Accident
Investigation Board
Norway

Issued November 2016

REPORT SL 2016/11

REPORT ON SERIOUS AVIATION INCIDENT AT SVOLVÆR AIRPORT HELLE ON 2 DECEMBER 2010 INVOLVING BOMBARDIER DHC-8-103, LN-WIU, OPERATED BY WIDERØE'S FLYVESELSKAP AS

Accident Investigation Board Norway • P.O. Box 213, N-2001 Lillestrøm, Norway • Phone: + 47 63 89 63 00 • Fax: + 47 63 89 63 01
www.aibn.no • post@aibn.no

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.

Photos: AIBN and Trond Isaksen/OSL

TABLE OF CONTENTS

SERIOUS INCIDENT REPORT

Type of aircraft:	Bombardier Inc. DHC-8-103
Nationality and registration:	Norwegian, LN-WIU
Owner:	Widerøe’s Flyveselskap AS, Bodø
Operator:	Same as owner
Persons on board:	38 (commander, first officer, cabin crew and 35 passengers)
Injuries:	None
Material damage:	None
Accident site:	Approx. 1.5 km north-northeast of the threshold of runway 19 at Svolvær Airport Helle (ENSH) (approx. 68°15'24"N 14°41'11"E)
Accident time:	Thursday 2 December 2010 at 18:18 hours.

All times given in this report are local time (UTC + 1 hour), if not otherwise stated.

NOTIFICATION

The Accident Investigation Board Norway (AIBN) was only made aware of the incident in December 2012, two years after it had taken place. AIBN assessed the existing information, and collected further information. After an evaluation, AIBN concluded in June 2013 that the occurrence was to be considered an aviation incident. An investigation was not opened.

In February 2015, the incident was subject to significant attention, and AIBN found that the incident could contain a greater learning potential than first assumed. The decision not to investigate was changed. AIBN initiated an investigation in mid-March 2015. Following initial investigations, the Accident Investigation Board reclassified the case as a serious aviation incident.

In accordance with ICAO Annex 13, *Aircraft Accident and Incident Investigation*, AIBN notified the investigation authority in the manufacturing country Canada (Transportation Safety Board, TSB) of the incident and announced that an investigation had been opened. TSB appointed an accredited representative who assisted with the investigation, supported by advisors from Bombardier.

SUMMARY

Widerøe's flight WIF814 was en route from Bodø to Svolvær with three crew members and 35 passengers on board. It was dark, with cumulonimbus clouds, rain and hail showers in the area. There were gale force winds with strong gusts at Svolvær Airport.

The commander (the captain), who was Pilot Flying, was about to perform a visual circling over the sea in order to land towards the south. Just before turning into the final approach, the airplane began to buffet and lose altitude, and there was a significant loss of airspeed. Despite full power being applied, the airplane continued to lose both airspeed and altitude. The stall warning (stick shaker) activated. The nose of the aircraft was lowered and stalling was prevented, or a stall recovery performed, but the altitude above the terrain became very low (25 m) before the aircraft began to climb, and the situation was resolved. The first officer further increased engine power, to the maximum available, and at some point took over the flight controls on his own initiative. After the incident, which transpired over the course of approx. 10 seconds, the crew interrupted the approach

and continued to Leknes where they landed normally. The Accident Investigation Board Norway (AIBN) concludes that the airplane was exposed to severe wind shear from a cumulonimbus cloud. There was no aircraft damage and no physical injuries.

The crew perceived the incident differently. The commander has described that he had brought the situation under control and that he therefore could, even though it was not necessary, hand the controls over to the first officer. The first officer asserts that he had to intervene to prevent the aircraft from going into the sea. The facts are insufficient for AIBN to be able to determine with certainty which of the pilots did what during the seconds in question. Nor has it been possible to determine the specific time and sequence of actions, and what effect each action had in isolation. Consequently, it is not possible to draw any definite conclusions regarding whether the first officer's intervention had impact on the outcome. However, it is indisputable that the joint actions of the crew resulted in the aircraft starting to climb in time to avoid collision with the sea.

The manoeuvring to regain control of the aircraft took place with sparse visual references and with no visible horizon. The investigation shows that the conditions were right for the commander to possibly have experienced a somatogravic illusion. However, the Accident Investigation Board has not found any basis which warrants a conclusion that sensory illusion had any impact on the way the wind shear was handled.

In this investigation, AIBN has paid particular attention to assessing risk management and safety margins in connection with circling in darkness. No obvious system faults or other defects that could have had an impact on the sequence of events or causal relations have been uncovered. The incident is an important reminder of the vulnerability associated with manoeuvring at low altitude above terrain with few visual references, in darkness and turbulent air. It also serves as a reminder that operators, and pilots, with thorough local knowledge, experience and training beyond current government requirements are better equipped to handle critical situations such as this one in a safe manner.

Several relevant safety barriers have been strengthened since 2010. Double PLASI[1], circling lights, turbulence warning, etc. were put in place as a result of the continuous preventive air safety cooperation between operators and Avinor. Goal-oriented simulator training in order to raise awareness concerning sensory illusions was also planned by Widerøe, independently of this incident.

No safety recommendations are proposed. AIBN will nevertheless encourage Widerøe to consider whether further reduction of the residual risk in the base segment at Svolvær is possible. In addition, AIBN encourages Widerøe to apply the lessons learned from this incident in a broader perspective (cf. 2.11.4).

[1] Visual tool to determine altitude in relation to distance from the landing site.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Introduction

1.1.1.1 The mapping of the sequence of events is mainly based upon the crew's written reports, their in-depth explanations and data from the flight recorder. The crew were interviewed more than four years after the incident took place. It must therefore be taken into consideration that the passage of time is likely to have affected the memories of the involved parties. Furthermore, some essential information of significance for the investigation has been lacking. This will be discussed in greater detail later in the report.

1.1.1.2 Description of key parameters from the flight recorder, plotting and a summary of what these indicate about the sequence of events are available in Chapters 1.11, Figure 8 and Figure 9. Note that the critical phase the flight crew has described, from a perceived normal situation via an acute hazardous situation with a sharp pull up from a very low altitude above the sea and until the situation was resolved, all transpired over the course of scarcely 10 seconds (cf. 1.11.4.1).

1.1.2 Flight preparations

1.1.2.1 The first officer was called out on stand-by to fly round-trip Bodø-Svolvær on the afternoon of 2 December 2010. The commander (the captain) and the cabin crew (flight attendant) had started their working day earlier. They had just landed after a round trip flight Bodø-Narvik, and had an hour-long break when they met the first officer at the base in Bodø.

1.1.2.2 On the day of the incident, the commander had got up early. He said he was tired, and went to the lounge to relax during the break. When he returned approx. 10 minutes later, the crew assessed the weather situation and conducted a pre-flight briefing. The relevant wind conditions at Svolvær Airport were wind from 240° 30 kt, with gusts up to 44 kt. Visibility was 8 km. It was overcast, with rain and hail showers, and there were cumulonimbus clouds in the area (cf. Chap. 1.7 for detailed weather information). The braking effect on the runway was reported to be good. Svolvær is located north of the Arctic Circle, and it was completely dark on this December afternoon.

1.1.2.3 The applicable TAF (cf. 1.7.2.2) and SIGMET (cf. 1.7.3.3) could indicate that the wind and turbulence were decreasing, and the crew decided to start the flight to Svolvær.

1.1.3 First part of the flight

1.1.3.1 Widerøe flight WIF814 from Bodø Airport (ENBO) to Svolvær Airport Helle (ENSH) departed at 17.55 hours, with three crew members and 35 passengers on board.

1.1.3.2 The aircraft reached cruising altitude flight level FL90 (approx. 9,000 ft.) approximately 5 minutes after departure. En route, the crew established radio communication with the AFIS duty officer in Svolvær and received updated information concerning the wind. The wind was strong at the time, and the direction variable, and exceeded the company's operational limit[2].

1.1.3.3 After a while, the wind calmed somewhat. The pilots has in retrospect indicated that they remembered the wind was in the order of 10–12 kt when, after approx. 20 minutes

---

[2] With variable wind in the sector 240-340 degrees, Widerøe has a restriction of 25 kt, including wind gust strength in the last 2 minutes, cf. government requirements ENSH AD 2.23 Item 2.

of flight, they were nearly at their destination (see also Items 1.1.6 and 1.1.9). They could thus start the instrument approach directly, without having to enter a holding pattern first.

1.1.3.4 The crew on WIF814 commenced the ordinary procedure in south-westerly winds, which is an instrument approach northward (LOC 01) down to a set minimum descent altitude (MDA) of 580 ft. If the aircraft at that altitude has descended below the clouds and the crew has good enough visibility, one can perform visual circling east of the airport and position for landing on runway 19 (towards the south). Maps and visual "circling pattern" (Precision Circling RWY 19) are shown in Figure 1 and 2.

1.1.3.5 Visibility below the clouds was good, and they had the airport lights in sight well before descending to the minimum altitude. They descended to 600 ft., and continued as planned with visual circling above the fjord to the east and northeast of the airport. On the downwind leg in the circling pattern, they lowered the landing gear, set flaps to 15° and adjusted the engine and propeller controls for landing (condition levers max). The crew agreed with the AFIS duty officer that they would receive running wind readings on their way in.

1.1.3.6 The commander (the captain) piloted the aircraft (Pilot Flying, PF) while the first officer handled the other tasks (Pilot Monitoring, PM[3]). The standard procedure during the circling phase is that the PF looks out and mainly bases the flying on visual references, while the PM monitors the instruments and calls out any deviations from the correct speed and flight path (cf. 1.17.3.4 for a more detailed description of the circling procedure and "call-outs").

1.1.3.7 During the downwind leg, the commander was aware that the wind would carry the aircraft away from the airport more quickly, and towards the mountains which have hazard signs in the form of lights emitting white flashes (avoidance lights) (see Figure 2). At one point, the first officer noticed a drop in airspeed, and called out "Check speed". The commander adjusted the engine power, but only marginally, as he saw and perceived that the velocity did not deviate significantly from 110 kt, which he had planned. They had not discussed increasing the airspeed, which is often done in order to increase margins in strong winds and with unstable wind conditions. There was not particularly strong turbulence, neither en route nor while in the circling pattern.

1.1.3.8 The commander disengaged the autopilot prior to starting the turn in toward the "base" (from northern to western courses). The only remaining configuration change was to set flaps at 35° when they were correctly positioned for the final approach.

1.1.4 <u>The commander's description of the critical phase</u>

1.1.4.1 The commander has explained in interviews with the AIBN in 2015 that he maintained normal speed and started the turn to "base" at the regular point, meaning he had passed the airport and could see the airport lights behind him, to the left (approximately 45°, cf. section 1.17.3.4 and Appendix C for more information concerning circling). It was dark, and he could not see the horizon nor the contours of the sea below him while he was turning and flew the "base leg". In this phase, he knew the lights from airport were visible to the left, whereas other terrain references were restricted to a couple of red obstruction lights on land, approx. 1-2 km north of the airport, approximately in the exteded the runway centreline (see chart Precision circling RWY 19 in the lower right corner of Figure 2). He explained that the intention was to maintain circling altitude

[3] In 2010, Widerøe used the term Pilot Not Flying, PNF.

(600 ft.) until they had made the turn for final approach and had a good position for landing.

1.1.4.2 The commander has explained that he had not started the turn from "base" towards final approach when he noticed the first sign of something out of the ordinary. He remembered that the first officer had called "Check speed" twice in the circling pattern, and he was of the opinion that the second time was probably just before the abnormal situation occurred.

1.1.4.3 The commander perceived that the aircraft began to shake and that it fell, and corrected for this immediately, based on what he believed and knew would occur. He was certain that he gave Full power (certified torque 97.5%), but has explained that he does not remember the aircraft's pitch and bank at this time. The corrections did not have the expected effect. The airspeed continued to drop, and he felt that the aircraft was being "sucked" or "pushed" downward.

1.1.4.4 The commander has explained that he pushed the controls forward to prevent stalling. When he pulled the controls backward again in order to climb, the aircraft's stick shaker activated[4]. He instinctively understood that he had to ease up on the pull up to build up more speed first. While this was happening, he saw the red obstruction lights in front of him. He seemed to remember that he in this phase glanced at the altimeter, and that it showed approx. 300 ft. (about 90 m). When questioned, he could not remember to have noticed the stick shaker also *before* he pushed the controls forward, but he could not exclude this possibility.

1.1.4.5 The commander has also described that he focused on sighting towards one of the red lights, and "keeping flat", in order to build up speed so that he could pull the aircraft up without risking stalling. He knew he was low, but felt that he was in control of where ground level was. He felt it was difficult to estimate how long he "*held the aircraft down"*, but indicated 4-5 seconds.

1.1.4.6 According to the commander, this method worked, and the he started climbing and saw that they would pass above the light at a safe altitude. At this point, after he had gained good airspeed and was confident that the aircraft had started to climb, the first officer unexpectedly took over the controls and caused the aircraft to climb at a steeper rate. The commander has explained that, in his view, it was not necessary for the first officer to take the controls, but decided not to oppose this as the situation, in any event, was under control.

1.1.4.7 During the most critical seconds, between where the first officer called out "Check speed" and where he probably said "My controls", none of them made any standard "call-outs" or communicated in some other manner.

1.1.5 The first officer's description of the critical phase

1.1.5.1 The first officer has explained in conversations with the AIBN in 2015 that he monitored the instruments and had first called out "Check speed" once during downwind, and then once more at a point in the circling pattern. He believed the corrections were too small, considering the conditions, and that the commander should have increased the speed a bit more. The first officer expected that the altitude would be

[4] Mechanism which causes the controls to shake severely as a stall warning.

reduced in the turn, so that they could be established on the final approach and have "wings level" no later than when they were down to 300 ft.[5]

1.1.5.2 The first officer has explained that as they turned in for final approach, the stick shaker was triggered. He remembers that he was startled when the controls started shaking. The first officer has described that he was ready and waiting for the measures required in such situations, but the expected callouts and reaction from the commander did not come. What happened next was that the nose of the aircraft dropped significantly, and he has stated that he then "*Stared straight down onto the black sea".* He remembered seeing a red light on an islet below.

1.1.5.3 The first officer has further explained that he had the impression that the commander, in this critical situation, held the stick in an approximately neutral position, as if he had "frozen" on the controls. To prevent collision with the sea, the first officer instinctively grabbed the stick and pushed the engine controls all the way forward (power levers fully forward, approx. 116%) until they stopped. He believed that he said "My controls" and pulled the control column backward with both hands and considerable force, while thinking that there was no way that this could end well. However, the aircraft eventually started to climb, and they climbed to a safe altitude and got out of the critical situation. He estimated that they may have been as low as 150-200 ft.

1.1.5.4 In interviews with AIBN, the first officer stated that he was convinced that the fall, and the pitch down, were caused by forces outside the aircraft. He did not know why the stick shaker activated and could not judge whether the aircraft stalled.

1.1.6 Previous written reports concerning the sequence of events

1.1.6.1 In 2012, AIBN received two written Widerøe reports from the Civil Aviation Authority – Norway. As AIBN understands it, it is the commander's description which has been incorporated into these two reports in the company's deviation management system. The first was quite brief, and focused primarily on possible "overtorque" in connection with a missed approach as a result of wind shear.

1.1.6.2 The second report was somewhat more detailed, and the following is quoted from this report:

> *Summary: Severe "downdraft" during circling to RWY 19 at Svolvær, Helle: Scenario: Established upon LOC and VMC (approx. 1300 feet) a "wind check" was obtained, which indicated 2 min wind: 240/30 variation 220-300 (approx.). Upon inquiry concerning tendency, it was stated that it appeared the shower was about to pass because the wind strength was now declining. We then decided to establish ourselves in holding position on downwind (circling pattern) with constant wind readings and subsequently a new "2 min. wind". We then interrupted LOC visually and the altitude was reduced to 600 feet, which is circling altitude. New wind info said 250/17. On downwind leg 250/15 and 250/13. When we turned base at 600 feet and were in the process of asking for a new 2 min. wind, the prevailing wind was reported to be 250/10. In the turn, the aircraft started to lose altitude to 500 feet. IAS fell rapidly and is (at 105kts) compensated for with increased power setting. Felt then that the aircraft started to fall, pitched up and increased power. Got stick shaker and set power levers to Firewall (condition levers were in max). Pitch forward to avoid Stall, gain control of Speed and pitch up.*

[5] One of the company's criteria for 'stabilized approach'.

1.1.6.3 None of the reports mentioned anything about the first officer having taken over the flight controls, and they contained no information concerning the aircraft's lowest altitude.

1.1.6.4 The first officer's written statement, which AIBN received two years after the incident, mentioned that he increased up to the maximum available engine power. However, it did not provide a detailed description of the circumstances surrounding the takeover of the flight controls as he described it for AIBN in 2015:

> *The captain establishes at 600 feet, and velocity is now at approx. 1.4 speed. Speed then drops towards 1.3 speed, whereupon I say "check speed". Correction is made, but is insufficient, given the circumstances. I therefore repeat my call, "check speed" again. Correction is made, but once again, it is not enough in the current weather conditions. We get "runway free" from the tower and the wind is within our limits for landing. The captain then turns the aircraft from base and in to the final 19, and I estimate the altitude to be approx. 500 feet. Then the aircraft's stick shaker is activated, correction is made without the captain increasing power. The aircraft then "mushes" through with a nose-down attitude at low altitude, still without power being increased. I then decide to take over the aircraft controls, and run the power levers into the "firewall". The aircraft gradually achieves sufficient speed and engine power and starts to climb, speed increases and a "normal" climb westward can begin. Estimate that the aircraft was down to an altitude of approx. 150-200 feet.*

1.1.7 Previous verbal explanations concerning the sequence of events

Widerøe's flight operations management called the crew in for conversations on two occasions a few days after the incident. AIBN learned from Widerøe that everyone agreed regarding the sequence of events when the parties left at the end of the meetings. In brief, the aircraft had been exposed to severe wind shear, and the crew had done the right thing by interrupting the approach. The reaction to, and the handling of, the incident could appear to have been somewhat excessive, with severe "nose down", significant engine power and acceleration to a somewhat high speed in the "recovery". However, the actions were basically correct and worked as intended, so that control was regained in time. Widerøe claims that in 2010 there was agreement that the first officer took over the flight controls at the same time as the engine power was increased from "full" (approx. 100% torque) to maximum available (approx. 120%).

1.1.8 Further sequence of events

1.1.8.1 After the first officer had taken over the flight controls, the commander assumed the role of Pilot Monitoring and acted in accordance with the procedures for missed approach. This included retracting the landing gear and flaps and reducing engine power. During this phase, he became aware that they probably had overloaded the engines. The crew decided to fly to Leknes, where weather conditions were better, and to land there.

1.1.8.2 Under way to Leknes, the first officer gave the passengers a brief orientation. He mentioned that they had encountered wind conditions that had forced them to abort the approach, and that they would continue to Leknes. The commander resumed the role as Pilot Flying, and the aircraft landed at Leknes approx. 23 minutes after the incident. The passengers were transported by bus to Svolvær.

1.1.8.3 In retrospect, both pilots have said that they were shaken after the incident. According to the commander, it became clear in the conversation between them in the aircraft immediately after the incident that the first officer had not realized that the stick shaker had activated during the pull up, and that this was a significant reason why they assessed execution of the "recovery" phase (corrections in order to regain control) differently.

1.1.8.4 The explanations from the various crew members also differ somewhat as regards the subsequent return flight from Leknes to Bodø, as well as regards what happened after that. However, AIBN cannot see that the differences have any impact on aviation safety aspects of this incident, and have chosen not to expend resources attempting to clarify details. The following can be determined:

- The Technical Department was informed about possible engine over-torque at some point after departure from Leknes.
- Upon arrival at Bodø, the three crew members went to the crew room together and found a vacant room where they could sit and talk together, make phone calls and take notes, etc.
- The commander skipped the subsequent flight, but resumed service and completed the last part of the flight program the same evening.
- The first officer had, in any event, completed his program for the day, while the cabin attendant opted to drop out of the flight program for the rest of the evening.

1.1.9 AFIS duty officer's description

1.1.9.1 The following is from the report the AFIS duty officer at Svolvær Airport wrote a few days after the incident (more information about the weather can be found in Chap. 1.7):

> *WIF814 is inbound from ENBO, RWY 19 in use with info concerning wind from 230 and 20-30 kt measured with our official anemometer RWY 01. When 814 is established on LLZ 01, approx. 5-6 nm away, I see that the anemometer on RWY 19 shows a substantial deviation compared with stated wind. This shows 23022G32kt, but the direction varies between 200 and 270 degrees. Wind info for RWY 19 is provided to 814, which responds that this is too much wind for landing and that they will abort the approach. I call BO ATC to inform them regarding this when 814 comes on the radio again and says that they will try.*
>
> *The wind lets up a bit after this, and I ask 814 whether I should read instant wind for them for the way in, to which 814 responds yes. From this point in time and until WIF 814 is on short final, the direction varies between 180 and 270 degrees, force between 14-23kt, the wind is read several times until 814 is about 1nm out; the wind has then increased in strength and is more than 20 kt, on short final I stop reading wind in order not to disturb the pilots, the wind is then at 27027kt. At about 0.5nm, I observe that 814 falls a bit through the altitude (perhaps 50-100ft.), I look at the wind gauge and the direction is then at 270-300gr 27kt. WIF814 climbs immediately after and reports MA [missed approach], then proceed on LLZ01 and gets Holding KN 6000, after a couple of minutes, 814 requests clr [clearance] to ENLK, gets this, and diverts there. Communications are transferred to ENLK.*
>
> *The situation was not perceived as critical, as seen from the tower.*

1.1.9.2 The report from the AFIS duty officer also states that the observed wind for the last 10 minutes for runway 19 varied in direction between south and west-northwest, with speeds of 23 knots and gusts up to 39 knots (24023G39KT 180V300).

1.1.10 Additional information from the cabin attendant

The cabin attendant was sitting securely buckled into her seat with her back towards the cockpit, looking backward into the cabin. She has explained to AIBN that everything was normal until they encountered a "downdraft" during approach, which is not uncommon. She expected a bit of revving from the engines, followed by a climb. However, the expected climb did not occur in this case, although she heard very substantial revving from the engines. She felt that they were being pressed downward. Through the window on the right side of the aircraft she could see that they passed a red light, and she remembered that one of the passengers in the forward row commented "*that light is not supposed to be there*". They were still being pressed downward, and she was thinking that this was not going to end well. She estimated that it took 30–40 seconds before the aircraft began to climb.

1.1.11 Additional information from other witnesses

One passenger interviewed by AIBN clearly recalls that they were in a highly intense "*tropical*" rain shower, with large drops beating down when they passed the airport heading north during the circling. AIBN has also obtained statements from witnesses on the ground. The statements correspond well with the flight recorder data and the information provided by the flight crew.

