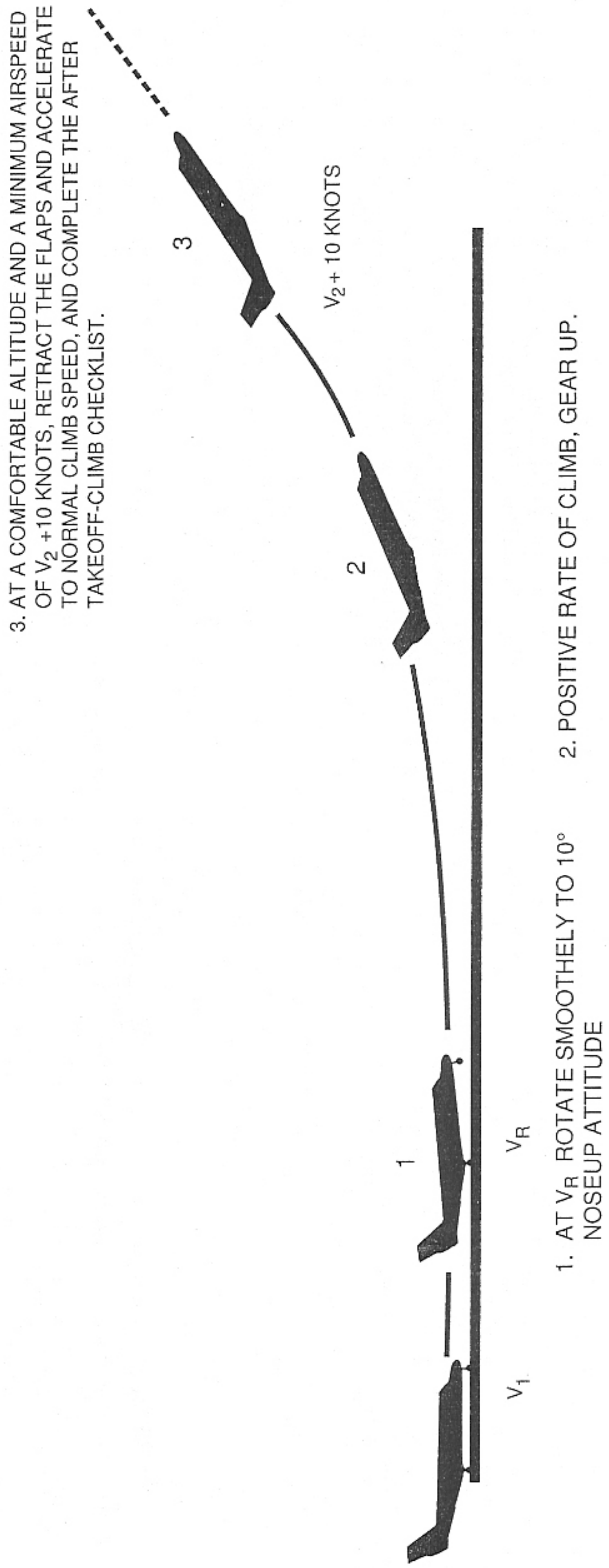


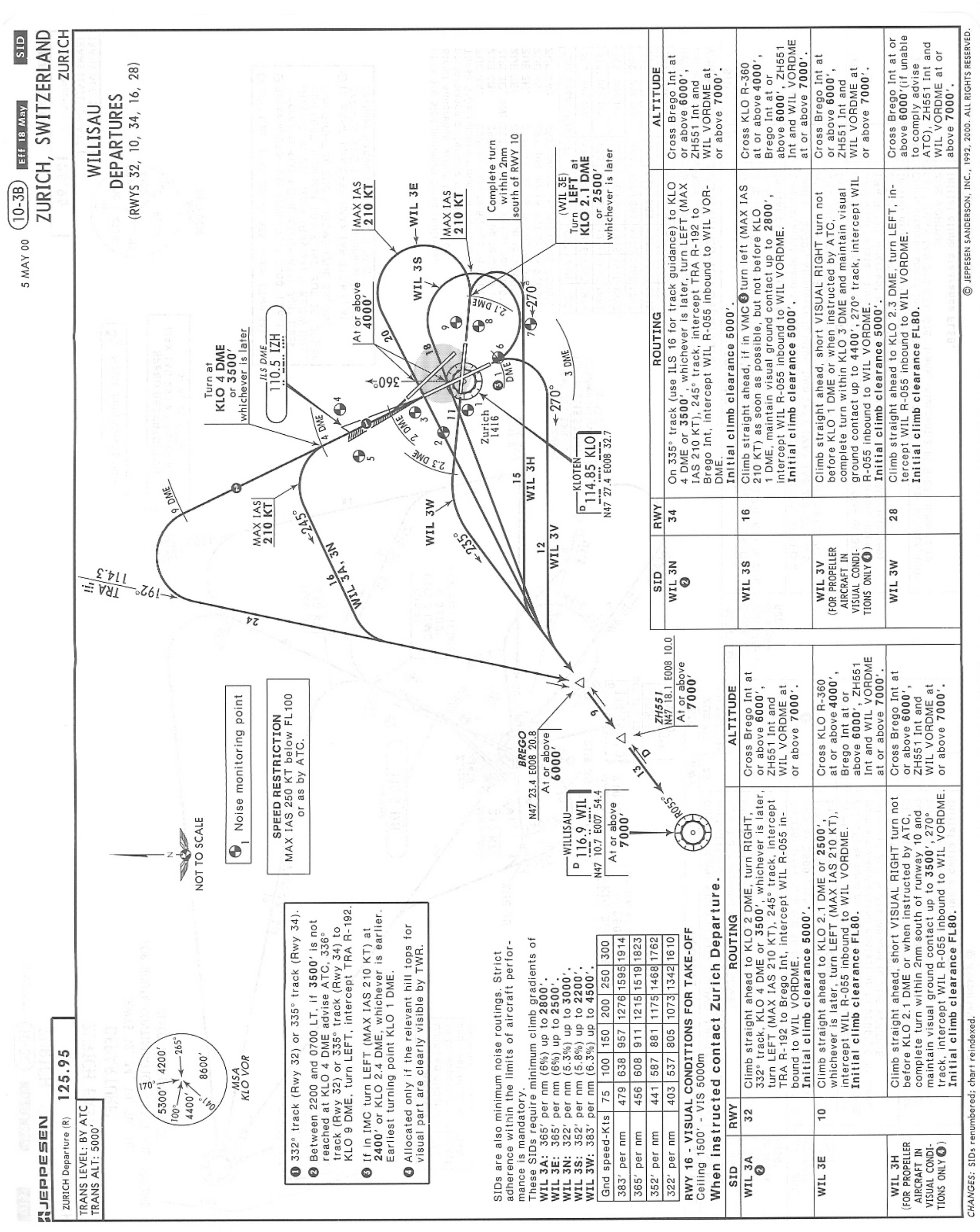
Figure GEN-1. Takeoff—Normal

5.3 Application of low visibility procedures in Zurich

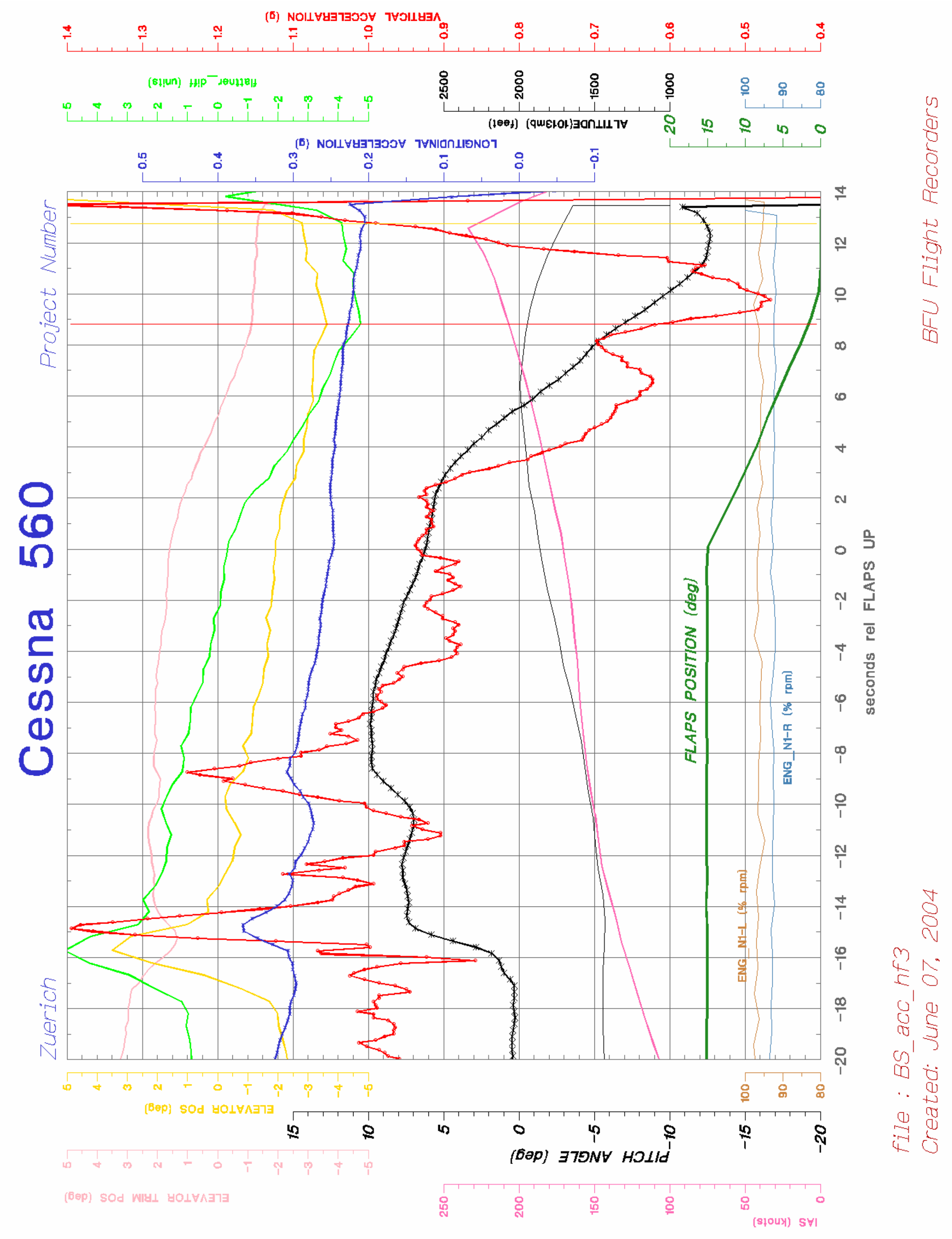
LVP	RVR	CAT	
		CAT I	
LVP Prep Phase	750m		
	600m		
LVP Application Phase	550m		
	500m	CAT II	
	375m	LVTO	
	350m		
	325m		CAT III
	0m		

Activation	Via ATIS or RTF: **"Low Visibility Procedures In Operation".**
Application	Arrivals: RVR for TDZ 550 m or less. Low visibility take-offs: RVR 375 m or less at any RVR position on the departure runway.
Protection of ILS sensitive areas	Ensured by ATC as per Section 4.
Radar vectoring	Arriving aircraft are vectored so as to ensure LLZ intercept according to local procedures.
Clearance for approach	ATC issues clearance for an ILS approach regardless of the ILS category applied or the prevailing weather conditions.
Meteorological information	Prior to commencing final approach, the RVR value will be transmitted. Additionally, the latest RVR values will be transmitted by TWR.
Clearance to land	Normally given before an arriving aircraft reaches 2 NM from touchdown; exceptionally a clearance should not be delayed to less than 1 NM from touchdown, provided that the flight crew are warned to expect a late landing clearance.
Deactivation of LVPs	If weather conditions indicate sustained improvement to RVR 600 m or greater, LVP application will be cancelled. Pilots will be advised by RTF - " Low visibility procedures cancelled at time…." The ATIS will be updated, removing any reference to LVPs. The preparation phase will remain in force until the RVR improves to 800 m or greater.

5.4 Standard instrument departure „Willisau 3N“



5.5 Graphical representation of flight data recordings



5.6 Attitude on impact

5.7 Accident location