Accident Investigation Board Norway HSLB

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REPORT ON THE AIR ACCIDENT ON 30 NOVEMBER 2001 AT SKIEN AIRPORT GEITERYGGEN NORWAY, INVOLVING BRITISH AEROSPACE JETSTREAM 31, SE-LGA, OPERATED BY EUROPEAN EXECUTIVE EXPRESS AB

This report has been translated into English and published by the AIBN to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

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AIR ACCIDENT ON 30 NOVEMBER 2001 AT SKIEN AIRPORT GEITERYGGEN NORWAY, INVOLVING BRITISH AEROSPACE JETSTREAM 31, SE-LGA, OPERATED BY EUROPEAN EXECUTIVE EXPRESS AB

Aircraft type:	British Aerospace (BAe) Jetstream 31
Registration:	SE-LGA
Owner:	European Executive Express AB Box 599 SE-651 13 Karlstad Sweden
Operator:	As owner
Crew:	2
Passengers:	11
Accident site:	Skien Airport Geiteryggen, Norway (ENSN) (N59^{o} 11.1’ E009^{o} 34.0’)
Accident time:	Friday 30 November 2001, at time 1828

All times in this report are local time (UTC + 1 hour), unless otherwise indicated.

NOTIFICATION OF THE ACCIDENT

The officer on duty at the Accident Investigation Board Norway (AIBN) was notified of the accident on 30 November, at time 1900, by the Joint Rescue Coordination Center South-Norway. The AIBN was notified that a Jetstream 31 belonging to European Executive Express AB (EEE) had run off runway 19 at Skien Airport Geiteryggen (ENSN) while landing. There were 13 people on board, 7 that were injured, one of them seriously. The AIBN arrived at Skien at time 0745 the next day.

In accordance with the ICAO Annex 13, Aircraft Accident and Incident Investigation, the British (country of manufacture) Air Accidents Investigation Branch (AAIB) and the Air Accident Investigation Branch in Sweden (Swedish operator) were notified. The Swedish Branch appointed an accredited representative to assist in the investigation.

SUMMARY

The company, European Executive Express AB (EEE), operated a route between Skien Airport Geiteryggen (ENSN) and Bergen Airport Flesland (ENBR) using the aircraft type

Jetstream 31. On Friday, 3 November 2001, SE-LGA (radio call signal EXC 204) was on its way to Skien with a crew of two and 11 passengers. During the flight, ice was observed on the aircraft's wings, but the ice was considered to be too thin to be removed. During descent towards runway 19 at Geiteryggen the aircraft's ground proximity warning system (GPWS) sounded a total of three times. The aircraft was then in clouds and the crew did not have visual contact with the ground. The warnings, combined with somewhat poorly functioning crew coordination, resulted in the crew forgetting to actuate the system for removing ice from the wings. The subsequent landing at 1828 hrs was unusually hard, and several of the passengers thought that the aircraft fell the last few metres onto the runway. The hard landing caused permanent deformation of the left wing so that the left-hand landing gear was knocked out of position, and the left propeller grounded on the runway. The crew lost directional control and the aircraft skewed to the left and ran off the runway. The aircraft then hit a gravel bank 371 metres from the touchdown point. The collision with the gravel bank was so hard that the crew and several of the passengers were injured and the aircraft was a total loss.

It was dark, light rain and 4 °C at Geiteryggen when the accident occurred. The wind was stated to be 120^o 10 kt. The investigation shows that it is probable that ice on the wings was the initiating factor for the accident. The AIBN has not formed an opinion on whether the ice resulted in the high sink rate after the first officer reduced the power output of the engines, or whether the aircraft stalled before it hit the runway. Investigation has to a large extend focused on the crew composition and training. A systematic investigation of the organisation has also taken place. In the opinion of the AIBN, the company has principally based its operations on minimum standards, and this has resulted in a number of weaknesses in organisation, procedures and quality assurance. These conditions have indirectly led to the company operating the route Skien – Bergen with a crew that, at times, did not maintain the standard that is expected for scheduled passenger flights. The investigation has also revealed that procedures for de-icing of the aircraft wings could be improved.

As a result of its investigations, the AIBN has submitted 7 safety recommendations.

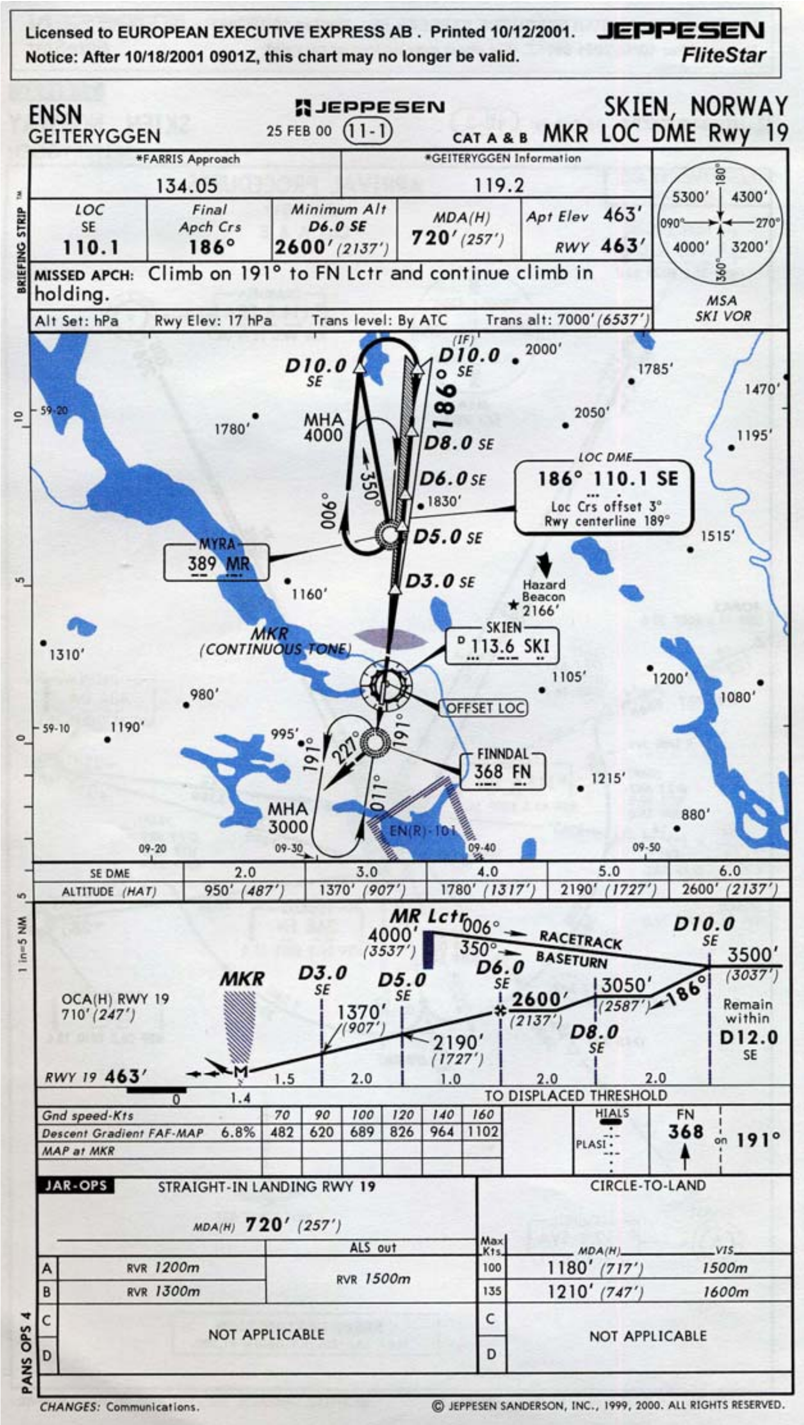
1. FACTUAL INFORMATION

1.1 History of flight

1.1.1 The company, European Executive Express AB, started its scheduled flights between Bergen Airport Flesland and Skien Airport Geiteryggen on 1 October 2001. The company flew return trips twice daily between the two towns from Monday to Friday. The accident occurred during the last scheduled landing on a Friday. The crew had flown together for the past two weeks, and this was the last flight before the Commander was going to begin an off-duty period. On the day of the accident, the crew left their hotel in Skien at time 0707 and drove to the airport, arriving a few minutes later. The Commander carried out the Pre-Flight Inspection on SE-LGA in the hangar that the company rented, and signed this off at time 0730. There were no comments to the inspection. The Commander then collected weather data, and examined relevant NOTAM. The first departure from Skien, with the radio call sign EXC 201, was at time 0800. After landing in Bergen at time 0900, the crew rested at a hotel, in which they had a dayroom at their disposal. A new departure from Bergen took place at time 1435 (EXC 202) and from Skien at time 1600 (EXC 203). After landing in Bergen, 200 l fuel was filled.

1.1.2 The Commander had flown the first flight of the day (Flying Pilot - FP), and the first officer had flown the two following flights in order to gain as much flight experience as possible. Before departure from Bergen the Commander asked the first officer if he also wanted to be FP during the final flight. He answered yes to this, and the first officer was also FP during the flight from Bergen to Skien (EXC 204). The Commander was, therefore, Non Flying Pilot (NFP) and took care of radio communication. The flight took place according to an IFR ‘repetitive flight plan’ (RPL). The departure at time 1740 from Bergen and the following climb to flight level (FL) 150 was normal.

1.1.3 The flight at FL 150 took place above the cloud cover. After passing the report point SOPAS, the Descend Checklist was carried out. The conversations in the cockpit from this point in time are not registered on the voice recorder, but the Commander has confirmed that the ice conditions were not commented in connection with the Descend Checklist. A descent for an LLZ/DME (Non-precision) approach to runway 19 at Skien was then initiated. The crew used the instrument landing chart from Jeppesen FliteStar that the company has published in a special folder for the Skien – Bergen – Skien route. The crew also used the instrument landing chart published by SAS Flight Support.



The Instrument Landing Chart used during landing

1.1.4 In understanding with air traffic control, the company flew directly towards a point (a fix) at a distance of 12 NM DME (hereafter called D12) along localizer (LLZ SE) to runway 19. During the descent through the clouds down to Geiteryggen, some ice formed on the wings. The further description of the sequence of events is mainly based on information retrieved from the aircraft's Cockpit Voice Recorder - CVR) and Flight Data Recorder – FDR.

1.1.5 Around eight minutes before landing, the Commander turned on the wing inspection lights and commented "We have ice". At about D15, the crew received signals from the instrument landing system LLZ and the Commander informed Farris approach (APP) of this. At time 17:21:40 the Commander contacted the AFIS officer in the Geiteryggen tower and informed him that LLZ contact was established at a distance of 14.5 NM.

1.1.6 To begin with the mood in the cockpit was relaxed, but the Commander made repeated instruction-like comments to the first officer about how to fly the plane. At D12 the Commander again commented the ice situation by saying "We have ice – we have ice." At the same time, the first officer was acknowledged for his flying in the comment: "Now you start to think very correct."

1.1.7 During the descent from 5,000 ft to 2,000 ft, speed varied between 145 kt and 185 kt. The Commander directed the first officer's attention to flight speed several times, saying e.g. "Go back to 174", meaning increase speed to 174. The minimum crossing altitude of 3,500 ft was maintained until D10. The Commander once again confirmed that there was ice on the wing in this period. The next minimum crossing altitude is 3,050 ft at D8. 3,100 ft was passed at around D8.5 and just before D8 was passed the aircraft's Ground Proximity Warning System (GWPS) sounded and warned: "Terrain – terrain. Pull up – pull up." At the same time as the activation of the GPWS, the Commander said: "Just easy, easy, easy – easy that is all right", a little later followed by: "8 miles OK – it's just here. So next time you fly, don't descend too fast to 3,100." At D7, the ice on the wings was commented on again (FP- Flying Pilot, NPF – Non Flying Pilot):

18:24:10	NFP	For the ice – you want that?
18:24:13	FP	You can choose if you want
18:24:15	NFP	I think we wait a little
18:24:16	FP	OK - it is perfect for me

1.1.8 Immediately after passing D7 the GPWS activated again: "Terrain – terrain. Pull up – pull up – pull up." The Commander commented this by "It's OK", and a new warning about not descending so steeply. D6 was passed probably 100 ft too low in relation to the approach procedure and the GPWS again activated: "Terrain – terrain. Terrain – terrain. Pull up." The first officer began to climb, and the Commander shouted:

> "Are you climbing? You are going to 2,200 ft Sir. Don't start to f…. it up again now (first officer's name)."

As a result of the climb, the aircraft passed the locator Myra (MR) at an altitude of 2,800 ft, around 600 ft too high, and the descent to D3 was steep. The tone in the cockpit was strained and the Commander began to give orders to the first officer.

18:25:54	NFP	4 miles – 3 miles at 1,400 ft. You have 1,100 ft to go to 1,400 ft
18:26:00	FP	Ok
18:26:01	NFP	We need to go under
18:26:04	NFP	Stick to the localizer – stick to the localizer, don't do anything stupid. You have to –just – Continue. You are just going at the same heading - you have to intercept.

18:26:19	NFP	Descend - or we never gonna make it.

At about this time, the aircraft came out of the cloud that was at an altitude of around 2,000 ft MSL. It was dark and visibility was good below the clouds.

18:26:21	NFP	3 miles, are you going to minima? OK
18:26:26	FP	OK, Sir
18:26:29	NFP	OK, want the gear?
18:26:33	FP	Yes, 3 miles gear down
18:26:35	NFP	We never gonna make this (said under breath)
18:26:40	NFP	Come on, go down, go down. Stay on the localizer, stay on the localizer.

1.1.9 Just before D2 the speed was reduced down towards 130 kt, the landing gear lowered, flaps set at 20^o and the propeller controls set at 100% RPM. At time 18:26:50 the Commander asked for the last wind information from the tower, and was told that it was blowing 120^o 8 kt. The Commander then went through the check list:

18:27:05	NFP	Props is forward, yaw damper is off, gear is down, flaps is 20^o. We have full flaps to go – and the flows.
18:27:15	FP	I got them – catch the runway
	NFP	130 on the speed
18:27:20	NFP	Full flaps
18:27:22	FP	Yes please
18:27:25	NFP	Complete
18:27:33	NFP	It is coming from 120, that is the wind is coming from left
18:27:35	NFP	Speed is 125, 120^o
18:27:40	AFIS	12010 (wind)
18:27:42	NFP	115
18:27:51	NFP	110
18:27:56	NFP	115
18:27:57	NFP	Centerline is to the right
18:28:01	NFP	You have 40% torque
18:28:08	NFP	115
18:28:15	NFP	Oh

Information from the FDR and CVR indicates that the aircraft maintained an indicated speed of approx. 110 – 115 kt when the aircraft encountered an abnormally high sink rate and hit the runway.

1.1.10 Both of the crew members thought that they were a little high on final approach because the white light (PLASI 3.30L) flashed a few times. According to the Commander, the aircraft developed a high rate of descend in flare at the same time as the Power Levers were pulled back to Flight Idle 2.5 – 3 seconds before landing. According to the passengers, the landing was especially hard, and several thought that the aircraft fell the last metres down onto the runway. The breath was knocked out of one passenger momentarily when the aircraft hit the ground. According to a printout from the FDR, the load was 6 g at the moment of landing (equivalent to a technical value of 4,000 in the printout in Appendix 1).

1.1.11 The landing led to permanent deformation of the left wing on the forward wing beam. As a result of this deformation, the left landing gear leg was bent backwards, with the engine and propeller pointing obliquely downwards. The left propeller touched the runway and the crew lost directional control so the aircraft skewed out to the left and left the runway (see diagram in subparagraph 1.12.1.3). It continued, skidding in an arc to the left, crossed a taxiway twice and hit a gravel bank with great force. The gravel bank was hit by the nose of the aircraft and the left propeller at an assumed angle of 45° in the horizontal plane. The aircraft continued up the gravel bank in a virtually horizontal attitude while the tail was thrown out to the right. Then the aircraft fell so that it was resting on its tail and main wheels with the nose up on the gravel bank.

Photograph taken looking south the day after the accident. Note the unusual position of the wing, engine and landing gear

1.1.12 A pilot from another airline who sat in the passenger seat immediately behind the first officer observed that some ice formed on the windscreen during the flight. He could not hear what the crew were talking about, but noticed that the Commander used the wing inspection light before beginning the approach. He did not notice anything abnormal during the flight. Just before the aircraft hit the ground, he saw the Commander lift his hands to protect his face. He also saw that the aircraft was on its way towards the gravel bank, and he had time to tighten his seatbelt and prepare for the collision that he estimated happened at a speed of 50 - 60 kt. After the collision, he stood up and shouted that everyone had to evacuate the aircraft. Another passenger had already begun to remove the emergency exit on the right-hand side, and this was open after an estimated 15 sec. At the same time as the emergency exit was opened, one of the passengers at the rear of the aircraft managed to open the left rear main door. All of the passengers evacuated the aircraft quickly.

1.1.13 The first officer noted that the landing was hard, but was immediately engaged in keeping the aircraft on the runway. He explained to the AIBN that it was completely impossible to maintain directional control. When he realised that the aircraft would leave the runway he braked with the wheel brakes, but the effect of this was reduced after the wheels left the runway and were on the wet grass. He kept the right pedal in until the aircraft hit the gravel bank and this may explain how he broke his right ankle.

1.1.14 The Commander has explained that he understood immediately that something gave way during the hard landing. Both crew members explained that they must have lost consciousness for a short period after the collision with the gravel bank, because when they looked back there were no passengers in the cabin.

1.1.15 During discussions with AIBN the day after the accident, the crew had no explanation as to what had happened. Stall at low altitude was rejected as an explanation because they maintained a speed that was over the threshold that was approx.10 kt over V_{ref}, and they had not heard or noticed any warning that the aircraft was about to stall. They were of the opinion that the last part of the approach was stable and went as expected. The first officer said that the Commander in certain ways carried out the flight in another way than he was used to. He pointed out as an example that the Commander maintained a higher approach speed than expected, and that he read off the relevant speeds during the last part of the approach and not the deviation from V_{ref} , which he was used to. The first officer also stated that the runway at Geiteryggen was short, and that therefore you had to fly precisely.

1.1.16 At a later date, once the content of the CVR was known, the Commander was asked about the reason for not removing the ice from the wings in conjunction with the ice first being observed. He responded then that this was in accordance with the company's Standard Operations Procedures (SOP) (see subparagraph 1.6.9.5).

1.1.17 The AFIS duty officer saw the whole approach after the aircraft came into view under the clouds. From his position, he had a good view, but in the dark only the lights were visible from the aircraft. He could not see anything abnormal before the aircraft had landed. It then appeared as though the aircraft made an abnormal yaw. A few seconds later it began to skew off the runway and continue until it disappeared behind a gravel bank. He understood that an accident had happened and raised the full alarm at time 18:28:36. He alarmed the fire department, police and the medical services (AMK) in that order.

1.1.18 One of the employees of the airport was walking his dog along the airport perimeter fence to the west of the runway and saw the approach. The approach seemed normal, but because of the terrain the aircraft vanished from view as it landed on the runway. Abnormal sounds after the aircraft had landed made him realise at once that something had gone wrong. When he heard the alarm at the airport and seconds after heard the sound of the airport fire tenders' sirens, he jumped over the airport fence and ran across the runway. He arrived at the crash site just after the fire and rescue service and at around the same time as the last passengers came out of the plane. Together with the fire and rescue service he participated in organising the crash site and leading the passengers over to the terminal building.

1.2 Injuries

INJURIES	CREW	PASSENGERS	OTHER
FATALITIES			
INJURED	1	2	
LIGHT/NONE	1	9	

1.3 Damage to aircraft

The aircraft was a total loss (see subparagraph 1.12.2 for details).

1.4 Other damage

None

1.5 Personnel information

1.5.1 <u>The Commander</u>

1.5.1.1 The Commander, Norwegian citizen, male 45 years old, got his private pilot's licence at Den sivile flyskolen (a private pilot school) at Fornebu in 1981 and C certificate with instrument rating in the USA the next year. As it was difficult to get work in Norway after he had converted to Norwegian licences, he travelled back to the USA in 1984 and flew some months there before returning and beginning as an instructor and taxi pilot for Den sivile flyskolen in Norway. He flew for AS Mørefly in the period 1986 – 97, where he became in time captain, head of training and instructor. AS Mørefly became part of Lufttransport AS, based in Tromsø and in that connection the Commander left the company and began to work as a freelance pilot. He first flew a period for Master Aviation at Fornebu before, in 1999, beginning to fly for Coast Air and obtained type rating on BA 31s in January 2000. After a period with Coast Air, he flew BA 31s in Africa and was first officer on B 737-300 for Icelandflug. The Commander was Flight Operations Manager in the company Guard Air, before signing a contract with European Executive Express AB on 11 October 2001.

