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# REPORT ON SERIOUS INCIDENT

(Law on Aircraft Accident Investigation no. 35/2004)

**Republication of AAIB UK Report EW/C2006/06/07 published in March 2007 Bulletin**

## M-03906/AIG-20

**TF-CSB**
**Dornier 328-100**
**11 June 2006**

**INCIDENT**

| | |
|---|---|
| **Aircraft Type and Registration:** | Dornier 328-100, TF-CSB |
| **No & Type of Engines:** | 2 Pratt and Witney PW 119B turboprop engines |
| **Year of Manufacture:** | 1997 |
| **Date & Time (UTC):** | 11 June 2006 at 1256 hrs |
| **Location:** | Near Sumburgh Airport, Shetland |
| **Type of Flight:** | Public Transport (Passenger) |
| **Persons on Board:** | Crew - 3 Passengers - 17 |
| **Injuries:** | Crew - None Passengers - None |
| **Nature of Damage:** | None |
| **Commander's Licence:** | Airline Transport Pilot's Licence |
| **Commander's Age:** | 61 years |
| **Commander's Flying Experience:** | 18,000+ hours (of which approximately 280 were on type)<br>Last 90 days - 120 hours<br>Last 28 days - 36 hours |
| **Information Source:** | AAIB Field Investigation |

**Synopsis**

During a visual approach to Sumburgh Airport, the aircraft encountered worsening weather conditions and inadvertently flew into close proximity with the terrain. The crew were alerted to the situation by on-board equipment, but the commander did not respond to the 'PULL UP' warnings it generated. The approach was continued and a safe landing made at the airport. The investigation identified a number of organisational, training and human factors issues which contributed to the crew's incorrect response to the situation. Two recommendations were made, concerning crew training and regulatory oversight of the aircraft operator.

**History of the flight**

The aircraft was engaged on a return charter flight from Aberdeen Airport to Sumburgh Airport in the Shetland Isles. The flight crew, comprising a very experienced captain and a relatively inexperienced co-pilot in his first commercial flying position, reported for duty at 1100 hrs. During pre-flight preparations the flight crew noted that the wind at Sumburgh was forecast to be from 150º(M) at about 12 kt, so the possibility of a visual approach to Runway 15 was discussed. The main instrument runway at Sumburgh was Runway 09/27. The commander was familiar with Sumburgh Airport, although he had last operated there with a different company seven or eight years previously. The co-pilot had only been to Sumburgh once, about six months previously. The commander,

who was to be the handling pilot, stated that he discussed with the co-pilot a route inbound to the airport which went further to the west than was necessary, in order to show him some of the local terrain features. However, the co-pilot's recollection was that the discussion was limited to the possibility of a visual approach, and did not extend to the routing or possible reasons for it.

The aircraft took off from Aberdeen at 1222 hrs. On board were the two flight crew, a cabin attendant and 17 passengers. During the cruise portion of the flight, the co-pilot obtained the Sumburgh ATIS report 'Juliet', timed at 1220 hrs:

> *"...Runway 09 in use, surface wind 150 degrees at 9 kt, visibility 7,000 metres, few clouds at 600 feet, temperature 13°(C), Dew point 11°(C), runway dry, No RVR available".*

The commander reported that he briefed for a visual approach to Runway 15, along the lines that had been discussed before the flight. He also briefed the Localiser/DME approach to Runway 09 in case the visual approach was not possible or not approved. The commander then entered a navigation waypoint into the Flight Management System (FMS); the waypoint was 5 nm to the west of the Sumburgh VOR/DME which was located at the airport. He briefed the co-pilot that he would fly towards this point and then towards the high ground of Fitful Head before turning right towards the airport and flying to a 'right base' position for Runway 15 (Figure 1). However, the co-pilot recalled that the commander briefed for the instrument approach to Runway 09, and added as a 'footnote' that they should request a visual approach to Runway 15. The co-pilot did not recall the commander briefing a route, configurations, speeds or altitude targets for a visual approach.