1.1.12 Widerøe's approach map and circling course

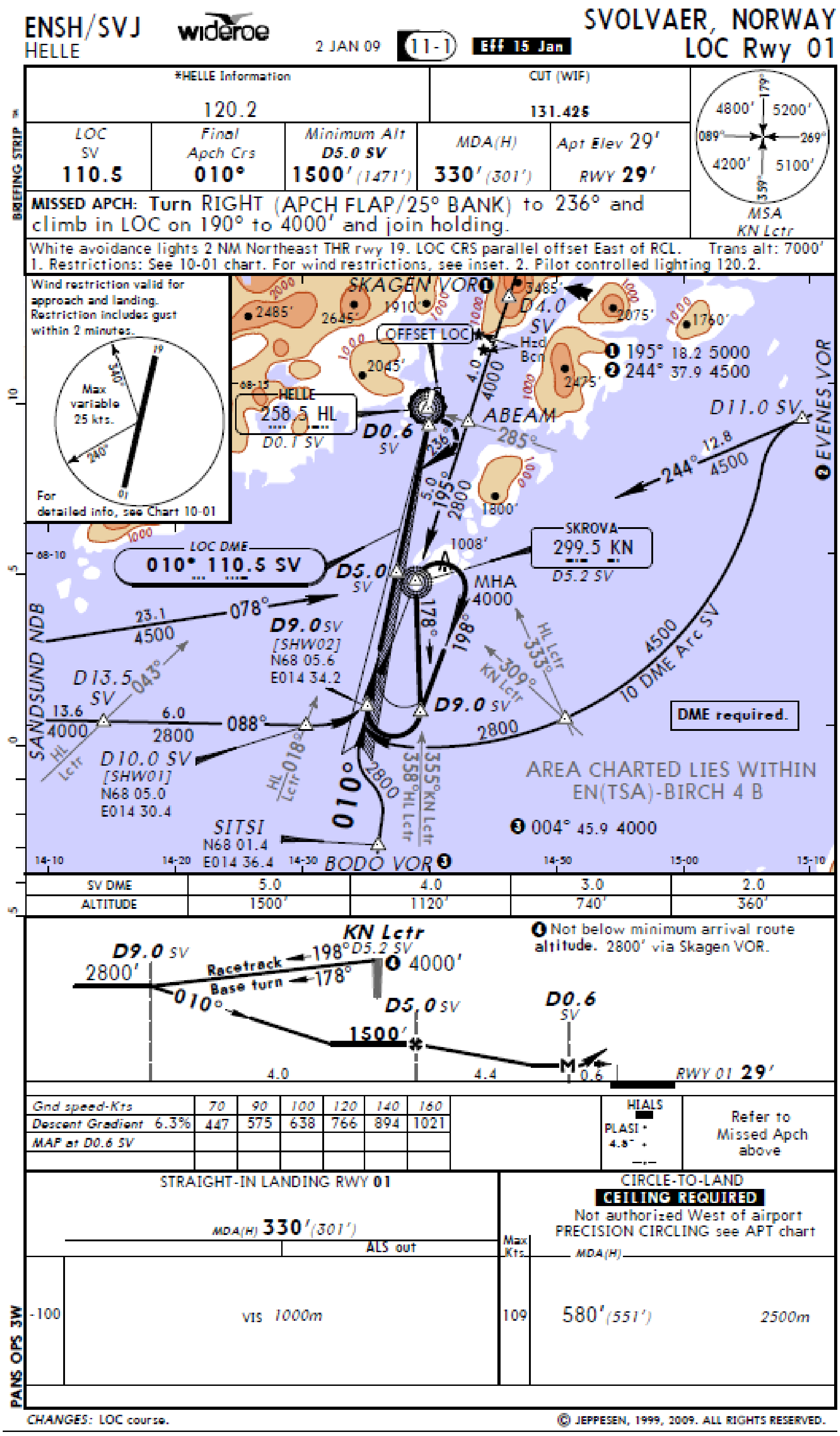


Figure 1: Widerøe's applicable approach map for ENSH at the time of the incident. For landing towards the south the "Circle-to-land" procedure is followed. See also Figure 2. Source: Widerøe

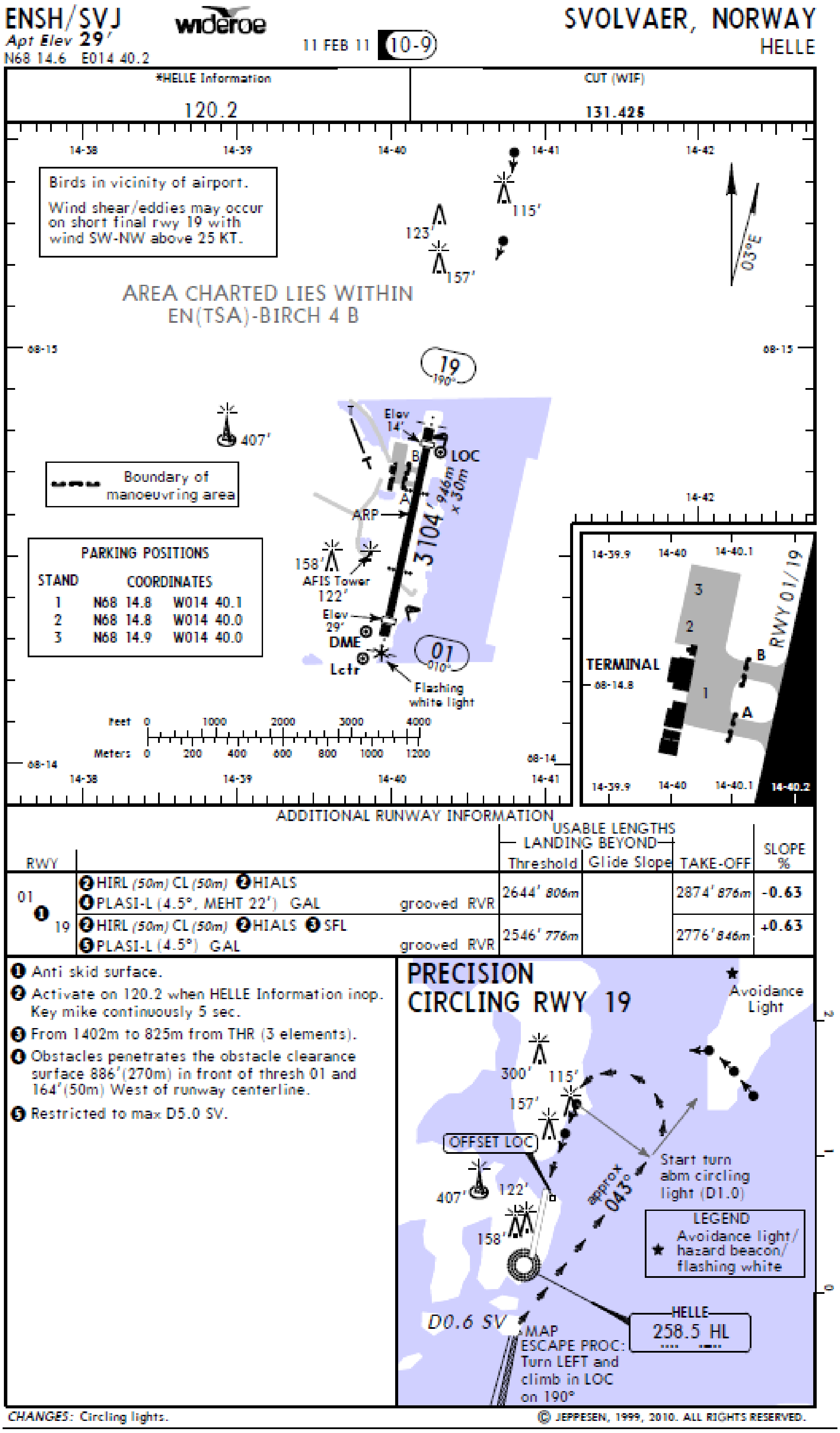


Figure 2: Widerøe's map of ENSH 11 Feb. 2011 (actual map not available), showing "Precision Circling RWY 19" in the lower right-hand corner. The circling lights in the northeast and at the final approach were installed after the incident. Source: Widerøe

1.2 Injuries to persons

Table 1: Injuries to persons

Injuries	Crew	Passengers	Other
Fatal			
Serious			
Minor/none	3	35	

1.3 Damage to aircraft

None. Cf. Chapter 1.6.

1.4 Other damage

None

1.5 Personnel information

1.5.1 Commander

1.5.1.1 At the time of the incident, the commander (the captain) was 43 years old. He attended commercial pilot training in the USA in the early 1990s, and acquired pilot experience from the USA, Africa and Sweden before he got a job with Widerøe in 1999. He worked for the company as first officer on Dash 8 and was based in Bodø for 3 years and subsequently in Bergen for 6 years, before being checked out as captain in 2008, after which he was again stationed in Bodø.

1.5.1.2 His pilot's licence (Airline Transport Pilot License, ATPL(A)) was valid at the time of the incident. His last medical check-up was on 29 November 2010. The last OPC/PC was on 15 November 2010.

Table 2: Flying experience commander

Flying experience	All types	On type
Last 24 hours	1:35	1:35
Last 3 days	1:35	1:35
Last 30 days	26:05	26:05
Last 90 days	117	117
Total	8,549	5,626

1.5.2 First officer

1.5.2.1 The first officer was 42 years old at the time of the incident. He trained as a commercial pilot and received his Commercial Pilot Licence, CPL(A) in Norway in 2001. Among other aircraft types he flew DHC-6 Twin Otter and C-208B Cessna Caravan before being employed by Widerøe. He started flying Dash 8 based in Bodø in 2003. His Class 1 medical certificate was valid at the time of the incident. Last OPC/PC prior to the incident was on 6 June 2010.

Table 2: Flying hours first officer

Flying experience	All types	On type
Last 24 hours	0:40	0:40
Last 3 days	0:40	0:40
Last 30 days	37:25	37:25
Last 90 days	79:10	79:10
Total	Approx. 3,940	3,090

1.5.3 Performance during pilot training and proficiency check

A review of historical data from the airline's training department showed that both the commander and the first officer maintained a "*solid and good WF standard, good CRM [Crew Resource Management], no serious issues were revealed, only minor remarks, good level of knowledge, able to find information in the manuals"*. They received *"good standard demonstrated"*, which is the most common category for the company's pilots.

1.5.4 Sleep and rest

1.5.4.1 The commander was not in a particularly strenuous period. He had had normal, good sleep the nights prior to the incident. However, the last night before the incident his sleep was a little restless. He got up at 5 a.m. and travelled as a passenger on the Bergen-Oslo-Bodø route before starting the working day flying a round trip Bodø-Narvik. On the afternoon in question, he felt tired, and spent his break resting. The working day had otherwise been normal for that time of year. During an interview with AIBN, both the first officer and the cabin attendant stated that they had noticed that the commander seemed tired.

1.5.4.2 The first officer remembers sleeping well at night and feeling rested and alert.

1.5.4.3 Neither the commander nor any of the other crew members had any other negative remarks concerning their own health condition, how they were feeling on the day in question, etc.

1.5.5 Cabin crew

The cabin attendant was employed by Widerøe in 1995. She was based in Bodø and had about 10 years of active service at the time of the incident.

1.6 Aircraft information

1.6.1 Introduction concerning aircraft type and status of LN-WIU

Aircraft of type Bombardier DHC-8-103, often called Dash 8, a twin engine turboprop aircraft with pressurized cabin accommodating a maximum of 39 passengers.

Owner:	Widerøe
Manufacturer:	Bombardier Aerospace Inc.
Type:	DHC-8-103
Serial no.:	378
Production year:	1994

Airworthiness Review Certificate (ARC): Valid until 27 February 2011

Engines:	2 Pratt & Whitney PW121
Aircraft total time:	34,500:45 hours / 39,114 landings

Mass at the time of the incident[6]: Approx. 14,802 kg (32,633 lbs.)

Centre of gravity location: DLI 36.6

1.6.2 A few selected limitations

Permitted centre of gravity range for departure:	DLI 35–57
Maximum permitted take-off mass:	15,649 kg
Maximum permitted landing mass:	15,377 kg
Stall speed (relevant mass, power off, flaps 15):	76.5 KCAS
Maximum general crosswind component for landing:	36 KCAS
Maximum speed flaps 15 (VFE):	148 KCAS
Maximum g-load with flaps 15:	2.0 G

1.6.3 Limits Exceedance Requiring Mandatory Inspection

1.6.3.1 *Engines and propellers*

According to Pratt & Whitney Canada Maintenance Manual, torque can be up to 145.6% for up to 20 seconds, or up to 125% for more than 10 minutes before triggering mandatory engine inspection.

According to Hamilton Sundstrand Maintenance Manual, torque can be 125% or higher before triggering mandatory inspection of the propeller.

FDR data showed that both left and right engines had been up to 116–118% for approximately 35 seconds, with propeller speed of 1,200 RPM (cf. 1.11.3).

1.6.3.2 *Aircraft structure*

The Aircraft's Maintenance Manual describes the procedure for "*Inspection after severe turbulence or buffeting"*. The following are described as causes that trigger such an inspection:

> *(3) A pilot report of severe turbulence, such as entry in the Flight Defect Report, is sufficient to do a conditional inspection for possible damage caused from the event.*
>
> *(4) If severe turbulence is suspected to have occurred, the aircraft vertical and lateral acceleration data may be downloaded from the Digital Flight Data Recorder (DFDR).*

Inspections must be performed if the vertical load exceeds the stated limitations. For the relevant mass - 32,633 lbs. - the limit is at 2.3 G.

FDR data showed that the vertical acceleration briefly reached 2.7 G (cf. 1.11.3). Widerøe has stated that LN-WIU was in for a structural "High G" check on 24 March

[6] The original mass and balance form was no longer available when the investigation was opened in 2015. AIBN therefore asked Widerøe to try to recreate this, as it is of significance for the interpretation of FDR data, etc. The form that was subsequently prepared is included as Appendix B.

2011, without discovery of structural damage. Widerøe has not been able to document whether a structural inspection was performed prior to this.

1.6.4 Stall warning system

The aircraft has a stall warning system which warns the crew before the wing stalls. A sensor installed in front of each wing (Lift transducer) records when airflow around the wing approaches critical angle. Two independent stall warning computers then send signals to a stick shaker installed on each stick, causing the sticks to start vibrating before the wing stalls. The computers also use signals for flaps position to calculate when to activate a stall warning. The stall speed is also indicated on the aircraft's flight director (EHSI, Electrical Horizontal Situation Indicator). If the stall warning activates, the signals from the ground proximity warning system will be blocked (see below).

1.6.5 Enhanced Ground Proximity Warning System – EGPWS

LN-WIU was equipped with a Honeywell MK VIII Enhanced Ground Proximity Warning System, series 965-1206-XXX. The system receives information from several of the aircraft's systems, e.g. Air Data Computer, radio altimeter, GPS and a terrain database. The warnings from EGPWS have a response time of 0.2–8 seconds. The warnings are blocked if the stall warning is activated.

The system has six different types of warnings:

1. Excessive Descent Rate. Excessive descent speed in relation to the relevant altitude. The audio warning has two different levels: "SINKRATE" and "PULL UP" as shown in Figure 3. In addition, the "PULL UP" warning light[7] comes on. In the event of steep approach angles (greater than 3.5°) the system sensitivity may be changed (Steep Approach Bias). This must be selected using a switch in the cockpit.

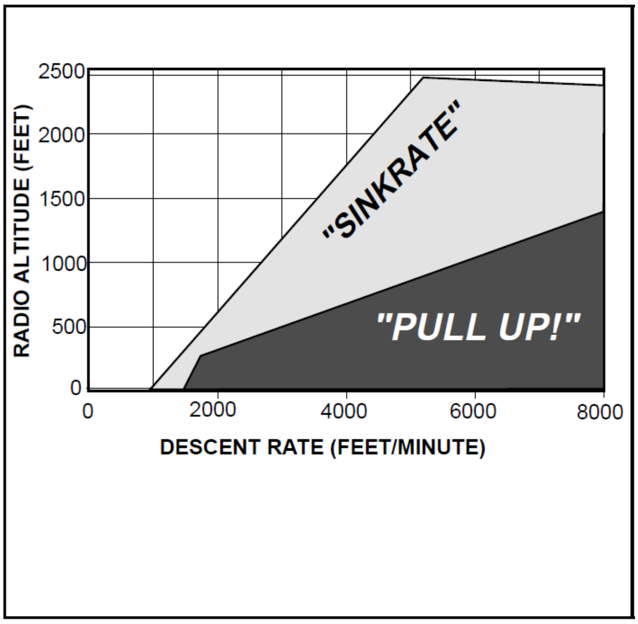


Figure 3: EGPWS Generated audio warning at Excessive Descent Rate. Source: Honeywell

2. Excessive Terrain Closure Rate (the distance to terrain declines too rapidly). The audio warning has two different levels: "TERRAIN, TERRAIN" and "PULL UP". In addition, the "PULL UP" warning light comes on. The warning is different depending

[7] The warning light is installed at the top of the instrument panel (Glare shield).

on whether the aircraft is on approach with flaps in landing configuration (2B) or not (2A).

3. Altitude Loss After Takeoff (decreasing altitude after take-off). Audio warning "DON'T SINK".
4. Unsafe Terrain Clearance. Warns that the distance to terrain is too small. Three different audio warnings are sounded, depending on the flight phase and aircraft configuration: "TOO LOW GEAR", "TOO LOW FLAPS" and "TOO LOW TERRAIN".
5. Below Glideslope. Audio warning with "GLIDESLOPE" if the aircraft dips below the glide path. The audio warning has two levels, depending on the severity of the glide path deviation. In addition, the warning light "GS" will appear at the top of the instrument panel.
6. It can issue a number of warnings, as specified by the operator. LN-WIU had an audio warning for high banking "BANK ANGLE, BANK ANGLE", and for selected decision altitude: "MINIMUMS".

Types 1–5 build on previous versions of the Ground Proximity Warning (GPWS) system. In EGPW, warning types 1, 2, 4 and 5 are improved using information from the aircraft's terrain database and GPS. Part of this improvement is the "Terrain Clearance Floor" function, which gives the notice "TOO LOW TERRAIN" if the aircraft comes too close to the terrain within a radius of 15 NM from the nearest airport. The surrounding terrain heights can also be displayed on the aircraft's instruments (EHSI).

1.6.6 Procedure in the event of wind shear/risk of collision with terrain

Abnormal and Emergency Procedure for Wind shear/Terrain Recovery describes callouts, actions and crew cooperation (cf. OM B 3.4.4.15, Appendix D). PF shall initially call "*GO AROUND – FULL POWER"*, while simultaneously initiating the correct pitch for optimal rate of climb and full engine power. PM shall fine adjust to maximum power (certified torque 97.5%). The further sequence of events depends on whether the distance to terrain increases or decreases. The PM must monitor this and provide running information (*TERRAIN CLOSING/CLEAR OF TERRAIN*). In an emergency, engine power must be increased to the maximum available, maintain optimal flight speed (V_2/V_{GA}) and reduce the angle of the nose just enough to stop the stick shaker, if it is triggered.

1.6.7 Procedure to avoid imminent stalling

1.6.7.1 The general introduction to the flight manual states e.g. that the stick shaker gives sufficient advance warning of stalling in all situations, and that control can quickly be regained when one relaxes the stick pull, or pushes it forward slightly (cf. Appendix D). Loss of altitude is minimized by resolutely increasing engine power. If the aircraft actually stalls, the nose will pitch down naturally. In that connection, the manual cautions against excessive movement of the stick forward since one could risk a too steep angle in the recovery.

1.6.7.2 *Abnormal and Emergency Procedure for Stall Recovery* describes callouts, actions and crew cooperation in the event that the stick shaker is triggered (cf. OM B 3.4.5, Appendix D). As in OM B 3.4.4.15 (cf. 1.6.6), cooperation to set Full Power is assumed. Among other things, the procedure also mentions that one must be vigilant in avoiding over-torque, and not accelerate to more than 140 KIAS.

1.7 Meteorological information

1.7.1 Introduction

It was completely dark when the incident occurred. Information about experienced wind and weather during the cruising phase and information about the AFIS duty officer's wind readings in connection with the approach is also available in the description of the sequence of events (cf. Chap. 1.1).

1.7.2 Observed and forecast weather

1.7.2.1 METAR (weather observations for aviation purposes expressed in meteorological code) issued for Svolvær Airport Helle (ENSH) for the period 1550–1750 UTC[8](the incident took place at 1718 hrs. UTC):

1550 UTC 24030G44KT 8000 -SHRAGS FEW008 SCT012CB BKN014 05/03 Q1001=
1650 UTC 24030G44KT 8000 -SHRAGS FEW008 SCT012CB BKN014 05/03 Q1000=
1750 UTC 23030G41KT 9000 -RAGS FEW008 SCT010CB BKN012 05/03 Q1000=

1.7.2.2 The following weather forecast (TAF, Terminal Aerodrome Forecast) was valid for Svolvær Airport for the afternoon and evening in question (issued at 1400 hrs. UTC):

0215/0221 24030G45KT 9999 –SHRA SCT012 BKN020 TEMPO 0215/0221 24020G35KT 4000 SHRAGS BKN012CB

1.7.3 Weather information obtained after the incident

1.7.3.1 Upon request from the Accident Investigation Board, the Norwegian Meteorological Institute (MET Norway) prepared a report on the weather situation in the area around Svolvær. The following extract is from MET Norway’s report:

> ***General weather situation:***
>
> *A series of minor low pressures created a situation with a continuous front system extending from Nova Semlja in the northeast to Iceland in the southwest. This resulted in a strong south-westerly wind and heavy precipitation in large parts of northern Norway, in Lofoten in the form of rain showers.*
>
> ***Clouds, visibility and precipitation:***
>
> *There was a cold front passage in Lofoten in the period between 1700 hrs UTC and 1900 hrs UTC. CB, rain and hail showers were observed in each METAR from 1350 hrs UTC until 1950 hrs UTC. It was overcast all day, and a low cloud base between 1000-2000 feet.*
>
> ***Surface wind:***
>
> *There was a south-westerly wind in Lofoten, at ENSH the average wind was around 30 knots, but with stronger gusts throughout the day. Further out in the open sea of Vestfjord the average wind was stronger, 35–45 kt.*
>
> ***Wind at altitude:***
>
> *The wind data models show the wind increasing from the ground up to 5000 feet, and then decreasing in strength up to 10000 ft.*

---

[8] For decoding of meteorological abbreviations, see: https://www.ippc.no/ippc/help_met.jsp and https://www.ippc.no/ippc/help_metabbreviations.jsp

Wind profile from 1600 hrs to 1800 hrs UTC:

500 feet: 30–40 knots

2000 feet: 40–50 knots

5000 feet: 50–60 knots

10,000 feet: 35–45 knots

South-westerly at all altitudes.