1.5.1.2 The Commander carried out a combined Operator Proficiency Check (OPC) and Proficiency Check (PC) with the company's Flight Operations Manager on 11 October 2001. The practical tests were carried out during a flight from Västerås (ESOW) to Norrköping (ESSP) and the return flight, logged at 1:10 hours and 0:30 hours respectively. The result from the PC was documented without remarks on the Swedish Civil Aviation Authority form 'Type-rating multi-pilot aeroplane'. The flight was carried out with SE-LGA. According to the Flight Operations Manager, this flight also served as an evaluation of the Commander before his employment by the company.

1.5.1.3 The company carried out no special Ground Training or Emergency and Safety Equipment Training in connection with his employment. This was confirmed by the Commander, who among other things had not received training in use of the company's Load Sheet. The Commander has explained to the AIBN that he did not see the need for formal training in these subjects for persons with a previous 'type rating' on BA 31. The Commander had also undergone training in Cockpit Resource Management (CRM) and Dangerous Goods at Coast Air in February 2000. According to the company's Flight Operations Manager, the Swedish Civil Aviation Authority accepted this training in Dangerous Goods. In the case of CRM, it was accepted that new pilots followed the ongoing training in the company, without the whole subject having to be undergone in one period initially. The Commander had, therefore, not undergone CRM training at EEE. In interviews with AIBN, the Commander has explained that he did not undergo formal training in the company's manual system or quality system. He informed us that he had acquired this knowledge through self study of relevant documents.

1.5.1.4 According to documentation presented by the Flight Operations Manager, the Commander flew 25:15 hours Line Flying under Supervision. In addition to the two previously mentioned flights in connection with PC/OPC, this consisted of 19 flights between Skien and Bergen in the period 15 – 22 October 2001. These flights were carried out with another Italian first officer in the company. After 22 October, the Commander flew regularly between Skien and Bergen until the accident.

1.5.1.5 According to the Flight Operations Manager, the Commander had been given the right to carry out Pre-Flight Inspections on the company's BA 31. This was not in agreement with a list, dated 25 March 2001, of Commanders Approved for Pre-Flight Inspection found in the aircraft's Flight Log Binder. The AIBN was later sent an equivalent list dated 15 October 2001, on which the Commander was listed.

1.5.1.6 The AIBN has contacted two former colleagues of the Commander in order to hear views about his previous employment. In his early career he was regarded as a good instructor who set high standards and who especially emphasised standardisation and use of procedures. He also took responsibility and attempted to solve problems that occurred. If the qualifications for younger pilots were not as expected, he could however seem impatient. He was vocal and could show frustration and in some cases this could lead to his relationship with other pilots becoming strained.

1.5.1.7 The Flight Operations Manager of European Executive Express thought that the Commander was a very suitable pilot for the Norwegian operation. He emphasised the Commander's broad experience and good knowledge of Norwegian conditions. It was also decisive that he had experience from BA 31, and that he had instructor experience. The Flight Operations Manager had to begin with received a good impression of the Commander, but a short time before the accident he had received a report from one of the company's first officers criticising the Commander's actions and cooperation in the cockpit. After the accident, the cooperation problems with the Commander were pointed out by several of the company's first officers.

1.5.1.8 The Commander had a Norwegian ATPL-A valid until 26 March 2006. He also had instructor rights on BA 31 valid until 13 January 2002. The Commander had a medical certificate, class 1, valid until 18 February 2002. The medical certificate was without limitations.

1.5.1.9 The Commander informed the AIBN that he had received sufficient rest before the accident and that he felt healthy and fit for flight on that day.

FLYING TIME	ALL TYPES	RELEVANT TYPE
LAST 24 HOURS	4	4
LAST 3 DAYS	12	12
LAST 30 DAYS	30	30
LAST 90 DAYS	86	86
TOTAL HOURS	6 590	600

1.5.2 First Officer

1.5.2.1 The First Officer, Italian citizen, male 34 years, got his pilot's licence in the US in 1990 and converted to an Italian licence in 1999. In the same year, he got a 'type rating', including simulator training, on BA 31. The first officer began to fly as first officer for the Italian airline Aliway on a route between Cuneo/Levaldigi (LIMZ) and Roma/Fiumicino (LIRF). This airline, however, became bankrupt. After new ownership interests had tried to operate the route for a period, EEE took over the flights. The first officer was then offered a pilot's job with EEE and his contract with EEE was signed on 1 February 2001. It was intended that he should fly permanently for the company on the route Cuneo – Roma.

1.5.2.2 The Flight Operations Manager of European Executive Express has explained that he had no doubts in employing the first officer. He was, however, aware of the first officer's somewhat limited flying experience and thought that flying in Scandinavia would provide useful experience. He thought that two weeks in Norway would provide a positive change and good experience to a first officer that the company wanted to keep. He admitted that the first officer was not regarded as one of the best qualified in the company. As Flight Operations Manager and head of the training department, he was, however, aware that people have different learning speeds, and he believed that the first officer would do a good job for the company. He also emphasised the first officer's good social skills. The Flight Operations Manager confirmed that he received a telephone from the Commander while in Skien in which the problems with marginal performance by the first officer was discussed. The Flight Operations Manager was, however, under the impression that the Commander had the situation under control.

1.5.2.3 The Commander indicated early that the first officer did not have the qualities he had expected. Encouraged by AIBN, he explained this further. He then described weakness in completely basic skills like maintaining speed and height, problems with handling radio communication and a general lack of 'situational awareness'. He had noted progress in the period that they had flown the route Skien – Bergen together, but in his opinion more training was needed.

1.5.2.4 The first officer had his Italian licence validated by the Swedish Civil Aviation Authority on 22 January 2001. He was then given the right to fly as first officer on Jetstream 31/32 for EEE. The right was granted for the same period as the Italian licence, i.e. until 7 June 2002. The right to fly BA 31 was renewed for the last time on 7 June 2001 in a combined Operator Proficiency Check (OPC) and Proficiency Check (PC) with the company's Flight Operations Manager. The practical tests were carried out during three flights between Cuneo/Levaldigi and Roma/Fiumicino, logged with 1:25 hours, 1:35 hours and 0:30 hours, respectively. The result from the PC was documented on the Swedish Civil Aviation Authority's form 'Type-rating multi-pilot aeroplane'. A validation form that was completed shows that the flight was logged at 1:25 hours. All of the tests were passed without comment, except for point 3.9.1 "Adherence to departure and arrival routes and ATC instructions". The following comment is appended to this: "Be more active and follow ATC instructions to 100%." Following employment with EEE, the first officer had undergone an annual quarter of the CRM training, organised by the SAS Flight Academy.

1.5.2.5 His last air medical examination was carried out in Switzerland on 31 January 2001. The first officer had a valid medical certificate without limits at the time of the accident.

1.5.2.6 The first officer started to fly on the Skien – Bergen route on 19 November 2001. In the period preceding the accident, he had made 8 night approaches to Geiteryggen, around half of which were to runway 19. The first officer informed the AIBN that he had had sufficient rest before the accident and that he felt healthy and fit for flight that day.

FLIGHT TIME	ALL TYPES	RELEVANT TYPE
LAST 24 HOURS	4	4
LAST 3 DAYS	12	12
LAST 30 DAYS	40	40
LAST 90 DAYS	321	321
TOTAL HOURS	1,700	390

1.6 Aircraft information

1.6.1 General

The aircraft type was developed from the Handley Page Jetstream 1 and the first production model of the BA 31 flew in 1982. BA 31 was delivered in several versions and was manufactured until 1993. The passenger version has 18 or 19 passenger seats. The aircraft has a pressurised cabin. Two fuel tanks, one in each wing, hold a total capacity of 1,755 l (3,090 lb) of fuel.

SE-LGA was entered in the Swedish aviation register on 15 September 1997 and bought by EEE two years later. The aircraft had valid Swedish registration, environmental and airworthiness certificates. The airworthiness certificate was valid until 30 September 2002.

1.6.2 Aircraft Data

Manufacturer:	British Aerospace (BAe) now BAE Systems
Type/model:	Jetstream 3100 model 3102
Year of manufacture:	1984

Serial number:	636
Total flight hours:	14,074 hours
Total no. of landings:	16 666
Engine type:	2 x Garrett TPE331-10UF
Serial number left engine:	P-42105
Serial number right engine:	P-42083
Maximum T.O. mass:	15 562 lb
Type of fuel:	JET A-1

1.6.3 Maintenance

The aircraft had undergone a combined A, B, C and D inspection at a total flight time of 13,977:10 hours. The inspections were signed out on 21 October 2001 by Karlstad Flygservice AB. Included in this inspection were the Pitot Static System Leak check and the Airspeed Indicator Calibration.

After this inspection, Skyways carried out a Service Check on the aircraft on the 27 November. In addition to the Service Check in the period between 21 October 2001 and the accident, there were mainly only minor maintenance tasks and Pre Flight Inspections carried out. The most comprehensive one was the replacement of the nose landing gear on 29 October as a result of repeated leakage in the damper. The work was carried out by Sun Air at Thisted in Denmark.

At the time of the accident the Hold Item List (HIL) contained three comments. One of these was “NAV # 2 U/S MEL 34-5” entered on Monday 26 November 2001. The comment contained no references to which point under MEL 34-5 was affected. The Commander has, however, explained to the AIBN that this did not affect flying because the information from NAV # 1 was transferred to the instruments on both sides of the cockpit.

1.6.4 The aircraft’s mass and balance

1.6.4.1 A copy of the Load Sheet for the flight in question was found in the aircraft. It had been drawn up by the first officer and signed by the Commander. The aircraft’s mass and balance were first calculated for 7 passengers and a crew of 2.

The completed calculation form shows the following:

Dry operating mass	10 000 lb
Traffic load	1 450 lb
Fuel	2 100 lb
T.O. mass	13 550 lb

Using these masses, the centre of gravity was found to be at the index 52.5. This is well within the limits of 47.5 – 58.

1.6.4.2 The details entered on the Load Sheet contained several inaccuracies. In accordance with a table dated 1 November 2000, which was found in the aircraft, the Dry Operating mass of SE-LGA was 10,648 lb. In addition, the crew took on board 4 people after calculations had been completed. This was a pilot from another airline and 3 ordinary passengers. Of these, only the three last passengers were included in the calculation form as ’Last minute changes’, but without the T.O mass being increased correspondingly. The pilot was entered as crew member no. 3, without increasing the dry operating mass from 10,000 lb. A calculation that takes into account all of the changes shows the following:

Dry operating mass	10 648 lb
Traffic load	2 190 lb
Fuel	2 100 lb
T.O. mass	14 938 lb

Calculation shows that these changes move the centre of gravity forward by 1 – 2 index points. The maximum permitted take-off mass is 15,562 lb.

With an estimated fuel consumption of 600 lb, the mass on landing was 14,338 lb. The maximum permitted landing mass is 14,900 lb.

After the accident, 210 lbs of luggage was found in the rear luggage hold. This makes an average of 19 lb per passenger and seems to have been allowed for in the crew’s calculations.

1.6.5 Stall protection

1.6.5.1 The aircraft was equipped with two independent stall warning systems. Each system consists mainly of a wing-mounted vane that registers the angle of attack of the wing, a stickshaker and an alarm klaxon in the cockpit. The system sounds and activates the ‘stickshaker’ individually. When both warning systems are activated, the control columns are also pressed forward by a hydraulic actuator with a force of around 55 lb until the elevators are 10^{o} below neutral position.

1.6.5.2 If the aircraft’s wings are contaminated with ice, stalling may occur before the warning system registers an angle of attack that leads to warning activation. This situation is highlighted by BAE Systems in a letter to the AIBN, as follows:

> ”The Jetstream 31/32 stalling characteristics were assessed and demonstrated to be acceptable during extensive certification flight testing carried out in natural icing conditions.
>
> The stall identification with ice accreted on the airframe was the speed below which there was a significant increase in lateral/directional activity in the presence of heavy buffet (minimum of 0.5 ‘g’ in amplitude). This was considered to be an adequate definition of the stall and was accepted as such by Airworthiness Authorities including the CAA and FAA. The development of buffet and ‘g’ break,

together with the progressive degradation of lateral stability in the approach to the stalls are such that the aircraft behaviour is distinctly different from flying in turbulence. Although FAR 23.201 requires the stall to be shown by an uncontrollable downward pitching motion of the aircraft, or until the control reaches the stop, the stall identification of the Jetstream 31/32 is considered to be of sufficient intensity of aircraft control behaviour to provide an equivalent safety standard.

Adequate controllability and margin between the stall identification speed and the recommended AFM speeds was demonstrated, and the presence of unmistakable stall warning was considered to be sufficient to allow an inadvertent deviation from the AFM icing speeds without endangering the safety of the operation of the aircraft or reaching any adverse handling characteristics.

It was demonstrated that the aircraft stick shaker and stick pusher system does not always provide a consistent warning or identification of the stall with a significant build up of ice around the lift transducers of the wing leading edges. However, the inherent aerodynamic characteristics of the aircraft are such that a clear unmistakable warning of the stall is available to the flight crew. This was demonstrated in all configurations for both normal operation and simulated failure of the airframe de-icing system. Where stick shake and/or stick push did not activate there was invariably a significant build up of ice around the lift transducers in the wing leading edges.

During flight testing, it was also shown that the stall characteristics did not vary significantly with the ice depth on the protected leading edges and sudden losses of lift were not encountered. This suggests that the trailing edge stall characteristics of the Jetstream 31/32 are primarily affected by the presence of contamination on the leading edge and not significantly by the type or shape of the ice accumulation. This was also found to be the case during the icing certification of the Jetstream Series 4100 aircraft, which has the same airfoil section and similar stall characteristics."

1.6.6 Icing

1.6.6.1 *Description of the aircraft's systems*

Jetstream 31 is equipped with systems for preventing icing (anti ice) and for removing ice (de-icing) on the aircraft during flight. These are:

- A system for removing ice that forms on the leading edges of wings and tail surfaces (Airframe de-icing). This consists of many inflatable rubber pockets (boots) that are fixed to the leading edge. These are manufactured by B F Goodrich. When the boots are inflated, the ice is supposed to be broken off, before the pockets are deflated by underpressure. The air that operates the boots is tapped from the engine compressors, and inflation may take place automatically using a timer or manually. The Jetstream 31 does not have boots on that part of the wings that is between the body of the aircraft and the engines (this is only found on Jetstream 32).

- Another system prevents icing in the engines' air intake. Warm air is applied from the engines' compressors and ensures that exposed areas are heated enough to prevent the ice building up (anti ice). The system is turned on and off manually.
- The systems that prevent icing on the propeller blades, the stall vane, pitot head and the windscreen (anti ice). These have in common that they consist of electrical heating elements that are activated by switches in the cockpit.

1.6.6.2 *Information in the Approved Flight Manual*

The following quotes are taken from the "Approved Flight Manual for the Jetstream Aircraft Limited Jetstream Series 3100, Model 3102":

Section 2, page 13:

> "Icing conditions exist when precipitation or visible moisture is present with an IOAT of +5 ^{o}C or colder and end in these meteorological conditions when the temperature rises to +10 ^{o}C or warmer."

and

> "Airframe de-icing must be switched OFF during take-off and below 200 ft on the approach to landing."

Section 4, page 40:

> "<u>After entry into icing conditions</u>
> CAUTION: If the airframe de-icing system is operated before a significant ice build-up, the ice may flex and bridge over the inflated boots.
> 1.Operate the airframe de-icing system only when a significant build-up of ice has occurred. The optimum thickness for ice shedding will vary depending upon the nature of the ice, but 0.5 in. (13 mm) of ice should be allowed to accumulate on the wing boots before operating the airframe de-icing system."

Section 5, page 58:

> "When airframe icing is suspected on any part of aircraft, the target threshold speed may be increased by a maximum of 15 kt IAS to remain clear of airframe buffet."

1.6.6.3 *Supplementary information from the aircraft manufacturer BAE Systems*

The aircraft manufacturer British Aerospace, later BAE Systems, has published an information folder entitled "Think Ice" for many years. The content of the folder has changed over time. In the version that was issued in 2000, the main chapters were as follows:

- Understanding ice
- Ice protection systems
- Ground operations
- Flight operations
- Appendix I: Jets

- Appendix II: Turboprops

The information is meant to cover all aircraft types from BAE Systems, but also contains specific descriptions for each of the aircraft types when they deviate from the general description. The folder describes how ice affects the stall characteristics of the aircraft and their stall warning systems. It does not mention, however, that ice can lead to stall before the stall warning systems are triggered. Nor does the folder contain any guidance as to how the Wing de-ice system shall be operated in connection with landing, or how much ice should have accreted on the wing before the system is activated.

BAE Systems has also issued a CD, entitled “Cold weather operations”. This contains much relevant information, including the “Think ice” folder, but does not contain any further information about the stall warning system or operation of the Wing de-ice system.

A Service Information Leaflet about Cold Weather Operation issued by British Aerospace in November 1994 is mainly devoted to ground handling. This does not contain information about the stall warning system or operation of the Wing de-ice system.

Based in the warning given in the Approved Flight Manual, the AIBN contacted BAE Systems to gain the manufacturer’s view of ice bridging and use of airframe de-icing (see also subparagraph 1.18.6 and 1.18.7). We quote from the reply letter from the Head of Flight Safety:

> “Our current focus is not related to ice bridging but effective clearance of the boots which will ensure that ice shapes become no more hazardous than those evaluated during certification.
>
> --------------------
>
> In order to change the de-icing procedures to that of “operate at the first sign of icing” would require the system performance to be re-certified with no guarantee that it would be acceptable in terms of aircraft or system performance. BAE have undertaken a review of the procedure appropriate to final approach. We are establishing if a final one-off operation of the boots can be triggered as a standard operating procedure irrespective of the amount of ice on the protected surfaces. This is likely to be during configuring the aircraft for landing to ensure that the level of ice accretion will be no worse that that certified.
>
> During the icing certification of the aircraft which resulted in a considerable number of flights flown in natural icing, the aircraft landed with approx. ½ inch of ice on protected surface and greater than 1 inch on unprotected surfaces. No handling difficulties were encountered with this level of ice accretion when operated at correct speeds for flight in icing.”

1.6.7 <u>Ground Proximity Warning System (GPWS</u>

The aircraft was equipped with GPWS MK 6 delivered by Sundstrand (AlliedSignal). The system warns in six different situations (modes):

1. At Excessive Descend Rate
2. At Excessive Closure Rate to Terrain
3. At Descend After Take-Off
4. At Insufficient Terrain Clearance
5. At Inadvertent Descent Below Glide Slope
6. At Altitude Callouts & Excessive Bank Angle

In the company's Operating Manual Jetstream 3100 (OM part B) the following is written about mode 2:

> "Mode 2 gives two types of alerts and warnings.
>
> Mode 2A is active when:
> - flaps are not in the landing position
> - GPWS FLAP OVRD is not selected
> - the aircraft is not on ILS approach or the glide slope mode has been manually cancelled or the aircraft is more than 1.3 dots below the glide slope.
>
> There are two stages of closure, Initial Closure and Persistent Closure:
>
> Initial Closure - GPWS alert captions come on
> - Single TERRAIN-TERRAIN aural warning.
>
> Persistent Closure - GPWS alert captions stay on
> - Repetitive PULL UP aural warning with normal emphasis.
>
> Mode 2B is active when:
> - flaps are in the landing position
> - GPWS FLAP OVRD is selected
> - The aircraft is on an ILS approach with the glide slope not cancelled with a valid deviation of less than 1.3 dots below the glide slope.
>
> There are two stages of closure, Initial Closure and Persistent Closure:
>
> Initial Closure - GPWS alert captions come on
> - Single TERRAIN-TERRAIN aural warning
>
> Persistent Closure - GPWS alert captions stay on
> - Repetitive TERRAIN aural warning."

In a system description from AlliedSignal, the description of mode 2 includes:

> "Mode 2 supplies warning protection when terrain below the aircraft is rising dangerously fast. These warnings are given well ahead of the aircraft's projected collision with terrain. Radio Altitude (AGL) and Terrain Closure Rate are monitored to determine Mode 2 alerts. Mode 2 also expands as a function of aircraft

speed. The faster the aircraft is travelling, the sooner the excessive closure rates are given.”

1.6.8 Nosewheel steering

The aircraft is equipped with a double nosewheel that can be steered hydraulically. The nosewheel steering is operated by a small steering wheel down on the left side of the left pilot’s seat. When the nose wheel steering is not activated by this wheel, the nosewheel can swing freely.