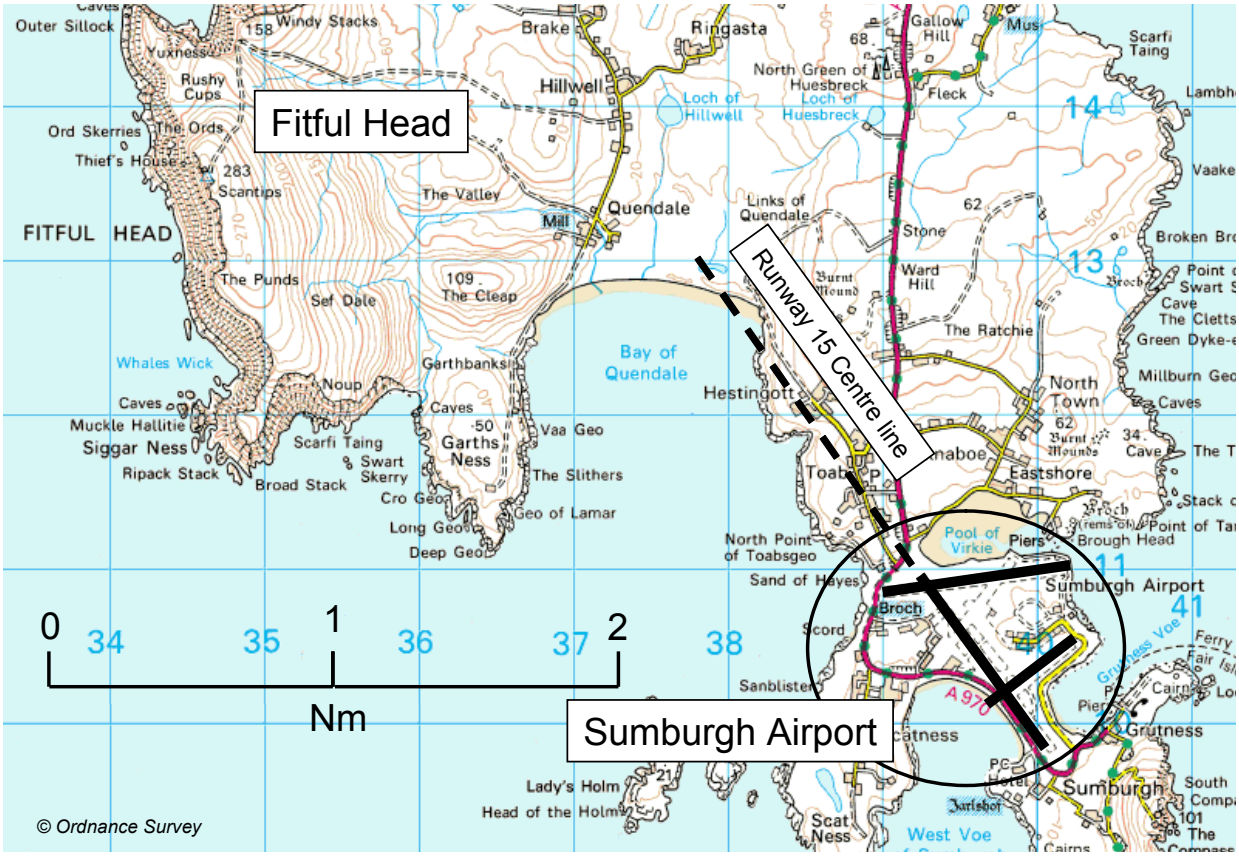


**Figure 1**

Area map

The commander later stated that, if the weather did not permit a visual approach, his plan was to turn right at the FMS waypoint, towards the VOR/DME, and from that point seek radar assistance for an instrument approach. This was not included in the briefing he gave the co-pilot.

On first contact with Sumburgh Approach Control, and in accordance with the commander's instructions, the co-pilot requested a visual approach to Runway 15, which was approved. At this stage the aircraft was routing towards the FMS waypoint but the crew were not visual with the airport. The co-pilot later reported that he was content with the plan for a visual approach, being aware that the commander had operated into Sumburgh many times beforehand.

Having approved the crew's 'own navigation', the Approach controller instructed them to reduce airspeed to 180 kt, as there was other traffic ahead, flying from left to right and following the Localiser/DME approach to Runway 09. The crew were cleared to descend to 2,100 ft altitude which was the Sector Safe Altitude (SSA) for aircraft approaching the airport from the south-west. The commander instructed the co-pilot to advise ATC that they were able to continue visually. The Approach controller then cleared the crew for a visual approach to Runway 15, with no further ATC descent restriction.

The co-pilot reported that he could not see the airport as it was obscured by cloud, but could see high ground ahead and to the right. He asked the commander if he intended to turn to the right before the high ground, and the commander said he would. At this point the co-pilot thought that the high ground he could see was Fitful Head, and recalled that, on his last visit to Sumburgh some six months previously, he had flown a visual approach which turned comfortably inside Fitful Head from a downwind position on Runway 15, having flown a published 'cloud break' procedure. The co-pilot later thought that the high ground he saw was that to the north of the airport, since Fitful Head was actually obscured by clouds at that stage.

As the aircraft descended below the selected altitude of 2,100 ft the altitude alert sounded, and the commander asked the co-pilot to silence the alert. The co-pilot momentarily selected a higher altitude which cancelled the alert, then reset the selector to 2,100 ft, which was also the 'missed approach' altitude. The commander did not specify which altitude he intended descending to, and the co-pilot did not query this. The commander later said that he had intended to descend to 1,000 to 1,200 ft, being a height appropriate to a downwind position.

The aircraft continued to descend whilst flying towards the high ground of Fitful Head (elevation 930 ft amsl). Neither the commander nor co-pilot were visual with the coastline or the headland itself, though both were in visual contact with the surface of the sea. As the aircraft descended the visibility decreased, in what the commander later described as "thickening haze". The commander thought that he had descended to about 1,000 ft, and was abeam the FMS waypoint, when he decided that conditions were not good enough for a visual approach. He therefore started a turn to the right, and later reported that his intention had been to position the aircraft for an instrument approach. The commander said that he was about to voice these intentions to the co-pilot when the crew received the first Enhanced Ground Proximity Warning System (EGPWS) alert, "CAUTION TERRAIN".

Neither crew member recalled looking at the EGPWS display (a small dedicated display on each pilot's instrument panel, which produces a graphic display of

the surrounding terrain, based on the aircraft's position and an internal terrain database). The "CAUTION TERRAIN" alert was followed by a "TERRAIN TERRAIN PULL UP" warning. The co-pilot described looking up and seeing a cliff or steep hill ahead of the aircraft as the commander increased the bank angle to the right. The co-pilot thought that the aircraft was below the level of the highest terrain, and was aware of sea birds in the vicinity. Soon afterwards, the co-pilot heard the landing gear warning siren. This aural alert was accompanied by a flashing red light in the landing gear selector handle, which indicated that the aircraft was below 500 ft radio altitude with the landing gear not down.

The commander was aware of the "TERRAIN TERRAIN PULL-UP" warning, but was visual with the terrain and thought that his turn was taking the aircraft clear of it. He was also in sight of the sea surface and considered that the safety of the aircraft would not be jeopardised by continuing with the visual approach. He did not increase altitude, as he thought that to do so may cause him to lose visual contact with the terrain or the sea surface. Both crew members subsequently stated that they had the impression that the aircraft had been tracking towards the most southerly end of Fitful Head, and that the area to their right was clear of terrain.