1.7.3.2 The IGA prognosis[9] (International General Aviation) for “Nordland coastal and fjord districts” forecast local, severe turbulence from 1400 to 2400 hours on 2 December 2010. Local CB activity was also forecast between 1,000 and 2,000 feet.

1.7.3.3 Six SIGMETs (Significant Meteorological Information) were issued during 2 December 2010. These covered the whole day (24 hours), and forecast local, strong turbulence in the area. SIGMET for when the flight took place:

ENBD SIGMET D05 VALID 021630/022030 ENVN-ENOR NORWAY FIR
LCA SEV TURB FCST N OF N6700 AND W OF E02000 BLW FL080. WKN=

1.7.4 Turbulence

1.7.4.1 MET Norway had archived data from the time of the incident which showed substantial turbulent kinetic energy in the area (SIMRA forecast model). This was also supported by the runway wind measurements. MET Norway concluded the following:

1. We estimate that there has been short-term wind shear of as much as 20 m/s [39 kt] at 400 feet at the maximum. This estimate is based on experience and assessments compared with observations and model calculations. We are indicating an estimate since we do not have observations of wind shear.

2. We expect that there have also been wind gusts of 20 m/s [39 kt] with a downward component in connection with strong cumulonimbus clouds in the area. As under Item 1, this estimate is based on experience and assessments compared with observations and model calculations. Again, we are indicating an estimate since we do not have observations.

1.7.4.2 The figure below (Figure 4) illustrates the turbulence conditions using the same template as used at Avinor IPPC (Internet Pilot Planning Centre). The chart shows the height of a funnel-shaped flat area with the runway at the bottom (thick black line). The grey areas made up of squares indicate where the mountains in the model protrude through the funnel-shaped flat area.

1.7.4.3 Surrounding the thin black line that illustrates the linear approach and departure routes, isolines indicate the height of the flat area for each 500 ft. Wind arrows indicate the strength and direction of the wind in the funnel-shaped area (short line for each five knots, long line for each 10 knots and filled-in triangular shape for every 50 knots). The isolines also show the turbulence intensity (square root of the turbulent kinetic energy). The turbulence indicator has a red-orange colour range. The strongest colour indicates more than 4 m/s.

[9] This was from the ground and up to, and including, FL100. This produce forecast surface wind, wind at 2000 ft., FL050 and FL070, icing and turbulence.

1.7.4.4 Obtaining old archived data required a lot of resources, and the vertical section was not recreated.

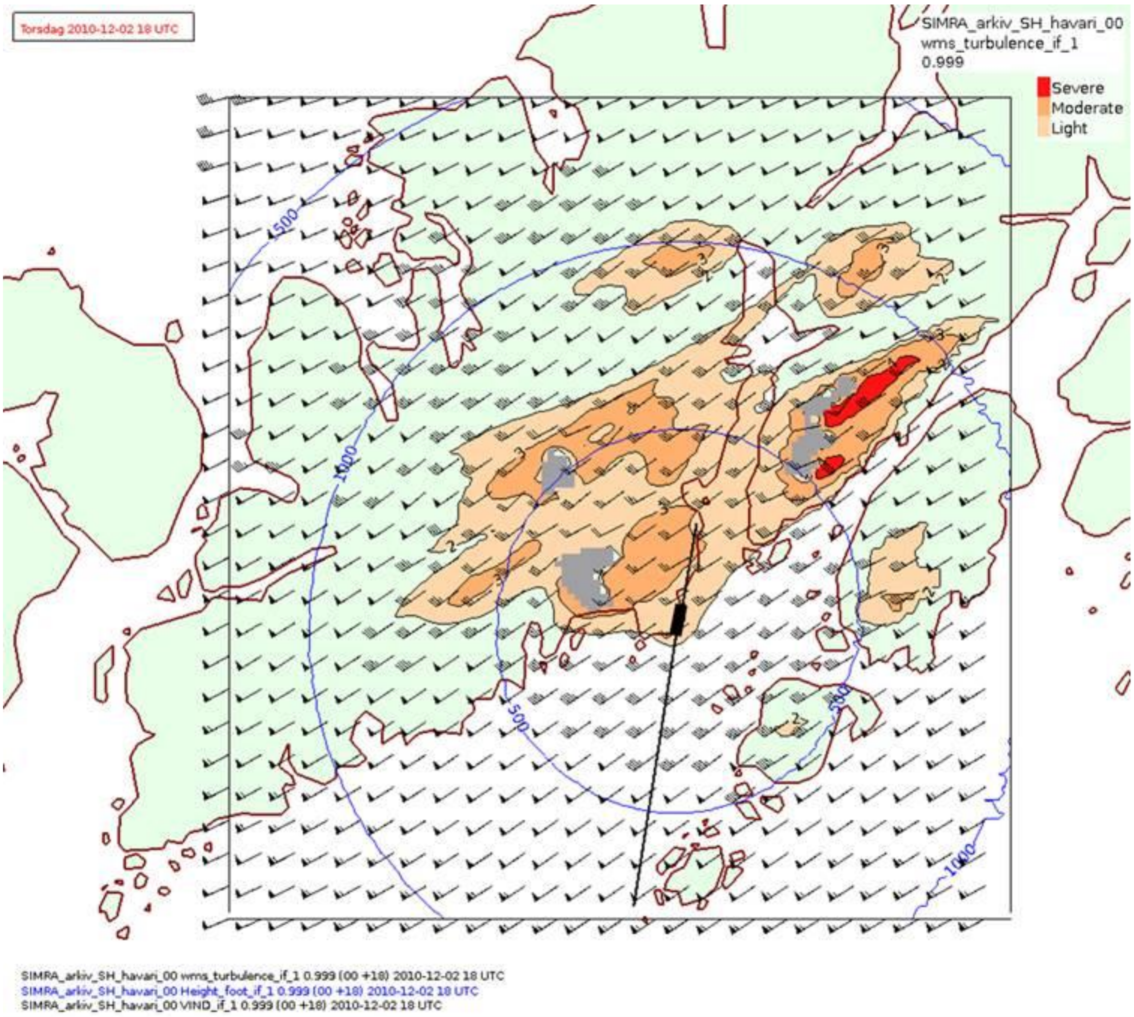


Figure 4: Horizontal section showing the modelled turbulence picture approximately 45 minutes after the incident. Supplementary explanations of the model are available at www.ippc.no. Source: The Norwegian Meteorological Institute

1.7.5 <u>Wind shear</u>

1.7.5.1 In this connection, wind shear means a sudden change in wind direction and/or strength, of such nature, scope and duration that an aircraft may experience major problems in maintaining its planned speed and trajectory. It is a well-known fact that wind shear at low altitude constitutes a serious threat. At worst, it can cause an airplane to stall and fall without control, or have such a significant deviation from the planned profile that it flies into the ground, even with fast and correct reactions on the part of the crew.

1.7.5.2 Strong local wind shear, often of short duration, can occur when vertical wash out below a cumulonimbus veers off and spreads horizontally as the air hits the ground (so-called microburst, see Figure 5).

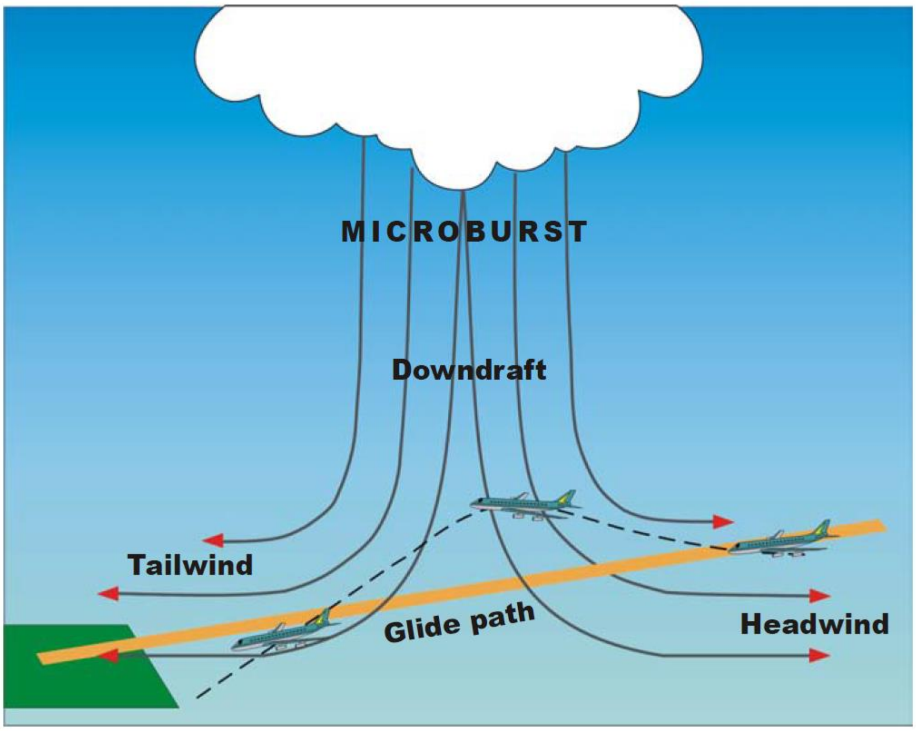


Figure A4-3. Wind shear brought by a microburst

Figure 5: Wind shear caused by microburst. Source: ICAO Manual on Low-level Wind Shear

1.7.6 Information about wind conditions

1.7.6.1 2 minutes' mean value is used to provide information about surface wind to aircraft before departure and landing, including significant variations from the mean value. Significant variations mean, e.g., maximum wind force and variations in wind direction. According to the aviation regulations, the maximum wind force must reflect the last 10 minutes, but in Svolvær and other places Widerøe only uses the last 2 minutes as their basis. The wind information in METAR is based on 10 minutes' mean wind.

1.7.6.2 Information about instant wind is only given occasionally and by agreement, typically when a pilot requests "continuous" wind readings during the final approach or has requested windcheck. Then the tower provides information about the strength and direction of the instant wind. In this instance, it was agreed that the AFIS duty officer would read the instant wind while the aircraft was downwind (cf. 1.1.6.2).

1.8 Aids to navigation

At the time of the incident, Svolvær Airport was equipped with a localizer (LOC), distant measuring equipment (DME), two non-directional beacons (NDB) and a VHF direction finder. No irregularities were reported as regards the aids for approach in connection with the incident.

1.9 Communications

Communication between the aircraft and AFIS unit proceeded as normal on the 120.200 MHz frequency. There are no recordings left of the radio correspondence after the incident[10].

[10] It is routine that Avinor keeps recordings for at least 30 days. After that, they can be taped over, unless otherwise agreed with AIBN.

1.10 Aerodrome information

1.10.1 Introduction

1.10.1.1 Svolvær Airport Helle (ENSH) is located at the outer edge of Austnesfjorden in Lofoten (position 68°14'36"N 014°40'09"E). The site is surrounded by mountainous terrain in the west-north-east sector (see Figure 7). The airport is located at 29 ft. above sea level (MSL). The runway direction is 01/19. The airport has instrument approach for landing towards the north (RWY 01). Landing distance available (LDA) for landing on RWY 19 is 776 m. The threshold height on RWY 19 is 14 ft., and in this direction the runway has an upward slope of 1.5% in a segment south of the middle.

1.10.1.2 According to AIP Norway, at the time of the incident there were two high-intensity flashing lights that marked mountain formations to the northeast of the airport. These could be used as references for circling to RWY 19, but were not guiding lights. Their function was to warn about terrain. Other lights in the terrain were two red obstruction lights just north of the threshold on runway 19, near the extension of the centreline [11](cf. Figure 1).

1.10.1.3 Svolvær had PLASI (Pulse Light Slope Approach Indicator) for approach from both directions. The PLASI angle to RWY 19 was 4.5°, with range of application within 5 NM. The visible sector was 16 degrees. None of the crew members on LN-WIU remembered having seen the light from PLASI during the incident.

1.10.1.4 Svolvær Airport is classified as "Class C", which is the most demanding category. Class C entails special requirements for operators who perform commercial air transport (cf. EU-OPS 1.975 *Route and aerodrome competence qualification*). For example, operators shall ensure that the commander has a special checkout, and set limitations for surface wind.

[11] Avinor has stated that the actual number of obstruction lights was higher than designated in the AIP, and that, during the period in question, there might have been additional information concerning changes in NOTAM.

Figure 6: Illustration photo ENSH, seen from the northwest (runway 19). Note red obstruction lights north of the airport. Photo: Avinor

1.10.1.5 Svolvær Airport had two wind gauges and two windsocks when the incident occurred. The anemometer for RWY 01 was near the windsock and was the primary wind gauge which gave the basis for METAR. At the north end, there was a windsock on the east side, and an anemometer on the west side of the threshold to RWY 19. Previous experience had shown that the wind gauge and the windsock in the north could give different readings at certain wind directions, and they have subsequently been gathered on the east side of the threshold.

1.10.2 Announced warnings

AIP Norway contained the following warning:

> *Wind shear/vortexes can occur in the last part of the final approach to RWY 19 at wind sector SW-NW greater than 25 KT.*

1.10.3 Company's specific briefing for Svolvær Airport

1.10.3.1 Widerøe had set the following special wind restriction for approach and landing at Svolvær Airport:

> ***RESTRICTION:***
>
> *Variable wind within sector 240°-340°*
>
> - *Max wind speed 25 kts including gust within 2 minutes (variable means there is variation in direction 60° or more).*

1.10.3.2 In conformity with the AIP Norway warning (cf. Item. 1.10.2), there was also a warning about wind shear on short final to Runway 19:

CAUTION:

- *Wind shear/eddies may occur on short final RWY 19 with wind SW-NW above 20 kts.*

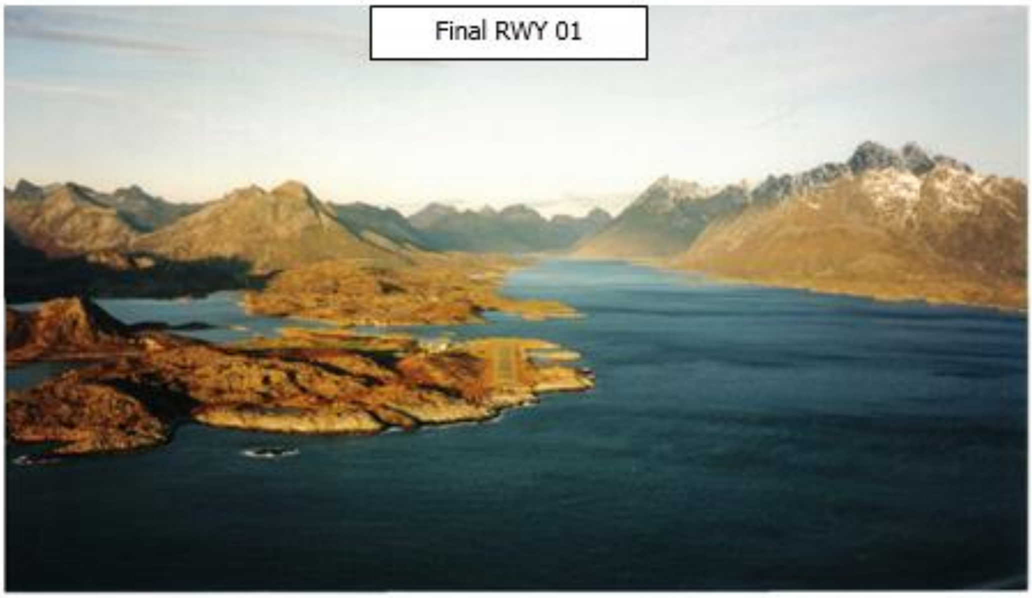
widerøe 14 NOV 10

10-01

AIRPORT BRIEFING

Airport Category **C**

SVOLVÆR
HELLE, ENSH/SVJ



Svolvær Lufthavn, Helle ligger på E-siden av en halvøy nær strandlinjen med småkupert nærterreng og med sjø på alle kanter unntatt mot W-NW. På avstand omkranses flyplassen av relativte høye fjell i sektoren W-NE. Plassen ligger ca. 6 KM fra Svolvær sentrum.

RESTRICTION:

The following restrictions apply for approach and landing:
Variable wind within sector 240°-340°

- Max wind speed 25 kts including gust within 2 minutes (variable means when there is variation in direction of 60° or more).

Take-off RWY 01: OBST 158 ft., 800M N of RWY must be visible at brake release.

CAUTION:

- When wind exceeds 20 kts from NW, be aware of wind shear/eddies/downdrafts on short final to RWY 01.
- Wind shear/eddies may occur on short final RWY 19 with wind SW-NW above 20 kts.
- Downslope RWY 01.

AIRPORT CATEGORY C

Risk factors: Wx, turbulence, mountainous terrain, approach to one RWY only, special missed approach procedure (25° bank/flap 15°)/course reversion, tight circling procedure, black hole effect, special CLP RWY 01(immediate turn), AFIS /no TMA or radar)

SPECIAL BRIEFING:

- Recommended circling altitudes for continuous descent to RWY 19
- Escape Procedure in marginal Wx.

Issue No. 3 *Property of © Widerøe*

Text in picture:
"Svolvær Airport, Helle is located on the E side of a peninsula near the shoreline with undulating terrain and sea on all sides except to the W-NW. Further away, the airport is surrounded by relatively high mountains in the W-NE sector. The airport is located about 6 km outside the centre of Svolvær."

widerøe 14 NOV 10 | 10-02 | **AIRPORT BRIEFING**

SVOLVÆR
HELLE, ENSH/SVJ

ESCAPE PROCEDURES:
RWY 01: Start immediate climb and follow CLP 01.
Circling RWY 19:

- On downwind or on base to final: Start immediate Left climbing turn towards HL and follow CLP 19.
- On final, start immediate climb and follow CLP 19

VÆR
Flyplassens beliggenhet gjør den utsatt for vind, spesielt i vinterhalvåret. Statistikk viser at fremherskende vindretning er fra SW men når vindstyrken er 30 kts. eller sterkere, er også sektorene NE og E fremtredende.
Det er variabel vind fra W og NW over 20 kts som skaper de største operasjonelle problemer, spesielt ved landing da W og NW høydevind gir variabel bakkevind. Særskilte vindrestriksjoner gjelder for variabel vind i sektoren 240°-340°. Under slike forhold er det moderat og i blant sterk turbulens under siste del av innflygingen til bane 01 og under sirkling. Det er registrert til dels sterke downdrafts på finalen til begge baner under slike forhold. E og NE vinder forekommer oftest i sommermånedene og kan gi noe turbulens under innflygingen. SW-lig vind er relativt stabil, hva angår styrke og retning.

Med SW-vind får en som oftest en heving av skybasen over plassen, mens det kan være lavere skybaser mot S, E og N. Med vind fra S-lig kant får en dannelse av stratus mot fjellene nord for plassen, men avstanden er så stor at dette vanligvis ikke er til hinder for sirkling NE for flyplassen.

Lav stratus/tåke forekommer oftest vår/sommer. Plassen er noe beskyttet mot havtåke fra NW. Adveksjonståke kommer som oftest inn fra sektor SW-S sen kveld eller natt, og løses opp om morgenen/formiddagen.

Figure 7: Excerpt from Widerøe's special briefing for Svolvær Airport. Source: Widerøe

Text in picture:
"WEATHER
The airport's location exposes it to wind, particularly in the winter months. Statistics show that the predominant wind direction is from SW, but when the wind force is 30 kts or more, the NE and E sectors are also prominent.

Variable wind from W and NW above 20 kts creates the greatest operational problems, particularly during landing, since W and NW upper wind gives variable surface wind. Special wind restrictions apply for variable wind in the 240°-340° sector. Under such conditions, there is moderate and sometimes strong turbulence during the last part of the approach to runway 01 and during circling. Strong downdrafts have been registered on the final approach to both runways under such conditions. E and NE winds occur mostly *in the summer months and can give some turbulence during approach. SW wind is relatively stable as regards strength and direction.*

A SW wind generally creates a lifting of the cloud base above the airport, while there may be lower cloud bases towards S, E and N. A wind from S creates stratus clouds towards the mountains to the north of the airport, but the distance is normally so great that it does not prevent circling NE of the airport.

Low stratus/fog mostly occurs in the spring/summer. The airport is somewhat sheltered from sea fog from NW. Advection fog mostly comes in from the SW-S sector in the late evening or night, and dissipates during the morning."

1.10.3.3 The weather warnings are nearly identical to the description the airport has in its local regulations, and the main content is also announced in AIP Norway.

1.10.3.4 Long before this incident, Widerøe had identified relevant risk factors associated with circling in darkness at Svolvær Airport. This was reflected in the risk factors mentioned under the heading "Airport Category C" in the company's specific briefing. In addition to general warnings concerning weather, turbulence, mountain terrain, special procedures for missed approach, etc., the risk of "black hole effect" and "tight" circling procedure is mentioned.

1.10.3.5 In its risk analyses in connection with the obstacle situation at Svolvær Airport, Avinor had pointed out both in 2005/2006 and 2010, that circling to runway 19 entailed danger of loss of visual references in an area surrounded by high terrain. Turbulence warnings and circling lights were measures that were planned to improve safety. Double PLASI was also mentioned as an option.

1.10.3.6 Widerøe has stated that circling is somewhat more common in Svolvær that what the wind conditions would warrant. This is presumably linked to the fact that some pilots, particularly during slippery runway conditions, and even when there is no wind, prefer to circle and land toward the south (Runway 19), since the upward slope of the runway yields the shortest stopping distance.

1.11 Flight recorders

1.11.1 Cockpit voice recorder (CVR)

LN-WIU was equipped with an L3 Communications Solid State cockpit voice recorder (SSCVR) with 30 minute storage capacity. Recordings from the aircraft's cockpit voice recorder were not secured after the incident. Recordings are automatically recorded over after 30 minutes, unless power is cut off to the unit. AIBN has thus not had access to recordings of the crew's communication amongst themselves, or the communication between LN-WIU and Air Traffic Control.

1.11.2 Flight Data Recorder, FDR

1.11.2.1 LN-WIU was equipped with a Honeywell Solid State Flight Data Recorder (SSFDR), which is a different type of FDR than what is standard in Widerøe. When the incident occurred, the company lacked the proper set-up for reading this type of recorder. However, the Technical Department ensured that the data were downloaded externally. FDR data for selected parameters were available just a few days after the incident. They were also presented at the second meeting described in 1.1.7.