1.6.9 The company’s Standard Operating Procedures (SOP) for Jetstream 31/32

1.6.9.1 General

The company’s SOP is based on the aircraft manufacturer’s ‘Approved Flight Manual’ or equivalent documentation. The standards set by the aircraft manufacturer must be regarded as a minimum requirement and the company’s SOP must meet these requirements. The SOP must be accepted by the Authority.

1.6.9.2 *Check lists*

B in the check lists indicates that both crew members shall take part in the execution of the point.

DESCEND
(PNF read)

Pressurization………………….	….……………Set	PNF
Landing Data/Approach Briefing	…....……Complete	PNF
Ice Protection…………………..	…………..As Req.	… B
Boost Pumps (below FL 200)….	………………OFF	PNF

APPROACH
(PNF read)

Altimeters………………………	Set/Cross Checked	... B
Fuel Crossfeed/Content………..	..………Off/Check	PNF
Hydraulic Pressure…………….	...……….4 at 2000	PNF
Landing lights…………………..	……………….On	PNF
Cabin Sign……………………..	……………….On	PNF

BEFORE LANDING
(PNF read)

Landing Gear…………………..	.……Down 3 green	… B
Brakes…………………….………	.…………Checked	PNF

Flaps……………………………	….……..(Position)	… B
Prop Sync………………………	..………………Off	PNF
RPM……………………………	.……………….Set	PNF
	<u>At 500 feet above Minimum</u>	
Flow Selectors…………………	……………..…Off	PNF

1.6.9.3 *Approach speeds*

Page 16-1-12:

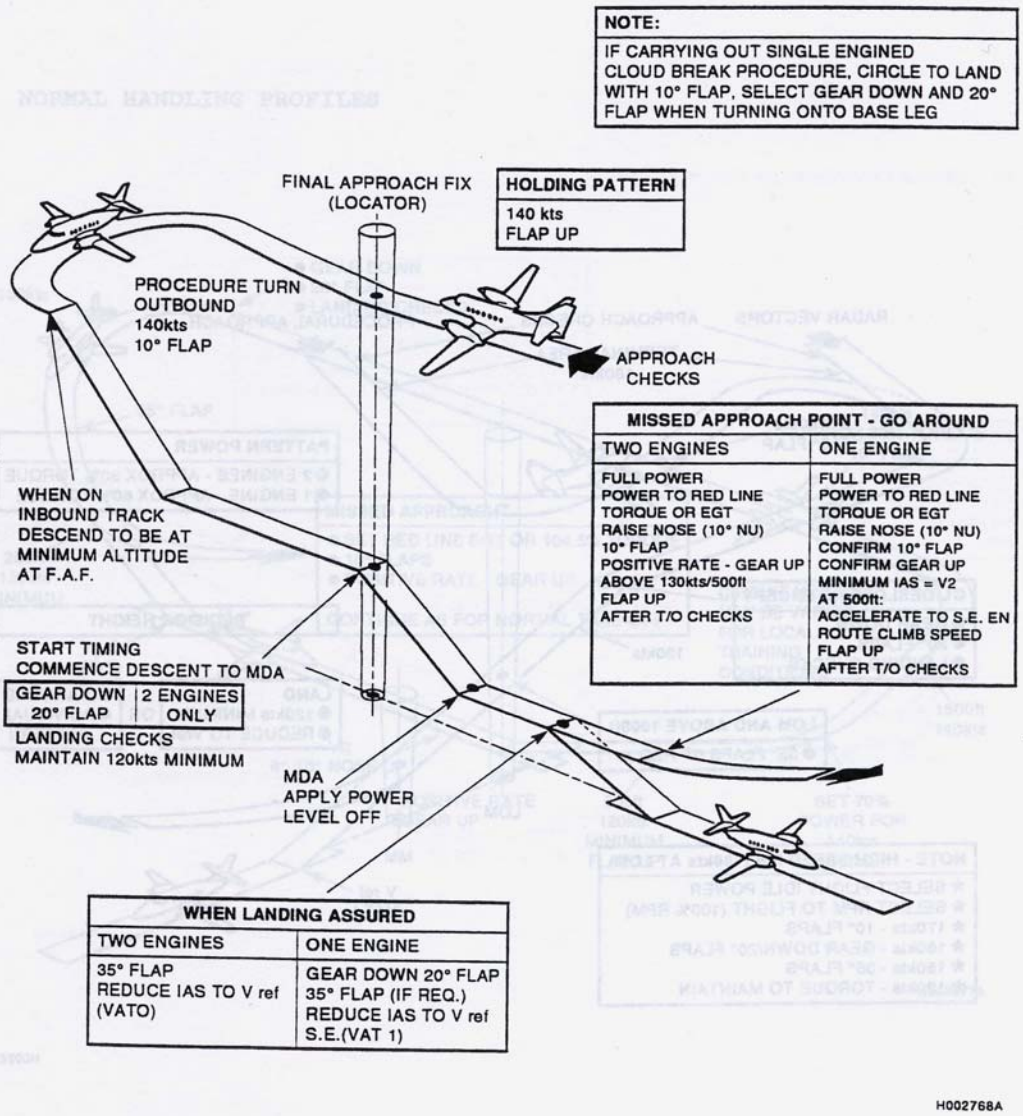
"22. NON-PRECISION APPROACH (TWO ENGINES)

Outbound, reduce speed to 140 Kt and select 10^o flap. Passing the F.A.F. inbound, start the stopwatch, select gear down and 20^o flap, and initiate descend to MDA, minimum speed 120 kt.

When landing is assured, select 35^o flap. Below 200 ft reduce speed to achieve the appropriate speed at threshold."

In the company's SOP a NON PRECISION APPROACH is described in the following manner:

BRITISH AEROSPACE
JETSTREAM
THIRTY-ONE
CREW MANUAL



NON PRECISION APPROACH
FIG.4

1.6.9.4 *Stalling Speed*

Page 16-1-16:

According to Table 1, the Power off Stalling Speed with 35° flap, and a mass of 14,338 lb is 87 kt.

1.6.9.5 *Icing*

Page 16-6-1 and page 16-6-2 about "OPERATION IN ICING CONDITIONS":

> "Icing conditions begin-
> 1.1 When true Outside Air Temperature (OAT) on the ground and for take-off is +5 °C or below, (or when IOAT in flight is +5 °C or below) and visible moisture is present in any form, cloud, fog (with visibility of one mile or less), rain, snow, sleet or ice crystals in the atmosphere.
> 1.2 If there is surface snow, ice, standing water or slush on ramps, taxiways or runways.
> Icing conditions end when the above conditions no longer prevail and the IOAT is above +10 °C."

and

> "Only when a significant ice build-up has been observed (typically half an inch on the leading edges) should the airframe de-icing boots be used. Operations should be limited to selective 5 second MANUAL selections of WINGS and TAIL. This will prevent ice formation bridging the ridges of the boots making them ineffective and produce greater drag than the original ice. For this reason, it is recommended that the use of Airframe de-ice in AUTO mode and random use of MANUAL mode should be avoided in all but severe icing conditions."

and

> "During landing, careful use of nosewheel steering, wheelbrakes and reverse thrust is recommended to prevent skidding."

1.6.10 Other relevant information about approach and landing

1.6.10.1 *Landing speeds*

According to the table in the company Operating Manual (OM) part B Jetstream 3100 page 15-4-4, the Landing Approach Speed with 35° flap and a mass of 14,250 lb (the actual landing mass was 14,338 lb) must be 110 kt. The crew calculated the landing mass incorrectly as 12,950 lb. According to the same table, at 13,000 lb, a Landing Approach Speed must be 105 kt.

According to the table in the ‘Approved Flight Manual for the Jetstream Aircraft Limited Jetstream Series 3100, Model 3102’, page 60, the ‘Target Threshold Speed’ with 35^o flap at the actual landing mass of 14,338 lb should be 107 kt. As stated above, the crew calculated the landing mass as 12,950 lb. According to the same table, the ‘Target Threshold Speed’ should then be 103 kt.

A list (speed booklet) was found in the aircraft that indicated speeds in relation to the mass of the aircraft. Based on this list, it was possible to read that the speed should be 103 ($V_{F35}{}^o$) at a mass of 13,007 lb and with 35° flaps. The list had no reference to type of aircraft, validity date or managing publisher.

On the background of the differences in information provided in the OM and the Approved Flight Manual, AIBN sent an enquiry to BAE Systems. We were then informed that the information in the OM was based on an FAA version of the ‘Crew Manual’. The landing speeds are calculated differently between the FAA and the CAA, and consequently EEE should have bought a new ‘Crew Manual’ when the aircraft was entered into the Swedish register, based on a CAA approval. The correct speeds were, therefore, to be found in the ‘Approved Flight Manual’.

1.6.10.2 *Approach and landing*

OM page 17-13-1

“Caution: BEFORE LOWERING THE FLAPS IN ICING CONDITIONS ESTABLISH THAT NO ICE HAS BUILT UP ON TAIL. THIS COULD CAUSE AN UNEXPECTED TRIM CHANGE.”

Page 15-4-11/12

“4.6 Landing With Visible Airframe Ice
If there is any ice visible on the aircraft during the approach, the landing must be made with 20^o flap.”

From tests in the simulator, BAE Systems has found that the engine torque readings normally are 30 – 35% during approach in conditions equivalent to those that led to the accident. Those values were obtained without the wings being contaminated by ice.

1.6.10.3 *Runway length requirement*

The AIBN has made calculations based on the requirement for landing distance in accordance with the AFM for the Jetstream 31 and JAR-OPS 1. This calculation is based on the figures the crew had available before departure from Flesland. In addition, the following have been used as a basis:

- Landing mass: 12,950 lb (5,874 kg)
- QNH: 1018 hPa
- The altitude of the airport above sea level : 450 ft
- Flaps: 35^o

- Wind: 120^o 10 kt
- Dry runway
- Slope: –0.84%

According to the AFM, calculations give a required runway length of 965 m. According to JAR-OPS 1.520, the available landing distance must be a minimum of 115% when the runway can be expected to be wet at the time of approach. In that case, the available landing runway must be at least 1,110 m under otherwise similar conditions.

The crew calculated the wrong take-off mass. If the crew had used the actual take-off mass in the calculations, the landing mass would have been 14,338 lb (6,504 kg). On a dry runway, a minimum landing distance of 1,040 m would then have to be available. This provides a margin of 153 m in relation to Landing Distance Available (LDA). Equivalent figures for the correct landing mass on a wet runway would require 1,196 m (3 m more than LDA).

The crew stated that they increased the estimated Landing Approach Speed by 10 kt. According to the information in the AFM, 5the target threshold speed can be increased by up to 15% because of ice on the wings without further increase in calculated landing distance.

1.7 Weather

1.7.1 General

1.7.1.1 The weather over eastern Norway on 30 November was affected by an occluded front that reached from Denmark northwards along Norway up to Spitzbergen. The front moved slowly north and weakened during the afternoon. There were clouds from the ground up to FL 080 over eastern Norway, to the west of the front. The air was moist and this resulted in fog and rain. A warm front in the North Sea was on its way to the east towards western Norway.

1.7.1.2 An IGA forecast for Oslo Flight Information Region (FIR), valid for the period 30 November at time 1600 to 1 December 0100, stated that the 0-isotherm was between the ground and 1,500 ft. Moderate icing was forecast that would decrease, first in the south.

1.7.2 TAF, METAR and ice warning

1.7.2.1 No TAF was given for ENSN. The following TAF for the closest airports provides a picture of the weather expected:

ENGM 301524 16010KT 8000 –RASN SCT005 BKN015 TEMPO 1524 5000 –SNRA BR BKN010 PROB30 1524 0800 FG VV001=

ENTO 301523 15015KT 9000 BKN012 PROB40 TEMPO 1523 4000 DZ BR BKN003=

1.7.2.2 METAR issued at time 1650 (for planning):

ENSN 301550Z 14007KT 8000 SCT010 BKN012 04/03 Q1018=

METAR issued at time 1750 (actual):

ENSN 301650Z 14007KT 6000 SCT008 BKN011 04/03 Q1018=

1.7.2.3 The following ICE-MESSAGE was valid:

ENOS ICE MESSAGE 01 VALID 301615/302015 ENMI-
OSLO FIR LOC MOD ICE OBS AND FCST BLW FL150. 0-ISOTERM SFC-4000FT.
HIGHEST SW TART. NC.=

1.7.2.4 After landing in Bergen on flight number EXC 203, the crew reported ice. This led to the following AIREP:

AIREP 301600 ENBR
BA-31 REP MOD ICE 15-20 NM N-OF ENSN, BTN 4000 AND 8000FT=

1.7.3 Observations

1.7.3.1 The AFIS officer has stated that there was light rain, dark and good visibility below the clouds when the accident happened. Around 35 seconds before the landing, the AFIS officer reported wind from 120 ^{o} 10 kt. The wind was at no point in time over 15 kt in the 10 minutes preceding landing.

The crew has stated that they saw the airport visually at a distance of 3 – 5 NM. The wind was as expected and they did not note turbulence of any significance.

The witness who was walking along the runway was surprised that visibility was so good, despite the drizzle and light rain.

1.8 Aids to navigation

The primary aid for approach to runway 19 at Skien Airport Geiteryggen is the Localizer (LLZ) in combination with the Distance Measuring Equipment (DME). LLZ/DME (SE) transmits on a frequency of 110,100 MHz and is positioned east of the runway, around 250 m south of the threshold of runway 19. Localizer SE gives an approach course of 186^{o}. This deviates 2.64^{o} in relation to the direction of the runway, which is 188.64° (offset approach). The radio beacon (locator) Myra (MR) on frequency 289 kHz, is positioned at a distance of 4.75 NM DME (SE). A marker beacon (MKR), Missed approach point is located at a distance of 1.3 NM DME (SE). Runway 19 is also equipped with VOR/DME (SKI) that is on a frequency of 113.600 MHz. This equipment is physically located to the east of the runway, around 300 m south of the threshold of runway 19.

1.9 Communications

During the entire flight there was normal two-way VHF communication between the crew of SE-LGA and the respective Air Traffic Control units. During the last part of the flight, the crew was first in contact with Farris Approach on frequency 134.05 MHz and later Geiteryggen Information on frequency 119.20 MHz.

1.10 Aerodrome information

1.10.1 Skien Airport Geiteryggen offers AFIS services

1.10.2 The asphalted runway is 1,401 m long and 32 m wide. The threshold of runway 19 is located 463 ft above sea level and the equivalent for runway 01 is 425 ft. In the area where the accident occurred the slope was - 0.84%. The Landing Distance Available (LDA) stated for runway 19 is 1 193 m.

1.10.3 Runway 19 has Light Intensity High (LIH) and Light Intensity Low (LIL) approach lights, threshold lights and runway edge lights. The visual approach slope indicator (PLASI L - Pulsating Light Approach Slope Indicator installed on the left-hand side) is at a 3.3^{o} angle. Minimum pilot Eye Height over Threshold (MEHT) is 19 ft.

1.10.4 The instrument landing chart from Jeppesen FliteStar (see point 1.1.3) places the radio beacon (locator) Myra (MR) outside D5 on the profile chart. On the horizontal chart, Myra is placed between D4 and D5. This is in agreement with the information stated in AIP Norway, AD 2 ENSN 5-3.

1.10.5 AIP Norway, AD 2 ENSN 1-6, contains the following text about downdraughts:

> “Downdraughts may occur on final RWY 19 when wind SE to W, above 12 kt.”

1.10.6 In May 2002, the Norwegian Civil Aviation Authority issued AIC - I 11/02 “Special requirements to operators of professional air transport at a number of Norwegian airports”. The airports are divided into three groups with respect to operational conditions that may be significant for air safety. Skien Airport Geiteryggen is placed in group 2. For airports in Group 2 there is a requirement to document fulfilment of special requirements on request by the airport operator or the Civil Aviation Authority.

1.10.7 In conversations with the AIBN, the Commander stated that it was not unusual to be given warnings from the GPWS during approach to runway 19 at Geiteryggen. He had experienced this personally previously in visual flying conditions when he was able to establish that they were at a safe height above the terrain. After the accident, the AIBN has been made aware that it was a known fact among some pilots who flew into Geiteryggen that the GPWS could issue warnings during apparently normal approaches.

1.10.8 On request by the AIBN, information was provided by Luftfartstilsynet (the Civil Aviation Authority – Norway, CAA-N) that no reports had been submitted concerning unintentional warnings from the GPWS linked to Skien.

1.10.9 The Duty Officer at Skien Airport Geiteryggen has confirmed that the runway was inspected 15 min. before the landing. The runway was then damp, without surface water. It was free of ice, but there was some sand on the runway, remaining from earlier gritting. He took a simple measurement of the friction on the runway and confirmed that the friction conditions were good. For this reason, no full friction measurement of the runway was made.

1.10.10 Daily control of the runway's lighting equipment was carried out by airport personnel on the day of the accident. No remarks were recorded for the control. The monthly control of the visual glide path (PAPI/PLASI) was carried out on 19 November 2001 without remarks.

1.10.11 The witness who walked along the runway had worked for periods as an airport officer at Geiteryggen. As he passed the runway threshold, he observed that both the high intensity and low intensity lights were on. Instinctively he noted that all of the lamps in the low intensity lights were lit.

1.11 Flight recorders

1.11.1 SE-LGA was equipped with a Flight Data Recorder (FDR) model F800, manufactured by Fairchild. It has the part number 17M900-274 and serial number 277. This is in accordance with the equipment requirements of JAR-OPS 1. The FDR was taken to the Air Accidents Investigation Branch (AAIB) at Farnborough in England for data retrieval in collaboration with the AIBN. A fault in the unit led to the data being stored at incorrect tape speed. This led to considerable extra work, and limited to a certain extent the amount of data that could be retrieved. The flight data recorder only registered four parameters. Especially engine parameters could have provided valuable information about the accident if they had been registered. The data that was available has however, proved important in the reconstruction of the approach, and the FDR information has been confirmed by the crews' statements and information retrieved from the aircraft's Cockpit Voice Recorder (CVR). A printout of the data from the FDR is appended as annex 1.

1.11.2 SE-LGA was equipped with a CVR model A100A, manufactured by Fairchild. This has part number 93-A100-84 and serial number 59914. This is in accordance with the equipment requirements of JAR-OPS 1. The CVR was taken to the AAIB at Farnborough in England for data retrieval in collaboration with AIBN. The unit stores the last 30 min. of information gained from three sources, sound registered from the Commander and first officer's speakers/microphones respectively, and sound registered by the area microphone in the cockpit. Data retrieved from the CVR contributed to a great degree in clarifying the sequence of events during the flight. Because of a lack of engine parameters on the FDR, attempts were made to analyse the engine's acoustic signature recorded on the CVR. This showed that the engine RPM began to decrease 2.5 – 3 seconds before the aircraft hit the runway. The acoustic signature was also assessed with regard to whether the engines were reversed while the aircraft was in the air. The work was carried out by an accident inspector from the AAIB who had long experience with that aircraft type. He concluded definitely that no reversing had taken place.

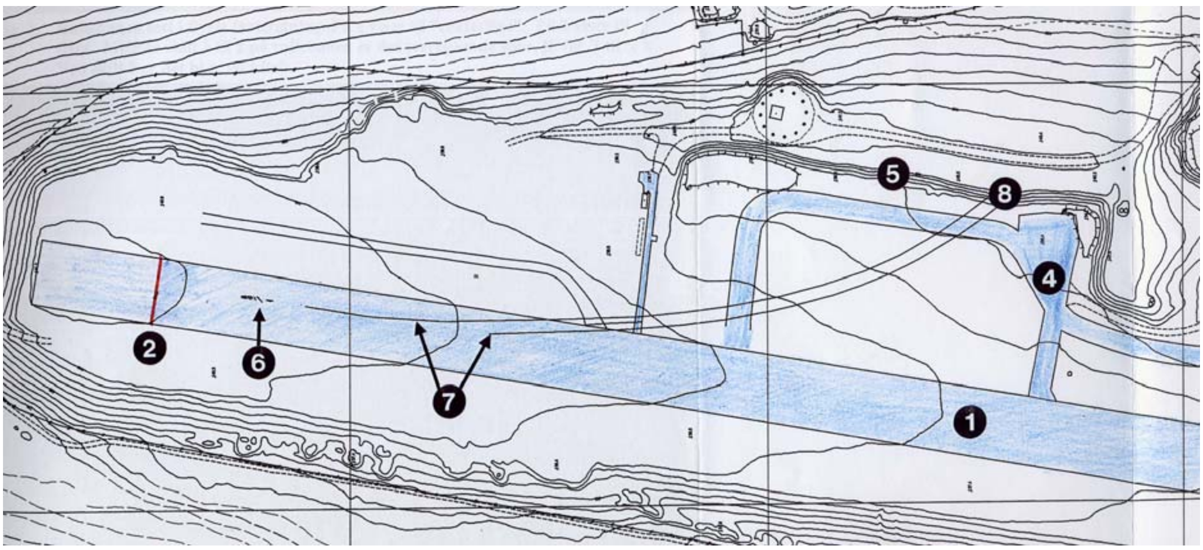
1.12 Wreckage and impact information

1.12.1 Accident site

1.12.1.1 The first trace of the landing is a mark on the runway caused by the left propeller. This mark was 41.7 m into the runway, measured from the middle of the threshold marking lines and 3.75 m to the left of the runway's centre line. 13 lateral strike stripes from the propeller blade were found, with a distance of 46 cm between the 1st and 2nd strike. After this strike, the distance shrank by 1 cm per strike until the 7th strike where the distance once again increased. After the 13th, the marks in the asphalt become longitudinal and irregular, and there were small pieces of paint and plastic in the vicinity. Apart from a few short stretches, it was possible to follow the trail of the aircraft along a 371-metre trail from the place that the propeller touched the runway to the place where the aircraft came to rest.