The "TERRAIN TERRAIN PULL-UP" warning continued after the aircraft had turned right and was flying along the line of the cliff, still at about 400 to 600 ft and below the level of the cliff top. The landing gear warning siren was also sounding, making communications difficult between the two pilots and between the co-pilot and ATC. The co-pilot was alarmed by the situation and considered taking control from the commander. However, he thought that to attempt to do so whilst the aircraft was manoeuvring at low level might place the aircraft in a more hazardous situation, especially as communication between the two pilots was being hindered by the warning sounds.

As the aircraft turned eastwards and flew towards the airport the ground proximity warnings ceased, although the landing gear warning continued until the landing gear was lowered. The remainder of the approach and landing was uneventful. After landing the commander queried the broadcast weather conditions with ATC, expressing an opinion that they were poorer than the ATIS information suggested.

**Recorded information**

The incident was captured in part by the radar on Fitful Head itself, the output of which was recorded and available for analysis. Radio transmissions on the Sumburgh Approach and Tower ATC frequencies were also recorded. The Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) were already in the possession of the AAIB at the time of notification, as the same aircraft had been involved in a later accident. However, the data for the incident flight had been over-written. The aircraft was equipped with an EGPWS which incorporated a memory module capable of storing triggered alerts and warnings, together with basic flight data. The EGPWS data was successfully downloaded by the manufacturer and was available for analysis.

*Radar and R/T information*

Figure 2 shows the aircraft's radar track and significant R/T exchanges. When the co-pilot contacted the Sumburgh Approach controller he was told that the aircraft would be radar vectored for the Localiser/DME procedure for Runway 09. The co-pilot acknowledged this, but requested a visual approach to Runway 15, if it was possible. The commander then transmitted "…WE'VE SET UP OUR NAV BOX TO PUT US ON A

FIVE MILE RIGHT BASE FOR ONE FIVE IF THAT'S OK WITH YOU"; the controller replied "… ROGER, YOUR OWN NAVIGATION".

As the aircraft tracked towards a point 5 nm west of the Sumburgh VOR/DME (which was the waypoint entered into the FMS), the crew was cleared by the Approach controller to descend to 3,000 ft and to reduce airspeed to 180 kt. The controller subsequently instructed the crew "…DESCEND TO ALTITUDE TWO THOUSAND ONE HUNDRED FEET AND REPORT WHEN YOU HAVE VISUAL".

On the commander's instruction, the co-pilot transmitted "…HAPPY TO CONTINUE, AND VISUAL". At this point the aircraft was at 2,100 ft, bearing 250º(M) from the VOR/DME at a range of 5.7 nm, and still tracking towards the FMS waypoint. The controller replied "…YOU'RE CLEARED VISUAL APPROACH RUNWAY 15 FOR THE RIGHT BASE AT 5 MILES, NO DESCENT RESTRICTION". As the controller began this transmission the SSR Mode C altitude indicated that the aircraft began descending below 2,100 ft, with an initial descent rate of between 1,500 ft/min and 2,000 ft/min.

As it approached the FMS waypoint, the aircraft commenced a gentle turn to the right. It passed about 0.2 nm to the east of the waypoint, whilst descending at about 1,500 ft/min through a Mode C altitude of 1,300 ft. The aircraft continued in a very gentle right turn towards the high ground of Fitful Head. The average descent rate reduced as the aircraft descended below 1,000 ft, to about 1,000 ft/min. When the aircraft was about 0.6 nm from the coastline as shown on the radar display, and at a Mode C altitude of 700 ft, the Approach controller asked "… JUST CONFIRM YOU ARE VISUAL WITH FITFUL HEAD?" The co-pilot replied with the single word "AFFIRM" and the subsequent radar returns showed the aircraft's turn rate to the right increased significantly until the aircraft had turned to track approximately