1.11.2.2 The flight recorder in question had a series of parameters showing pitch, bank, airspeed, altitude, control column movements, control surface deflections, engine power setting, turn rate, acceleration forces, etc. The recorder had no parameters that could show the aircraft's geographical position or ground speed. Moreover, it did not record the wing's angle of attack, stalling, or activation of the stall warning (stick shaker), or who was at the flight controls (from which side of the cockpit).

1.11.2.3 When AIBN opened its investigation in March 2015, the FDR data Widerøe had preserved after the incident was sent to the manufacturer Bombardier for assessment. FDR parameters for the entire flight follow in Appendix E. Extracts showing the incident follow in Figure 8 and Figure 9.

1.11.3 Systematic description of relevant FDR data

AIBN cooperated with aircraft manufacturer Bombardier to verify the quality of the flight recorder data, and to analyse these data. Below is a rendition of factual information from the flight recorder, in chronological order:

Factual Observations

Based on a review of the relevant flight data from the FDR, as presented in [SHT Figure 8] and [SHT Figure 9], the following factual observations can be made in chronological order (sample times are in seconds):

(1) The aircraft was configured with flap 15 for approach and throughout the period of this analysis.

(2) From sample time 103190.0 through 103196.0, the aircraft magnetic heading decreased from 239 to 233˚, radio altitude decreased from 409 to 354 ft, and roll attitude decreased from -2˚ to -16˚ (LWD), indicating the aircraft was on a circling approach to runway 19. Airspeed is between 107.4 and 110.0 KCAS while the VREF at incident flap setting and estimated weight is 100 KCAS. From the radio altitude during this period, the rate of descent is calculated to have averaged 552ft/min and is consistent with a 3˚ approach.

(3) From sample time 103196.1 to 103197.1, the airspeed decreases from 110.5 to 94.0 KCAS. During this period of time, longitudinal acceleration experiences little variation, remaining below 0.1 g while vertical acceleration decreases from 0.9 to 0.6 g.

(4) At sample time 103197.0, engine 1 and 2 torque are both at 42.0% and increase to 97.5% and 99.9%, respectively 3.0 seconds later. Normal engine torque operating range is 0-97.5%. Correspondingly, longitudinal acceleration is seen to increase from 0.1 to 0.5g during this period. Left and right elevators are at 6.0˚ and 2.2˚ respectively and ramp up to 9.8˚ and 6.3˚ 2.3 seconds later.

(5) At sample time 103198.1, the speed has risen to 99.4 KCAS, but begins dropping rapidly. Pitch attitude is 5.9˚ nose up and increasing. The vertical acceleration is 0.6 g.

(6) At sample time 103199.3, the elevators travel TED for approximately 1.0 second before reversing sharply.

(7) At sample time 103199.8, airspeed drops below 76.5 KCAS, the estimated stall speed for the aircraft based on the AFM at the incident flap settings and estimated weight. The aircraft remains below the declared stall speed for approximately 0.7 seconds, decelerating to its lowest point of 72.0 KCAS at 103200.1. According to the AFM, VMCL for the aircraft is 74.0 KCAS.

(8) At sample time 103199.9, the pitch attitude is 9.3˚ nose up and begins dropping.

(9) Between sample time 103200.3 and 103203.3, the left and right elevator deflections move TEU from –4.4˚ and 1.7˚ to 20.9˚ and 17.7˚ respectively. Speed increases from 72.7 to 127.7 KCAS while the rate of descent is calculated to be 2240ft/min over this span of time.

(10) Between sample time 103201.9 and 103202.2, vertical acceleration is 0.4 g during which the pitch attitude is between 14.0 and 14.4˚ nose down.

(11) The lowest nose down pitch attitude of 14.7˚ is reached at sample time 103202.4 and begins nosing up.

(12) From sample time 103202.5 to 103204.9, the pitch attitude increases from 14.3˚ nose down to 11.2˚ nose up where it steadies. At sample time 103203.3, the elevator deflections begin to reduce.

(13) At sample time 103203.2, engine torque, having slowly increased over the previous 3.2 seconds to 104-5% now begins to ramp up. By sample time 103205.7 it is at 116% and remains at around 115% for the remainder of the analysis. Cautionary range for engine torque is 97.5-112.5%. During the interval which the torque is ramped up, airspeed climbs from 127.7 to 151.0 KCAS. VFE at flap 15 is 148 KCAS according to the AFM.

(14) At sample time 103204.4, the minimum radio altitude of 83 ft was reached.

(15) At sample time 103204.5, the vertical acceleration reaches the maximum incident value of 2.7 g. According to the AFM, the maximum maneuver load limit with flaps extended is 2.0 g (2.5 g with flap retracted).

(16) Between sample time 103204.4 and 103208.4, radio altitude increases from 83 to 212 ft at an average calculated rate of climb of 1935 ft/min. Airspeed settles at around 150 KCAS beginning at 103205.1 and the pitch attitude reaches 11.3˚ nose up and settles. The left and right elevator deflections settle at 3.9˚ and 0.7˚, respectively, beginning at 103205.3, varying no more than 2˚ for the remainder of the analysis.

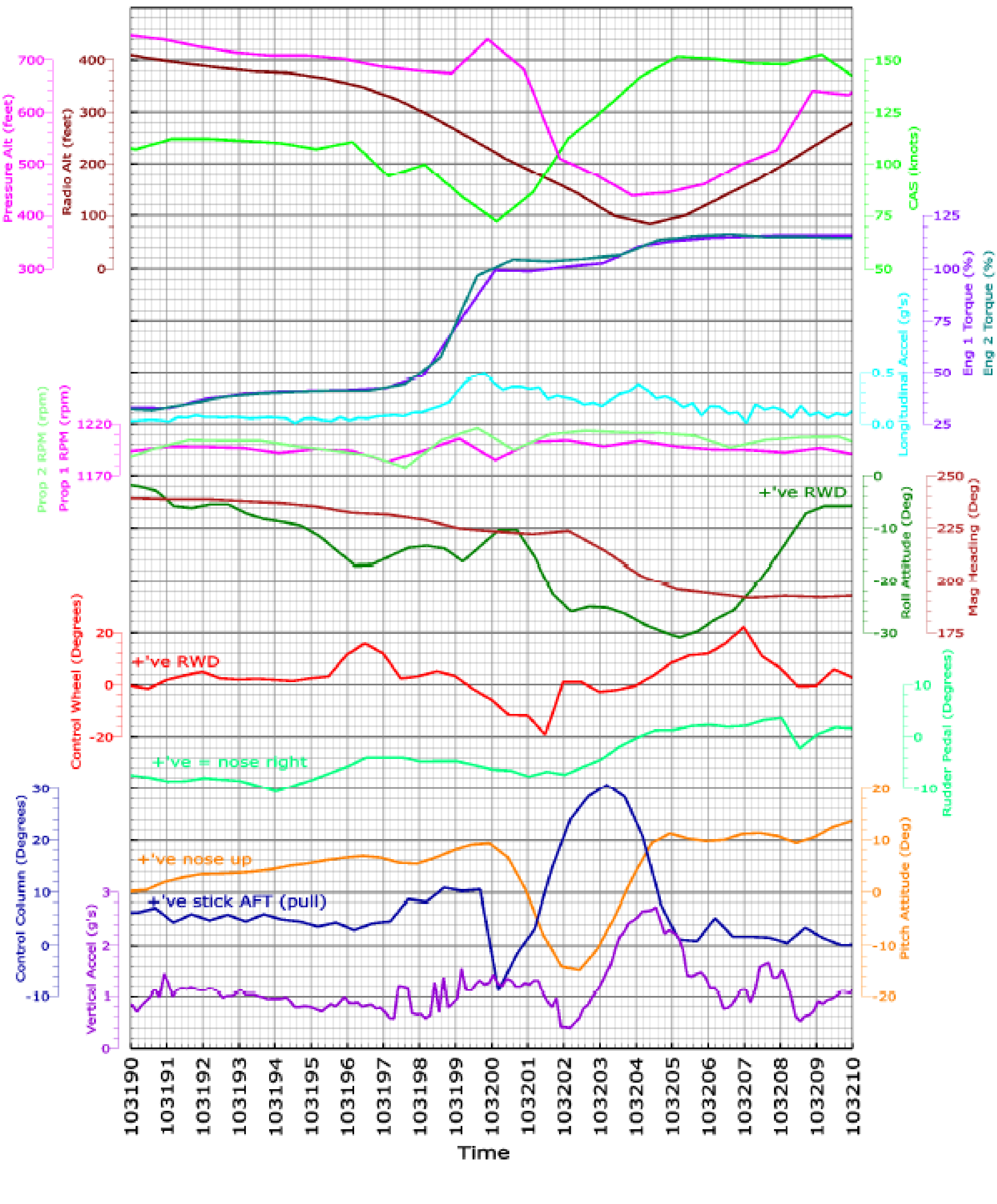


Figure 8: Overview of relevant FDR parameters from a few seconds prior to the critical phase starting, and until the situation was under control again. The timeline in the figure covers a total of 20 seconds. Source: Bombardier

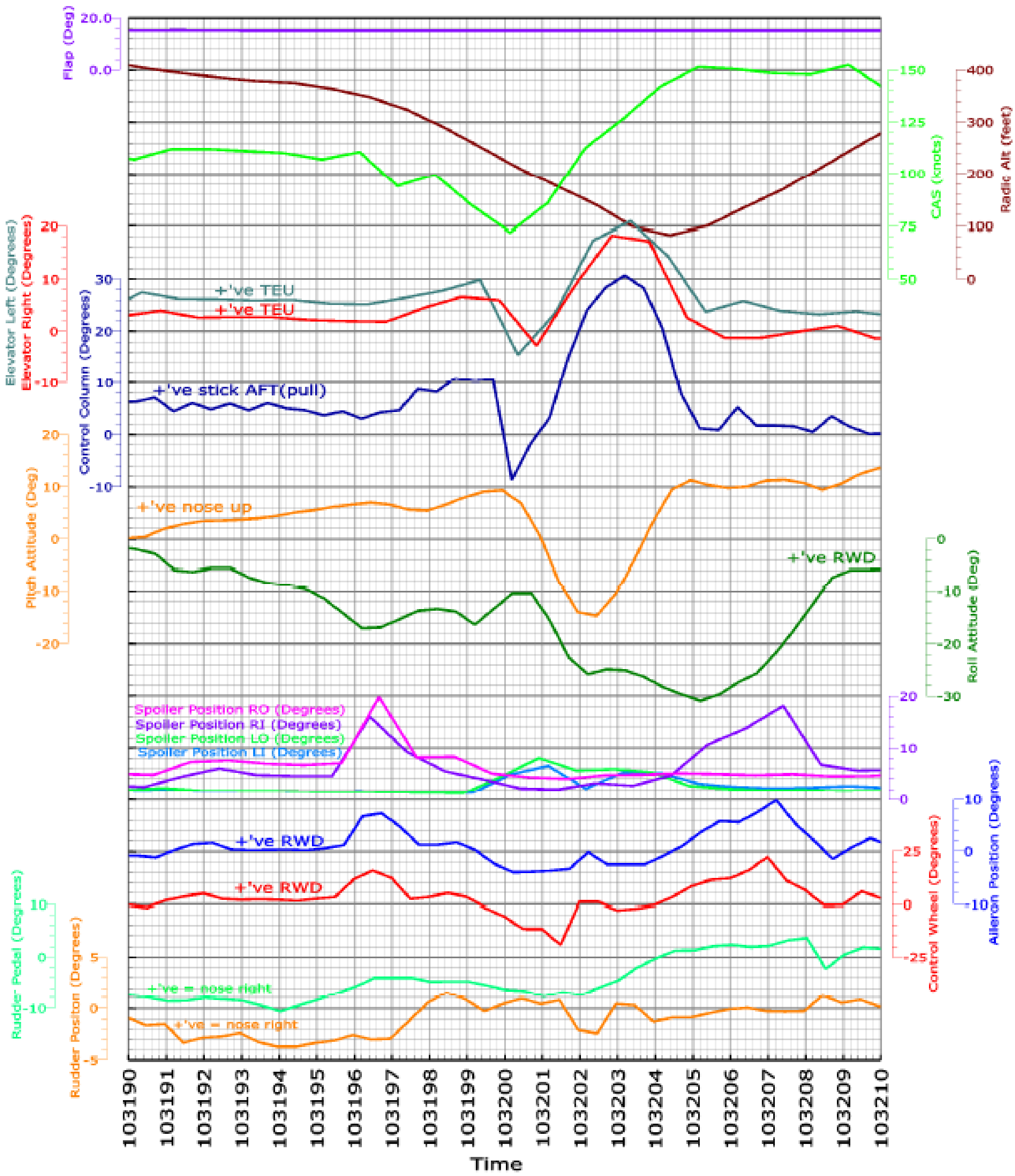


Figure 2: LN-WIU FDR Control Surface Parameters

Figure 9: FDR parameters related to flight attitude and flight control positions in the same 20-second period as Figure 8. Source: Bombardier

1.11.4 Summary of what a selection of FDR parameters shows

1.11.4.1 *History of the flight*

Briefly summarized and expressed in a less precise manner than the account provided above, data from FDR show that the aircraft was in the transition between "base" and "final" (heading approx. 230 degrees) when the problems started (cf. Time 103196). The altitude was then approx. 350 ft (radio altimeter), engine power was approx. 41%, condition levers max and airspeed approx. 108 kt, which was the correct value (not corrected for wind) for relevant mass[12]. The critical phase the flight crew has described, from a perceived normal situation via an acute hazardous situation with recovery which ended up in a very low altitude above the sea and until the situation was under control, unfolded over the course of approx. 10 seconds (cf. Figure 8, FDR time 103196–103205).

1.11.4.2 *Loss of speed and correction*

FDR registrations showed variation in airspeed without movement of the controls (cf. Time 103195–103197), which indicates external forces (wind shear). FDR data confirmed a marked loss of speed. The engine power was quickly increased to approximately the maximum certified limit (approx. 97.5%), while at the same time, the aircraft nose was elevated from 6 to nearly 10 degrees above the horizon.

The data showed that, despite increased engine power, airspeed continued to fall, and that it fell to 72 kt, which is approx. 5 kt lower than the aircraft's given actual stall speed.

The FDR registrations showed that the control column, when airspeed was at its lowest, was moved rapidly forward from a position of approx. 10 degrees behind to a position of approx. 9 degrees in front of neutral (the stick movement forward took approx. 0.4 seconds) at the same time as the radio altimeter showed 220 ft. Right after the resolute stick motion forward, the nose pitched sharply down.

1.11.4.3 *Climb and flight attitude*

The backward stick motion (initiated pull up) started immediately after the control column was first moved fast forward (Time 103200.3). Speed was at its lowest, and the aircraft nose was still approx. 8 degrees above the horizon, when the stick movement was reversed. In other words, at this point the nose had only just started lowering from the starting point of 10 degrees up.

The aircraft's nose position moved during the course of approx. 4.5 seconds in a continuous "bucking motion" from approx. 10 degrees above the horizon down to approx. 14 degrees below the horizon, and up again to approx. 10 degrees while the airspeed was continuously increasing, and altitude decreasing. The angular velocity of the nose position while the aircraft was "bucking", was about the same going down and going up; approx. 12°/second.

FDR data for the stick position show that the control column was continually pulled backward for approx. 3 seconds (cf. Figure 8, Time 103200.3–103203.2). The rate of backwards motion of the controls (the speed of the angle of the control column) can be read from the graph. From the starting value, the rate changed a few times, with approx. 0.5 second intervals (from approx. 14°/sec, reduction to approx. 10°/sec., followed by speeding up to 24°/sec.), until the rate again declined in the last second of the climb and the stick movement was changed forward, back toward neutral.

The movement of the nose followed the stick motion, but with an approx. 1.5 second delay. The G forces (vertical acceleration) also increased more or less in parallel with the movement of the aircraft nose, i.e. with a 1.5 second delay relative to the movement of the stick. The maximum value of 2.7 G was reached when the aircraft's altitude was at its lowest, 1.5 seconds after the control column was pushed forward again toward neutral. The nose position then stabilized at approx. 10 degrees above the horizon, while the aircraft climbed out.

---

[12] 1.4 V_S, i.e. 40% margin above relevant stall speed. 1.4V_S for the estimated mass of approx. 14 800 kg = 108 kt.

The bank increased from approx. 10 to approx. 26 degrees to the left, while the stick was pulled backward.

1.11.4.4 *Adjusting engine power in connection with recovery*

Data from the flight recorder showed that the aircraft accelerated sharply in a longitudinal direction when full engine power was applied (from approx. 42% to approx. 100% in approx. 3 seconds). An additional increase in engine power, from 100% and up to approx. 116%, was recorded 3-4 seconds later. The first increase came before the control column was pushed forward, while the second increase (from approx. 100% to approx. 116% in approx. 1.5 sec) was initiated as the control column was pulled far back and the nose of the aircraft passed 10 degrees below the horizon pitching up.

FDR data showed that both left and right engines had been up to 116–118% for approximately 35 seconds, with propeller speed of 1,200 RPM.

1.11.4.5 *Loss of altitude and registered lowest altitude*

Altitude decreased rapidly, steadily, and continuously during the critical seconds, with an average sink rate in excess of 2 200 ft./min. Lowest recorded altitude above the terrain was 83 ft. (25 m). Data from the radio altimeter, which measures the shortest distance to the ground below the aircraft, show that the dramatic change of the pitch did not noticeably affect the sink rate. Rapid and significant variation in g-forces over a period of several seconds, indicates turbulence. The vertical acceleration fluctuated repeatedly down to approx. 0.5 G during the initial loss of speed and when the "bucking movement" turned upward. This will be experienced as if the aircraft is falling. Airspeed had reached 140 kt when altitude was at the lowest.

AIBN assumes that the aircraft was located above the sea in the critical period, and that the barometric altimeter therefore showed the same tendency as the radio altimeter. The FDR parameter for pressure height which is shown in Figure 8 is not adjusted for barometric pressure. Provided that they had actually recalibrated the reference from standard 1013 hPa to relevant QNH, which was 1000 hPa, the registered values thus do not correspond with the indication the pilots would have seen on the altimeter in the cockpit[13].

In the critical period when the control column was pushed forward and at the beginning of the pull up, both the barometric altimeter and the vertical speed indicator displayed unreliable values. Bombardier has confirmed that the error is due to the fact that the sensors, which are located below the aircraft windshields, have been exposed to abnormal air currents. The fault reading can indicate that the angle of the air current deviated from what the instruments are designed to measure.

1.11.5 Animation of FDR data

1.11.5.1 AIBN also commissioned an animation of FDR data. It is important to note that animation of FDR data does not provide a completely correct picture of the incident. In this case, the surroundings were not actually visible, as it was dark. Since positioning data is lacking, the location of the incident in the animation is estimated based on other sources. Wind effect means that the aircraft's path above the terrain prior to the actual incident is inaccurate. Important parameters such as acceleration do not lend themselves

[13] 1000 hPa theoretically yields approx. 390 ft reduction. There are probably additional sources of error, but the deviation has not been investigated further. See also Appendix E.

to good visualization with the available technology, and the barometric altimeter and vertical speed indicator do not show the values as they were indicated in the cockpit.

1.11.5.2 Despite inherent weaknesses in this, AIBN has determined that it is correct to publish the animation along with this report. The animation gives a good impression of how quickly things happened, a factor which is essential for understanding the sequence of events and the pilots' reactions and actions. The crew members and flight operations management in Widerøe have seen the animation, and have been given an opportunity to provide input. The animation can be downloaded from AIBN's website at https://www.aibn.no/Aviation/Published-reports/2016-11-eng.

Figure 10: Freeze-frame from the animation of the incident involving LN-WIU which shows the situation as engine output nears "Full power" just before the control column is pushed resolutely forward. Note: The animation is based on data from FDR. Surroundings, visibility and wind conditions are not representative for the incident in question, and the indications from the altimeter and vertical speed indicator do not correspond with what was shown in the cockpit. Screenshot: AIBN

1.12 Wreckage and impact information

N/A.

1.13 Medical and pathological information

Not investigated.

1.14 Fire

N/A.

1.15 Survival aspects

N/A.

1.16 Tests and research

1.16.1 Assessment of likelihood of sensory illusion

1.16.1.1 *Analyses conducted by the Institute of Aviation Medicine (FMI)*

Due to deviations in the pilots' explanations, as well as some deviations between the explanations and FDR data, AIBN decided to examine whether the crew may have experienced a sensory illusion. Consequently, the Accident Investigation Board requested assistance from the Institute of Aviation Medicine (FMI), which has specialized expertise in this field.

FMI prepared the report *"Analyse av hendelsene under Widerøes rute 814 fra Bodø lufthavn til Svolvær lufthavn Helle 2. desember 2010" (Analysis of the events during Widerøe's flight 814 from Bodø Airport to Svolvær Airport Helle on 2 December 2010)*. The report, which is in Norwegian only, is offered in its entirety as Appendix F to this report. The FMI report explains factors including the phenomenon of sensory illusions in general, and somatogravic illusion in particular. In addition, the report discusses what the literature says concerning the importance of pilot experience and fatigue in this connection, and a few examples are provided of accidents that were presumably caused by somatogravic illusions.