1.12.1.2 After the aircraft left the runway, it continued around 220 m over a grassy flat area. There are several paved roads/taxiways crossing this area, but the transition between these and the grass is even and in good condition. 100 metres before the aircraft hit the gravel bank, the distance between the right main wheel and the nosewheel was 3.55 m, which indicates that the aircraft had 7^{o} skid to the left with regard to the direction of movement. The aircraft then hit an approx. 5-metre high gravel bank that sloped steeply upwards. The bank, which consists of loose gravel mixed with stones, had earlier been even steeper, but some time before the accident some of the material had been removed so the angle is now around 35^{o}. As a result of this work, the bank was not covered by vegetation. The aircraft struck the bank at an angle of approx. 45^{o}, but the tail was thrown to the right so that the aircraft finally came to rest at an angle of around 100^{o} in relation to the bank (seen in the horizontal plane). The aircraft stopped with its nose 3 m up the bank (see picture under subparagraph 1.1.11).

1.12.1.3 Along the west of the runway, outside the approx. 50 m. wide safety area, the terrain is uneven and wooded.



1 runway, 2 threshold marking, 4 paved road/taxiway, 5 gravel bank, 6 marks from the left propeller, 7 wheel tracks, 8 collision point

1.12.2 The aircraft wreckage

1.12.2.1 The aircraft fuselage and cabin

Three seat backs in the cabin were bent backwards. These were the left seat in the third row, the left seat in the fourth row and the centre seat in the fifth row. The cabin was otherwise undamaged. The lower portion of the tail section of the aircraft was punched in, and the tail cone was bent upwards so that the rudder was locked in the maximum left position.

1.12.2.2 Left wing, the main landing gear, engine and propeller

The rear wing spar was bent upward in the area of the main landing gear assembly. The wing has, therefore, rotated (see inwards from the left wingtip) around the forward wing spar, so that the assembly angle was reduced by around 11^o. This led to the engine and propeller pointing an equivalent number of degrees downwards, with the main landing gear pointing diagonally backwards. The deformation led to comprehensive damage in the wing section between the engine and the aircraft fuselage and significant fracture of the fuel tank, which is an integrated part of this structure. The landing gear was mainly undamaged, but the hydraulic actuator, which operates the landing gear, was torn in two. The left propeller was knocked off at the mounting flange on the engine gearbox and was found by the aircraft's left wingtip. All of the four propeller blades were bent backwards, were heavily twisted and had scrape marks. The left engine was sent to SAAB Nyge Aero in Sweden for rebuilding, but was later considered to be a total loss. The engine had rotated at the same time as it had drawn sand/gravel into the compressor. Marks in the compressor indicated that the engine had been exposed to high G loads, both while it rotated and when it was still. There was a sheared shaft in the gearbox, resulting from high torque.

No ruptures of the brake lines or brakes were found that resulted from the damage that occurred during landing.

The left flaps were found in 35^o position.

1.12.2.3 Right wing, main landing gear, engine and propeller

The right wing was apparently only slightly damaged. The hydraulic actuator that operates the landing gear had, however, been forced into the wing attachment and had caused significant structural damage between the engine and the aircraft fuselage. Except from possible hidden overload damages, the main landing gear was apparently undamaged. All of the four blades on the right propeller had bent tips. The pitch change mechanism was damaged so that the pitch of each blade could be changed individually by hand. The right engine was sent to SAAB Nyge Aero in Sweden for rebuilding. The extent of the damage to this engine was less than on the left engine, but when the general condition of the engine was taken into account, the damage was found to be so comprehensive that this engine was also written off. The engine had rotated at the same time as it has drawn sand/gravel into the compressor. Marks in the compressor also indicated that it had been exposed to high G loads, both while rotating and when it was at rest. There was rupture of the axle connection internally in the gearbox, resulting from high torque.

No fractures were found in brake leads or brakes that resulted from damage that occurred during the landing.

The right flaps were found in the 35° position.

1.12.2.4 *Cockpit*

The nose area of the aircraft was heavily damaged during the crash. The radar and the entire electronic compartment were crushed and depressed upwards and backwards. The nose landing gear well was equivalently crushed and the landing gear itself was bent backwards. The instrument panel in the cockpit was pressed backwards so that the distance between the crew seats and the instrument panel was reduced by an estimated 15 – 25 cm.

The two speed bugs on the Commander's airspeed indicator were fixed at 103 kt and 117 kt. Equivalent figures for the first officer were 103 kt and 110 kt. Both altimeters were adjusted to 1018 hPa.

The flap handle was found in the 35° flaps position.

The other instruments and equipment in the cockpit were not examined in detail.

1.13 Medical and pathological information

Routine blood samples were taken from both crew members. No traces of alcohol, medication or narcotic substances were found.

1.14 Fire

No fire occurred during the crash.

1.15 Survival aspects

1.15.1.1 The damage in the cockpit reduced the distance between the crew seats and the instrument panel so much that the crew were nearly pinned in.

1.15.1.2 No seat belts failed during the crash, but a total of three seat backs were bent backwards. The cabin was otherwise undamaged. After the crash, a number of loose books (Route Manuals) were found in the aisle, but the AIBN have not received information about personal injury caused by loose objects in the cabin.

1.15.1.3 The airport's fire and rescue service was alarmed by the AFIS officer immediately after he realised that the aircraft had crashed. The airport's inspection vehicle arrived on the scene of the accident around 30 seconds after the alarm was raised, and the airport's emergency vehicle arrived around 30 seconds later. When the two airport officers arrived, most of the passengers had already evacuated the aircraft without assistance. The aircraft was searched without finding more passengers, and the aircraft was partially covered by foam. The left wing and engine were covered by foam first as there was a considerable fuel leakage in the area. Then the right engine and wing were covered in foam. Soon after a third airport officer, who was walking his dog, arrived. Together with the two previously arrived airport officers, he organised work at the crash site and led the passengers to the terminal building.

1.15.1.4 Skien Fire Service, the AMK central and the Police authorities were alarmed at around time 1833. As a result, there arrived in turn several fire and rescue vehicles from the Skien Fire Service, six ambulances and two ambulance helicopters at the crash site.

1.15.1.5 The passengers who were not sent to hospital by ambulance gathered in the terminal building and to begin with were taken care of by airport personnel. For a period there was doubt about whether all of the passengers had been brought to safety, and searches were made for a possible passenger in the woods to the east of the crash site. However, after a short time it was established that all of the passengers were accounted for, and the search was called off.

1.15.1.6 The aircraft's emergency locator transmitter (ELT) was automatically triggered by the crash and began transmission. It was later turned off manually.

1.16 Tests and research

None

1.17 Organisational and management information

1.17.1 Authority inspection

1.17.1.1 The JAA (Joint Aviation Authorities) originated in 1970 when the work began on forming a common certification code for building large passenger aircraft in Europe (Airbus). The agreement between the current members of the JAA is based on the JAA Arrangements that were originally adopted in 1990. 36 European countries have joined together to achieve uniformly high safety levels in the aviation industry. The common standards that are achieved must lead to equal competition conditions within the member countries. In the same way, the JAA is working to make civil aviation more efficient. The JAA has issued a number of pan-European regulations (Joint Aviation Requirements JAR) with associated AMC (Acceptable Means of Compliance), IEM (Interpretative/Explanatory Material) and AGM (Administrative & Guidance Material). The common European regulations are not legally binding for the member countries, but the intention is that the content should be included in each country's legislation.

1.17.1.2 The aviation authorities in each individual member country control access and issue Air Operator Certificates (AOC) to companies registered in the respective member countries. The authorities also supervise the companies' activities. An AOC entitles a company to carry out air operations in all member countries. On this basis, the Swedish Civil Aviation Authority issued an AOC based on JAR-OPS 1 to European Executive Express AB.

1.17.1.3 EEE was one of the first companies in Sweden to be given an AOC in 1998. At that time, the company was called CNA International and was granted AOC no. S-016. Several of the requirements and wording in JAR-OPS 1 were at that time relatively new and unfamiliar both for the Authority and for the companies that applied for approval. To aid in the process, the JAA issued guidance material in the form of 'Acceptable means of compliance and interpretative/explanatory material' (AMC & IEM). Even so, both inspectors in the supervision section of the Swedish Civil Aviation Authority and the company's management admitted to AIBN that there were discussions about the interpretation of many of the requirements and how they should be adhered to. Understanding of the requirements has, however, improved considerably over the past years.

1.17.1.4 EEE was formed as a continuation of CNA International AB on 12 May 2000. As a result of this, the company was object to an access process by the Swedish Civil Aviation Authority and granted AOC on 23 May 2000. The company retained AOC no. S-016.

1.17.1.5 Supervision of companies holding a Swedish AOC is carried out by the surveillance section of the Swedish Civil Aviation Authority. In practice, this is carried out by technical and operative inspectors being allocated a number of companies to supervise. Some of the inspection and monitoring takes place through annual inspections of the companies. Usually, inspection of the technical and operative departments takes place at the same time, and parts of the inspection are carried out together. The AIBN has been given access to reports from two inspections that were carried out at the company in February 2002 and January 2003, in other words, after the accident. In addition, the inspection section carried out an inspection of the company's Technical Department (Subpart M) in June 2001. The surveillance section cannot document that any inspections of the operations department in company were carried out in the period between the issue of the AOC in 1998 and up to the accident.

1.17.1.6 The inspection that was carried out in February 2002 was divided into 8 main subjects as follows:

1 The company
2 Premises
3 Personnel
4 Operative
5 Quality system
6 Training
7 Follow-up systems
8 Aircraft and parts

The report states that no physical inspection of the aircraft took place. The inspection revealed three matters in the company's manuals that led to remarks. It was remarked that Ground De-icing was not included in the training papers under Ice and Rain Protection for Ground School. Follow-up of this point was left to the company. Two matters were regarded as being more serious and required follow-up by the surveillance section. One of them concerned lack of reference between the OM D and OM A regarding name of instructors. The other was the requirement for revision of the description of the MEL system where, among other things the missing definitions had to be in the hands of the surveillance section by the end of March 2002.

1.17.1.7 The inspection in January 2003 was only carried by operative personnel. The group of inspection areas was at this time in accordance with the manual structure in JAR-OPS, i.e. OM section A - D. The inspection revealed 4 non-conformances, all related to the company's manuals. All of the non-conformances were reported as closed on 17 February 2003.

1.17.1.8 JAA has published guidelines for authority inspection in the form of the Administrative & Guidance Material. Section Four: Operations, Part Two: Procedures (JAR-OPS) contains an Appendix 5 that discusses INSPECTIONS: CONTINUED COMPETENCE OF AOC HOLDER. We quote from this:

> "1.1 What follows is an attempt to summarise the most important inspections which should be conducted periodically by an Authority once an AOC has been granted."
>
> and
>
> "**3 Operator's Quality System Inspection**
> 3.1 Periodic inspections of the Operator's Quality System should be performed to verify its continued effectiveness. This inspection should include:
> - Quality System management evaluation;
> - Audit schedule and reports;
> - Corrective actions/follow-up system;
> - Quality System training;
> - Quality System records."
>
> and
>
> "**4 Operations Manual**
> 4.1 ---------------The thorough and regular examination of the Operations Manual is the core of the inspector's task. The importance of Operations Manual inspections should be seen in this light."
>
> and
>
> "**10 Pre-flight preparation (Crew)**
> 10.1 An inspector with relevant experience of flight operations should periodically observe the operator's crews at the flight planning and pre-flight preparation stage."
>
> and
>
> "**12 Flight Inspection**
> 12.1 The Authority should aim to make sufficient flight inspections to cover a representative sample of an operator's network in the course of a year."

1.17.1.9 In 1996, the European Civil Aviation Conference (ECAC) started a programme for Safety Assessment of Foreign Aircraft (SAFA). An important element of this work is that unannounced inspections are made and that the result of these inspections is reported to, and analysed by, a central coordinator. This forms the basis of anonymous statistics. In the case of serious irregularities, aircraft can be kept back. The Norwegian CAA carried out such inspections on 7 December 2001 at Gardermoen and 13 December 2001 at Torp. Both of these inspections pointed out a number of irregularities in, among other things, the company's procedures and the crew's knowledge of them. It is not known whether the company has been the subject of SAFA inspections before the accident.

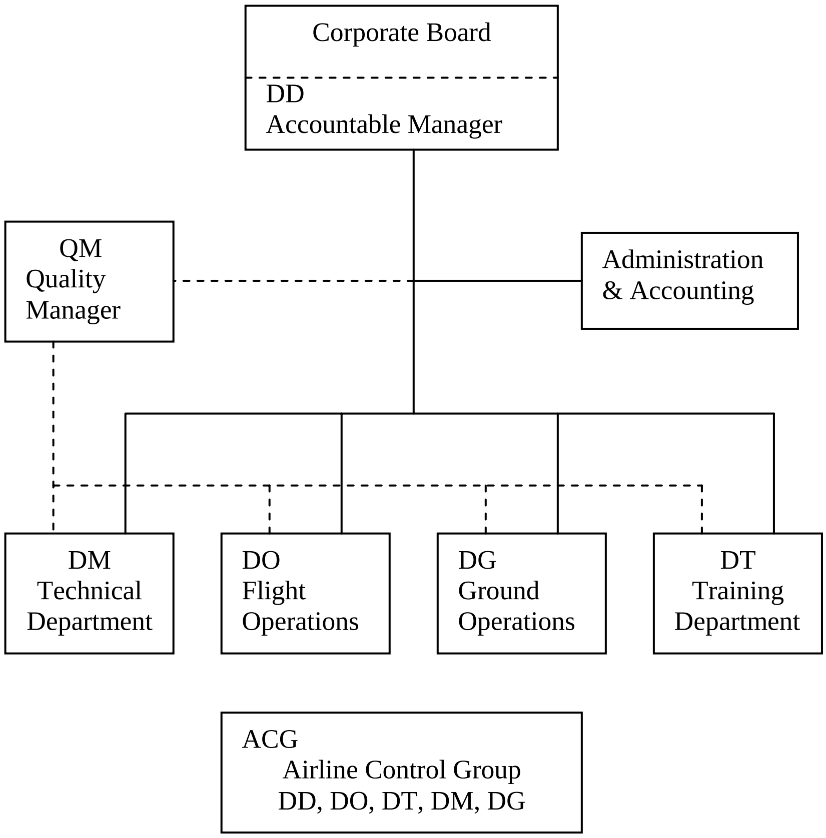
1.17.2 <u>The company</u>

1.17.2.1 European Executive Express AB was formed on 12 May 2000, but is a continuance of the company CNA International AB, which was established in 1987. The Flight Operations Manager of the company holds considerable ownership shares and is a member of the board of directors of the company.

AOC no. S-016 was awarded by the Swedish Civil Aviation Authority on 23 May 2000.

The company has a licence granted by the Swedish Civil Aviation Authority "for civil aviation for business purposes with passengers, mail and freight in accordance with the provisions of the Council's directive (EEG) no. 2407/92 of 23 July 1992 concerning issue of approvals for air transport companies and in accordance with the enclosed licence conditions. The licence applies for activity with aircraft whose maximum permitted take off mass is less than 10 tonnes and/or which have fewer than 20 seats."

1.17.2.2 At the time of the accident, the company had the following organisation:



In connection with the issue of the AOC, the Swedish Civil Aviation Authority has approved the following post holders in the company:

- Accountable Manager
- Flight Operations Manager
- Training Manager
- Maintenance Manager
- Ground Manager

The three first functions were held by the same person, who also acted as line pilot in the company.

1.17.2.3 The company's Maintenance Manager was primarily employed in an external JAR-145 organisation. This organisation carried out much of the maintenance of the company's aircraft.

1.17.2.4 The company's main base was at Karlstad in Sweden. At the time of the accident the company operated four BA 31 aircraft. The company employed a total of 16 people, 6 of whom were Commanders and 6 first officers. Two of these first officers did not have regular contracts of work, but were engaged when needed. The company's Italian flights were operated by a company 100% owned by EEE. Both of these companies operated under the same AOC. According to the company’s Flight Operations Manager, there were plans to extend the business considerably.

1.17.3 <u>The company’s quality system</u>

1.17.3.1 The requirements to a quality system for operators who are carrying out commercial air transport are documented in JAR-OPS 1.035. Quality System. In the explanatory parts of the JAR-OPS regulation (AMC / IEM / AGM), the quality system is described in detail with a number of ‘quality elements’, as well as a precise description of the method for ensuring continually correct quality in companies, a so-called Quality Assurance Program. In addition, the Accountable Manager is responsible for the design and implementation of the company’s own quality system, while the Quality Manager is responsible for monitoring the effect of the quality system, and ensuring that non-conformances are corrected. The quality requirements referred to in JAR-OPS 1.035 are to a great extent harmonised with the general system requirements that are used in well-developed companies and in organisations where safety is paramount.

1.17.3.2 The overall system description of the company’s quality system, as well as the goals and policy with regard to application of the quality system are documented in OM part A. This includes procedures and description of the quality audits. We quote from OM part A, chapter 3.1.3 ‘Purpose of the Quality System’:

> “The purpose of the quality system is to monitor compliance with JAR regulations and Company quality standards to ensure safe operations and airworthy aircraft.”

And from chapter 3.1.4.1:

> “The Quality Manager is responsible for establishing an independent quality system to monitor compliance with JAA requirements and maintaining a close liaison with the Authority on all matters affecting approval.”
>
> and
>
> “The Quality Manager is responsible for:
> - Monitoring flight operations in respect of safety and reliability
> - ----------
> - The Company’s established flight safety standard system and to inform, train and supervise all personnel in this matter.”

1.17.3.3 The company’s Quality Manager was a part-time employee and had a contract to work in the company a minimum of two days each month. According to the company’s Accountable Manager, the Quality Manager was somewhat more involved in the company’s business, especially in connection with the quality audits.

1.17.4 The Skien Operations

1.17.4.1 In accordance with the Council directive 2408/92, air transport companies holding an AOC and licence have the right to carry out Commercial Air Transport Operations within the EU. The Council directive has also come into force as a Norwegian regulation. Before flying may take place, the aviation authorities in the relevant country must be notified. On the background of this, European Executive Express started scheduled flights between Skien and Bergen on 1 October 2001.

1.17.4.2 The company could not provide formal documentation of the preparations that were made before starting the route. The Flight Operations Manager informed us that the flight between Skien and Bergen was not regarded as being special in any way. As a result, the preparation limited itself to entering into agreements for ground services, fuel supply and hangar rental. To begin with, after the start-up, the company's Flight Operations Manager flew as a Commander. He informed the AIBN that was a way to gain a good insight into the operation, at the same time as carrying out the necessary quality assurance. Experience gained in Italy proved to the Flight Operations Manager the advantage of having locally familiar members of the crew. This was one of the reasons that the Flight Operations Manager considered the Commander at the time of the accident on 30 November to be well qualified as a Commander on the route between Bergen and Skien. According to the Flight Operations Manager, the Commander's familiarity with both Geiteryggen and Flesland was one of the reasons that no questions were asked about his ability to manage problems that potentially could occur during daily operations.