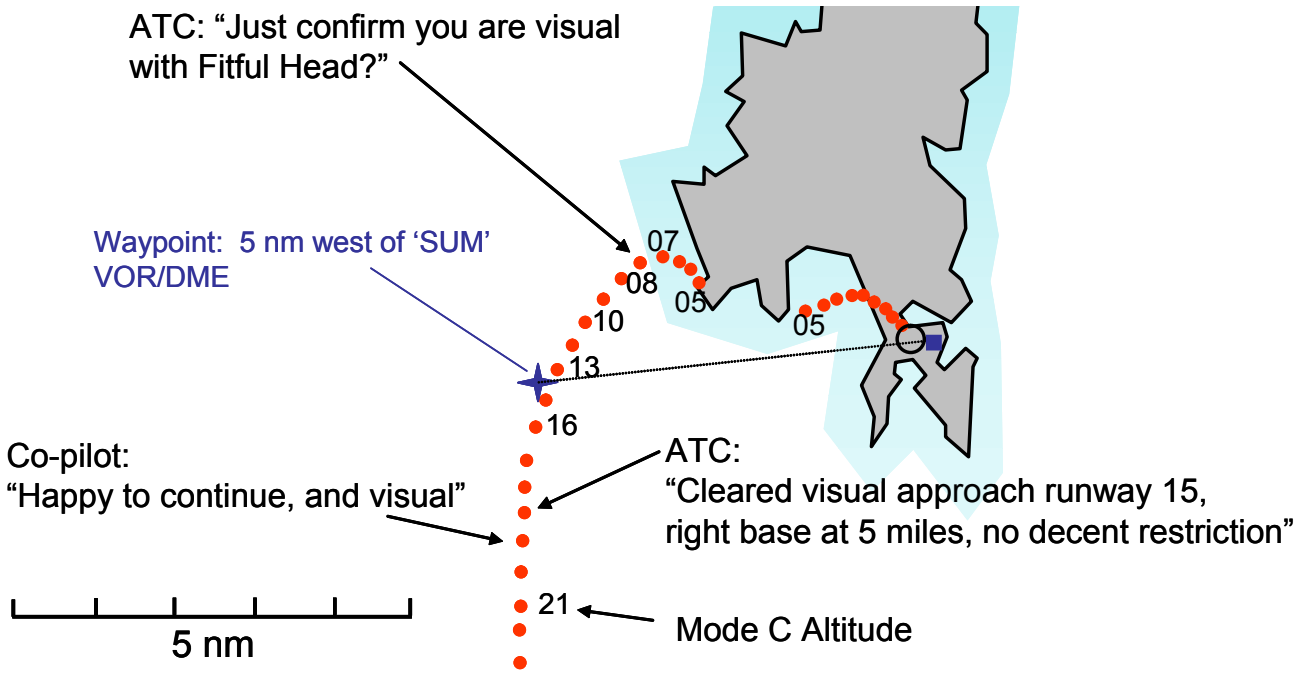


**Figure 2**

Radar plot and significant R/T exchanges

parallel to the coastline. The indicated altitude remained at 700 ft initially, then reduced to 500 ft. At that point radar contact was lost, as the aircraft became masked by the high ground.

When the aircraft reappeared on radar it was about 1 nm from the runway threshold and still indicating 500 ft. The co-pilot contacted the Tower controller and was immediately cleared to land on Runway 15. After landing the commander transmitted to the Tower:

"…VISIBILITY WAS NOT AS GOOD AS WE'D LIKE SO WE HAD TO POSITION FOR THE OTHER RUNWAY, SORRY ABOUT THAT".

The controller said that this had not caused ATC a problem, just a measure of concern. The commander responded:

"…WE DIDN'T GET FITFUL HEAD TILL THE LAST MINUTE, THE VISIBILITY IS NOT AS – NEARLY AS GOOD AS REPORTED".

*EGPWS information*

The position of warnings and cautions generated by the EGPWS are depicted at Figure 3; values in red are radio altitudes. Figure 4 shows the aircraft's vertical profile for the same period. Flight data for each significant event, commencing with the start of the recorded data, is given in Table 1. Two recorded parameters were common to each event, these were: landing gear up and landing flaps not selected.

**Meteorological information**

At the time of the incident a moderate to fresh southerly airflow covered the northern Scottish Isles, with a weak cold front lying over the Orkney and Shetland area. The southerly flow generated extensive low stratus cloud over the area, though it is possible there were relatively large gaps in this cloud layer. Cloud was reported at the time as few at 600 ft, but it is quite likely that the cloud cover could have increased at any time.