The following abstracts from the report, with figures, explain the illusion which can occur when a pilot flies the aircraft based on inadequate visual references and is exposed to acceleration forces in a longitudinal direction:

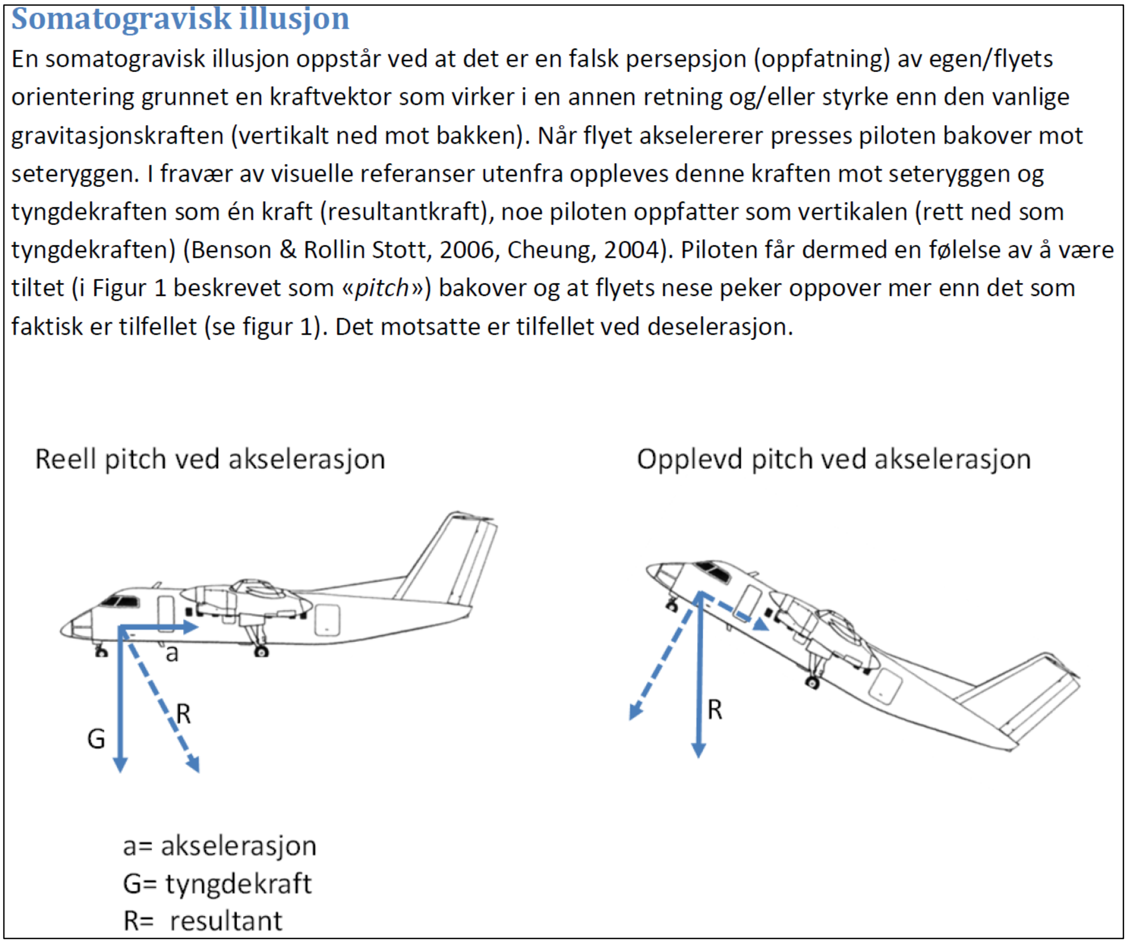


Figure 11: Resultant force and perceived pitch (nose position) in a somatogravic illusion. Source: FMI

Text in picture:

*"**Somatogravic illusion***

A somatogravic illusion occurs because there is a false perception of one's own / the aircraft's orientation due to a force vector that works in a different direction and/or strength than the normal gravitation (vertically down to the ground). When the aircraft accelerates, the pilot is pushed into the back of his chair. In the absence of visual references from the outside, this force against the back of the chair and the gravity are perceived as one force (resultant force), which the pilot perceives to be vertical (straight down, like gravity) (Benson & Rollin Stott, 2006, Cheung, 2004). The pilot thus gets a sense of being tilted (described in Figure 1 as "pitch") backwards, and that the nose of the aircraft points more upward than what is actually the case (see Figure 1). The opposite occurs during deceleration.

Actual pitch during acceleration *Perceived pitch during acceleration*
a= acceleration
G= gravity
R= resultant"

FMI has discovered that the forces that can create a somatogravic illusion were present in the critical phase of the approach to Svolvær during the relevant time period. The following figure illustrates the result of the calculations made by FMI based on the FDR data from LN-WIU during the incident:

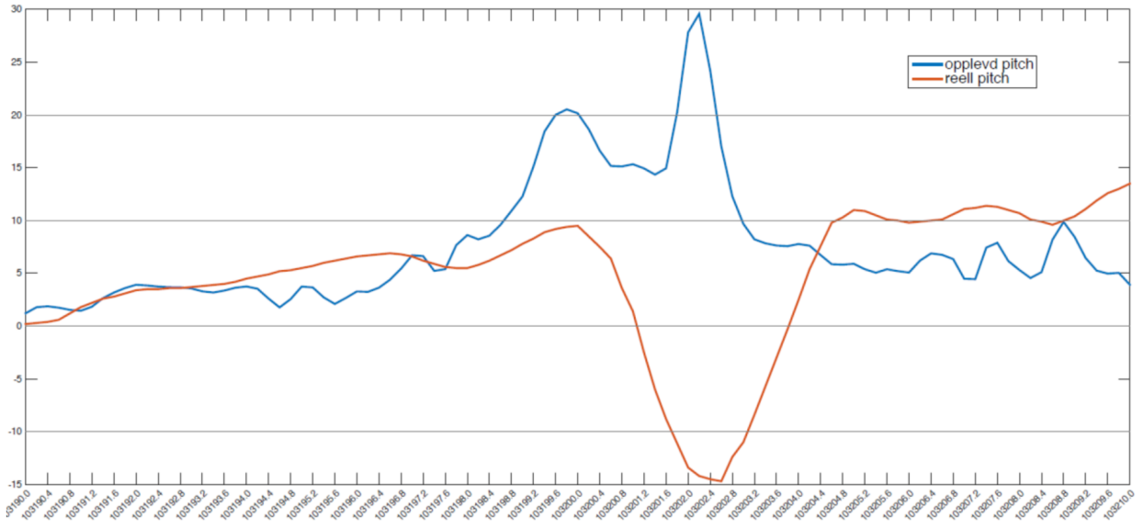


Figure 12: Sliding average (Fourier curve): Orange line, actual pitch (nose position) versus blue line, perceived pitch (resultant force) in degrees of deviation from the horizon (0). Source: FMI

The following is an excerpt from the conclusion in the report:

> *FMI's calculations of resultant force, i.e. potential perceived nose position (pitch), during the incident involving WIF814 on 2 December 2010 shows that the conditions were right for the PF to possibly have experienced a somatogravic illusion. The perceived nose position was up throughout the incident, with an increasing tendency just before, and especially while, the aircraft's nose actually pointed down. The force influence prior to the control column movement was probably not strong enough and did not last long enough on its own to have made PF move the control column forward. The force influence while the aircraft accelerated with its nose pointed down towards the sea surface, was stronger, and it is likely that a somatogravic illusion may have occurred. This would have complicated recovery of the aircraft, and may have influenced the commander to keep the nose of the aircraft lower than he would have done with good visual references.*
>
> *The first officer's perception of the situation would probably be less influenced by the illusionary forces as he mainly focused on the instruments.*
>
> *The literature indicates that fatigue potentially makes a pilot more susceptible to sensory illusions. During the incident involving WIF814 on 2 December 2010, the PF was, according to his own statement, somewhat tired, and it can therefore not be ruled out that this could have made him more susceptible to sensory illusions.*
>
> *The literature further indicates that pilot experience cannot provide much protection against experiencing sensory illusions, but it may contribute to better recovery. The pilots' experience during WIF 814 is not considered to have been decisive for determining whether they experienced a sensory illusion.*

1.16.1.2 *Analyses undertaken by TNO*

AIBN also commissioned a separate analysis from the Dutch research institution TNO which, in cooperation with aircraft manufacturer Boeing, has recently developed a data analysis tool to illustrate sensory illusions (Spatial Disorientation Tool, SDiT). The tool was shown at an international conference on investigations of aviation accidents in 2015 (International Society of Air Safety Investigators, ISASI).

Boeing has pointed out that accident investigation boards through the years seem to have lacked adequate expertise on sensory illusions, and thus may not have identified this as a factor. One study found 17 accidents and 1 serious aviation incident involving scheduled flights where sensory illusions have presumably contributed to losing control of aircraft, or collisions with terrain. The following message was, for example, communicated at ISASI 2015:

> *[The TNO tool] shows what the pilot's vestibular system was telling the pilot about his or her orientation and motion. Certainly, this input is only part of the whole picture; but when there is a degraded visual environment, we have seen that the vestibular inputs can drive the pilot's actions into a larger upset and loss of control. In some cases, the reality generated by these false perceptions can be strong and enduring and, unless there is a rapid and forceful response from the PM, can lead to a crash.*

It was also mentioned that a somatogravic illusion typically occurs during a missed approach in poor visibility, where the illusion results in the PF unawarely steering the aircraft down toward the ground because he/she feels that it is climbing too much. This may result in considerable challenges in the crew cooperation. In most investigated cases, the first officer did not dare to say anything or intervene due to too much respect for the captain (too steep authority gradient). More examples of relevant scenarios are available in the article based on the presentation (cf. ISASI Forum Magazine Jan-Mar 2016).

The report TNO prepared for SHT is called *"Final report on SD analysis of incident with DHC-8 at Svolvær Airport Helle, Norway 2 December 2010"*, and has been enclosed as Appendix G to this report. It contains background information and an explanation of the model that was used as a basis, and describes assumptions, limitations, necessary input, etc.

The figure below is a snapshot from SDiT. The recording has been paused when the nose was at the lowest point. The vertical red line shows the Time 11.2, corresponding to an FDR Time of approx. 103202 in Figure 8. In this situation, a deviation of approximately 17 degrees between actual and perceived pitch is shown:

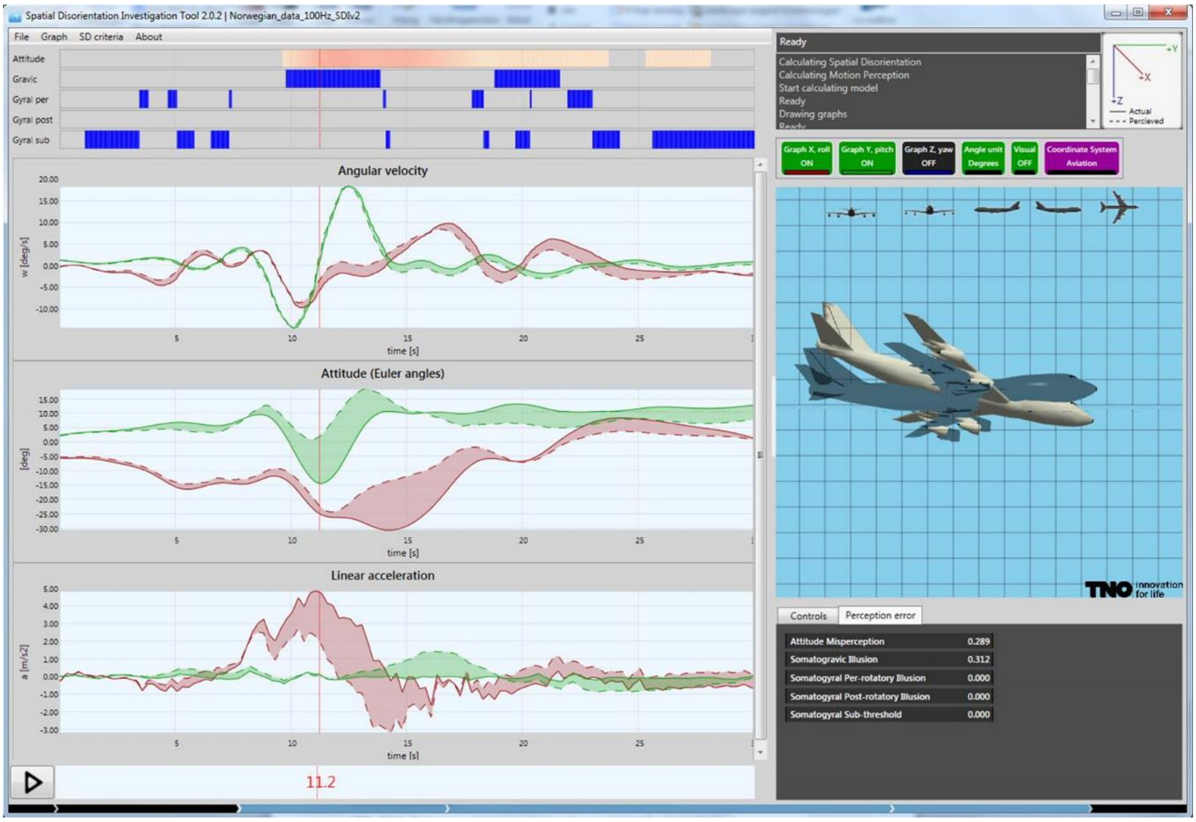


Figure 13: Screen shot from SDiT. The picture shows a deviation between actual and perceived pitch in LN-WIU at the time when the illusionary forces were the greatest (distance between the solid and dotted line in the green graph in the middle section of the picture, at approximately 103202 FDR Time). The red graph shows roll. Se Appendix G for a more detailed description of what is shown in the figure. Source: TNO

TNO found that the conditions were conducive to sensory illusions also for a short period after the situation had been resolved. This is considered insignificant and will not be discussed in more detail here. The conclusion in the TNO report as regards the critical seconds largely coincides with FMI's findings.

TNO mentioned that the roll movements may also have been influenced by sensory illusion, but this has not been examined in more detail. The following is an excerpt from the conclusion in TNO's report:

> *The SDiT analysis identified two phases in the recorded flight profile where the vestibular inputs gave rise to a somatogravic illusion in the pitch plane (assuming that no visual information was available). In particular the first phase may have induced a strong perception of nose-high attitude, while the actual attitude was nose-down. The illusion (i.e., the mismatch between perceived and actual pitch attitude) even intensified due to the forward acceleration that resulted from the nose-down action. When the pilot flying based his control behaviour on this erroneous perception, this would result in stronger pitch forward inputs.*
>
> *Although the time histories also showed a slight over-pitch sensation when the pitch down input starts, it seems too small to be identified as a somatogravic illusion. Therefore it is more likely that the decision to push the nose down was due to the flight condition (e.g., low airspeed), and not on a false pitch sensation.*

The data showed that the flight was uncoordinated at that time[14]*, which resulted in errors in the perceived angle of bank. We have not further addressed this in the current analysis.*

1.16.2 Risk during visual circling in darkness – assessment of perceptual issues

1.16.2.1 AIBN also ordered a separate report from FMI where the task was to identify potential hazards during visual circling in darkness during the approach to Svolvær Airport. FMI was also asked to make a statement about the risk at the time of the incident compared to the current situation. For the purpose of achieving the best possible impression of both operations and surroundings, FMI conducted document studies, simulator flights and visited Svolvær.

1.16.2.2 The FMI report is called *"Utredning av visuell sirkling i mørke inn til rullebane 19 ved Svolvær Lufthavn Helle"* (*Assessment of visual circling in darkness during approach to Runway 19 at Svolvær Airport*), and has been enclosed in its entirety as Appendix H to this report. The report, which is in Norwegian only, describes a number of sensory illusions that a pilot may experience on his/her approach to Svolvær Airport in darkness (somatogravic, G-excess, oculogravic, elevator, auto-kinetic and black hole illusion). Such illusions are rare when there are well-defined, external visual references, but FMI states that they can easily distort the pilot's situational awareness for instance at nighttime, when only a few stars or isolated lights are visible.

1.16.2.3 As described in Chap. 1.18.1, the lighting, PLASI, circling pattern, etc. at the airport were changed during the period in question. FMI divided the approach route into three zones and compared the hazards then and now:

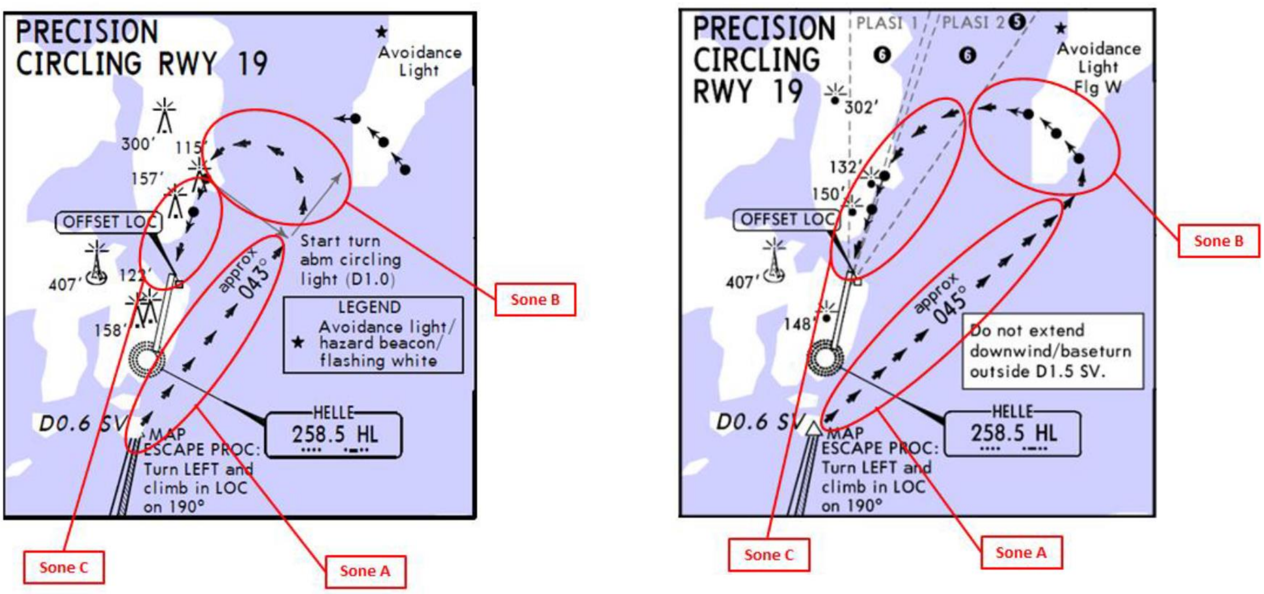


Figure 14: Comparison between Widerøe's chart dated 11 Feb. 2011 and 20 Feb. 2015. Source: FMI

1.16.2.4 The report concluded as follows:

Based on the information the Institute of Aviation Medicine (FMI) received, the risk of sensory illusions was relatively low in Zones A and C in 2010. The risk is considered to be have been higher in Zone B. The 2010 incident involving WIF 814 took place in Zone B.

[14] May be due to insufficient side rudder compensation when the engine power was increased.

Also today the risk is considered to be relatively low in Zones A and C. Flying in Zone B is still considered higher risk than in the other zones. When it is dark and/or visibility is poor in Zone B, we find that there are still insufficient visual references or aids to prevent sensory illusions. Consequently, there is a residual risk.

FMI has proposed a few potential measures, both relating to procedures and of a technical nature, that may lower the residual risk. Creating awareness and teaching pilots about sensory illusions, simulator training on sensory illusions, and further development of procedures are likely to reduce the risk. Introducing new technological solutions could potentially lead to a further reduction of the residual risk.

1.16.2.5 Proposed procedural measures include increasing the pilots' awareness of sensory illusions through instruction and training. FMI points out that it is challenging to alternate between looking out of the cockpit and in again to check the instruments. It may be appropriate to introduce as a policy that the PM must provide more mandatory feedback to the PF in the most critical zone, to reduce the risk of sensory illusions.

1.16.2.6 Technological measures mentioned in the study include establishing instrument approach or creating sufficient external references to guide the flight accurately until PLASI becomes visible. However, an assessment of technological feasibility is outside FMI's core area and is not discussed in detail.

1.17 Organizational and management information

1.17.1 A brief description of Avinor

Avinor is a wholly-owned state limited company under the Ministry of Transport and Communications. The company is responsible for the 46 state owned airports in Norway, of which 12 are operated in cooperation with the Norwegian Armed Forces. Avinor also operates control towers, control centres and other technical infrastructure for safe air navigation. The main office is in Oslo.

1.17.2 A brief description of Widerøe

1.17.2.1 Widerøe’s Flyveselskap AS was established in 1934 and is thus Norway's oldest airline. In 2015, the company claimed to be the largest regional airline in the Nordic area, with a fleet of 42 Dash 8 (100, 200, 300 and Q400) serving 47 different destinations. The airline's main base is in Bodø.

1.17.2.2 Widerøe holds an Air Operator Certificate (AOC) based on the common European regulations. DHC-8-103 and 202 are used on the short field network (runway length less than 1 199 metres). The airline's operations have been facilitated by the company having obtained authorisation for special supplements to the official flight manuals.

1.17.3 Various procedures – circling procedures, take-over of flight controls, and approach during risk of wind shear

1.17.3.1 Since the DHC-8 entered operations in the early 1990s, Widerøe has had a special permit from the Civil Aviation Authority Norway which allows them to use so-called "Precision circling". This means, among other things, that one accepts a smaller extent of the obstacle-free area compared with what is the ICAO standard for the this category of aircraft. This allows a lower minimum altitude for circling.

1.17.3.2 A number of trade-offs and risk assessments form the basis. For example, it is desirable to get so close to the airport during circling that the likelihood of losing visual references is reduced. One will also want, insofar as possible, to avoid having to make a descent based on visual references, since that makes it difficult to maintain the correct energy on the aircraft throughout the circling. The objective is to avoid ending up too high on the short final approach, cf. OM A 8.1.2.7 Minima Considerations - Widerøe Shortfield Operation (OPS 1.225 / 1.430):

> *"Precision Circling" with prescribed track, which may be based on 1 km protected area measured outward from track. Inner 500m as primary area with MOC 295 ft. Outer 500m as secondary area with MOC decreasing linearly to zero. "Precision Circling" may also be used for restrictions associated with guidance lights, obstacle lights, etc. Such circlings are usually presented with advisory altitudes for continuous descent on the RM chart. The objective is to avoid ending up too high on short final.*

1.17.3.3 The minimum altitude in Svolvær was 580 ft., and no other altitudes were specified or recommended. At the time of the incident, the circling path was drawn with an approximate track of 43° from a defined point, and referred to "abeam" - a light in the extension of the runway, supplemented by DME distance 1 NM for commencement of base turn (cf. Figure 2). The FMI report in Appendix H contains additional details concerning "Precision circling".

1.17.3.4 Regarding execution of circling in general, it was described that PM shall monitor the flying and make standardized "call-outs" at any deviation from speed and altitude to ensure that the correct flight path is followed: *"PNF is responsible for monitoring instruments and call deviations from speed and briefed altitudes, position and distance"*. One can leave minimum altitude, provided that one has achieved and can maintain visual reference, has the threshold in sight and has at least 295 ft. ground clearance. The base leg shall be adjusted so that, after the turn to the final approach, one has level wings no later than at 300 ft. above the runway height, in position for normal glide path with flap setting 15 or 35 degrees. Speed shall be 1.4 Vs and shall be reduced to $V_{REF.}$ when passing threshold (cf. OM B 2.4.14.6 Circling Approach, Appendix C).

1.17.3.5 PM has a duty to insist on "go-around" and, if necessary, take over the controls if the circling is not stabilized at the latest by 300 ft. above ground. Mandatory callout for taking over the controls are *"MY CONTROLS"–"YOUR CONTROLS"* – except if incapacitation has been detected, where the first step is to take over the controls and say *"I have control"*.

1.17.3.6 The Dash-8 simulator used by Widerøe cannot realistically simulate a wind shear while the aircraft circles, as in the specific incident in Svolvær.

1.17.3.7 There is a section in OM-B containing special guidelines relating to approaches when there is a risk of wind shear (2.4.11.3 Wind Shear, cf. Appendix C). The procedure states, among other things, that Flaps 15 should be used if the length of the runway allows it, and that the PM must monitor the flight speed, sink rate, pitch attitude and power setting until flare commences. So far as the Accident Investigation Board has established, this procedure was not followed.