1.17.4.3 The company had based one aircraft and a crew at Geiteryggen. There were no other representatives of the company present. Ground services were leased from two separate companies at Skien and Bergen, respectively. The aircraft normally stood overnight in a rented hangar at Geiteryggen and the Pre Flight Inspection was carried out by crew members. If technical problems arose that could not be resolved by the Commander, the aircraft either had to be flown back to Sweden, or technical staff had to come to Norway. In accordance with current regulations, that type of aircraft had to be inspected by an aircraft technician at a minimum of every 14 days. This was normally accomplished by the aircraft that was stationed at Geiteryggen being flown to Västerås every Friday and returning on Sunday evening. The crew in Norway usually carried out this flight. As an alternative, another aircraft and crew came from Sweden and change of aircraft took place at Geiteryggen. The inspections were normally carried out by the JAR-145 organisation, SkyWays, in Västerås. The company also contracted maintenance services from the JAR-145 organisation, Karlstad Flygservice AB.

1.17.4.4 As part of preparation for the scheduled flights, the company issued a folder with the Instrument Landing Chart produced by Jeppesen FliteStar. The folder was dated 12 October 2001 and contained all relevant charts for Skien and Bergen.

1.17.4.5 The same crew was based at Geiteryggen usually for a week at a time. The documentation from the daily flights should be collected and put in an envelope (Flight Folder) and sent to the company's operative management without delay. In practice, the envelopes were stored until Friday and flown to Västerås. Other contact with the crews at the external bases and the head office of the company usually took place by telephone.

1.18 Additional information

1.18.1 Relevant information from JAR-OPS 1

JAR-OPS 1.940 Composition of Flight Crew:

“(a) An operator shall ensure that:

(1) The ………….
(2) ……………….
(3) All flight crew members hold an applicable and valid licence acceptable to the Authority and are suitable qualified and competent to conduct the duties assigned to them;”

JAR-OPS 1.945 Conversion Training and checking (a)

“An operator shall ensure that:

(1) A flight………...
(2) A flight crew member completes an operators conversion course before commencing unsupervised line flying;
    (i) When changing………
    (ii) When changing operator”

JAR-OPS 1.965 Recurrent Training and Checking (e):

“*Crew Resource Management.* An operator shall ensure that each flight crew member undergoes Crew Resource Management training as part of recurrent training.”

JAR-OPS 1.975 Pilot-in command – Route and Aerodrome Competence Qualification (See AMC OPS 1.975):

“An operator shall ensure that, prior to being [assigned as Commander or as pilot to whom the conduct of the flight may be delegated by the Commander, the pilot has obtained adequate] knowledge of the route to be flown and of the aerodromes (including alternates), facilities and procedures to be used.”

The following is stated under AMC OPS 1.945(a)(9)/1.955(b)(6)/1.965(e) point 2:

“If the flight crew member undergoes a subsequent conversion course with the same or a change of operator he should complete the appropriate elements of the CRM course. The flight crew member should not be assessed either during or upon completion of this training.”

The following is stated under IEM OPS 1.945(a)(9)/1.955(b)(6)/1.965(e) point 4:

> ”CRM training should also address the nature of the company’s operations as well as the associated crew operating procedures. This will include areas of operations which produce particular difficulties, adverse climatological conditions and any unusual hazards.”

1.18.2 Relevant quotations from the company’s manuals

1.18.2.1 From the company’s Operations Manual Part A. General/Basics we quote:

> **“2.3 Accident Prevention and Flight Safety Program**
> European Executive Express, Accident Prevention and Flight Safety Program are based upon the quality standards of the Company. In order to prevent accidents and to maintain the stipulated safety standards, it is of the utmost importance that discrepancies and findings are reported on FOR/TOR as described in this section of the OM.”

The company could not provide AIBN with formal documentation or other proof of activity associated with this programme.

> “ **2.4.9.2 The Use of FOR**
> The FOR shall be used for any occurrence, which causes:
> - Interruption of flight
> - Reduced airworthiness of aircraft
> - Unsafe technical condition
> - Unsafe operational condition”

> “**2.4.9.3 FOR List**
> The following occurrences indicated below shall always be reported by use of FOR. The report should be distributed to the Authority within 24/72 hours. The company Flight Operations Department shall accomplish this distribution without delay.
> ----------
>
> Navigation errors
> - Occurrences during flight causing risk of collision with terrain e. g. GPWS warning.”

> “**3.1.4.1 Scope of responsibility**
> -------------
> The Quality Manager is responsible for:
> - ------------
> - the Company’s established flight safety standard system and to inform, train and supervise all personnel in this matter.”

"**8.3.5.4 Basic GPWS**
------------ Whenever a warning is received, the immediate response must normally be to level the wings and initiate a maximum gradient climb to the minimum safe altitude (MSA) for the sector being flown, (but see para 8.3.5.5, below).

8.3.5.5 Warnings-Discretionary Action by Commander
The response to a warning, as outlined in paras 8.3.5.3 and 8.3.5.4 above, may be limited to that appropriate to an alert only if:

a) the aeroplane is being operated by day in conditions which enable it to remain 1 nm horizontally and 1 000 feet vertically from cloud, and in a flight visibility of at least 5 nm; and
b) it is immediately obvious to the Commander that the aeroplane is in no danger in respect of its configuration, proximity to terrain or current flight manoeuvre."

1.18.2.2 We quote from the company's Operations Manual Part D. Training:

"**2.1.2.6.5 Crew Resource Management**

Flight crew members should complete the major elements of the full length CRM course over a four year recurrent training cycle."

"**2.1.4.4 CRM TRAINING**

If the flight crew member has not previously completed an operator's conversion course then a full length CRM course will have to be completed. If the flight crew member undergoes a subsequent conversion course he shall complete the appropriate elements of the CRM course.

The syllabus for the course is held by the Flight Training Manager and will be issued to the Instructors and students at the appropriate time.

The student will not be assessed either during or on completion of specific CRM training, courses or exercises."

"**2.1.4.5 SYNTHETIC TRAINING DEVICE/AEROPLANE TRAINING**

2.1.4.5.1 General

Flying training………………..by suitably Qualified SFI/SFE/TRI/TRE.

Aeroplane / Flight Simulator training with a flight crew of two or more will place particular emphasis on the practice of LOFT and CRM."

"**2.1.4.6 FLYING TESTS AND CHECKS**

The following mandatory tests and checks will be carried out on or prior to completion of the conversion training and prior to commencing Line flying under supervision:
(a) Emergency and Safety Equipment Check;
(b) Pilot Type Rating Proficiency Check;
(c) Operator Proficiency Check;
(d) IR Renewal;"

"**2.1.4.7 LINE FLYING UNDER SUPERVISION**

Line flying under supervision provides the opportunity for a flight crew member to carry into practice the procedures and techniques he has been made familiar with during the ground and flying training of the conversion course."

"**2.1.5 Route Competence Training**

2.1.5.1 GENERAL

Prior to being assigned as Commander the pilot shall undergo training to ensure that he has obtained adequate knowledge of the route to be flown and of the aerodromes (including alternates), facilities and procedures to be used.

Route competence training will include knowledge of:
(a) terrain and minimum safe altitudes;
(b) seasonal meteorological conditions;
(c) meteorological, communication and air traffic facilities, services and procedures;
(d) search and rescue procedures; and
(e) navigational facilities associated with the route along which the flight is to take place."

1.18.3 <u>The company's recruitment of pilots</u>

1.18.3.1 According to OM Part A, the company must have a Company Selection Board. We quote from subparagraph 5.1.2:

> "The Company Selection Board will be established at any time recruitment or upgrading of flight crew is imminent. The Board consists of Accountable Manager, Flight Operations Manager and Ground Operations Manager.
> ----------------
> The Company Selection Board procedures shall be described with qualification checklists. Flight Operations Manager is responsible for these procedures.
>
> All Company Selection Board meetings shall be recorded and kept in file under lock."

1.18.3.2 The company's Flight Operations Manager explained that the supply of new pilots to the company was variable. Correspondingly, there were major variations in the length of time people stayed before applying to join larger companies. He clearly understood that the company was one step on a career ladder for most people, and that this could lead to a considerable turnover of personnel depending on the labour market for pilots. For that reason, it was generally difficult to retain experienced Commanders. During the period prior to the accident, however, many pilots had been enquiring with the company about work. This had led to a situation in which it was possible to employ experienced Commanders.

1.18.4 In-house training within the company

1.18.4.1 The company did not use a simulator in its periodic proficiency checks (OPC/PC). JAR-OPS 1 approves this being performed in aircraft. In JAR-FCL (Flight Crew Licensing) paragraphs 1.240 & 1.295 subparagraph 2, however, it states:

> "….. Flight simulators, if available and other training devices as approved shall be used."

1.18.4.2 The company did not have its own resources for tuition in CRM, but bought in this type of service from outside companies.

1.18.4.3 According to the company's documentation, the Commander performed Line Flying under Supervision with one of the company's first officers. According to the company's documentation, this first officer was not trained as a Line Training Captain nor had the first officer any other type of instructor skills qualifications. The company's Operations Manual Part D Section 3.1 Procedures for Training and Checking, has not been drawn up. Consequently, there are no procedures for the way in which Line Flying under Supervision should have been performed.

1.18.5 Later accident involving a company aircraft

The company had another air accident on 17 September 2003. SE-LNT, a Jetstream 31, had an accident on landing at Luleå-Kalix airport (ESPA) in Sweden. The flight was a normal scheduled flight, but there were no passengers onboard and the crew were uninjured. The aircraft was a total loss. The accident was investigated by the Swedish Board of Accident (Report RL 2005:07).

1.18.6 Accident involving Embraer EMB-120RT, N265CA at Monroe, Michigan 9 January 1997

1.18.6.1 The aforementioned aircraft operated by Comair Airlines Inc., flight number 3272, crashed after the flight crew lost control of the aircraft in icy conditions. All 29 people onboard were killed. The accident was investigated by the US National Transportation Safety Board (NTSB), and resulted in report no. DCA97MA017. One topic within the report covered the procedures concerning the operation of the aircraft's de-icing system. Conclusion no. 14 of the report states:

"Based primarily on concerns about ice bridging, pilots continue to use procedures and practices that increase the likelihood of (potentially hazardous) degraded airplane performance resulting from small amounts of rough ice accumulated on the leading edges."

1.18.6.2 This conclusion was written in the light of the fact that, on 12 April 1996, Embraer issued revision no. 43 to the AFM including the following text:

"Monitor ice continuously during climb/cruise. At first sign of ice formation, turn all ice protection systems on."

1.18.6.3 The accident also led to the FAA issuing a Notice of Proposed Rule Making (NPRM). This was issued in the form of a 'Proposed AD' which contained proposals for revisions of the aircraft's manuals so that the crew ensures that air operated systems for wing de-icing are switched on as soon as ice forms on the aircraft. In addition, it was proposed that the system was operated manually or automatic continuously to minimise the chance of ice build-up right up until the aircraft is out of ice-formation areas, or until it is entirely clear of ice.

As a response to this NPRM, BAE Systems wrote the document AE1100/J32, in November 1999. This contains a thorough historical review of the basic certification data and later testing and practical experience of the Jetstream 31 and 32 in icing conditions. Quote from subparagraph 3.1.1 Airframe De-icing System Design:

"The Jetstream 32 and 32 airframe pneumatic de-icing system was designed to operate after accretion of around ½ inch of ice on the protected leading edges. This was primarily due to the relationship of ice shedding performance (efficiency) with ice accretion depth and atmospheric conditions, which was determined during certification flight testing and by the de-icing boot manufacturer during development icing wind tunnel testing. In general, it was found that as ice depth increases the ice removal performance improves, with optimal ice shedding with around ½ to 1 inch of ice. At lower or greater ice depths there is a possibility of poor shedding efficiency leading to ice capping (bridging), asymmetrical ice removal, and accumulation of irregular and unusual ice shapes due to residual ice remaining after inflation."

Quote from subparagraph 3.1.5 Position of the De-icing Boot Manufacturer:

"B.F.Goodrich typically recommends that 0.25 to 0.50 inch of ice be accumulated to get the most efficient ice removal. This typically results in approximately an 80 %+ ice removal. The percentage of ice less than 0.50 inch thick would result in less than 80 % removal, and vary dramatically based on the thickness and air temperature (cold temperature/ less ice removal)."

Quote from the conclusion in paragraph 8:

"BAeRA concludes that the airframe de-icing system operation and the aircraft handling and performance characteristics determined by the current certification standard allows safe flight in icing conditions. There is no evidence to suggest that

> the Jetstream Series 3100 or 3200 have any deficiencies with regard to operation in icing conditions, and therefore, there is insufficient justification for the FAA to mandate a change in the current procedures for operation of the airframe de-icing system."

According to the information from BAE Systems, the proposed AD was withdrawn from the Jetstream 31 on the basis of this statement, among other things. The accident in question was, however, a contributory factor in SAAB changing its de-icing procedures for the SAAB 340 and SAAB 2000. Applicable procedures for these aircraft are actuation of 'airframe de-icing' at the first sign of ice formation on the wings.

1.18.7 Comments from BAE Systems on the basis of the draft report

On the basis of the draft report in which the AIBN expresses doubts about the danger of 'ice bridging', BAE Systems provided the following remarks:

> "With regard to ice bridging it is worth noting that the use of an automatic cycle of the de-icing boots may increase the risk of ice accretion starting to form on the tubes during the inflation sequence. Ice accretion initiated in this way can be difficult to remove. Although this is not classical ice bridging, where the tubes inflate in a cavity behind an ice cap around the leading edge, it is still ice that cannot be readily shed and is therefore a form of bridging."

1.18.8 The crew's review of the draft report

The crew is always given the opportunity to read and make comments on AIBN reports before these are made public. In this case, the Commander has turned down the offer to read the report, and it has not been possible to contact the first officer in Italy. The report will therefore be published without it having been reviewed by the crew members.

1.19 Useful or effective investigation techniques

In this investigation, no methods have been used which qualify for any specific reporting.

2. ANALYSIS

2.1 Introduction

The following analysis is being introduced with a review of what is often called the sharp end. In other words, the crew, the crew's conduct and the crew recourse management (CRM) during the flight. In addition, an analysis is made of possible explanatory factors for why the landing was so hard that the aircraft sustained structural damage and left the runway. However, it is important to be clear that the crew's actions were made within frameworks and requirements specified by the company, and ultimately by the inspection authorities. This is often considered to be the underlying and/or organisational factors. These circumstances do not have a similar obvious connection to the accident, but experience from accident prevention work indicates that organisational factors have an indirect effect on an individual's actions. For that reason, the AIBN has undertaken investigations of the company and the frameworks within which the company works. This is analysed in paragraph 2.9. In paragraph 2.10, the AIBN has chosen to use a model (The Swiss Cheese Model) drawn up by James Reason, Professor of Psychology at the University of Manchester. This model has gradually become widely used to illustrate the way in which latent and active failures can lead to an accident.

2.2 The flight crew

2.2.1 Introduction

After a collective evaluation of a series of individual requirements, the AIBN believes that the crew had documented ratings to serve on the flight in question. However, queries may be raised about whether the crew really were qualified and had attended relevant training courses. The AIBN believes that the background, instruction, training and standardisation of members of the flight crew are central factors in being able to understand what led to this accident. Below, these factors are assessed in further detail.

2.2.2 The backgrounds of members of the flight crew

2.2.2.1 The Commander and first officer had very different backgrounds. The Commander had been flying for 20 years and had gained a wide range of experience on light and medium weight aircraft. He had been employed by a number of airlines and had progressed through the grades from first officer to Commander, instructor and Flight Operations Manager. Although the Commander has not complained to AIBN about the progress of his flying career, there is reason to believe that the constant changes of employer that have taken place in the last few years prior to the accident had led to a certain type of mental fatigue. Short-term periods of employment lead easily to the bond between colleagues becoming weaker and to reduce the possibilities to develop loyalty to the company and employer. Frequent changes are challenging in that they place huge demands on abilities and the desire to learn new processes, and correspondingly to unlearn previous ones. During such constant changes, it is known that people easily fall back into previously learned patterns of activity and experience, particularly in stressful situations, and to a lesser extent manage to relate to constant changes in procedures.

2.2.2.2 The first officer had relatively limited flying experience. Although he had been flying for 11 years, he had gathered little relevant experience during the first 9 of those years. On the BA 31, his experience was essentially limited to the function of first officer between two Italian airports. In general, information from the Flight Operations Manager and Commander indicates that the first officer’s performance was below average. His performance during the flight which led to the accident must however be viewed in the context of the circumstances within the company and the work situation that the Commander created for the first officer.

2.2.3 Instruction and training within the company

2.2.3.1 In most circumstances, the company could be regarded as small. The ability to earn revenue from four 18-19 seater passenger aircraft is limited. This sets limits on the number of people that can be employed in administrative positions as well as the resources that can be put into instruction and training. The requirements for aircraft crews stated in JAR-OPS 1, subpart N, are very general, but seem to have been covered. With a little goodwill, the company also seems to have covered its own requirements for training as stated in the OM part D (see subparagraph 1.18.2.2). An essential point regarding training is that both members of the crew had type rating on the BA 31 when they were taken on by the company. Basic training on the BA 31 was therefore outside the company's control. In accordance with the company's own regulations, this meant that the Commander, for example, had not participated in basic CRM training under the company's direction. The AIBN believes that CRM training is of greatest effect when it is carried out under the direction of the airline, so that the company's experience, attitudes and standards become part of the concept. This is also emphasised in the informational material issued by the JAA.

2.2.3.2 The Commander had flown an Operator Proficiency Check/Proficiency Check with the company's Flight Operations Manager, but had otherwise not had any other formal training in the company's quality system, standards and procedures. Correspondingly, the first officer had had the minimum of training required in relation to regulations and the company's own procedures. If the instruction and training within the company is to be assessed on the basis of recognised criteria for safety, the company's organisation might be characterised as deficient. The two pilots had not undergone joint training with other flight crew members under conditions that came close to the company's operational activity (Route Check or Line Orientated Flight Training, LOFT). Neither had they had access to simulator training under the company's direction, and they had had limited instruction and experience on the company's procedures and quality system.

2.2.3.3 The Commander had only worked for the company since the middle of October and consequently had had limited time to get to know the company. In the opinion of the AIBN, neither had he been given relevant training in procedures and routines for the company's scheduled operations between Skien and Bergen. The Line Flying under Supervision that the company had documented was undertaken with another of the company's first officers who was himself inexperienced in the operations, and who did not hold the status of Instructor. One can assume that this can be linked to the fact that procedures for 'Training and Checking' in OM-D was not worked out.

2.2.3.4 The first officer had generally limited experience and had never previously flown a BA 31 on relatively short routes or in Norway in winter conditions. The AIBN is of the opinion that, on this basis, the crew was faced with an unnecessarily great challenge when they were set to operate between Skien and Bergen. It is doubtful whether the crew collectively had the necessary instruction and training to be able safely to carry out this type of flying.

2.2.3.5 <u>Crew workload</u>

The pilots gave the AIBN the impression that they felt fit to fly and had had sufficient rest before they began work on the morning of the day of the accident. Realistically, this might be considered to be relative to the crew's workload and opportunities for rest during the previous two weeks. Considering the occasionally tense relationship between the members of the flight crew, and the first officer's apparently high level of mental stress with several unfamiliar operational challenges, the picture might appear to be quite different.

2.2.3.6 Crew Resource Management (CRM)

As is clear from Section 1.1, occasionally there was very poor cooperation between members of the flight crew in the cockpit immediately prior to the accident. The AIBN sees a series of factors that could be involved in explaining how this accident could happen:

- The members of the flight crew had not been given sufficient CRM training. The Commander had had no CRM training under the company's direction, and the first officer had only attended a minor part of the company's overall training course. This type of training becomes particularly important when the flight crew members start out representing two different national cultures.
- During the period prior to the accident, the Commander had flown for a number of airlines and he was employed at EEE on contract with a period of notice of one month. This could be an unfortunate starting point from which to build good relationships between members of a crew. Similarly, this has an impact on loyalty to the company and ownership of the company's rules and procedures.
- EEE had drawn up few of its own standard operating procedures (SOP). With regard to approach procedures the company used very general procedures drawn up by British Aerospace. This lack of detailed procedures led, for example, to different views of 'call outs' when monitoring correct approach speeds.
- The crew could operate for lengthy periods without any contact with the company's operations management other than sporadic telephone calls.
- The Commander had only been flying for just over a month for the company.
- The first officer had previously never flown in Norway and the Commander believed that the first officer exhibited fundamental weaknesses in performing his duties.
- The company had not undertaken a formal Line Check of either the Commander or the first officer. The flight crew members' performances under conditions that were close to the company's operational activity were consequently unfamiliar to the company.