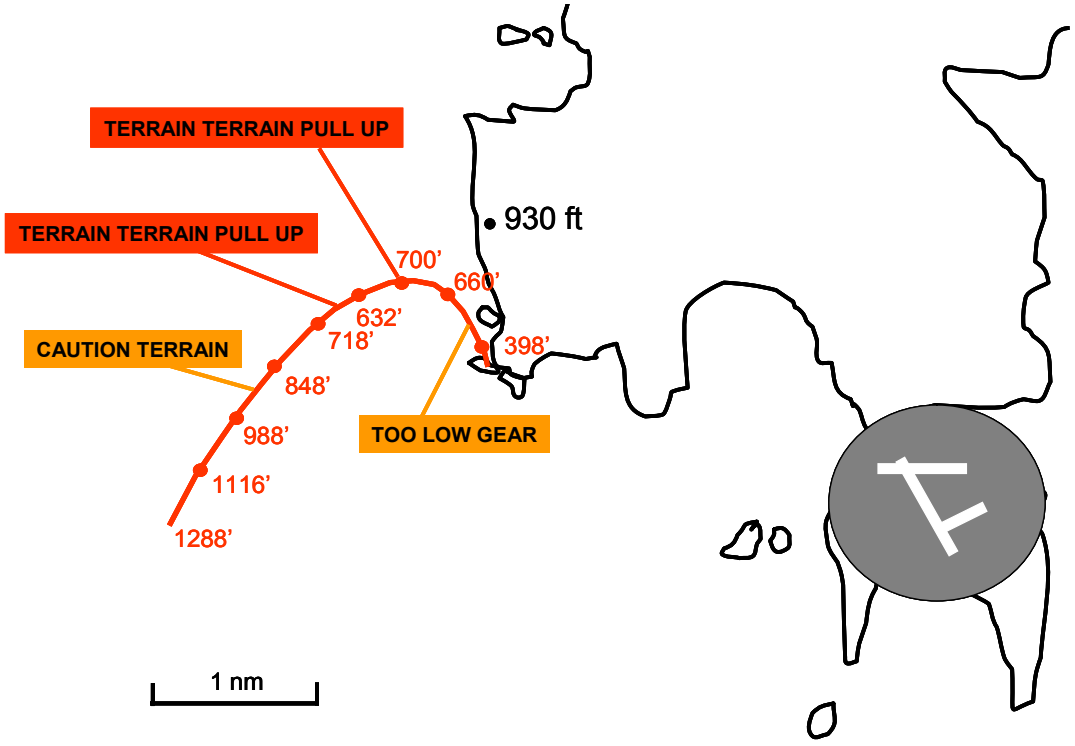


**Figure 3**

EGPWS record

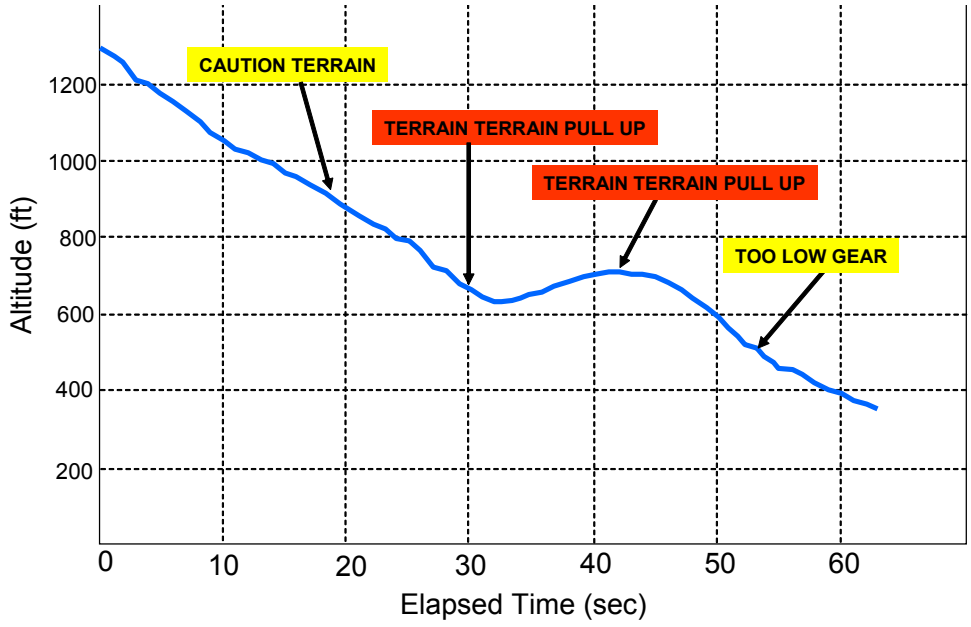


**Figure 4**

Aircraft vertical profile

To the north of the airport, the cloud cover was reported as broken or overcast at 100 to 200 ft. According to ATC personnel at Sumburgh, when south or south-easterly winds prevail, low stratus commonly affects the airport. On these occasions, Fitful Head is frequently obscured by low cloud.

The Sumburgh Terminal Area Forecast (TAF), issued at 0902 hrs on 11 June 2006 and valid for the period 1000 hrs to 1900 hrs, was:

> Surface wind from 150º(M) at 12 kt, visibility 3,000 m in mist, and broken cloud at 400 ft. Temporarily, the visibility may become 7 km, with broken cloud at 800 ft.

The Meteorological Aerodrome Report (METAR), issued at 1250 hrs, showed the following actual conditions:

> Surface wind from 140º(M) at 11 kt, visibility 7 km, few cloud at 600 ft, temperature 13º(C), dew point 11º(C), and QNH 1019 hPa.

**Reporting action**

The co-pilot sought to report the incident that evening on return to Aberdeen, but was unable to contact the company Flight Safety Officer (FSO), who was on a flying duty. Instead, the co-pilot discussed the incident with the FSO the next day, and suggested that the FDR and CVR be down-loaded to assist investigation into the incident. The FSO investigated the feasibility of removing the FDR (the CVR, with only a 30 minute recording history, would have been over-written by that time). As the aircraft would have been unable to continue to operate unrestricted without a FDR installed, the FSO decided against this course of action, believing that submission of an Air Safety Report (ASR) would meet the reporting requirements applicable to an incident of this nature. The co-pilot subsequently completed an ASR which the FSO sent by fax to the Icelandic Civil Aviation Administration (ICAA) on the evening of 14 June 2006. The ICAA reported the incident to the Icelandic AAIB on June 21 2006, which in turn notified the UK AAIB on 27 June 2006.

| Elapsed time | Event and flight parameters |
|---|---|
| 00:00 | Start of recoded data<br>Airspeed: 200 kt<br>Groundspeed: 227 kt<br>Radio altitude: 1263 ft<br>Vertical Speed: -1,500 ft/min<br>Heading (M): 028º<br>Bank angle: 7º right |
| 00:19 | **Look ahead "CAUTION TERRAIN"** ***(note 1)***<br>Airspeed: 190 kt<br>Groundspeed: 212 kt<br>Radio altitude: 874 ft<br>Vertical Speed: -1,079 ft/min<br>Heading (M): 049º<br>Bank angle: 4º right |
| 00:30 | **Look ahead "TERRAIN TERRAIN PULL-UP"**<br>Airspeed: 187 kt<br>Groundspeed: 197 kt<br>Radio altitude: 644 ft<br>Vertical Speed: -1,390 ft/min<br>Heading (M): 067º<br>Bank angle: 15º right |
| 00:42 | **Second look ahead "TERRAIN TERRAIN PULL-UP"** ***(note 2)***<br>Airspeed: 154 kt<br>Groundspeed: 153 kt<br>Radio altitude: 721 ft<br>Vertical Speed: +12 ft/min<br>Heading (M): 147º<br>Bank angle: 37º right |
| 00:53 | **Mode 4 "TOO LOW GEAR"**<br>Airspeed: 144 kt<br>Groundspeed: 121 kt<br>Radio altitude: 476 ft<br>Vertical Speed: -1,609 ft/min<br>Heading (M): 156º<br>Bank angle: 12º right |

Note 1: Typically generated at 40 to 60 seconds before terrain conflict, then repeated at 7 second intervals.

Note 2: When the aircraft enters the 'pull-up' warning envelope, a single aural warning is generated, together with the associated visual alerts. The system then remains silent for 12 seconds. If, after 12 seconds, the aircraft is still within the warning envelope, the warning is generated again and will continue to sound until the aircraft leaves the warning envelope.