1.17.4 Notifications, reporting and investigation of air accident/incident

1.17.4.1 *Relevant laws and regulations*

Notifications, reporting and investigation of air accidents and incidents are regulated in Chapter 12 of the Norwegian Aviation Act with associated regulations[15]. The Accident Investigation Board Norway must be notified by telephone immediately in the event of a serious aviation incident. Instances where risk of collision with the terrain was imminent or just prevented are examples of incidents that must be reported as serious aviation incidents. The main criterion for classifying an incident as a serious aviation incident, is that the circumstances indicate that an accident nearly occurred. The main rule is that the Accident Investigation Board has a duty to investigate all accidents and serious incidents.

In principle, the commander is responsible for notifying and reporting accidents and serious incidents. Other flight crew members, the user or owner of the aircraft, are, in order of priority, responsible if the commander is unable to notify or report, or fails to do so for other reasons. Notifications must take place by phone, and be followed up by a written report, which must be submitted to both AIBN and the Civil Aviation Authority Norway no later than 72 hours after the incident. Avinor employees also have an obligation to notify and report.

AIBN will be notified automatically of all air accidents and serious incidents reported in the electronic reporting system that was introduced in 2007. On a yearly basis AIBN receives well over 100 such reports a year, whereof experience shows only barely 20 fulfil the criteria for investigation by the Accident Investigation Board.

Other reported incidents are incorporated into the preventive air safety work performed under the management of the Civil Aviation Authority Norway. On an annual basis, the Civil Aviation Authority Norway receives about 6 000–8 000 reports. A system has been established where the Civil Aviation Authority Norway forwards potentially misclassified events to AIBN for assessment.

1.17.4.2 *Procedure in this case*

Widerøe did not classify the incident as a serious aviation incident, and, consequently, the Accident Investigation Board was not notified by telephone. The Civil Aviation Authority received written reports from Widerøe and Avinor within the deadline. The content in the relevant reports did not warrant a need for submission to AIBN.

Avinor centrally has stated that they conducted a simplified, internal investigation of the case. Procedures for communicating wind conditions were raised in the established flight safety committee, where flight operations personnel from both Widerøe and Lufttransport (another operator) participated. Based on follow-up locally in Svolvær, existing warnings in AIP Norway and Widerøe's wind limitations at the airport, no additional initiatives were proposed in the Avinor system.

Widerøe's handling of the case has been one of the topics of this investigation. The flight operations management held two meetings with the two pilots in the days following the incident. A small selection of flight data from the incident was available at the second meeting. The commander was asked to write a more detailed report, and this was entered

[15] Regulations relating to the duty of notification and reporting in connection with air accidents and incidents etc., BSL (Civil aviation regulations) A 1-3 and Regulations relating to public investigation of air traffic accidents and incidents in civil aviation, BSL A 1-4.

in the company's deviation management system (cf. 1.1.6). Later, the first officer requested, and received, a copy of the plotted flight data parameters.

A subsequent report from the first officer, which indicated that the incident was of a more serious nature, was not entered in the deviation management system, nor was it submitted to the aviation authorities. An internal investigation of the incident was not initiated. The company has in retrospect regretted the way they handled the incident, and shown that they have changed their routines to prevent recurrence.

The first officer informed the Civil Aviation Authority and the Accident Investigation Board of his version of the incident in December 2012, i.e. two years after the incident took place. At this time, the first officer had left his occupation as a pilot. The Civil Aviation Authority requested that AIBN investigate the matter. AIBN assessed the information available and obtained more information, including information about changes that had been made and were planned for implementation after the incident took place (cf. Chap. 1.18.1). Based on this and previous investigations where AIBN has issued reports concerning the challenges associated with the short field operations concept, AIBN decided in June 2013 that the case was considered an aviation incident that was not to be investigated.

When AIBN informed Widerøe that the incident would not be investigated, it was at the same time pointed out that the company had potential for improvement associated with reporting. Correct classification and decisions concerning a potential safety investigation depend on the aviation authorities receiving the relevant information within the specified time limit. AIBN also pointed out that the company should ensure that pilots and cabin crew were aware of the fact that reporting to the authorities can take place independently, should the crew disagree on the sequence of events or the severity of an occurrence.

In February 2015, the incident garnered significant attention, and AIBN found that the incident could contain a greater potential for learning than first assumed. The decision not to investigate was reversed, as the regulations allows for. AIBN initiated an investigation in March 2015. Following initial investigations, the Accident Investigation Board reclassified the case from an aviation incident to a serious aviation incident.

1.18 Additional information

1.18.1 Risk mitigation measures

1.18.1.1 Widerøe and Avinor have stated that they are making continuous and systematic efforts to improve flight safety, which has resulted in improvements in a number of areas. For example, circling to runway 19 in Svolvær had been identified with relevant risk factors several years before this serious aviation incident took place, and risk-reducing measures had been introduced or were in the process of being introduced. Difficult wind and turbulence conditions and potential loss of visual references had been found to be the greatest challenges. Putting a system for turbulence warning and circling and emergency lighting into place was prioritized.

1.18.1.2 Widerøe has described to AIBN a series of risk-reducing measures for operation at runways shorter than 1,199 m. They can, for instance, document that their crew members undergo training that is considerably more comprehensive than the current minimum requirements, and that they select pilots with more flying hours than the minimum requirement. This is considered necessary for safety reasons, as operations on that particular route network are very demanding.

1.18.1.3 The training program is goal-oriented and extensive, and the company’s flight simulator has been upgraded. Instructors, supervisory pilots and line pilots complete training relevant to the risks associated with circling in darkness and the risk of sensory illusions.

1.18.1.4 According to the regulations, a Flight Data Monitoring program (FDM) is required for aircraft over 27,000 kg. Widerøe has, on its own initiative, included all aircraft types in the company's FDM program, even though it is only the Dash 8 series 400 that are affected by the regulatory requirement. The company conducts regular analysis meetings with an employee representative participating. Technical exceedances and trends, which would otherwise have gone unnoticed, are for example discovered through this monitoring. Since the program was introduced, all data from the aircraft have been stored. The company has shown specific examples of safety improvements as a result of FDM.

1.18.1.5 One example of measures that Widerøe has been wanting to introduce, but which have not yet been included in any plans, is a system that can visually inform pilots when the wind exceeds limitations during the final part of the approach. This issue has, in particular, been raised in connection with the planning for remote-controlled towers at a number of locations in Norway.

1.18.1.6 Furthermore, Widerøe has taken the initiative vis-à-vis Avinor to clear up any ambiguities relating to communicating wind gusts during the last 2 and 10 minutes. The equipment is not identical at all airports, and it is important that all parties involved know what is measured and communicated.

1.18.1.7 Avinor and Widerøe have stated that, since 2010, the following safety enhancing measures relating to infrastructure, procedures, training, monitoring and reporting have been introduced or planned:

- November 2010: Turbulence charts for Svolvær Airport were established just prior to the incident. (Cf. *IPPC/briefing/vind&turbulens*).

- 2010: Changes to Avinor's local regulations: IPPC turbulence charts must be checked at duty-handover.

- 2011: New lights installed.

- 20 September 2013: New expanded circling pattern and approach lights in place after extensive consideration in the local and central safe aviation practice committee (cf. Figure 15).

- 2014: Dual PLASI introduced, providing earlier visual glide path information during circling onto runway 19 (sector at 34°).

- 2015: Preliminary study to establish anemometer in the Teisthaugan area (approximately 1 000 m north of Helle). Installation of wind metering equipment is scheduled for 2016.

- 2016: Moving the anemometer from the west side to the east side of the threshold runway 19.

- 2016: Frequency of METAR observations will be doubled (issued every 30 minutes).

- 2016: Celiometer planned in connection with circling lights northeast of the airport.

- 2011–2015: Recurrent training on situations similar to the one that occurred in Svolvær for all pilots during periodic simulator training.

- 2014: New visual system in simulator, with new visual models, including Svolvær.

- 2014: Precision circling during recurrent training. All pilots have completed the theory.

- 2015: New line check concept based on resilience theory developed in cooperation with Lund University (SHOOT).

- 2015: Goal-oriented training in e.g. *Upset Recovery and Prevention* (UPRT), including specific exercises with focus on somatogravic illusions, e.g. flying in darkness and circling.

- 2015: Improved instructor training, theory and simulator training with focus on illusions. Obtained additional knowledge through contact with expertise at FMI.

- 2015–2016: OPC 01/16 – All pilots complete an UPRT program with focus on illusions.

- June 2011: Modifications of Widerøe's Flight Data analysis tool enable automatic monitoring of incidents (Flight Data Monitoring, FDM) for the entire Dash 8-100 fleet.

- 2015: FDM routines updated in accordance with new common European requirements. The commander is identified/contacted to ensure that a separate report is prepared.

- 2014: New deviation management system introduced by Widerøe prevents storage and incorrect distribution of documents outside the system. All reporting must take place directly in the deviation management system.

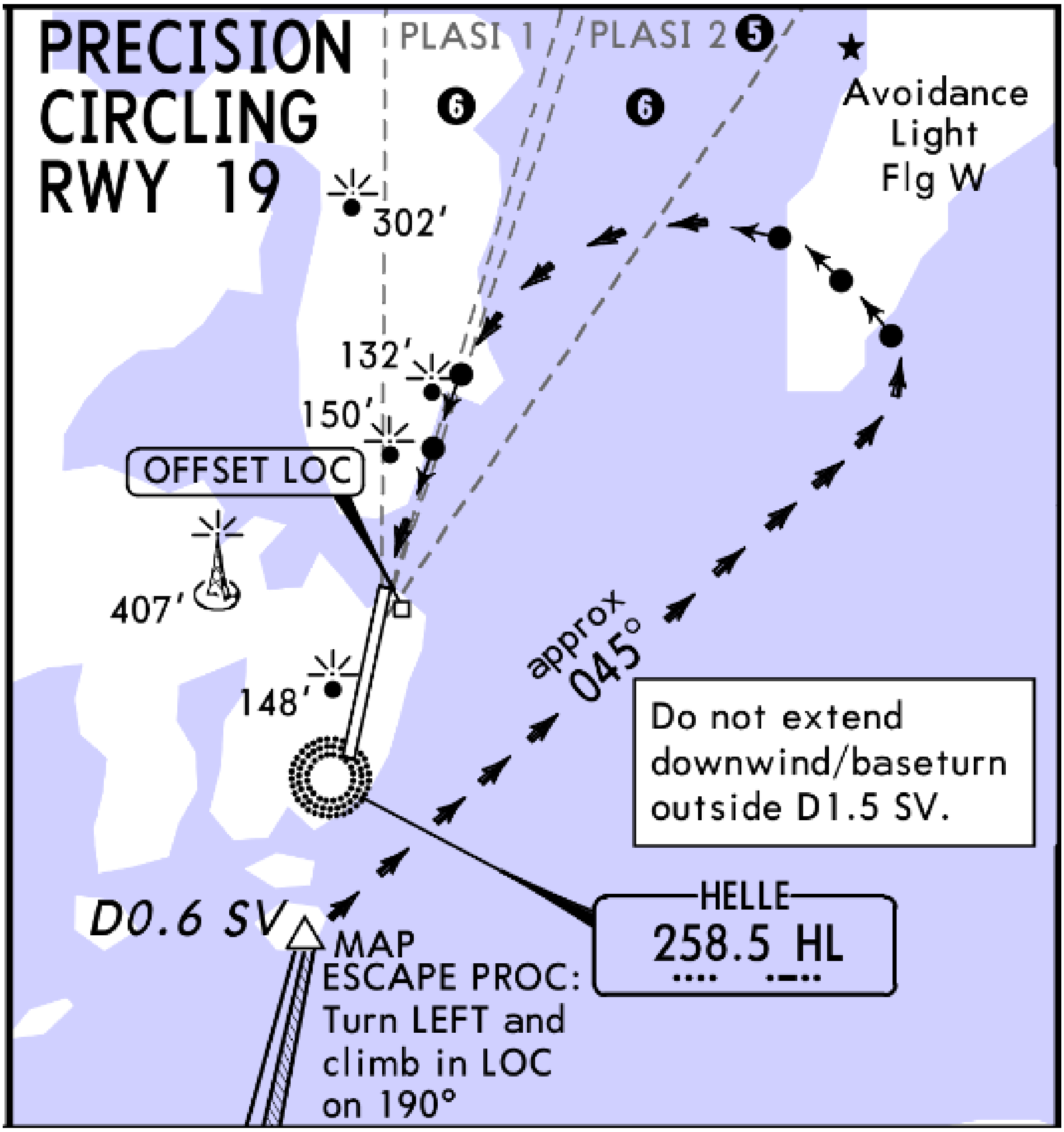


Figure 15: Widerøe's circling pattern in Svolvær dated 20 February 2015. Note circling lights onshore to the northeast and double PLASI. Source: Widerøe

1.18.2 Measurable effect of initiatives

1.18.2.1 Widerøe has analysed the situation before and after the new approach chart with the extended circling pattern was adopted on 20 September 2013, and can document measurable effect. The basis was FDM data during the period 1 January 2013–11 April 2014, with focus on the number of cases with excessive banking during approaches. The mapping distinguished between altitudes below 300 ft., where banking of more than 15° is considered excessive, and altitudes between 300 and 500 ft., where the limit is 30°.

1.18.2.2 The analysis showed that the percentage of excessive banking decreased in both altitude bands after the new approach map was adopted. Excessive banking was reduced from 25% to 15% at altitudes below 300 ft., and from 12% to 9% at 300–500 ft. (reduction of 40 and 26 percentage points, respectively.) The analyses also showed that the aircraft to a greater extent followed the designated tracks (greater precision) after the change.

1.19 Useful or effective investigation techniques

1.19.1 Special investigations or methods worth mentioning in this section include consultancy contributions from FMI and TNO. They are described in more detail in Chap. 1.16. The primary features of the methods applied are described in the enclosed reports.

1.19.2 As regards relevance for future examinations, the Accident Investigation Board would like to point out that expert assessments were necessary in order to determine whether sensory illusions may have taken place. Their methods and assessments were thus of great value for the investigation.

1.19.3 Additional data required in order to use the TNO tool were relatively complex and challenging to obtain. Both Widerøe and Bombardier had to provide information that was not easily accessible, and this delayed the process. The situation would most certainly have been simpler if the aircraft involved had been a Boeing, as Boeing has helped develop the tool and is likely to have performed much of the preparatory work already.

1.19.4 With some additional input from the developers, TNO's Spatial Disorientation Tool (SDiT) will probably become a useful and practical tool in future investigations. In particular, we believe that manufacturers and/or operators should be familiar with this tool regardless of whether an accident has taken place or not. TNO has stated that one operator has started using the tool in its preventive flight safety work. In such a case, it would be possible to obtain results quickly, if needed.

1.19.5 SDiT uses a model for human perception. Consequently, it is necessarily based on a number of assumptions and preconditions. For example, TNO has set a threshold value of a 6° deviation between perceived and actual pitch before one can say that a somatogravic illusion has taken place (cf. Appendix G). TNO's model incorporates aircraft movements in several axes. Variables such as a pilot's head movements may impact his/her experience, but have not been incorporated in the model. It is important to be aware that the result obtained from SDiT on this basis, does not provide an exact recreation of reality, and users of the tool should cooperate with the experts that have developed it to avoid drawing incorrect conclusions.

1.19.6 FMI's force calculation model is simpler. It is based solely on the forces in the aircraft's x and z axis obtained directly from FDR, as these forces were considered most important for the incident in question. In addition to the calculations of the forces, FMI has conducted expert assessments of the calculations and the incident in general. The FMI report is considered to cover AIBN's needs in this investigation.

2. ANALYSIS

2.1 Introduction

2.1.1 <u>The structure of the analysis</u>

2.1.1.1 The main part of the analysis consists of a sequential review of the critical phase of the sequence of events. How control of the aircraft was about to be lost and how the situation thereafter was resolved, is highlighted and discussed. Crew cooperation, recovery and takeover of the controls are also addressed. The likelihood of sensory illusion and the impact of this is discussed in Chap. 2.6.

2.1.1.2 This is followed by an assessment of the various safety aspects related to the incident, such as different operational conditions including wind, approach speed, terrain warnings and how circling was performed. Vulnerability in connection with circling in darkness is an issue that has been given particular focus in this case.

2.1.1.3 Finally, measures and safety margins are assessed, before we look at it from a different angle and ask why the situation ended well after all.

2.1.2 Delimitations and clarifications

2.1.2.1 There are no findings to indicate that technical faults or irregularities with the aircraft may have caused the incident or influenced the sequence of events.

2.1.2.2 The return flight and conditions associated with handling of the case in retrospect have not been discussed in detail. AIBN has established that loads on the engines and propellers during the incident did not indicate a need for special inspections, and that the aircraft was inspected without signs of structural overload being discovered (cf. 1.6.3.2).

2.1.2.3 Information in the fact section shows that criticizable matters have been discovered at several levels as regards notification, reporting and classification of the incident (cf. 1.17.4.2). The Accident Investigation Board will refrain from discussing these matters any further.

2.1.2.4 As far as the Accident Investigation Board has established, the crew did not follow the procedure for approach when there is a risk of wind shear (cf. 1.17.3.7). This can have connection with the crew not realizing that the wind was such that this was relevant pursuant to the company's warning in the specific briefing for Svolvær Airport (cf. section. 1.10.3.2), when they started the approach (cf. section. 1.1.3.3). Moreover, the warning was for the last part of the final approach. Since the incident involving LN-WIU happened in an earlier segment of the approach, the Accident Investigation Board will not discuss this in further detail, in order to delimit the investigation.

2.1.2.5 Organisational factors such as control, management and culture have not been studied in any detail in this investigation. Nor has AIBN considered it essential to discuss the general conditions related to this type of operation, such as oversight, regulations or financial matters based on this specific incident.

2.1.2.6 The complexity of the incident has made it necessary to discuss the various aspects of the critical phase of the sequence of events separately in this report. In particular, it is important to read Chapters 2.5, 2.6 and 2.7 as whole to obtain a full picture of how the Accident Investigation Board has assessed the critical phase of the sequence of events.

2.2 Diverging explanations

2.2.1 Statements obtained from the commander and the first officer in 2015 showed that they had more or less the same perception of the sequence of events until the loss of airspeed occurred at the base/in the turn towards the final approach. They also gave fairly similar statements to AIBN regarding what happened during the climb, after control was definitely regained (cf. 1.1.8.1). However, the two pilots' statements deviated significantly with regard to the critical phase (cf. 1.1.4. and 1.1.5). They agreed that the first officer took over the flight controls at some point, but had different views on how this impacted the sequence of events. Furthermore, there were elements in their most recent statements (cf. 1.1.4 and 1.1.5) that do not correspond with their original statements (cf. 1.1.6 and 1.1.7).

2.2.2 The Accident Investigation Board summarizes the deviations in their statements as follows:

The commander's statement	The first officer's statement
- Gave full engine power and lowered the nose of the aircraft when airspeed was lost and the aircraft started to shake. - The stick shaker activated during the climb and therefore intentionally kept the aircraft down and accelerated at a safe altitude towards a red obstruction light. - Airspeed increased and climb was initiated before the first officer unnecessarily took over the controls.	- "Stick shaker" activated. - The nose was lowered as a result of external influence, without corrective measures being implemented by the commander. - Instinctively took over the controls and increased engine power to avert crashing into the sea.

2.2.3 Despite the factual information about airspeed, altitude, flight attitude, engine power and g-loads, etc. provided by the flight recorder, there were still some unanswered questions. As no information was registered about when the stick shaker was activated, nor who moved the flight controls (cf. 1.11.2), it proved particularly challenging to verify the crew's statements.

2.2.4 The Accident Investigation Board finds it understandable and natural that the crew members' statements would vary on some points. Factors that may have contributed to the lack of agreement include:

- The time aspect – several years passed from the time of the incident until the crew members gave their statement to AIBN. Time may have had an impact on memory.

- Different perception at the time of the incident – the commander and first officer performed different tasks and their attention was directed at different aspects of the situation. Different perception and understanding of the situation at the time may later on have resulted in different descriptions of what happened.

- The conditions were right for the commander to possibly have experienced a somatogravic illusion. If so, the commander and the first officer, who did not experience a somatogravic illusion, would have perceived parts of the critical phase differently.

- Different perception of time – studies have shown that in a fright/threat situation, time is perceived to pass more slowly. There is great variation as regards how much a person perceives time to slow down. One or more crew members may have experienced a distorted time perception due to the distressing event. Both the pilots and the cabin attendant conveyed an impression that the incident lasted significantly longer than the 10 seconds established by the flight recorder.

- Changes in memory over time – a person will go over what happened in his mind, at the same time introducing new aspects and details which, over time, may become part of his memory of the incident. The new aspects will then be experienced as memories, whereas, in fact, they come from other people who experienced the same incident, leading questions during interviews, information from the press, review of data from flight recorders, own ideas of what may have caused the incident, etc. After such a long time, it is not only possible, but likely that all crew members, to a greater or lesser extent, experienced changes to their memory, compared with their perception immediately after the incident took place.

- The Accident Investigation Board has made a general observation that witnesses often provide accurate statements about what they did, but find it more difficult to remember the correct sequence.

- It is human nature, in retrospect, to wish one had performed the task well, which may also affect a person's memory over time.

2.3 Likely scenario

2.3.1 AIBN believes it has succeeded in establishing a description of a likely sequence of events, albeit with some uncertainty concerning the moment of the involved crew members' actions and reactions. The scenario is outlined briefly here, followed by a more detailed discussion of the different elements:

- The aircraft was exposed to severe wind shear.

- The commander executed "recovery" with Full power, but the aircraft continued to lose both altitude and speed.

- The stick shaker (stall warning) activated.

- The commander pushed the control column forward resolutely, before pulling it backward again.

- The aircraft accelerated while its nose fell to 14 degrees below the horizon.

- The first officer considered that the commander's corrections were not sufficient, and that there was an acute danger of the aircraft crashing into the sea. At one point, he took over the flight controls and increased the engine power to the maximum available.

- The result of the combined control movements made under the prevailing wind conditions was that airspeed increased, the loss of altitude was stopped in time and the aircraft climbed rapidly.

2.4 Wind shear as triggering factor

2.4.1 The chain of events started with a marked loss of velocity which was clearly visible on the flight recorder data. It has been established that the loss of velocity was due to external forces (cf. 1.11.4). Information concerning observed and forecast wind, rain and hail showers in the area, turbulence modelling and witness statements about passing through a "tropical rain shower" (cf. e.g. 1.7.2, 1.7.4 and 1.1.11), indicated that the effect was wind-related.