2.3 The approach

2.3.1 Relationship between the crew members

The atmosphere in the cockpit was relaxed at first and gave the impression of being a routine operation. As early as the initial phase of the descent, however, the relationship between the two flight crew members was perceptibly not of the best. During this period, the Commander observed that they had ice on the wings. The comment "Now you start to think very correct" could initially seem like an acknowledgement, but it could also have the opposite effect by meaning "now you have finally done something right". During the descent to the first minimum crossing altitude of 3,500 ft, the AIBN, based on information obtained from the CVR, recorded that the Commander assumed a more dominant role and that the first officer became passive. On first actuation of the GPWS, the atmosphere in the cockpit became considerably more tense. In that context, the first officer was informed "so next time you fly, don't descend too fast to 3 100" in a manner that was not intended to be instructive or to build up self-confidence. When the GPWS was actuated for the third time, the first officer chose to climb by approx. 200 ft, causing the Commander to exclaim “don’t start to f…. it up again now (name of the first officer)”. In the opinion of the AIBN, the stress level had by this time increased so much between those two flight crew members that it was having a negative effect on their performance. The Commander was clearly irritated with the first officer’s performance and was actually carrying out the flying himself via commands to the first officer. The first officer’s passivity meant that, to a large extent, he only carried out the actions that he was instructed to do. The basic principle in a crew coordination in which one carries out actions and the other checks their execution, was not applied. In this situation, the ice on the wings was forgotten. During the last 90 seconds of the flight, once the airport was visible to them, the atmosphere in the cockpit eased. The Commander read the checklist and the first officer flew stabilised towards the runway threshold. Both flight crew members have given the AIBN the impression that the last part of the approach took place as expected.

2.3.2 Use of checklists

The occasionally high level of stress in the cockpit and the collapse of crew coordination were crucial factors leading to the ice on the wings being forgotten. Contributory to this was the fact that checking for ice on the wings is not included on the Before Landing Checklist (see subparagraph 1.6.9.2). The AIBN believes that the hazard of ice on the wings is something that might be expected (on all aerodynamic surfaces) prior to landing throughout a great part of the year in Norway. Ice has a considerable effect on the aircraft’s performance and has an effect on establishing landing speed and the use of flaps. It seems natural therefore that a check for ice should be included as part of the tasks prior to landing and that this should be linked to the Before Landing Checklist. The AIBN therefore believes that the aircraft manufacturer, BAE Systems, should assess whether such an addition should be included in the Approved Flight Manual, and that EEE should assess the introduction of the item in the company’s SOP.

2.3.3 The approach to Geiteryggen viewed in relation to the GPWS warnings

2.3.3.1 The terrain north of Geiteryggen is undulating with peaks of around 2,000 ft in height. In some places, there is less than 1,000 ft between the terrain below and the approach flightpath. During the relevant approach, the GPWS actuated Mode 2A. This actuates when the aircraft is moving too quickly towards the terrain (excessive closure rate). Closure rate is a result of the aircraft’s descent speed, the aircraft’s speed and the shape of the terrain. During the approach, the speed was at times up to 175 KIAS while the aircraft also undertook a descent at 1500 ft/min. Combined with occasional steep escarpments in the terrain below, this explains why the GPWS actuated. The AIBN is of the opinion that the warnings could have been avoided if the crew had maintained a lower approach speed, such as 140 kt, which is recommended for instrument approaches. Better control of the descent speed might also have prevented the warnings.

2.3.3.2 The GPWS actuated when the aircraft was in cloud. The degree of seriousness when such warnings are issued is emphasised by the fact that the ICAO mentions warnings from the GPWS during IMC as an example of a serious aircraft incident. The AIBN believes that the warning is an important safety barrier which contributes to preventing Controlled Flight Into Terrain (CFIT) accidents and that it must be taken seriously. The company is open to ignoring warnings when “it is immediately obvious to the Commander that the aeroplane is in no danger”. Such a situation-dependent assessment can have several weaknesses, and a number of CFIT accidents have occurred exactly when the Commander was convinced that the aircraft was not in danger. In this case, the first officer stopped the descent because of the GPWS warnings, but the Commander ordered a continued approach. This resulted in a serious conflict situation in the cockpit. In general, the AIBN is of the opinion that a crew in the case of a GPWS warning during approach with no visual reference to the ground shall initiate a climb.

2.3.3.3 For a period, the aircraft was in a position considerably above the vertical approach profile described. This made the Commander declare “we never gonna make it”. A natural consequence of such a statement would be for the Commander to abort the approach. Alternatively, the Commander could have taken over as ‘Flying Pilot’. However, the Commander neglected to intervene, and repeated the statement a short time later. In the opinion of the AIBN, this only succeeded in placing an extra burden on the first officer who was already working under great pressure.

2.3.3.4 Recording of GPWS warnings by other operators and with other types of aircraft indicates that the problem at Geiteryggen is not linked exclusively to EEE and flying the BA 31. However, no information about these warnings has been given to the Norwegian Civil Aviation Authority. The AIBN believes that it is extremely unfortunate that information about such ‘known’ problems is not being reported to the Authority. For example, the approach to Kristiansund airport, Kvernberget (ENKB), was changed on the basis of reports of this type.

2.3.3.5 It should be the responsibility of both the individual Commander and the airline’s flight operations management to inform the Norwegian Civil Aviation Authority of situations that could obviously threaten air safety. There is no absolute requirement for EEE to use FOR or any other forms of reporting in the event of GPWS warnings. However, the AIBN is of the opinion that the Commander, independently, should have made contact with the company’s flight operations manager when he set off GPWS warnings during previous approaches. Such contact might have led to an internal review of the approach procedures for Geiteryggen. The fact that this did not happen might indicate that the exchange of information between the Flight Operations Manager and the company’s secondary base was not functioning satisfactorily.

2.3.3.6 The approach procedure for runway 19 (LLZ DME) at Geiteryggen might be designated as demanding (see the map in subparagraph 1.1.3). The approach is ‘offset’ and, between the Initial Fix (IF) D10 and Missed Approach Point (MAPT), there are four altitude restrictions. In addition, the approach angle between D10 and D6 is 3.7°, and between D6 and MAPT 3.9°. This approach consequently involves a high workload and it can be demanding as regards maintaining an even descent speed. With inexperienced pilots, or with pilots who have never flown this approach before, this can take up most of their overall working capacity.

2.3.3.7 Based on the details that have emerged in connection with this accident, Avinor should undertake a review of the approach procedures to runway 19 at Geiteryggen, among other things with a view to reducing the chance of unintentional GPWS warnings.

2.4 The landing

2.4.1 Introduction

The AIBN has assessed several possible reasons for the aircraft hitting the runway with great force during the landing. The following have been assessed:

- effect of weather phenomena
- flare too high above the runway
- speed too low on final
- insufficient flare
- the propellers in reverse while the aircraft was still airborne
- high ‘sink rate’ due to ice contamination on the wings in combination with a reduction in engine power immediately prior to landing
- stalling due to ice contamination on the wings

2.4.2 Effect of weather phenomena

After the accident, the flight crew stated that the weather was as expected and that they had not noticed any significant turbulence. This accords well with the meteorological observations at the time of the accident. The wind that was given as being 120^{o} 10 kt 35 seconds prior to landing was outside the values that are warned against in AIP Norway (see subparagraph 1.10.5). On this basis, the AIBN cannot see that weather phenomena were the cause of the accident.

2.4.3 Flare too high above the runway

In its comments on the report, the company has indicated that the accident could, alternatively, have been caused by a too high flare, a consequent high sink rate and a hard landing. The AIBN finds this rather improbable, partly because the first scratches on the runway were found 41.7 m past the middle of threshold marking lines. If so, this indicates that the flare must have been completed long before the threshold and that the approach was not normal. This conflicts with the flight crew’s explanation that the approach was normal, although a little high. Viewed in the context of the recorded speed of 110 – 115 kt when the aircraft touched the runway, this indicates that the aircraft would have had to have lost a great deal of energy in a short space of time to hit the runway so close to the threshold, which was the case here.

2.4.4 Speed too low on final

The speed readings taken from the aircraft's FDR and the speed readings taken from the CVR are both in agreement. If the aircraft's airspeed indicator was calibrated correctly, this shows that the aircraft was maintaining a higher speed over the threshold than the correct V_{ref}. Due to the damage to the aircraft's nose section, it has not been possible to check the calibration on the aircraft's pitot & static system. However, it is improbable that the aircraft had been flying with a significant fault in both airspeed indicators. The AIBN therefore finds no reason to believe that the aircraft was being flown at too low speed at final.

2.4.5 Insufficient flare

The height of the nosewheel above the runway during landing depends on the sink rate and the aircraft's airspeed (and therefore the angle of attack). If the aircraft was being flown straight at the runway at 110 – 115 kt without flare, it is highly probable that the nosewheel would have hit the runway early, and would, in that way, have taken a major part of the load during landing. Damage to the aircraft and tracks on the runway, however, indicate that the left landing gear and wing were subject to major overloading. This indicates that the first officer had begun to flare when the aircraft hit the runway. In addition, there is reason to believe that flying directly into the runway at high speed would have led to the right landing gear having bounced up again and that the right wing (which was undamaged) would correspondingly have continued to provide lift. The aircraft would then most probably have been subject to a powerful rolling movement to the left. Witness statements and tracks on the runway do not support such an explanation. None of the crew members were able to explain what had happened when they were talking to the AIBN the day after the flight. A landing without flare, and with a possible subsequent bounce, ought to have been detected by one of the crew members or by the pilot who was sitting at the front of the cockpit. Also, the statements of some of the passengers that they had sensed a drop before the aircraft hit the runway does not fit in well with a theory that the aircraft was being flown straight into the runway.

2.4.6 The propellers in reverse while the aircraft was still airborne

Reverse thrust from the propellers while the aircraft is in the air can lead to a high 'sink rate' and damage to the aircraft on landing. Reverse thrust produces a distinctive sound which should be recognized on the CVR. No sign of reverse thrust was found in the relevant acoustic signature and, consequently, it can be established that reverse thrust was not a factor.

2.4.7 A high sink rate due to ice contamination on the wings in combination with a reduction in engine power immediately prior to landing

2.4.7.1 It has been confirmed that the aircraft had ice on the wings most recently when passing through the 3,500 ft level. At Geiteryggen, the temperature was 4ºC. If a standard temperature gradient of 2ºC per 1,000 ft is taken as a starting point, this would indicate that the aircraft would reach air temperatures of 0 °C at an altitude of 2,463 ft. This altitude was passed approximately 2 minutes and 20 seconds before the landing. Even if it is not possible to calculate how much of the ice would have melted in this period, there is reason to believe that there was still ice on the wings during the landing.

2.4.7.2 Information from the FDR and CVR indicates that the aircraft was maintaining an indicated air speed of approx. 110 kt when the aircraft hit the runway. According to the 'Approved Flight Manual', the landing speed (V_{ref} = 1.3 x stall speed) at the relevant flaps setting and mass should have been 107 kt. Under otherwise normal conditions, the wing should consequently not stop producing lift at 110 kt. Wings that are contaminated with ice would be less effective than clean wings. To produce the same lift, the wings would have to have a higher angle of attack than clean wings. Higher angles of attack imply higher induced drag and consequently a need for a higher power output from the engines than during otherwise similar conditions. This could explain the rather high power output of 40 % that was notified 14 seconds before the aircraft hit the runway.

2.4.7.3 On the basis of the CVR, it is clear that the first officer reduced the power output 2.5 – 3 seconds before the aircraft hit the runway with great force. Because the power output at the outset was higher than normal, the effect of the power reduction would also be greater than normal. Information from the FDR indicates that the first officer maintained a speed of approx. 110 kt even after the power from the engines had been reduced. In this period, the airflow over the wing behind the propeller was significantly reduced. This gave reduced lift at the same time as the wings most probably had a higher angle of attack than normal due to the icing. Altogether, this could give a high sink rate and would explain why the aircraft hit the runway with great force.

2.4.8 <u>Stalling due to ice contamination on the wings</u>

2.4.8.1 The aircraft hit the runway such that the left wing sustained structural damage. The powerful impact with the runway and the uneven distribution of forces transmitted via the main landing gear, could indicate that the aircraft stalled and that the left wing lost lift first. This stalling could be explained by the wings being contaminated with ice. The aircraft did not stall 24 seconds prior to landing when it was flying at a speed of 110 kt. The fact that the aircraft later did not tolerate such a low speed when it came in over the runway might be explained by the fact that the airflow over parts of the wings diminished when the first officer reduced the power output from the engines. In addition, the angle of attack of the wing increased in conjunction with the flare prior to landing.

2.4.8.2 The crew did not notice any sign that the aircraft was about to stall. They did not hear the stall warning nor did they recognize any actuation of the 'stickpusher' during the landing. Neither was the stall warning recorded by the aircraft voice recorder (CVR). The AIBN believes that this could be explained by the wings being contaminated by ice. Ice on the wings reduces the critical stall angle and leads to the wing stalling before the 'wing stall vane' detects a critically high angle of attack, thereby actuating the stall warning. According to the aircraft manufacturer, the aircraft has easily recognisable symptoms of stalling even if the stall warning system does not actuate (see subparagraph 1.6.5.2). The AIBN cannot with total certainty state why the flight crew did not perceive the symptoms that would have warned of incipient stalling. However, there is reason to assume that the symptoms came suddenly when the first officer reduced the power output from the engines and started the flare. In addition, a lack of awareness of an incipient stall could be due to the first officer's general level of stress and lack of experience. Regardless of the conditions during the actual landing, it is important to be clear about the limitations of the aircraft's primary stall warning system when the wings are contaminated by ice or hoarfrost. The AIBN is of the opinion that BAE Systems must actively provide information and warnings about this. The phenomenon is not limited to the Jetstream 31 aircraft type and represents a hazard that all pilots must know about.

2.4.9 Conclusion on why the aircraft hit the runway with great force

The AIBN is not forming a final opinion on whether the wings stalled or whether the aircraft hit the runway at great force exclusively because of a high ‘sink rate’. The AIBN believes that the hard landing could also be due to a combination of the two explanatory models, in other words that the aircraft stalled during an attempt to stop a high ‘sink rate’. However, both alternatives are based on the wings being contaminated with ice. Information from the FDR, CVR and the flight crew confirms that the approach was initially highly unstable. There is nothing to indicate however that the approach during the last 50 seconds was unstable enough to lead to an accident. Ice was consequently the only thing that separated this landing from previously apparently normal landings.

2.4.10 Approach speed

The speed bug on both airspeed indicators showed 103 kt. This speed matches the value in the speed booklet for a mass of 13,007 lb. The AIBN believes that this value was 4 kt too low in relation to the relevant landing mass of 14,338 lb and that this disparity was contributory to reducing the safety margin that the crew had put in with regard to speed. When the correct landing mass is used, the correct landing speed (V_{ref}) is 107 kt according to the Approved Flight Manual (see subparagraph 1.6.10.1). This is the value that the crew should have used at the outset. A potential increase above this speed, to increase the margins in the event of any ice on the wings and tail, would have given a realistic safety margin against stalling. In the case in hand, a proportion of the crew’s speed increase was lost in compensating for the incorrect calculations of the aircraft’s mass. The Approved Flight Manual does not contain any orders about increasing V_{ref} if there is any suspicion of icing. However, it does indicate that the flight crew can choose to add 15 kt to “remain clear of airframe buffet”. The crew’s increase of V_{ref} was consequently not a requirement. The increase in speed led, however, to the roll-out distance increasing and thus reducing the inbuilt margins of the runway length requirement.

2.4.11 Use of flaps

The landing was made with 35° flaps. If there was visible ice on the aircraft, this is a clear deviation from the procedures in the company’s OM B (see subparagraph 1.6.10.2). However, it appears clear that the crew had forgotten to check whether the aircraft had ice on the wings when they landed. Consequently, they did not limit the flaps extension to 20°. The AIBN is of the opinion that a further lowering of the flaps from 20° to 35° should have led to a conscious assessment of the ice conditions on the aircraft, and that such an assessment would have served as a reminder that it had been established at an earlier stage of the approach that there was ice on the wings.

2.4.12 Available runway length

Based on available information, the flight crew could plan on the runway at Skien being dry (see subparagraph 1.7). Consequently they had good margins as regards the length of the runway. If, on the other hand, consideration is given to a correctly calculated departure mass and the fact that the runway is wet, the runway was to short (see subparagraph 1.6.10.3. Viewed in the light of the fact that a pilot might expect reduced braking values at Geiteryggen in winter and that the aircraft only had 11 passengers during the landing in question, it is understandable that the first officer was occasionally concerned that the runway was short.

2.5 Loss of directional control

2.5.1 The aircraft hit the runway with great force. The FDR recorded 6 g, but it is highly probable that the actual impact was greater. This led to a permanent distortion of the left wing so that the left propeller came into contact with the runway. As a result, the propeller blade was bent and the transmission shaft to the engine fractured. The propeller stopped after approximately just over three revolutions. The friction between the bent propeller blades and the runway immediately subjected the aircraft to a force that tried to turn it to the left. Tracks on the runway confirm this. The aircraft continued in a gentle arc to the left until it hit the gravel bank at an estimated speed of 50 – 60 kt. The landing speed indicated was around 110 kt. If it is assumed that the headwind component of the wind was 3 kt, this indicates that the ground speed decayed by 47 – 57 kt over a distance of 371 m. This indicates that the aircraft had only had moderate braking over this distance. The AIBN does not have access to exact data concerning the power output from the engines or the use of brakes, but such a small reduction in speed, in the opinion of the AIBN, indicates that neither the wheel brakes nor a reverse thrust of the engines had been applied to any appreciable extent. The fact that this did not happen can be explained by the powerful impact that the crew encountered on landing, and the paralysing effect that probably followed on from that.

2.5.2 With hindsight, it could be said that, in this case, reverse thrust would make a positive contribution both to reducing speed and to maintaining directional control. Since the left-hand engine and the propeller were damaged, applying reverse thrust would only have given effect on the right-hand engine. Consequently, the effect this would have had would have been to turn the aircraft to the right.

2.5.3 According to the Commander, the brakes were used once he saw that the aircraft was going to leave the runway. The AIBN believes that the braking effect was very slight since the aircraft was moving over wet grass and loose gravel. However, there was no sign of braking tracks on the taxiway where it crossed, and this indicates that the brakes were not used at those locations.

2.5.4 The first officer has stated that he held the right rudder pedal down during the skid. This had an effect just after landing, but this effect diminished gradually with the decaying speed. The AIBN considers it to be natural that the rudder alone could not prevent a skid. The aircraft’s nose wheel is not controlled via the rudder pedals and swings freely when it is not being steered via the control column for nose wheel steering. This control column is primarily designed for manoeuvring at low speeds and the AIBN understands that the Commander did not try to steer the aircraft using the control column when the aircraft left the runway at high speed.

2.5.5 The aircraft landed with a wind of 10 kt 70^{o} coming in from the left. This is considerably below the maximum permitted sidewind component for this aircraft type, but the wind also contributed to the aircraft swinging to the left.

2.5.6 Because of the damage arising during the landing, the left propeller and engine were pointing downwards when the aircraft hit the gravel bank. In the impact with the gravel bank, the propeller and engine were bent down and back. As a result of this, the propeller was knocked off. In addition, it is probable that the most extensive distortion of the left wing arose during this impact. The AIBN believes that it was only at this time that the left-hand fuel tank was ripped open. The right-hand propeller was damaged when the aircraft was thrown to the right so that the propeller made contact with the gravel bank.

2.6 Use of the aircraft's de-icing equipment

2.6.1 The investigation has revealed that this accident most probably took place as a direct result of the aircraft landing with ice on the wings. The crew followed the procedures of both the company and the aircraft manufacturer when they allowed the ice to remain on the wings after it was detected at an early stage of the approach. The flight crew's only deviation from procedures as regards icing was that they used 35º and not 20º flaps during a landing with ice on the wings. This deviation may be linked to the fact that, during the landing, the crew forgot they had ice on the wings.

2.6.2 The AIBN has noted that the procedures for aircraft such as the Embraer EMB 120, SAAB 340 and SAAB 2000 involve de-icing equipment being switched on at the first sign of icing. On the basis of tests, experience and information from the equipment manufacturer, B F Goodrich, BAE Systems has drawn up a procedure for the Jetstream 31 that is based on there being 0.5 in (13 mm) of ice on the wings before airframe de-icing is switched on. One of the reasons for this is to prevent ice bridging from occurring on the leading edges of the wings (see subparagraphs 1.6.6, 1.18.6 and 1.18.7).