**Table 1**

The commander had not sought to submit an ASR, but was asked by the operator to do so after the co-pilot had alerted them to the incident. The commander later stated that he was unaware that an EGPWS warning necessitated a safety report, and that he was not familiar with the reporting procedures as far as the Icelandic authorities were concerned.

**Aerodrome information**

Sumburgh Airport, elevation 20 ft, is situated 17 nm south of Lerwick, and just north of Sumburgh Head, which is the southernmost point of the Shetland Isles. The airport has two runways available for fixed wing aircraft. Runway 09/27 was the main instrument runway and was 1,180 metres long; Runway 15/33 was 1,426 metres long, with no associated approach procedures. Runway 09 was served by a localizer/DME approach, a VOR/DME approach and an NDB approach. An ILS approach was available on Runway 27 only. A cloud break procedure was also available for aircraft approaching from the south, based on an inbound course of 010º(M) to the Sumburgh VOR/DME.

**Organisational information**

*General*

The aircraft was operated by an Icelandic company which was based in Reykjavik, but which operated aircraft in both Iceland and the UK. The company's Aberdeen-based aircraft were registered in Iceland and operated under an Icelandic Air Operators Certificate, issued to the operator by the ICAA. Day-to-day operations in the UK were conducted from Aberdeen. Flight operations and commercial management positions were held by personnel in Iceland, who oversaw the activities of both the Icelandic and Aberdeen-based operations.

*Safety management*

The operator had been subject to an independent safety audit about one month before the incident which had highlighted a number of deficiencies in the company's safety management system. At that time the operator's Director Flight Operations (DFO) was solely responsible for flight safety matters, including handling of incident reports, disseminating safety-related information and chairing safety meetings. As a result of the audit, the FSO post had been created and had been filled by a line training captain at Aberdeen. The FSO had then received related aviation safety training (which had been completed only shortly prior to this incident), and the new post promulgated to company staff. However, at the time of the incident the Operations Manual had not been revised to reflect the change and there were no terms of reference established for the FSO post. For the reporting of accidents and incidents, the operator used a 'Flight Occurrence Report' form which was available in the crew area at Aberdeen and in a folder on board the aircraft.

**Operational advice to flight crew**

The company's Operations Manual (OM) conformed to the Joint Aviation Requirements (JAR) format, although the investigation found a number of deficiencies relating to aircraft operations.

*Aerodrome categorisation*

In accordance with JAR - Operations 1 (JAR-OPS 1)[1], the operator's OM included a method of categorisation of aerodromes, with Category A being the least demanding for flight crews and Categories B and C being progressively more demanding. The OM also included a list of aerodromes and their categories; Sumburgh Airport was listed as Category B, because of terrain and weather considerations.

**Footnote**

[1] JAR-OPS 1 concerns Commercial Air Transportation.

Using wording taken directly from JAR-OPS 1, the OM stated that commanders should be briefed, or self brief, by means of 'programmed instructions' on Category B aerodromes, and that commanders should certify as having done so. However, the investigation established that there were no instructions available to commanders for *any* Category B aerodromes, including Sumburgh. Nor was there in place any method by which commanders could certify as having been so briefed. Additionally, the OM required that any airport 'special briefing' be included in the handling pilot's approach and landing briefing.

*Descent below safety altitude*

There was a discrepancy between the operator's OM Part A and another manual issued to flight crews, entitled '*D328 Standard Operating Procedures*'. The OM contained the following text concerning descent below safety altitude when not on a published procedure or under positive radar control:

> *" An aeroplane must not descend below the appropriate safety altitude except ... when in continuing visual contact with the ground and able to ensure adequate clearance from all obstacles affecting the intended flight path."*

The equivalent section in '*D328 Standard Operating Procedures*' states only that the aircraft must be:

> *"Maintaining VMC plus good contact with the ground".*

The operator's OM contained the weather minima for VMC flight, including the requirement for a minimum in-flight visibility of 5 km.

*EGPWS*

JAR-OPS 1 required that the OM contain information regarding response to GPWS warnings and limitations on high rates of descent close to the surface. The operator's Part A contained only a reference to the Airplane Flight Manual (AFM) in this respect. The AFM contained instructions regarding actions in the event of a GPWS "PULL UP" warning, though it was not on issue to flight crews and therefore the information was not available for self-study, as is also required by JAR-OPS 1. However, both crew stated at interview that they were familiar with the response required by this warning. The OM contained no reference to limitations on high rates of descent near to the surface.

**Crew training**

Both pilots underwent training for the Dornier 328-100 at a separate Type Rating Training Organisation (TRTO) in the United Kingdom; this training was completed in November 2005. The Computer Based Training (CBT) ground school course included a technical overview of the GPWS, its modes of operation and the types of warnings and cautions that could be generated. It did not include any of the predictive features of EGPWS.

The co-pilot's Type Rating Skill Test schedule (a UK Civil Aviation Authority form) recorded that practical training had been completed in the section titled *'Ground Proximity Warning System, weather radar, radio altimeter, transponder'*. The TRTO confirmed that the flight simulator used during training was capable of reproducing GPWS alerts and warnings (but not EGPWS predictive functions) but that practical exercises in GPWS responses were not included in the training syllabus; only normal and abnormal operation of the equipment itself would have been covered.

**Regulatory requirements**

The Joint Aviation Requirements stipulated that the aircraft be fitted with a GPWS system which included a predictive terrain hazard warning function. The EGPWS equipment met this requirement. Joint Aviation Requirements – Flight Crew Licensing 1 (JAR-FCL 1) contained the training, testing and checking requirements for the issue of crew licences and aircraft type ratings. The only requirement relating to GPWS was that flight crew were trained in the normal and abnormal operation of the system; there was no specific requirement for crew to be trained in, or demonstrate an understanding of, the correct response to GPWS alerts. Furthermore, there was no requirement for training or checking in the predictive or 'look ahead' functions which had been specifically required to be installed on aircraft such as TF-CSB from 1 January 2005.