2.4.2 AIBN believes that the aircraft, as it was nearly time for turning into final approach, flew in under a cell (cumulonimbus, CB) and was exposed to severe wind shear (microburst, cf. Figure 5). The aircraft was probably exposed to both downdraft and horizontal wind shear. The modelled turbulence picture for the area (cf. Figure 4) shows an increase in mechanical turbulence when there is a strong south-westerly wind over the mountainous terrain. This could have made the situation worse and possibly also extended the duration of the adverse external affect. An unfortunate coincidence may have caused the aircraft to be exposed to an unusually severe and long-lasting wind shear.

2.4.3 Whereas in daylight one can see the cumulonimbus clouds and the area affected by downburst on the ground and the sea, the chances of detecting such a downburst visually in darkness are small. At certain airports in other locations around the world, where tropical storms often occur, ground-based systems have been established that can give warnings concerning wind shear, so-called Low Level Wind Shear Alert Systems (LLWAS). Insofar as AIBN is aware, such systems have not been considered for northern latitudes.

2.4.4 Dash 8 has a weather radar, which in some instances will be a valuable tool for detecting cells/cumulonimbus clouds that are not visible to the crew. However, the benefit is greatest in the cruising phase, well above the terrain. It is not realistic that the PM, in a busy phase, will sit and adjust the weather radar (tilt and range) in an attempt to view contours and differentiate between nearby mountain masses and cells. The weather radar was thus not an efficient safety barrier for LN-WIU, nor were there any other aids on board or on the ground that could have provided the crew with trustworthy advance warning concerning wind shear ahead.

2.4.5 Systems have been developed which can detect and predict wind shear from aircraft (wind shear warning), but there is no requirement that such equipment must be installed in Dash 8, and it was neither installed in LN-WIU. Increased engine power setting in turboprop aircraft results in increased slipstream over the wings and creates lift (powered lift). According to the pilots of this type of aircraft, increased engine power on Dash 8 usually results in a nearly immediate positive response. Such aircraft types thus have greater resistance against being "struck to the ground" by wind shear, compared with e.g. larger jet airplanes. However, there are no aircraft types that are invulnerable to this phenomenon, if the wind shear is severe enough.

2.4.6 Wind conditions and turbulence as a result of the local topography must be acknowledged as one of the greatest challenges in connection with approach and landing on the short field network. Therefore, it is natural that also the LN-WIU crew focused mainly on the wind measurements when they assessed the weather conditions in connection with the approach to Svolvær.

2.4.7 In this case, there was probably an extra threat in the form of a cumulonimbus cloud that was difficult to detect. It may appear that the crew did not sufficiently consider this additional threat, and were surprised by the powerful wind shear it triggered.

2.4.8 Flying in underneath an invisible cumulonimbus cloud may be asserted as being bad luck. In hindsight, one can see that information that there were showers in the area and that recent gusts at the airport had been strong, were warning signs that could have attracted the crew’s attention. However, to truly understand the threat, it would have to be seen in the context of the risk associated with visual manoeuvring in darkness. Wind conditions and vulnerability when circling in darkness are discussed in more detail in Chap. 2.9 and 2.10.

2.5 Critical phase of the sequence of events

2.5.1 Coping with the wind shear

2.5.1.1 To ensure minimal loss of altitude in a wind shear, engine power must be increased to the maximum and the aircraft held up against the angle of attack which triggers the stall warning ("ride the Shaker", cf. 1.6.6).

2.5.1.2 The commander reacted quickly when the disturbance occurred, and increased engine power as described in the procedures. Viewed on its own, the engine increase should have provided increased speed and lift and caused the aircraft to climb, but in this case, the energy appears to have been absorbed by the external wind conditions.

2.5.1.3 Registrations on the flight recorder show that the aircraft was in a turn with the control column somewhat behind neutral and a tendency to increasing pitch in the seconds prior to the commander giving Full power. In parallel with the engine power increase, the control column was pulled further backward (cf. Figure 9 Time 103197.2–103198.7). The nose position rose to nearly 10 degrees above the horizon in combination with full engine power. This is a recognized method of stopping the descent rate and initiating a missed approach in a wind shear, but at the same time, it would reduce the margin to stall (cf 1.6.6 and 1.6.7).

2.5.1.4 AIBN finds it likely that what the commander perceived and described as his attempt at recovery to fly out of the abnormal situation, was that the engine power increase and the pitch increase took place in parallel (Time 103197.6–103199.8). Accordingly, it was during this increase that the stick shaker activated. The immediate control column movement forward stands out as resolute and possibly somewhat exaggerated. This is natural when something unusual and unexpected happens, such as when the stick shaker activates. AIBN believes the stick shaker probably activated at 103199.8 hours FDR.

2.5.1.5 The assumption that the stick shaker activated *before* the nose of the aircraft "bucked" down, is not in line with the commander's 2015 statement (cf. 1.1.4.4), but fits well with the early written report concerning the incident (cf. 1.1.6.2) and with the first officer's statement (cf. 1.1.5). Another factor that supports this hypothesis is that the erroneous reading on the barometric altimeter was approaching maximum value at this time. This indicates that the angle was then at its highest (cf. 1.11.4.5), which indicates that margin to stalling was at a minimum.

2.5.1.6 The actions initially taken by the commander were instinctive reactions in a stressful situation. It was not obvious to the crew what was happening when the wind shear caught the aircraft. Increasing engine power was essential. Real risk of stalling with activation of the stick shaker during flight is a very rare occurrence. As the situation escalated and there was a need to avoid, or recover from stalling, it was correct and necessary to lower the nose of the aircraft.

2.5.1.7 The situation became particularly serious as the altitude was already low and the problem turned out to be of a more serious nature than the usual correction of temporary turbulence. The first officer's role and intervention are described in more detail in Item 2.7.

2.5.1.8 The procedures that have been prepared and that the pilots practise regularly, contain standardized call-outs, which will support cooperation between the crew in situations where there is no time for dialogue or reflection (cf. 1.6.6). A recognisable call-out such as “GO-AROUND – FULL POWER” would have brought the first officer "in the loop", and could have been the start of better synchronized collaboration to regain control. The fact that the crew members did not communicate during the most critical seconds (cf. 1.1.4.7), indicates that the crew cooperation collapsed in terms of both call-outs and synchronized actions.

2.5.1.9 Both pilots have stated that the incident in Svolvær was unlike the scenarios they have trained for in the simulator. Modern simulators are invaluable aids, but are not necessarily programmed for, or designed to recreate, any situation the aircraft could find itself in. The fact that the crew had never trained for such a scenario, could have contributed to them not immediately recognising the situation as one that necessitated actually aborting the approach.

2.5.2 Assessment of whether LN-WIU stalled

2.5.2.1 At one point, LN-WIU's airspeed became critically low, approx. 5 kt lower than the given actual stall speed (cf. 1.11.3). If one disregards other factors and estimates the angle of attack based only on the registered airspeed, the vertical speed and the position of the aircraft's nose above the horizon, for a short moment a highest angle of up to 30 degrees is indicated.

2.5.2.2 It is; however, impossible to perform meaningful aerodynamic calculations of lift and the wing angle of attack in the critical seconds when the aircraft was exposed to strong variable external forces, increased slipstream and rapid pitch variations. As the aircraft most likely was affected by a strong downward vertical wind component, the angle of attack was probably lower. Likewise, the parts of the wing that were inside the propellers' slip-stream would have had a significantly lower angle of attack.

2.5.2.3 AIBN's analysis of the flight recorder data, in consultation with experts from the aircraft manufacturer Bombardier, does not support the theory that the aircraft stalled. When stalling, you expect to see a significant reduction in G-load. The G-load change pattern in the critical period for LN-WIU does not concur with this. The values did not fall below 1 G in connection with the drop of the nose, and the G-load showed small fluctuations (around 1.2 to 1.3 G). Nor was there at this time any pronounced increase in the vertical speed, which one would expect to see in a stall.

2.5.2.4 However, AIBN does not want to rule out the possibility that the aircraft stalled, thus contributing to the "bucking movement". If so, one must assume that the external forces camouflaged the expected G-load pattern. In any case, AIBN finds it likely that the stick shaker activated, and that the aircraft was on the verge of stalling.

2.5.2.5 Whether the aircraft stalled or not, the increase of engine power and reduction of angle of attack initiated by the commander were crucial in regaining control of the aircraft. The large and resolute control column movement may have been favourable. However, how much the nose should be lowered is a difficult balance, cf. the warning in AFM that one could risk too steep an angle in the recovery if the aircraft actually stalls (cf. 1.6.7.1).

2.5.3 The pull up

2.5.3.1 How quick the pull up could be performed after the nose of the aircraft pointed downward was determined by the airspeed and G–load. A too active pull up, too early (at too low airspeed) could have caused the aircraft to stall at this point and crash into the sea, whereas a too passive or too slow pull up would have resulted in excessive loss of altitude and impact with the sea.

2.5.3.2 The commander's description that he encountered stick shaker activation at the beginning of the climb, indicates that he may have pulled too hard on the control column in relation to the aircraft's angle of attack. The correct reaction in this case is to slack off a bit, as he explained that he did.

2.5.3.3 Pulling the control column backward, which started at 103200.2 hours according to the flight recorder, stands out as the most significant and longest-lasting ”pull up”. AIBN assumes that the commander had experienced the stall warning at this time, and that it was here that he deliberately "held the aircraft down" to accelerate to prevent stalling when climbing above the obstacles in front (cf. 1.1.4.5 and 1.1.4.6).

2.5.3.4 It can be observed that the rate at which the control column was pulled backward, which started at Time 103200.2, briefly declined (duration approx. 0.5 sec) in relation to the starting value, before it again increased (cf. 1.11.4.3). The first adjustment can be perceived as "hesitation", and fits with the explanation that the commander prioritized building up speed (cf. 1.1.4). Airspeed increased quickly whereas the vertical acceleration was more or less constant, which indicates that the margin to stalling was rising. However, the aircraft simultaneously lost altitude rapidly, and the nose pointed downward.

2.5.3.5 It is known that judging height above a uniform surface without known reference points of familiar size, is very difficult. AIBN finds it understandable that the pilots perceived the lowest altitude differently, and that neither of them realized how low they actually were. If they had glanced at the altimeter while it showed an incorrect reading, this could also have had a negative impact on their perception of the situation (cf. 1.11.4.5).

2.6 Sensory illusion

2.6.1 The commander has explained that when the aircraft suddenly lost altitude, his intention was to make a recovery by increasing the airspeed at a low, but safe altitude. He would then pull the aircraft up with sufficient margin to the stick shaker and stalling risk. Consequently, he flew towards the red obstacle light in front of him, while working on regaining control of the aircraft. He has not mentioned having seen the sea below him. He thought the lowest altitude was approx. 300 ft, and believed that the aircraft had started to climb when the first officer took over the flight controls (cf. 1.1.4.4–1.1.4.6).

2.6.2 The flight recorder data showed that the aircraft was building up speed while the nose was in a constant "bucking movement" and altitude decreased to 83 ft (cf. Figure 8). The aircraft had not started to climb at the moment AIBN believes was the likely time of control take-over (cf. Item. 2.7).

2.6.3 Under the conditions at the time, with sparse visual references and with no visible horizon, there is a risk of sensory illusions. Calculations made by FMI showed that the force influence just before, and particularly when, the aircraft accelerated nose down toward the sea, created conditions conducive to somatogravic illusion (cf. 1.16.1.1). TNO arrived at approximately the same conclusion with its model (cf. 1.16.1.2).

2.6.4 Such an illusion would have created an incorrect feeling of the aircraft pointing virtually horizontally or upward, whereas it in reality continuously pointed downward towards the terrain. AIBN is of the opinion that a potential sensory illusion would also have made it difficult to assess whether the aircraft was descending, climbing or in level flight. A single point of light moving around in front of the windshield, and the feeling of sitting comfortably in the seat (vertical acceleration above 1 G) while the nose "bucked" downward, could have been confusing.

2.6.5 The first officer, who was monitoring the instruments and related to the aircraft's artificial horizon, probably did not experience any sensory illusions.

2.6.6 If the commander was exposed to somatogravic illusion, it is easier to understand why the two pilots' explanations diverged as much as they did and why they seem to have experienced the severity of the situation differently (cf. Item 2.2.1).

2.6.7 AIBN believes that the commander, while flying in darkness with sparse visual references, may have been exposed to somatogravic illusion. However, based on the available facts, it is not possible to say with certainty whether this was the case or not.

2.6.8 Furthermore, the Accident Investigation Board has not found any evidence in the flight recorder data which warrants a conclusion that sensory illusion, if any, had an impact on the way the wind shear was handled.

2.7 Take-over of flight controls

2.7.1 Crew cooperation in the event of wind shear entails among other things that PF chooses and calls out *GO-AROUND* ,that is, increasing power to approx. 80% torque and orders PM to set *FULL POWER* (cf. Appendix D). Going to absolute full engine power is possible on Dash 8, and can be used in emergencies to avoid collision with terrain. PM has a duty to insist on a "go-around" and, if necessary, take over the controls if the circling is not stabilized at the latest by 300 ft. above ground (cf. 1.17.3.5). Normally, there will always be dialogue between the crew members, so that PM makes PF aware of deviations and PF him or herself assesses the situation and takes the necessary actions. However, in an experienced acute hazardous situation, where there is no time for call-outs and synchronisation between the crew members, takeover could be the factor that saves the situation from becoming an accident.

2.7.2 In this case, the crew cooperation failed with a view to "call-outs" and synchronized actions (cf. discussion in Item 2.5.1.8). The Accident Investigation Board believes that the situation, as explained by the first officer in 2015, where the aircraft's pitch was very low, just above the sea, and where he had the impression that the commander failed to take action (cf. 1.1.5), indicates that it was correct to intervene. This is in accordance with good Crew Resource Management (CRM), and also in line with how Widerøe trains for CRM.

2.7.3 The Accident Investigation Board believes that it was sensible of the commander of LN-WIU not to oppose takeover of the flight controls, based on the assessment that the situation was in any event resolved (cf. 1.1.4.6). However, takeover of flight controls is a complex issue. It is impossible to give general advice that is correct in all contexts, and this becomes evident when taking into account the risk of sensory illusions (cf. Item 1.16.1.2).

2.7.4 The pilots' perceptions diverge both as regards the timing and the significance which the takeover may have had in avoiding an accident. In Item 2.2.4 the Accident Investigation Board has mentioned the commander experiencing sensory illusion as a potential explanation. The following conditions may also have had an impact:

- *Inertia in the aircraft's movement*
  Mass inertia around the lateral (pitch) axis caused the nose position to reverse to a pitch up, and the aircraft beginning to climb, with a delay in relation to when the climb was initiated by moving the control column backward. This may have obscured the fact that the commander had already implemented the measures the first officer was waiting for.

- *Differences in subjective mental processes*
  It has been a long time since the incident, and some memories have probably been lost. Furthermore, the pilots' attention was directed at different aspects of the situation, and their memories have probably been altered over time. Both pilots have probably perceived the critical phase as longer than what FDR shows. This could have contributed to the first officer feeling that the commander did not act quickly enough, and that the commander believed that the control takeover took place later than it probably did. Taken together, it is the assessment of the Accident Investigation Board that these subjective mental processes on the part of the pilots have contributed to the discrepancies between them regarding a few points.

2.7.5 The first officer's opinion that the aircraft was in the process of crashing into the sea without the commander doing enough to prevent it, can, in AIBN's opinion, at least be partly explained by mass inertia and how the pilots experienced time. The delay of approx. 1.5 seconds could feel like "an eternity" when one fears that one was about to crash. AIBN believes that the first officer may have taken over the flight controls at a time when the commander had started to pull up and the tendency to lose altitude had been reversed, but where the actions taken by the commander had not yet had a pronounced effect. FDR data do not support the allegation that the commander had "*frozen" on the controls*" (cf. the first officer's statement in Item 1.1.5.3).

2.7.6 AIBN compared statements from the crew with FDR data, and believes to have identified the most probable time when the control column was taken over. The time that AIBN believes stands out, is 103201.3 hours FDR. The FDR data show that this time coincides with the hastened movement of the control column backward, the second before the engine controls were pushed all the way forward to stop (cf. 1.11.4.3). At this point, the aircraft's nose was still below the horizon and the loss of altitude had not yet been halted, which concurs with the statement the first officer gave in 2015.

2.7.7 A further indication that this may have been the takeover time, is that in the same tenth of a second, a marked change in control column movement is registered for the aileron. This aileron deflection may be an indication that a hand is on the controls to pull it backwards.

2.7.8 Takeover of the controls most likely did not occur after the aircraft had started to climb. In such case, it would have been after the additional increase in engine power which the crew agree that the first officer initiated. This does not concur with the first officer allegedly having pulled the control column backward with significant force, since, at the time, the control column was on its way forward again.

2.7.9 There is no doubt that the climb was initiated by the commander, but there is uncertainty whether it was he or the first officer who intensified it. If the first officer intervened at Time 103201.3, there is nevertheless no one who knows how the commander would have moved the controls in the following seconds if this had not taken place. This is a fact regardless of whether the commander was experiencing a sensory illusion or not. Bombardier has, however, determined that the tendency had changed at Time 103201.3. Interpolation indicates that the aircraft, with the pull-up that already was under way, would have started to climb in time to avoid collision with the sea, but then with a smaller margin.

2.7.10 AIBN cannot establish for certain whether the extra increased engine power or the last observed adjustment of the control column pull, were crucial for the outcome. AIBN finds that it is not possible to draw any certain conclusions as to whether the first officer's intervention affected the outcome.

2.7.11 AIBN is of the opinion that the joint actions of the crew prevented an accident when the aircraft was exposed to unusually strong wind shear at low altitude. Marginally longer response time and/or less resolute application of engine power would probably have resulted in collision with the sea.

2.8 The importance of the commander being tired

2.8.1 The commander himself informed that he was tired (cf. 1.1.2.2). The Accident Investigation Board believes it was favourable to mention this as a "caution" to the rest of crew, without being relieved from one’s responsibility to assess whether one are "fit for flight".

2.8.2 The AIBN asked the commander to provide several details concerning his sleep during the night, length of his working day, activities etc. AIBN has considered the information, and believes that the combination of insufficient sleep and a long, hectic day would make it likely that he was both tired and worn out. The darkness may also have had a negative impact on the tiredness. On a positive note, the flights were short and there was little monotony. Challenging conditions and uncertainty as to whether they could land may have had a positive impact in the form of higher autonomous activation.

2.8.3 FMI does not preclude that tiredness may have had a negative impact on the commander's situational awareness and potentially made him more exposed to sensory illusions. However, they also emphasize that sensory illusion is something anyone can experience, regardless of fatigue or level of experience (cf. 1.16.1.1).

2.8.4 The overall judgement is that the commander probably was tired and worn out, but AIBN cannot find support for asserting that this had a negative impact on his performance in the relevant incident.

2.9 Assessment of flight operations conditions

2.9.1 Wind conditions and limitations

2.9.1.1 Both forecast (TAF) and reported (METAR) wind conditions in Svolvær meant that one could not take a landing for granted. SIGMET advisory about the risk of strong local turbulence at lower levels, meaning great care had to be taken (cf. Item 1.7.3.3) both in connection with planning and execution of the flight. Weather forecast seems to have been good.

2.9.1.2 The procedure applied by the crew was the same that is usually followed during squally weather when suitable conditions are expected to only be temporary (cf. Items 1.7.2.2 and 1.10.3.1). An overall assessment is made before flying towards the destination. If there is an alternative airport nearby with acceptable landing conditions, one can choose to divert, if the wind is too strong and/or variable compared with the company's limitations and the conditions do not seem to improve within a reasonable time.

2.9.1.3 Based on reports prepared immediately after the incident took place, there is reason to assume that the moderate wind force subsequently referred to by the pilots, was instant wind (cf. 1.1.6.2 and 1.1.9.1). Hazards related to special local conditions, variable wind conditions and issues relating to communication of wind and instant wind in connection with landing, have been discussed in detail in the Accident Investigation Board's report on the air accident at Hammerfest airport on 1 May 2005 involving DHC-8-103, LN-WIK (SL 2009/22).

2.9.1.4 A dilemma may occur if the wind changes after the approach has started. The decision to abort an approach that has already started must be taken on a case-by-case basis. Information about deviating values from different anemometers can also make it difficult to maintain the mental picture. AIBN would claim that thinking that the circling pattern can function as a holding position while awaiting a more favourable 2-minutes' wind, is to push the limits (cf. the written report enclosed in 1.1.6.2). This incident is an important reminder of the risk factors associated with manoeuvring at low altitude above terrain with scarce visual references, in darkness and turbulent air. Any waiting must take place at a safe altitude in established holding patterns for instrument flying.

2.9.1.5 Widerøe has based its wind limitations in Svolvær on long experience. According to leading flight operations personnel, Svolvær is not an airport with particularly difficult wind conditions in the approach sector. The disruptions one wants to avoid by the restrictions that have been set, primarily occur during the short final approach (cf. 1.10.3).

2.9.1.6 The incident in Svolvær was not a classic landing incident resulting from difficult local wind conditions, and AIBN believes that the learning potential is not primarily from whether the wind was inside or outside the limitations when the approach formally started. The wind shear from the cumulonimbus cloud had no direct connection with the wind restrictions for approach and landing.

2.9.2 Approach speed

2.9.2.1 In the 2015 interviews, the commander and first officer seemed to have different opinions on what the speed should be during the approach (cf. 1.1.3). AIBN cannot find any conclusive guidelines regarding what was correct in the company's 2010 procedures (cf. Appendix C), but leading flight operations personnel in Widerøe have stated that it would be possible and reasonable in given situations to increase the speed somewhat to ensure a slightly greater margin to stalling speed. As regards this case, the company believed that it was correct to not increase the speed beyond 1.4Vs, as there was no turbulence to speak of during the approach (confirmed by flight recorder data).

2.9.2.2 In isolation, higher approach speed provides greater margins to wind shear and turbulence. However, the speed must not be increased so much that it becomes difficult to follow the defined circling pattern, which is something that the pilots must control visually. Just before landing, speed must be reduced to the speed that has been used as a basis for the landing calculation (normally 1.3 x Vs above the edge of the runway), to ensure that this type of aircraft is able to stop with sufficient margin on a runway which is barely 800 metres long.

2.9.2.3 If one chooses to increase the margins in one area, they might be weakened in other areas. One example is choosing to land "uphill" even if it entails circling (cf. 1.10.3). To re-examine the considerations that were made with regard to approach speed involves examining the complex big picture relating to the "short field concept", and go beyond the framework of this investigation.