2.6.3 The AIBN is of the opinion that the procedure that applies to the Jetstream 31 raises two problems. One was demonstrated in this accident. The flight crew postponed actuating the system for airframe de-ice because they wanted to size up the situation. This was in line with the company's SOP and the aircraft's AFM (see subparagraph 1.6.9.5). Later on, they forgot to check for ice on the wings prior to landing. The AIBN believes that a simple actuation of the system for airframe de-ice shortly before landing could, under no circumstances, have made the situation worse. Consequently, this type of item should be included in the before landing checklist. An item like this in the checklist ought also to be linked to a check for ice on the wings, so that a decision can be made on the use of 35º flaps and a possible increase of the landing speed (V_{ref}).

2.6.4 The second problem is linked to the opportunity for the flight crew to determine the thickness of the ice on the wings. The procedures for the Jetstream 31 are based on the crew being able to assess the thickness of a layer of ice without having a specific tool for undertaking such an assessment. The AIBN therefore believes that the current procedures will not be satisfactory until the crew are given a tool to indicate ice thickness (an ice accretion meter).

2.7 The aircraft's technical status

Investigations undertaken by the AIBN have not detected any technical faults on the aircraft which might have had an impact on the course of events. This is confirmed by the flight crew, which has provided the information that all of the aircraft's systems functioned as expected. The failure in the aircraft's navigation system (NAV # 2) had no effect on the flying because information from NAV # 1 was transferred to the instruments on both sides of the cockpit. Because of the lack of entries in the HIL, it has not however been possible to assess whether the aircraft formally was equipped for the planned flight.

2.8 Survival aspects

2.8.1 The aircraft left the runway at high speed. The chance of surviving such an accident was consequently completely dependent on the nature of the terrain that existed outside the runway. In this case, the aircraft continued for around 200 m along a flat surface before hitting a gravel bank. The long distance during which speed was decaying before hitting the gravel bank, the angle of impact and the angle of the gravel slope, were all factors contributing to limit the collision forces. If, on the other hand, the aircraft had had a similar accident on the west side of the runway, the outcome might have been much more serious, since there is undulating forested terrain 50 metres from the runway.

2.8.2 Essentially, the crew and passengers were exposed to physical stresses three times during the accident. During the hard landing, the passengers close to the main wheels were exposed in particular to a powerful vertical stress. The AIBN is not aware that anyone was injured by this. During the collision with the gravel bank, everyone onboard was thrown forward with great force. It was most probably during this sequence that people sustained injuries. The aircraft cabin remained intact, and this was a crucial reason that all of the passengers survived. The flight crew who were held in by four-point seatbelts were injured because the front of the aircraft was pushed into the cockpit. A further compression of the cockpit could first have trapped the members of the flight crew and then have become directly life threatening. After the aircraft came to a halt up on the gravel bank, it fell back onto its tail. All of the people and seat-backs were bent forward at the moment of collision, and were then thrown backward with great force when the aircraft fell down on its tail. The AIBN believes that three of the seat-backs broke backwards during this sequence.

2.8.3 No fire arose, despite the left-hand fuel tank sustaining major leaks during the accident. If the fuel was distributed equally between the two wings, there would have been approx. 750 lb (425 l) of fuel left in the left wing. A strong contributory factor to the fact that this did not catch fire was the low outdoor temperature (4 ^{o}C) and rain. Despite the fact that the aircraft was evacuated rapidly, a fire in the area around the left-hand engine could easily have meant a serious situation for the flight crew and passengers.

2.8.4 The passengers evacuated the aircraft by themselves in a very good, efficient manner. The crew also managed gradually to get out by themselves. The rapid reaction on the part of the fire and rescue service consequently made only a minor contribution to the successful evacuation. However, the AIBN would like to emphasise that only chance prevented this accident from becoming a much more serious accident. An effective fire and rescue service would then be absolutely crucial to the outcome of an accident.

2.9 The company and important framework conditions

2.9.1 Introduction

In the opinion of the AIBN, the investigation has uncovered a series of weaknesses that could be linked to the organisation, procedures and execution of the company's operations. Important prerequisites for flight operations in Norway came from the Joint Aviation Requirements, the Swedish Civil Aviation Authority and the company's approved manuals and quality system. Aspects of these conditions will be analysed below.

2.9.2 Joint Aviation Requirements

2.9.2.1 The Joint Aviation Requirements (JAR) have the objective of setting uniformly satisfactory flight safety standards and ensuring equal conditions for competition between operators in the member countries. The regulations are general in places, however. Consequently, several of the regulations have associated guidelines and proposals for acceptable implementation (AMC & IEM). Within some areas, this provides a good guideline. Examples of such general regulations are given in subparagraph 1.18.1. In AIBN's opinion, the regulations still provide huge opportunities for variable interpretation by bodies such as the Authorities and operators. This could mean that the tasks of initial surveillance for approval and inspection make heavy demands on resources. In addition, the individual operators have a huge responsibility as regards ensuring a high standard of flight safety.

2.9.2.2 The requirements for the basic training of flight personnel are contained in JAR-FCL. The accident took place in a period of transition between training based on national regulations and the introduction of the Joint Aviation Requirements in JAR-FCL 1. JAR-OPS 1 Chapter N – Aircraft Crew, contains important formal requirements for composition, continuity of experience and periodic checks of flight crews. In addition, there is discussion of conversion to other types of aircraft and appointment to the post of Commander. The relevant people were appointed by the company as Commander licensed for the BA 31, and first officer licensed for the BA 31, respectively. JAR-OPS 1.945 states that flight crew members should complete the airline's conversion course when they change operator (see subparagraph 1.18.1). It is the opinion of AIBN that it is not clear from this how a conversion course of this type should be implemented for crew members who are already authorised for an aircraft type or class. The AIBN does not believe that this type of supplementary information is contained in the AMC / IEM either. In particular, the AIBN finds no requirements for training in the company in respect of CRM, the quality system and the procedures and manuals in general. This deficiency is also reflected in the company's OM Part D, which is largely a copy of the requirements contained in JAR-OPS.

2.9.3 Inspection by the Authority

2.9.3.1 The AIBN understands that during the implementation of JAR-OPS 1, the Authority and operators might have different views as regards the way in which the new requirements should be interpreted. In addition, it would be natural for the process of issuing AOCs to a number of new companies over a relatively short period to be heavy on resources for the Swedish Civil Aviation Authority. However, the AIBN is critical with regard to the inspection and monitoring of the operations department that was performed during the period 1998 – November 2003 (after initial surveillance for approval in 1998). The investigation after the accident has discovered that the company had selected minimum solutions, to a large extent, and has a number of serious weaknesses in its organisation and quality system, for example. The AIBN believes that an authority ought to be aware when a company chooses minimum solutions in several areas, because the sum of these could lead to unintentionally low safety margins. In addition, the company has not been able to present formal documentation of a number of internal processes and controls. This is a situation that an inspection authority ought to have detected, and which ought to have been followed up with the company.

2.9.3.2 As far as the AIBN has been able to find out, the Authority's inspection work has largely been based on inspections of the company's manuals. These manuals appear to have been written to cover the requirements of JAR-OPS 1, and in isolation provide a picture of a company satisfying the current requirements. A system inspection assumes that the company's systems are functioning as described. This investigation has shown that a number of less serious deviations and conditions worthy of criticism within a company, in combination, led to an accident. The AIBN is of the opinion that several of the conditions that have been discovered in this inspection could have been discovered earlier if the Swedish Civil Aviation Authority had systematically undertaken inspection and monitoring of the company and the activities that were carried out in reality. Or, expressed in other words, if the Swedish Civil Aviation Authority had followed the guidelines given by JAA (see subparagraph 1.17.1.8).

2.9.3.3 Among other things, JAR-OPS 1 is intended to prepare for free competition within member countries under equal circumstances. The regulations place little emphasis on language barriers, cultural differences, and climatic and geographical differences. Consideration of these problems is left up to the individual operator. The system thus allows a national Authority to permit access for a company to operate in another country with crews from a third country without any compensatory measures being required, which take into account any problems such as those mentioned above. This circumstance is not unique to this accident. The accident illustrates, however, that weaknesses in the civil aviation system in one member country could have consequences in other member countries. The individual member countries must unilaterally accept the initial assessment process and the procedures for assessing the continued competence of an AOC-holder in all member countries, and could to a minor extent themselves verify the current standard of safety of a party operating within the country's borders.

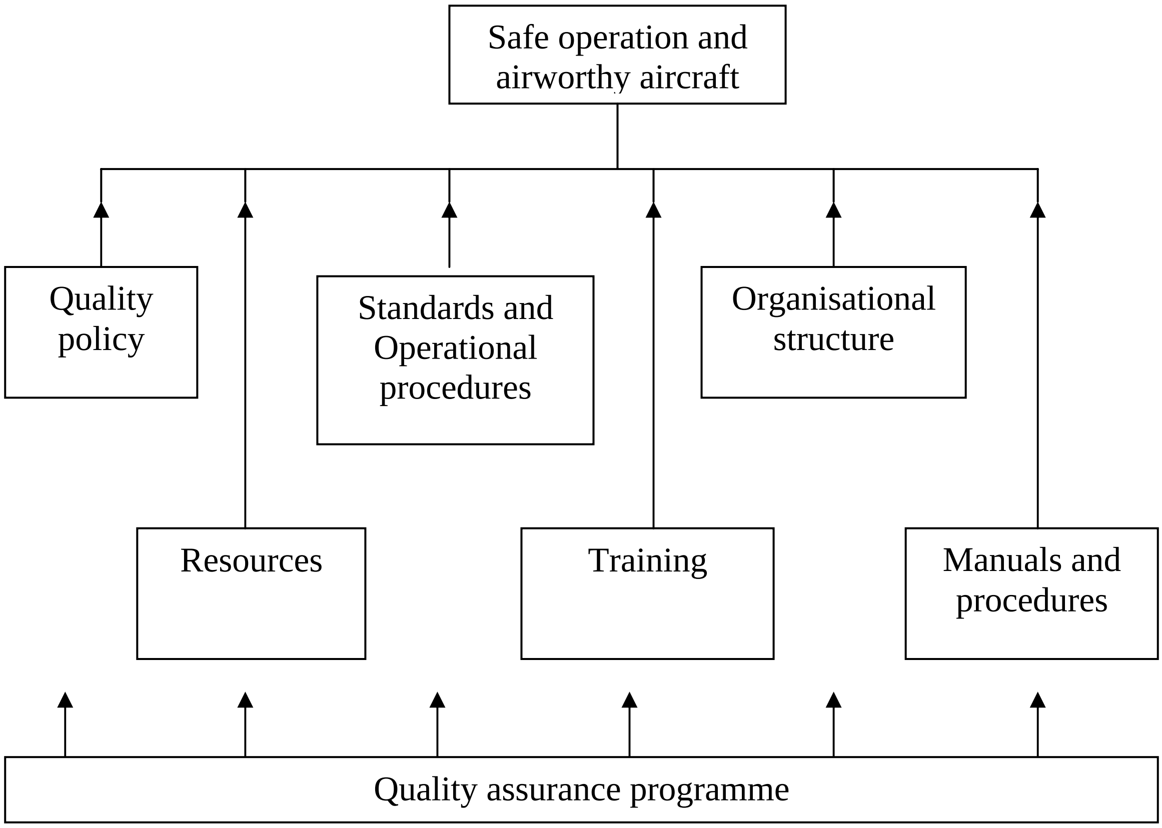
2.9.3.4 Experience has shown that flight safety is a difficult term to define and that it is not possible to specify or verify an absolute standard. Consequently, flight safety is a result of the resources applied, the skills possessed and the ability of a company to translate this into safe flying. In a period with a constant focus on prices and earning capacity, flight safety can become a casualty. With such an external framework, therefore, it is important for the inspection authorities in the individual countries to be given resources to perform inspections in a satisfactory manner. In the opinion of the AIBN satisfactory inspection work is conditional on not just inspecting documentation. There must also be verification that the activity that takes place is in line with the procedures described.

2.9.4 The company’s quality system

2.9.4.1 The quality system as described in JAR-OPS is a suitable ‘tool’ for planning, preparing, implementing and verifying all activities in connection with commercial air transport. A full implementation of the systems would thus largely guarantee the business’s options for safe, efficient operation. The AIBN is of the opinion that EEE has documented a quality system in its OM Part A which conforms to the requirements of JAR-OPS. Correspondingly, the quality system described has been satisfactory and sufficient to enable the Swedish Civil Aviation Authority to issue AOC (S-016) in 1998.

2.9.4.2 The accident at Skien airport on 30 November 2001, however, has shown that the company did not succeed in achieving its objective as described in its quality system (see subparagraph 1.17.3). The AIBN has consequently focused on the company’s quality system, with a view to clarifying the extent to which tasks and activities in advance of the actual accident were carried out in compliance with the relevant quality requirements. In that context, it would be appropriate to give a reminder of the principal objective of the JAR-OPS quality system, which is to ensure: ‘Safe Operational Practices and Airworthy Aeroplanes’. To be able to fulfil this principal objective, all elements of the quality system must each display conformity with a defined standard (be of the ‘right’ quality).

2.9.4.3 The model below shows, systematically, the way in which achievement of the principal objective is dependent on the right quality for each individual quality element.



In an actual operational situation, this would mean that if one or more of the individual elements in the system were not satisfactorily prepared or used, the system would be incomplete, and the principal objective of the operations would therefore be impossible to fulfil. Expressed differently: if all parts of the system were not 'showing the green light', the final result would not be 'green' either. This methodology is often used in safety analyses, but is also used in making evaluations of whether a system is 'ready for operation'.

2.9.4.4 In a situation in which an airline has decided to extend its business or establish a new scheduled flight area, introduce a new type of aircraft, or change organisational structure, a review and assessment of each individual area (element) within the quality system would be necessary, in line with the methodology outlined above.

2.9.4.5 The company extended its activities by starting scheduled flights between Skien and Bergen a short time prior to the accident occurring. In talks with the AIBN the company's management were not able to prove that a complete system review had been performed in line with the assumptions of the quality system prior to expansion. In other words, the company omitted to take the system requirements of a JAR-OPS quality system into consideration during the process of planning, preparing and implementing the operation. Although personnel within the company have undertaken discretionary informal assessments of safety issues, this has led to an impairment of important preconditions for being able to carry out operations in a responsible manner as regards safety.

2.9.4.6 This conclusion is based on investigations and analyses of the following individual elements of the quality system (see the model on the previous page):

Quality policy

The investigation has shown that the company's management is adhering to the minimum requirements of JAR-OPS. This is also given expression in talks with the 'Accountable Manager'. He did not express a need for the company to develop a systematic, holistic view, among other things to allow the quality system to be used in processes of change and development.

Standards and operational procedures

No form of risk analysis has been documented prior to starting operation of the scheduled route Skien – Bergen. Special procedures for safe aircraft operation were not established, particularly with a view to the rather special conditions at Skien airport. Neither were any measures inserted to compensate for the weaknesses that existed in crew training within the company (see also subparagraph 2.2.3).

Organisational structure

An organisation in which one and the same person possesses the posts of 'Accountable Manager', 'Nominated Post Holder Flight Operations' (flight operations manager) and 'Nominated Post Holder Crew Training' (crew training manager), as well as being an active pilot, is not reliable within a quality system. In an actual operational situation, circumstances linked to delegation of responsibility and authority would become problematic, while the lines of reporting as regards operations would become unrealistic. The fact that the same person also has considerable interests in the ownership of the company does not make the situation any better.

The 'Quality Manager' spent little time working in the company. In the opinion of the AIBN, this greatly limited his options for monitoring the daily operations of the company. In addition, this gave little capacity for implementing the following assigned task: 'responsible for the Company's established flight safety standard system and to inform, train and supervise all personnel in this matter'. For example, the AIBN has not found any documentation to show that the members of the flight crew had been provided with such training.

An organisation with a 'Nominated Post Holder Maintenance System' (technical manager) who was employed in an outside business, by which the aircraft were maintained (subcontractor), as in the case of EEE, is unsatisfactory from a qualification perspective.

Resources

The AIBN believes that the company is characterised by marginal organisational resources (cf. organisational structure). This might be said to be a common feature of many small companies competing in a marketplace in which price is a decisive factor for whether a company is competitive. It is doubtful whether the company's resources permitted sufficient supervision of the company's operations (technically and operationally).

Training

The weaknesses in training that were detected during the investigation, and which were contributory to poor crew coordination and the indirect cause of the accident, were not defined as exceptions or detected by the quality system.

Manuals and procedures

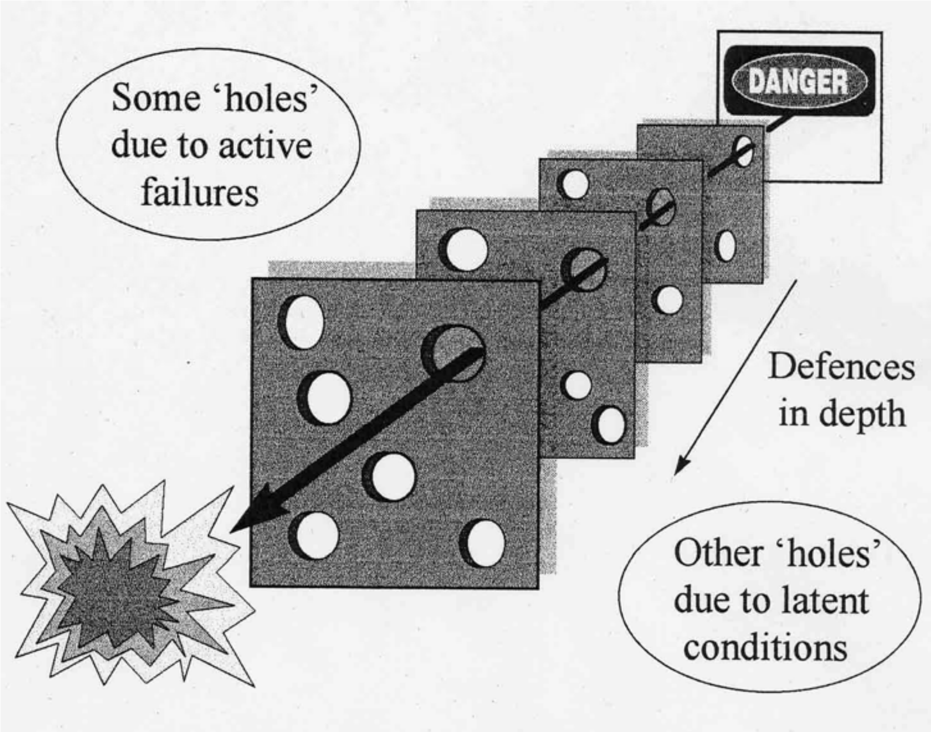
The company's Operations Manual (OM) appears to be in conformity with the minimum requirements specified in JAR-OPS 1. The company had only drawn up very general procedures for monitoring crews and operations from secondary bases. The practical implementation of the operations was consequently largely left up to the individual Commander.

Quality assurance programme

There is no programme for assuring the quality of processes linked to planning and commencing operations in a new scheduled route area. As a consequence of this, neither has any formal management evaluation process been performed to clarify whether the business can fulfil a predefined, acceptable level of safety for operating in the new scheduled route area. During the period in which operations were carried out in this route area, no quality audit had been carried out within the flight operations or technical fields. The AIBN has gained the impression that the quality assurance carried out in the company was informal and largely dependent on individual employees' abilities and goodwill.

2.10 'The Swiss cheese model'

In order best to show the link between organisational conditions and the accident, the AIBN has chosen to apply Reason's 'Swiss cheese' model, below.