## Safety action by the operator

After interviewing the flight crew, the operator recognised that the advice to crews about GPWS warnings was not readily available and therefore issued a Flight Crew Notice (FCN). The FCN reproduced that part of the AFM dealing with GPWS warnings, including the following text:

> *"Whenever the aural announcements TERRAIN TERRAIN, SINKRATE SINKRATE, TOO LOW FLAPS, TOO LOW GEAR or GLIDESLOPE are heard, take appropriate action to correct the unsafe condition.*
>
> *Whenever the TOO LOW – TERRAIN or WHOOP WHOOP PULL UP announcements are heard, establish the power setting and attitude which will produce maximum climb gradient consistent with the airplane configuration."*

At the time of the incident, the operator was preparing a revision to the OM. The revision included responses to GPWS warnings, (as detailed in the AFM and reproduced in the FCN), though it did not include information on 'look ahead' alerts of the type received by the crew in this incident. In response to the incident, the operator undertook to distribute to all flight crews technical advice and operational guidance on the EGPWS.

The OM revision included a fully updated section on the handling, notifying and reporting of occurrences. A further revision, being prepared at the time of the investigation, was to address the discrepancy regarding decent below safety altitude, as well as including guidance regarding high decent rates close to the surface.

**Safety action by the ICAA**

The investigation highlighted possible shortcomings in the operator's Crew Resource Management training, as well as issues of crews' awareness of company procedures. The ICAA considered that these were issues associated with the operator's crew conversion training and checking programs. The ICAA has therefore added to its oversight program a special emphasis on the operator's conversion course.

**Analysis**

In this serious incident a serviceable public transport aircraft with 20 persons on board flew at low altitude and in poor visibility into close proximity with terrain, despite the availability of a suitable instrument approach aid and radar assistance. Mandatory equipment designed to prevent such an occurrence functioned correctly and may have averted an accident, though the crew's reaction to the alert it generated was not in accordance with established procedures.

*The approach plan*

It is not clear from the two pilots' differing accounts exactly how detailed the briefing for a visual approach was. During R/T exchanges and in their individual reports, both pilots refer to a 'right base' join for Runway 15, and it is this that was approved by the controller. Had the aircraft turned towards the airfield at the 5 nm waypoint, it would have been well placed to fly to a right base position, but it did not. The ATC clearance to descend without restriction was subject to the crew having reported "visual" with the airport. The co-pilot's account and subsequent events indicate that the crew were in fact not visual with the airport when the "visual" call was made.

The commander stated that he intended to fly towards the high ground with the intention of showing the terrain to the co-pilot (though the co-pilot was unaware of this). The commander also said that the 5 nm FMS waypoint would serve as a point beyond which he would not proceed if the weather or visibility was worse than expected. He thought the conditions were suitable to continue the visual approach, as he was in sight of the surface. However, to maintain surface contact he needed to descend the aircraft to an unusually low level, considering the aircraft's distance from the airport. If, as stated, the commander actually intended flying towards the highest ground in the vicinity, then it is remarkable that he continued to do so in conditions of poor and reducing forward visibility (almost certainly to less than the VMC minima of 5 km) and without informing ATC of the fact.

*Human factors*

The aircraft's radar track suggests that the commander, and probably the co-pilot, did not appreciate their position relative to the high ground of Fitful Head, thinking instead that the aircraft would fly to the east of the high ground on its way to a right base position. The co-pilot's question about whether the aircraft would turn inside the high ground, and the commander's response that it would, supports this view and may have served to reinforce in both pilots an incorrect mental model of the aircraft's situation. This is supported by the prompt, and initially rapid, final descent which began as soon as the Approach controller cleared the crew for a visual approach.

If the aircraft track was displaced only 2 nm further east, it would indeed have flown inside the high ground, and the vertical profile would then be more appropriate to the aircraft's position (had the crew been visual with the airport at that stage). The fact that both pilots thought the high ground they had seen to be the extreme southern end of Fitful Head also supports this hypothesis, as does the commander's statement that he intended to descend to a height appropriate to a downwind position. Furthermore, the commander described the incident as having taken place whilst turning on 'right base'. Because of this incorrect mental model of the situation, both crew thought that a turn to the right would take the aircraft into a clear area, when in fact, as the radar data shows, the aircraft actually turned towards the high ground. This would also account for the commander's incorrect reactions to the EGPWS alerts, and may have been a factor in the co-pilot's reluctance to assume control or order an immediate climb.

*EGPWS reaction*

The commander was aware of the high ground at Fitful Head, and when the 'CAUTION TERRAIN' alert sounded he probably thought it was triggered by ground he was turning away from, since otherwise his continued descent and gentle turn would be inexplicable. When the first 'TERRAIN TERRAIN PULL UP' warning sounded, the

aircraft was descending through 644 ft radio altitude at a rate of 1,390 ft/min. The warning would not have agreed with the commander's probable mental model of the situation, but the EGPWS data shows that he did arrest the rate of descent and increase the turn rate slightly. However, he still did not carry out the prescribed manoeuvre, which would have been to level the wings and carry out a maximum performance climb.

It would have been at some point between the two 'TERRAIN TERRAIN PULL UP' warnings, probably about the point that ATC queried whether the crew were visual with Fitful Head, that the crew probably realised that high ground lay directly ahead of the aircraft. However, the commander still did not initiate the required maximum performance climb, but instead increased the turn rate to avoid the terrain. His action were probably based on his perception that the terrain he could see ahead was the extreme southerly tip of the headland, and that by turning the aircraft to the right he would be flying into a clear area. Although the commander stated that he was visual with the headland during this period, and did not consider that the terrain was a hazard, separation with the terrain continued to decrease and the aircraft actually flew over the extreme south-westerly point of the headland at less than 400 ft radio altitude.