The model has not been defined with regard to what the various barriers (defences) consist of. Below, the AIBN has listed the circumstances that the Board believes may have had an effect on the accident. The AIBN has chosen to define the barriers within the following groups:

- JAA
- Authority inspection
- Airline
- Procedures
- Crew actions
- Last line defence mechanisms and physical barriers

JAA

- The introduction of JAR-OPS for a time led to a generally reduced level of knowledge about the current regulations in both national Authorities and operators
- The requirements specified in JAR-OPS are partly general and less detailed with regard to how the requirements are to be met. An important part of the responsibility for ensuring that safe flying is achieved is given to the national Authorities and individual operators
- JAR-OPS contains few requirements for company-adapted training of recently employed Commanders and first officers when these already have type ratings for performing relevant service in accordance with JAR-FCL
- There are no formal requirements for approval of secondary bases

Authority inspection

- The Swedish Civil Aviation Authority carried out no inspections of the company's operations department during the period 1999 – 2001
- In general, the Swedish civil Aviation Authority only carried out inspections based on a review of documentation
- None of the deficiencies in the company discovered by the AIBN during this investigation were detected by the Swedish Civil Aviation Authority prior to the accident

The Company

- The company employed many minimum solutions, particularly in respect of training and instruction, staffing operational management, monitoring bases and quality policy
- The Commander did not undergo any formal Route Check
- The Commander did not attend any CRM training within the company
- The first officer was not given any formal Line Training on the scheduled route segment Skien – Bergen
- The company did not use a simulator for training and instruction
- The activities surrounding the company's quality system were considerably limited for performing planned internal audits
- There was no check of the crew's level of knowledge concerning the OM
- In reality, the crew had the daily responsibility for the company's operations from Skien despite the fact that the Commander had only been working for the company for six weeks, and that the first officer had had little experience of flying in Norway and winter operations
- The company's monitoring of activities at Skien was principally exercised by means of receiving log information on a weekly basis

Procedures

- The approach to runway 19 at Geiteryggen is a Non-precision Approach, an approach that statistically provides a lower level of safety than an equivalent approach with a glide slope (ILS) (cf Flight Safety Foundation CFIT Checklist)
- The direction of approach to runway 19 at Geiteryggen forms an offset angle with the runway's orientation (Offset Approach)
- Checking for ice on the wings was not included as an item on the 'Before Landing Checklist'
- The company had no clear procedures for operational actions to be taken in the event of GPWS warnings under IMC
- The company had no clear procedures for reporting warnings from the GPWS
- The company had not drawn up procedures for Training and Checking in the OM-D

Flight crew actions

- The Commander tolerated repeated flights in which basic safety barriers based on crew coordination were missing (Errors of omission)

- The flight crew calculated the wrong landing mass, and therefore got the wrong reference speed ($V_{ref.}$) during the approach (Errors of commission)
- The flight crew maintained a higher approach speed than recommended for the areas in which warnings might be expected from the GPWS (Errors of commission)
- The flight crew did not initiate a go around when they got warnings from the GPWS during IMC (Errors of omission)
- The flight crew forgot to check the wings for ice prior to landing (Errors of omission)

Last line defence mechanisms and physical barriers

- Fundamental safety barriers based on crew coordination, with one performing tasks and the other checking them, were not in place (failure of CRM)
- It can be difficult to determine the thickness of ice accretion out on a wing while airborne. In addition, the aircraft had no automatic warning about ice on the wings
- The stall warning system does not give a warning in time, in the event of a stall when the wings are contaminated by ice

3. CONCLUSION

3.1 General conclusions

3.1.1 General

a) The accident took place during a scheduled flight from Bergen to Skien in accordance with an IFR flight plan
b) European Executive Express started flying the route in question on 1 October 2001. Consequently the company had little experience in operating the route.
c) The accident took place on the fourth and last flight on a Friday before the flight crew was to have two days off
d) Before the accident, it was known by a number of pilots that the Ground Proximity Warning System (GPWS) could activate during apparently normal approaches (LLZ DME) to runway 19 at Geiteryggen. The Norwegian Civil Aviation Authority was unaware of this information
e) During a previous flight for the company, the Commander had received a warning from the GPWS during visual flying conditions, but no warning or report was given to the operations management at EEE
f) The accident took place in conjunction with a Non-precision Approach, an approach that, statistically, provides a lower level of safety than an equivalent approach with a glide slope (ILS)

3.1.2 Sequence of events

a) The crew calculated a departure mass that was 1,388 lb lower than the actual departure mass. This meant that the crew had calculated an approach speed that was 4 kt too low.
b) The crew established early in the approach that the aircraft had ice on the wings.

c) The crew received a total of three warnings from the GPWS while flying IMC during the approach to Skien. The first officer levelled off and started a climb as a result of this, but the Commander ordered a continued approach. This gave rise to a serious conflict situation in the cockpit.
d) The approach speed was occasionally considerably higher than recommended by the aircraft's manufacturer. This contributed to the warnings from the GPWS being issued.
e) Checking for ice on the wings was not included as an item on the Before Landing Checklist. This contributed to the fact that ice on the wings was forgotten during the approach.
f) The crew believed that they were maintaining a speed during the last part of the approach that was 10 kt higher than the calculated V_{ref}. Due to mistakes in the calculations, the aircraft was actually maintaining a speed that was only 6 kt higher than V_{ref} according to the Approved Flight Manual.
g) The landing was so hard that the aircraft sustained structural damage to the left wing and the left propeller came into contact with the runway.
h) Because of the structural damage, the aircraft lost directional control immediately after landing and continued outside the runway until it hit a gravel bank.
i) The aircraft was subjected to considerable structural damage during the impact with the gravel bank.

3.1.3 Survival aspects

a) After leaving the runway, the aircraft continued for 200 m outside the runway before hitting a gravel bank. The terrain along this stretch was relatively flat and grassy. This limited the scale of the damage.
b) The physical stresses during the collision with the gravel bank were considerably more powerful than during the hard landing.
c) The crew avoided any life-threatening injuries because the gravel bank had a relatively gentle slope and because the aircraft hit the bank at an offset angle.
d) A significant reason for the survival of all passengers was that the aircraft cabin remained intact.
e) No fire arose despite major fuel leaks. The low temperature and rain were major contributory factors in this.
f) The evacuation was carried out swiftly, partly because the passengers evacuated the aircraft at their own initiative.
g) The airport's fire and rescue services were rapidly on site and led the work at the site of the accident. The circumstances surrounding the accident however meant that an effective fire and rescue service was not crucial to the outcome of the accident.

3.1.4 The aircraft

a) The aircraft was built in 1984.
b) The aircraft had valid Swedish registration, environmental and airworthiness certificates.
c) Investigations undertaken by the AIBN have not detected any technical faults on the aircraft that could have had any impact on the events.

d) Due to deficiencies in the entries on the aircraft's Hold Item List (HIL), it has not been possible to establish whether the aircraft formally was equipped for the flight in question.
e) The aircraft type does not have equipment to provide automatic warnings of ice on the wings. This was a contributory factor in making it possible to forget that the wings were contaminated by ice.
f) The stall warning system does not activate in time when the wings are contaminated by ice.
g) The procedures for using the aircraft's de-icing system assume that the flight crew can assess the thickness of ice accretion on the wings. However, the aircraft type is not equipped with a usable aid for assessing this thickness.

3.1.5 The flight crew

a) The flight crew possessed the necessary certificates and authorisations to serve onboard.
b) The Commander had a Norwegian ATPL-A.
c) The Commander had had several short-term periods of employment with a series of operators before starting to work for EEE.
d) The Commander signed a contract with EEE on 11 October 2001.
e) The Commander had not attended any CRM training under the direction of the company.
f) The Commander was very familiar with the conditions at Skien airport, Geiteryggen.
g) The Commander had approx. 600 hours' experience on the BA 31.
h) The Commander has informed the AIBN that he had had sufficient rest prior to the accident, and that he felt well and fit for flight on the day in question.
i) The Commander expressed the feeling that the first officer had weaknesses in several fundamental skills as a pilot.
j) The first officer had an Italian CPL-A validated by the Swedish Civil Aviation Authority, and was authorised to fly as first officer on the Jetstream 31/32 at EEE up until 7 June 2002.
k) The company was only able to provide documentary evidence that the first officer had attended a mandatory minimum of training after being employed by the company.
l) The first officer had attended the annual training course in CRM under the direction of the company.
m) The first officer had only been flying for two weeks in Norway when the accident occurred.
n) The first officer had had approx. 390 hours of experience on the BA 31.
o) The first officer has informed the AIBN that he had had sufficient rest prior to the accident and that he felt well and fit to fly on the day in question.
p) Collectively, the AIBN believes that the crew had had a marginal background and training, viewed in the light of the tasks they were to carry out and the actual responsibility they held as representatives of operations for EEE in Skien.

3.1.6 The company

a) The predecessor of EEE, CNA International, was granted a Swedish AOC in 1998.
b) EEE, which is an extension of CAN International, was formed on 12 May 2000, and was granted Swedish AOC no. S-016 on 23 May 2000.

c) The company's Operations Manual (OM) appears to be in conformity with the minimum requirements specified in JAR-OPS 1.
d) The AIBN believes that the company's organisational structure was problematic because one and the same person was Accountable Manager, Nominated Post Holder Flight Operations (flight operations manager), Nominated Post Holder Crew Training (training manager) and line captain while also having a considerable interest in the ownership of the company.
e) The Quality Manager spent little time at the company. This limited his capacity to monitor the company's daily operations.
f) No procedures were drawn up for Training and Checking in OM-D.
g) The company's monitoring of the base at Skien was informal and essentially based on occasional telephone contact and the transmittal of operational documentation. The responsibility for safe flying was consequently largely left to the relevant Commander.

3.1.7 Authority inspection

a) In 1998 as one of the first companies in Sweden CNA International was granted an AOC in accordance with JAR-OPS 1.
b) The requirements of JAR-OPS 1 were relatively new in 1998 and during the initial period, there was some discussion about how some of the requirements were to be interpreted and introduced in practice.
c) The Swedish Civil Aviation Authority carried out no inspections of the operations department within the company during the period from initial surveillance for approval in 1998 and up to February 2002.
d) In the opinion of the AIBN the Swedish Civil Aviation Authority had not carried out inspection and monitoring of EEE in line with the guidelines provided by JAR.
e) The Authority inspection of the company has largely been based on a system inspection, with very little attention being directed towards the actual operational activities in the company.

3.1.8 JAA

a) The Joint Aviation Requirements (JAR) are in part general and allow room for interpretation. The level of flight safety will therefore depend considerably on the initial assessment process and the process for accessing the continued competence carried out by the individual country's inspection authorities, and on the company's quality system.
b) JAR-OPS 1 contains no clear requirements to guarantee training in the CRM, the company's OM and the company's quality system when a company takes on a flight crew member with adequate type rating and authorisation to be a Commander.

3.2 Significant investigation results

a) The decision was made to wait to remove the ice from the wings because, according to the SOP, it should only be removed if it had been "typically half an inch on the leading edge". This postponement was a contributory factor in the ice being forgotten.
b) At times, the relationship between the flight crew members was very tense during the approach to Skien. This led to a breakdown in crew coordination.

c) Among the consequences of the warnings from the GPWS was a very high workload for the crew. In combination with the defective crew coordination, this contributed to the ice on the wings being forgotten.
d) It is probable that the aircraft hit the runway with great force because the wings were contaminated with ice. The AIBN is not forming a final opinion on whether the wings stalled, whether the aircraft developed a high sink rate due to ice accretion or whether the hard landing was due to a combination of the two explanatory models.
e) The company could only provide documentary evidence to show that the Commander had attended an absolute minimum of training after being employed within the company. Parts of the mandatory training had taken place by means of self-study without any form of formal verification of achievement of results.
f) The company's operation was largely based on minimum solutions. This reduced the safety margins within company operations.
g) The company's quality system contributed little to ensuring 'Safe Operational Practices' in the company.
h) Authority inspection of the company was deficient.

4. SAFETY RECOMMENDATIONS

During the investigation, the AIBN has become aware that pilots have received warnings from the Ground Proximity Warning System (GPWS) during apparently normal approaches to runway 19 at Skien airport Geiteryggen. This can undermine respect for the warning system. Inadvertent GPWS warnings were also a factor relating to the accident in question here. The AIBN recommends that Avinor should undertake a review of approach procedures (LLZ DME) for runway 19, among other things, with a view to reducing the opportunity for inadvertent GPWS warnings (SL recommendation no. 10/2005).

The investigation has discovered that the Swedish Civil Aviation Authority largely based its inspection work on inspections of the company's manuals, and to a lesser extent verified the company's actual practices. The AIBN recommends therefore that the Swedish Civil Aviation Authority should assess whether, to a greater extent than previously, its inspection activities should also be directed towards verifying the actual practices within a company (SL recommendation no. 11/2005).

A review of the quality system at European Executive Express has uncovered a series of weaknesses. The AIBN recommends that the Swedish Civil Aviation Authority should undertake a new assessment of the quality system at European Executive Express AB (SL recommendation no. 12/2005).

The accident in question can, with great probability, be linked to the fact that the aircraft was landing with ice on the wings. Current procedures for this aircraft type do not contain any items that would guarantee a maximum possible degree of ice-free wing before landing. The AIBN therefore recommends that the Civil Aviation Authority in the UK (CAA-UK) should order BAE Systems to introduce a procedure that would reduce the possibility of landings with wings contaminated with ice (SL recommendation no. 13/2005).

The procedures for removing ice on the wing are based on the crew being able to assess the thickness of the ice without having a specific tool to undertake such as assessment. The AIBN therefore recommends that the Civil Aviation Authority in the UK (CAA-UK) should order BAE Systems to assess whether a form of ice accretion meter should be installed on this aircraft type. (SL recommendation no. 14/2005).

The Jet stream 31 is equipped with a stall warning system which activates on the basis of the wing’s angle of attack. If the aircraft’s wings are contaminated with ice, stalling can occur at smaller angles of attack than the criteria for issuing a warning. This is not discussed in the Approved Flight Manual (AFM), and the flight crew in this instance were apparently unfamiliar with the situation. The AIBN recommends therefore that the Civil Aviation Authority in the UK (CAA-UK) should order BAE Systems to inform and warn operators of the fact that the stall warning systems do not function as assumed when the wings are contaminated with ice (SL recommendation no. 15/2005).

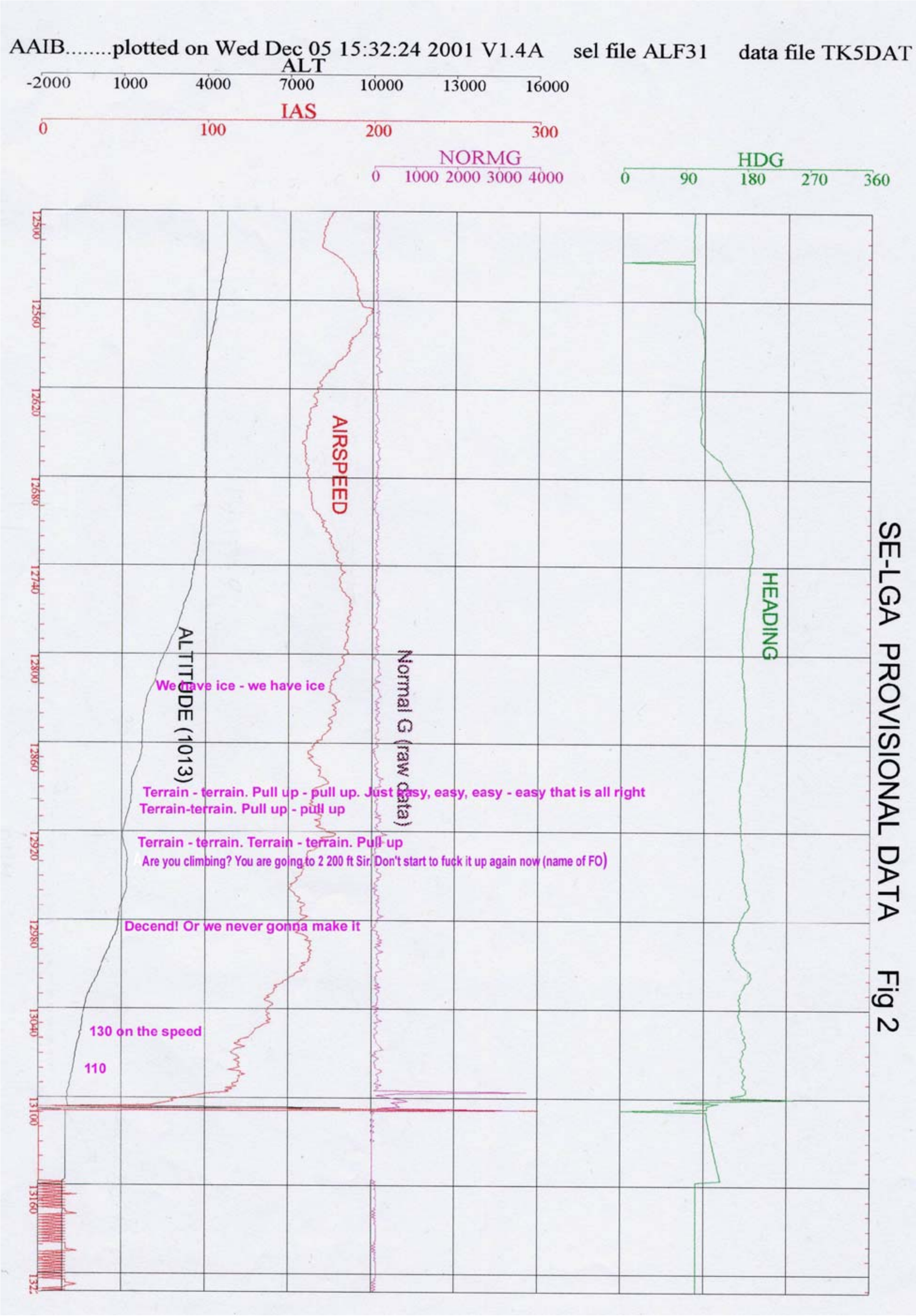
The investigation has discovered that the Joint Aviation Authorities (JAR-OPS 1) have very general requirements for training when a company employs flight crew members with adequate type rating and possibly authorisation to act as Commander. These requirements form the basis for the training that the Commander was given within the company, and which the AIBN believes was marginal. The AIBN therefore recommends that the JAA should assess whether the requirements for training should be increased within the CRM, the company’s OM and the company’s quality system. (SL recommendation no. 16/2005).

5. APPENDICES

Information from the FDR

6. ABBREVIATIONS

ACCIDENT INVESTIGATION BOARD – NORWAY (AIBN)
Lillestrøm, 6 April 2005


AAIB........plotted on Wed Dec 05 15:32:24 2001 V1.4A sel file ALF31 data file TK5DAT
ALT
-2000 1000 4000 7000 10000 13000 16000
IAS
0 100 200 300
NORMG
0 1000 2000 3000 4000
HDG
0 90 180 270 360
AIRSPEED
ALTITUDE (1013)
Normal G (raw data)
HEADING
We have ice - we have ice
Terrain - terrain. Pull up - pull up. Just easy, easy, easy - easy that is all right
Terrain-terrain. Pull up - pull up
Terrain - terrain. Terrain - terrain. Pull up
Are you climbing? You are going to 2 200 ft Sir. Don't start to fuck it up again now (name of FO)
Decend! Or we never gonna make it
130 on the speed
110
SE-LGA PROVISIONAL DATA Fig 2

ABBREVIATIONS

AAIB	Air Accidents Investigation Branch
AFIS	Aerodrome Flight Information Service
AFM	Approved Flight Manual
AGM	Administrative Guidance Material
AIBN	Accident Investigation Board - Norway
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AMC	Acceptable Means of Compliance
AOC	Air Operator Certificate
ATPL-A	Air Transport Pilot Licence, Airplane
BKN	BroKeN
BR	Weather code for haze/mist
CAA	Civil Aviation Authority
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment
DZ	Weather code for drizzle
EEE	European Executive Express AB
ENBR	ICAO code for Bergen lufthavn Flesland
ENGM	ICAO code for Oslo airport Gardermoen
ENSN	ICAO code for Skien airport Geiteryggen
ENTO	ICAO code for Sandefjord airport Torp
FAA	Federal Aviation Authorities
FDR	Flight Data Recorder
FIR	Flight Information Region
FOR	Flight Occurrence Report
FP	Pilot Flying
GPWS	Ground Proximity Warning System
HIL	Hold Item List
hPa	hektopascal
ICAO	International Civil Aviation Organization
IEM	Interpretative/Explanatory Material
IFR	Instrument Flight Rules
IGA	International General Aviation
IMC	Instrument Meteorological Conditions
IOAT	Indicated Outside Air Temperature
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
kHz	kilohertz
KT/kt	Nautical Mile(s) (1 852 m) per hour
lb	Pound (0,454 kg)
LDA	Landing Distance Available
LLZ	Localizer
LOFT	Line Orientated Flight Training
MEL	Minimum Equipment List

METAR	METeorological Aerodrome Report
MHz	megahertz
MSL	Mean Sea Level
NAV	Navigasjonsradio
NFP	Non Flying Pilot
NM	Nautical Mile(s) (1 852 m)
NOTAM	NOtice To AirMan
OAT	Outside Air Temperature
OM	Operating Manual
OPC	Operator Proficiency Check
PC	Proficiency Check
PROB	Weather code for probability
RASN	RainSNow
SCT	ScatTered
SE	Identification letters for radio beacon
SNRA	SnowRain
SOP	Standard Operations Procedures
TAF	Terminal Aerodrome Forecast
TEMPO	Weather code for temporary
UTC	Universal Time Coordinated
V_{ref}	Reference velocity
VOR	VHF Omnidirectional Radio range

ACCIDENT REPORT