When the first 'TERRAIN TERRAIN PULL UP' warning sounded, the aircraft was 1 nm from the highest terrain. Allowing for a reaction time of 5 seconds, and assuming constant groundspeed (ie no trade of airspeed for climb rate), the aircraft would only need to have achieved an initial climb rate of about 1,500 ft/min in order to clear the highest ground in the area by 50 ft. When the warning sounded a second time, the aircraft was 0.6 nm from the highest terrain, though turning away from it. A climb rate of 1,400 ft/min would have been required, allowing for a reaction time of 3 seconds. The climb rates required could comfortably have been achieved for the short duration required to clear the terrain, especially as excess airspeed was available.

*Crew Resource Management (CRM)*

The flight crew had very different backgrounds and experience. The commander had an extensive flying background and had accrued a large number of flying hours. In contrast, the co-pilot had joined the company less than a year earlier for what was his first commercial flying position. There was thus a very 'steep gradient' across the flight deck in terms of experience and authority.

The co-pilot was comfortable with the commander's initial decision to fly a visual approach, and although it may not have been briefed in any detail, had confidence in the commander. He admitted to feeling less comfortable as the descent progressed, but still trusted the commander's experience. The authority gradient, together with an erroneous mental model similar to the commander's, is probably the reason why the co-pilot did not seek further information about the visual approach during the briefing and did not question some of the commander's intentions during the descent, such as when the aircraft descended below the altitude target of 2,100 ft. The flight deck gradient appears to have been such a strong inhibitor for the co-pilot that, despite the EGPWS alerts and the ATC radio call, it was at a relatively late stage that the co-pilot considered taking control from the commander, at which point he decided that to do so would possibly place the aircraft in greater jeopardy.

There is a considerable onus on a commander to recognise the well-publicised problems of a steep authority gradient and to create an environment whereby a co-pilot feels able to question a commander's actions if he thinks them inadvisable or inappropriate. Similarly, for a two-pilot crew to operate most effectively, good communication

between them is essential. In this case there appears to have been little effective communication, either regarding the approach plan or the developing situation, and it is probable that the co-pilot felt uncomfortable questioning the commander until the situation had clearly become very serious. However, the co-pilot's actions in bringing the incident to the attention of his company afterwards were commendable.

*Organisational factors*

The operator's OM clearly stated that Sumburgh was considered a Category B airport because of terrain and weather, both of which were factors in this incident. Had the operator met the requirements of JAR-OPS 1 and its own OM in regard of the provision of briefing material for Sumburgh Airport, the crew would have been reminded of the significant terrain and would probably have been reminded about the local weather effects that could affect Fitful Head. With this information fresh in their minds, the situation may have been avoided. Such a brief would also have raised the co-pilot's awareness of potential problems and may have prompted him to question the commander's intentions or actions before the situation became critical.

*Crew training*

The GPWS training received by both pilots during type rating training did not extend to practical handling exercises, nor was there a requirement for this under existing regulations. The crew received no training in the predictive functions of EGPWS, and there was no company information or guidance on such alerts. This was more significant for the co-pilot, as the commander had operated EGPWS equipment previously.

When the first 'CAUTION TERRAIN' alert sounded, the EGPWS display would have given a visual display of the terrain ahead of the aircraft which, had one of the crew seen it, would have alerted them much earlier to the true situation. Although the commander had experience of the system, the co-pilot's lack of training meant that he, as monitoring pilot, was not as well equipped to respond to the alert.

Although basic GPWS has been in use for many years, equipment with predictive functions has only recently been mandated in all large public transport aircraft (since 1 January 2005 in this case). However, there is no corresponding requirement that flight crews be trained in the enhanced functions of the system, or demonstrate an understanding of the correct responses to such alerts. It is recognised, however, that many modern simulators faithfully represent the latest GPWS standards and provide excellent training in this regard.

The situation regarding training may be compared to the carriage of Airborne Collision-Avoidance Systems (ACAS) which are also mandated and yet which carry a specific requirement that flight crews be trained in the interpretation of the ACAS display and the correct responses. Although GPWS warnings require less interpretation and handling finesse on the part of the pilot than ACAS alerts, accidents have still occurred due to incorrect crew responses. Had there been mandatory training in the predictive terrain hazard warning function of EGPWS, it is possible that this aircraft would not have come into such close proximity with terrain as it did.

It is therefore recommended that:

**Safety Recommendation 2006-130**

The Joint Aviation Authorities should review the training requirements for flights crews operating aircraft required to be equipped with a predictive terrain hazard warning function, with a view to ensuring that such crews are adequately trained in its use, interpretation and response.

*Regulatory oversight*

A number of organisational shortcomings were identified during the investigation, some of which have been addressed by the operator. At the time of the incident the operator's OM contained inadequate guidance to crews regarding responses to GPWS warnings, and no guidance or limitation on high rates of descent near to the surface, both of which were required under JAR-OPS 1. Furthermore, although the OM contained details of aerodrome categorisation, the system of briefing and certification of such was non-existent. Additionally, there was a discrepancy between the OM and another manual regarding the requirements for flight below safety altitude.

The ICAA was responsible for regulatory and safety oversight of the operator and, whilst acknowledging that the ICAA has already taken steps to increase its oversight of the operator's crew training programs, the following recommendation was made.

It was recommended that:

**Safety Recommendation 2006-131**

The Icelandic Civil Aviation Administration should conduct a safety audit of Landsflug ehf (City Star Airlines) in the light of the shortcomings identified during the investigation into this serious incident.