2.9.3 "Precision circling"

2.9.3.1 The Accident Investigation Board also considered whether there were elements of the company's circling procedures or the concept of “Precision circling” that it would be relevant to point out in this case (cf. Chap. 1.17.3). Without making terminology a main issue, AIBN would like to point out that the term "precision" may be perceived as misleading here, as the position support in the circling pattern in Svolvær is not very precise. The fact that the circling pattern has been designed based on a maximum speed of 109 KIAS, illustrates the obstacle situation and considerations that have been made (cf. Figure 1). The margins are small. Consequently, the precision requirements for execution will be high.

2.9.3.2 Leading personnel in the company responsible for flight operations, training, navigation as well as performance have stated that it is considered unproblematic to keep within the defined area with prescribed ground clearance using the current aids (course indication, DME, circling lights and double PLASI). Various risk factors have been assessed against each other, and Widerøe has had good experience with the chosen solution (cf. 1.17.3).

2.9.3.3 Based on what the pilots could remember when they made their statements to the Accident Investigation Board, it may seem as if their views differed prior to the incident as regards when the minimum altitude should be abandoned. The procedure states that the altitude profile must be included in the brief, and that maintaining the planned altitude is one of the parameters that the PM must monitor (cf. 1.17.3.4). No specific altitudes had been indicated for Svolvær, and Widerøe did not find this necessary, as 580 ft. is low in any case.

2.9.3.4 The Accident Investigation Board agrees that the need to designate specific altitudes is reduced when the circling altitude is low, but believes that it is essential to have a common understanding of the altitude profile when circling in darkness. If it is correct that the first officer expected a descent towards 300 ft in the turn, whereas the commander intended to keep the aircraft at 600 ft, e.g. until PLASI became visible, and this was not included in the briefing, one has dropped a callout which is would contribute to early detection and correction of altitude deviations. Such a callout can help the PF detect unwanted loss of altitude when there are scarce visual references. This observation is also relevant in connection with FMI's statement that the current procedures provide little support (non-routine callouts) from the PM in Zone B in the circling pattern (cf. 1.16.2.5).

2.9.4 <u>Terrain warning system as safety barrier</u>

Neither pilot mentioned remembering having heard warnings or seen warning lights from the terrain warning system (EGPWS). Nor was this registered in the FDR. The way the system works indicates that one could expect warnings concerning excessive descent speed in relation to the relevant altitude, unless the signal was cancelled by activation of the stick shaker (cf. 1.6.4 and 1.6.5). The audio warning may also have gone unnoticed due to stress. In this incident, where everything took place very fast, and where during the experienced visual conditions there was danger of stalling at low altitude, any terrain warning would probably have been transitory and without practical significance.

2.10 Vulnerability when circling in darkness

2.10.1 The Accident Investigation Board can see that the circling procedure is based on thorough considerations, but has noticed that the lack of horizon and poor chance of spotting contours on the ground seem not to have been emphasized. Issues in connection with visual references during approach in darkness were also discussed in the Accident Investigation Board's report on the air accident at Namsos on 27 October 1993 involving DHC-6-300 Twin Otter, LN-BNM (SL 1996/07 page 77).

2.10.2 The investigation of the incident involving LN-WIU has identified three main areas relating to vulnerability when circling in darkness:

- Issues associated with monitoring the altitude in the base turn (cf. Items 2.5.3.5, 2.9.3 and 2.9.4).
- Lack of aids to detect cumulonimbus clouds in darkness (cf. Item 2.4).
- Problems associated with sensory illusions (cf. the enclosed reports from FMI).

2.10.3 AIBN believes that the possibility of further reducing vulnerability associated with the combination of darkness and inclement weather, should be evaluated. "Invisible" cumulonimbus clouds and sensory illusions are not threats in good weather and in daylight with a visible horizon, but should be taken seriously when the conditions are challenging. Missed approaches in darkness may constitute an increased risk as they often start off with visually-based manoeuvring while climbing in turns near the terrain (as was the case in Svolvær, cf. 1.10.3), which is challenging even in daylight and good flying conditions.

2.10.4 The risk to flying caused by sensory illusions has been known ever since the dawn of aviation. However, awareness of this has traditionally been higher in military aviation and in connection with light single pilot aviation. The Accident Investigation Board believes that the investigation of this incident and Boeing's initiative to raise awareness of sensory illusions (cf. 1.16.1.2) serve as reminders that this issue should be given more attention, also with regard to heavy, civil aviation.

2.11 Assessment of measures and safety margins

2.11.1 The Accident Investigation Board's investigation has not uncovered systematic failure or obvious deficiencies that could have had an impact on the sequence of events or causal relations.

2.11.2 Several relevant safety barriers have been strengthened since the incident involving LN-WIU. Double PLASI, circling lights, turbulence warning, etc. were put in place as a result of the continuous preventive air safety cooperation between operators and Avinor. Goal-oriented simulator training in order to raise awareness concerning sensory illusions was also planned, independently of this specific incident and the findings in this investigation (cf. 1.18.1).

2.11.3 The Accident Investigation Board believes that safety margins in the circling pattern to Runway 19 in Svolvær have been improved since the incident took place in 2010, but will nevertheless encourage Widerøe to evaluate the opportunities to further reduce the residual risk on the base-segment in Svolvær. In this connection, reference is made to the proposal mentioned in the FMI study (cf. 1.16.2 and Appendix H).

2.11.4 This investigation concerns Svolvær in particular, but a learning organisation will, as part of its safety work, use experiences from "local" findings to assess whether there is a need for measures at other destinations or operations in general. AIBN encourages Widerøe to also apply the lessons learned in this incident in a broader perspective. In particular, focus should be on the risk of sensory illusions in combination with complex and demanding missed approach procedures.

2.12 Why did it turn out well?

2.12.1 It is also possible to discuss this incident by asking the question *why did it turn out well* as opposed to *why did it go wrong*. By switching the perspective, the Accident Investigation Board believes that we can achieve additional learning about what it takes to ensure that similar critical situations turn out well, after all. Such a perspective is in line with a systemic approach to safety and the discipline of *resilience engineering*[16]. This is about identifying and reinforcing the positive capacities of people and organisations which enable them to adapt efficiently and safely under pressure. Safety collaboration between organisations is also an important part of this picture (cf. 2.11.2).

2.12.2 People, at all levels of an organisation, create safety in systems through practice. This means that safety is not just about the absence of something, but the presence of *something*. This *something* is the ability to adapt to changes, conflicts and disturbances,

[16] The inherent ability of a system to adjust its function before, during or after changes and disturbances, so that it can maintain the necessary operations in both expected and unexpected conditions.

without it leading to collapse and catastrophic failures[17]. AIBN believes that this incident is an example of this.

2.12.3 It is normal that individual performance varies, and unfortunate coincidences and external circumstances will lead to unwanted situations. Selection, standardized procedures, extensive training, monitoring and follow-up are methods of controlling the variations. Intimate knowledge of local conditions and knowledge of the technical systems are important to be able to make sound assessments and determine relevant restrictions.

2.12.4 The Accident Investigation Board believes this incident is an example of something that actually worked, given the demanding operations with small margins – and not just of something that went wrong. The incident shows that technical barriers (for example the stick shaker), redundancy (in the form of two pilots), as well as the pilots' skills (substantial experience, relevant training, courage to assume responsibility), together amounted to a system which handled an unexpected and critical situation in a manner that averted an accident.

2.12.5 The incident also serves as a reminder that operators and pilots with thorough local knowledge, experience and training beyond current government requirements are better equipped to handle critical situations such as this one in a safe manner.

3. CONCLUSION

LN-WIU was exposed to severe wind shear from a cumulonimbus cloud (microburst). This resulted in the aircraft loosing speed, forcing it down towards the terrain as it entered the turn to final approach during visual circling in darkness. The wind shear could perhaps have been predicted, but it would have been difficult to detect with the equipment that was available.

The commander reacted quickly. First he parried by increasing the engine power, but the aircraft was still on the verge of stalling at low altitude. The commander then responded by resolutely pushing the control column forward. It was correct and necessary to lower the nose of the aircraft to prevent, or recover from, stalling.

The manoeuvring to regain control of the aircraft took place with sparse visual references and with no visible horizon. During a few critical seconds in the recovery phase, the commander may have been exposed to somatogravic illusion. However, the Accident Investigation Board has not found any evidence which warrants a conclusion that sensory illusion had an impact on the way the wind shear was handled.

At some point, the first officer intervened and took over the flight controls. Based on the available facts, it has not been possible to determine whether this affected the outcome.

---

[17] Dekker, S., Hollnagel E., Woods D. and Cook R. (2008): *Resilience Engineering: New directions for measuring and maintaining safety in complex systems. Lund University School of Aviation*.

The Accident Investigation Board is of the opinion that the combined actions of the crew averted an accident. A marginally longer response time and/or less resolute application of engine power would probably have resulted in collision with the sea.

3.1 Findings

3.1.1 Flight operations procedures

a) Both crew members had valid licences and had completed training, so they were qualified for this specific flight.

b) The crew members agreed that the wind was within the company's current limitations at the start of the approach. The turbulence was not particularly strong, and thus it was within the company's standardized procedure not to add on airspeed during the approach.

c) The flight continued normally until the aircraft, during circling for landing on runway 19 was exposed to external forces, in the form of severe wind shear from a squall (microburst), possibly in combination with terrain-induced turbulence.

d) The critical situation occurred suddenly, and was resolved after barely 10 seconds.

e) The first officer called "Check speed" twice during circling, the second time was probably just before the wind shear took hold of the aircraft.

f) The aircraft lost altitude and airspeed, despite the commander, who was flying the aircraft (PF), initiating recovery with full engine power.

g) The crew had not briefed when to leave the circling altitude, and do not appear to have had any common understanding of this.

h) Increasing the engine power was essential to correct for the wind shear that caused the airspeed to drop dramatically.

i) The airspeed fell further to a critically low value of 72 kt. The situation thus escalated and there was a need to avoid/recover from stalling by lowering the nose (lowering the wing's angle of attack).

j) Both flight crew members have explained that the stick shaker (stall warning) activated, but since the flight recorder did not have information about this warning function, it has not been possible to verify when it activated.

k) The flight recorder data show a marked forward movement of the control column, which is assumed to be the commander's response to the stall warning (stick shaker).

l) The control column was resolutely pushed forward for a few tenths of a second, directly followed by a reverse movement.

m) Then the control column was continually pulled backward at a varying rate for approx. 3 seconds. The first observed rate adjustment may indicate a short reduction to build up speed, whereas the following adjustment is an intensification of the pull up.

n) During the course of approx. 4.5 seconds, the nose position of the aircraft moved downward continuously from approx. 10 degrees above the horizon to approx.

14 degrees below the horizon, and up again to approx. 10 degrees while airspeed continued to increase, and altitude decreased rapidly.

o) The barometric altimeter showed an incorrect (too high) reading in the most critical phase.

p) The sink rate was more than 2,200 ft./min in the seconds immediately before the loss of altitude was stopped and the aircraft started to climb.

q) The aircraft lost approx. 270 ft. in 8 seconds and, at its lowest, was 83 ft (25 m) above the terrain.

r) The airspeed had increased to approx. 140 kt when the aircraft started to climb.

s) The highest registered vertical acceleration (G-load) was 2.7 G, when the aircraft was at its lowest.

t) The first officer increased engine power from full power to the maximum available just before the altitude above the terrain was at its lowest.

u) At one point, the first officer also took over the flight controls on his own initiative and has explained that this was necessary as the aircraft had a very low nose position right above the sea, and he had the impression that the commander did not react.

v) Standardized callouts and synchronisation were omitted in the seconds from when speed fell until after the first officer took over the controls.

w) The first officer probably took over the flight controls at a time when the commander had initiated a pull up and the tendency to lose altitude had been reversed, but where the actions taken had not yet had a pronounced effect.

x) The crew members have given differing descriptions concerning when the takeover of controls occurred, and as regards the necessity of intervening.

y) The flight recorder did not have parameters for/could not verify who moved the flight controls (from which side of the cockpit). Consequently, it has not been possible to verify for certain when the first officer took over the controls.

z) The time of the takeover is assumed to have been within those seconds when the commander deliberately let the aircraft accelerate to avoid a new, imminent stalling in the pull up that he was planning and that he thought would take them to a secure altitude above a red obstruction light that he could see ahead of him.

aa) The commander may have experienced a somatogravic illusion, and may, for a few seconds, have had an incorrect perception of the aircraft attitude. However, his actions to regain control were correct, and within what the company considers normal variations.

bb) A somatogravic illusion, if any, experienced by the commander may help explain why the crew members perceived the situation differently, but inertia in the aircraft's movement and differences in subjective mental processes may also have been influencing factors.

cc) The commander felt tired and the other crew members noted that he seemed tired, but AIBN cannot find any factual support for asserting that this had a negative impact on his performance in the relevant incident.

dd) The available facts are insufficient for the AIBN to be able to determine with certainty which of the pilots did what during the seconds in question. Nor has it been possible to determine the specific time and sequence of actions and what effect each action had in isolation.

ee) The investigation has not yielded any results that make it possible to draw any definite conclusions regarding whether the first officer's intervention had impact on the outcome.

ff) The combined actions of the crew resulted in the aircraft starting to climb in time to avoid collision with the sea.

3.1.2 The aircraft

a) The aircraft's mass and the location of its centre of gravity were within the permitted limits at the time of the incident.

b) No technical faults or irregularities on the aircraft which may have caused the incident or affected the sequence of events were identified.

c) The loads on the engines and propellers did not indicate a need for particular inspections.

d) FDR data showed that the vertical acceleration briefly reached 2.7 G, which mandates a structural inspection of the aircraft.

e) LN-WIU was in for a structural check on 24 March 2011, without discovery of structural damage.

3.1.3 Instruments/equipment

a) The aircraft had a functioning terrain warning system (EGPWS), but this is not presumed to have had an impact on the sequence of events.

b) The aircraft's stall warning system (stick shaker) activated and may have contributed to PF lowering the nose, thus preventing/recovering from stalling.

c) Data from the flight recorder was secured and provided very useful information for the investigation.

d) The aircraft had a weather radar, but it was not suitable for detecting cumulonimbus clouds or strong squalls in this case.

e) The aircraft did not have any special equipment on board that could detect wind shear, nor is this required.

3.1.4 The airline

a) Long before this incident, the airline had identified circling in darkness as a safety-critical scenario at Svolvær Airport, and had in cooperation with other actors worked to put into place double PLASI, turbulence warning and circling lights.

b) The airline could expand the circling pattern subsequent to a couple of the above actions were in place, and has subsequently, with the aid of their flight safety programme (Flight Data Monitoring), been able to document favourable effect, among other things in the form of reduced occurrence of unwanted excessive banking.

c) The investigation has not uncovered systematic failure or obvious deficiencies on the part of the company that could have had an impact on the sequence of events or causal relations.

3.1.5 The airport

a) Svolvær Airport has challenging natural conditions, and is classified as category C, which entails special requirements for the operators.

b) There was no anemometer in the terrain in the area when the incident occurred, and no installations on the ground could detect wind shear or cumulonimbus clouds in darkness.

c) The airport could refer to several relevant risk-reducing measures (double PLASI, circling lights, anemometer) that had come about as a result of preventive flight safety work in cooperation with the airlines.

d) The investigation has not uncovered systematic failure or obvious deficiencies on the part of the airport that could have had an impact on the sequence of events or causal relations.

4. SAFETY RECOMMENDATIONS

The investigation is closed without any safety recommendations being proposed.

AIBN will nevertheless encourage Widerøe to consider whether further reduction of the residual risk in the base segment in Svolvær is possible. In addition, AIBN encourages Widerøe to apply the lessons learned from this incident in a broader perspective (cf. Item 2.11.4).

Accident Investigation Board Norway

Lillestrøm, 22 November 2016

APPENDICES

Appendix A: Relevant abbreviations

Appendix B: Mass and balance calculation

Appendix C: Excerpts from the company's Normal Procedures

Appendix D: Excerpts from the company's Abnormal Procedures

Appendix E: FDR parameter plots for the entire flight from Bodø to Leknes

Appendix F: Analysis of the events during Widerøe's flight 814 from Bodø airport to Svolvær Airport Helle on 2 December 2010

Appendix G: Final report on SD analysis of incident with DHC-8 at Svolvær Airport Helle, Norway 2 December 2010

Appendix H: Report relating to visual circling in darkness onto runway 19 at Svolvær Airport Helle

APPENDIX A: RELEVANT ABBREVIATIONS

AFIS	Aerodrome Flight Information Service
AFM	Aircraft Flight Manual
AIP	Aeronautical Information Publication
AMM	Aircraft Maintenance Manual
AOA	Angle of Attack
AOC	Air Operator Certificate
ATPL	Airline Transport Pilot Licence
CPL	Commercial Pilot Licence
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
DLI	Dead Loaded Index
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
EGPWS	Enhanced Ground Proximity Warning System
EHSI	Electric Horisontal Situation Indicator
FAA	Federal Aviation Authority
FDM	Flight Data Monitoring
FDR	Flight Data Recorder
FL	Flight level
FMI	Flymedisinsk institutt (Institute of Aviation Medicine)
hPa	Hectopascal
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organization
IGA	International General Aviation
IMC	Instrument Meteorological Conditions,
IPPC	Internet Pilot Planning Centre

ISASI	International Society of Air Safety Investigators
KCAS	Kt Calibrated Air Speed
KIAS	Kt Indicated Air Speed
Kt/knot(s)	Nautical miles per hour
LDA	Landing Distance Available
LOC	Localizer
LWD	Left Wing Down
MDA	Minimum Descent Altitude
METAR	Aviation routine weather report (in meteorological code)
MOC	Minimum Obstacle Clearance
NTSB	National Transportation Safety Board
OM	Operations Manual
OPC	Operator Proficiency Check
PC	Proficiency Check
PF	Pilot Flying
PLASI	Pulse Light Slope Approach Indicator
PM	Pilot Monitoring
PNF	Pilot Not Flying
QNH	Altimeter set to show the altitude above sea level when standing on the ground
RM	Route Manual
SHT	Statens havarikommisjon for transport (AIBN - The Accident Investigation Board Norway)
SIGMET	Significant Meteorological Information
TAF	Weather forecast for airport (in meteorological code)
TED	Trailing Edge Down
TEU	Trailing Edge Up
TSB	Transportation Safety Board
UTC	Co-ordinated Universal Time

V_{FE}	Maximum flap extended speed
V_{MCL}	Minimum control speed, landing
V_{REF}	Landing reference speed
V_S	Stall speed

Appendix B: Mass and balance record prepared after the incident

Loadsheet and Loadmessage
All weights in kilos

Address: SVJKLWF

From	Originator	Flight	A/C reg.	Version	Crew	Date
BOO	BOOKLSK	WF814	WIU	WF DH139	2/1	2/12-10

				Zero Fuel	Take Off	Landing
Basic Weight	10395	Maximum Weights for		14515		15377
Crew	245					
Pantry	45	Take Off Fuel (+)		1350	Trip Fuel (+)	181
Dry operating weight	10685	Max. allowed T.O.W. lowest of a, b, or c		a 15865	b 15966	c 15558
Take off Fuel (+)	1350	Operating Weight (-)				12035
Operating Weight	12035	Allowed Traffic Load				3523

Dest.	No. of passengers Adults M	F	Ch	I	Cabin bag.		Total	Distribution - Weight 1	2	3	4	5	6	Cabin
SVJ	30	5				B	253	253						

Supplementary Info for Crew

Totals	30	5			253	253
Passengers weight					2695	

Passenger Boarding	TOTAL	LOAD	CABIN LOAD	CARGO	MAIL
35	35	253	—	—	—

Allowed Traffic Load: 3523
Total Traffic Load: 2948 (-) 2948
Underloaded before LMC: 575

ALT:
END:
ETE:

	Max.	
Dry Operating Weight (+)		10685
Zero Fuel Weight	14515	13633
Take off Fuel (+)		1350
Take off Weight	15966	14983
Trip Fuel (-)		181
Landing Weight	15377	14802

Last Minute Changes

Dest.	Specification	Cl Cpt	+/-	Weight

L M C total +/-

Balance and Seating Conditions

Section	Restriction	
E	min. 9 pax	DOI 32,6
RFS	BLK	DLI 36,6
		LIZFW

NTTL
NTOW

Security Search Yes / No Time:

Previous Station: Captains Signature:

Prepared by: [signature]
Approved by

EN SNAP-OUT BLANKETT FRA WITTUSEN & JENSEN - POSTBOKS 115 KALBAKKEN, 0902 OSLO - TELEFON 22 90 20 00
818722.01M

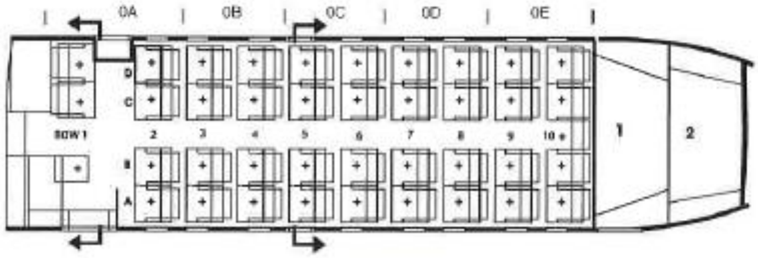
widerøe

DASH 8 SERIES 103

Flight No WF814
Date: 2/12-00

BALANCE TABLE I

39 PASSENGER VERSION

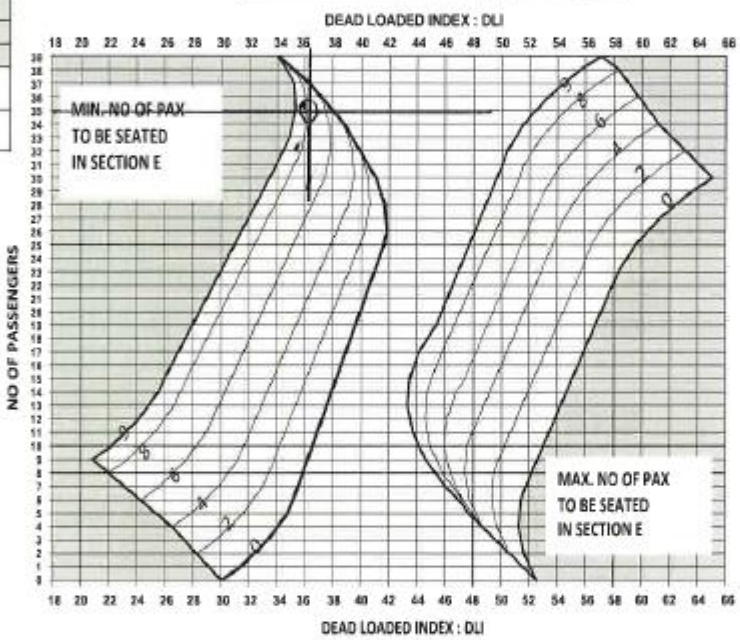


AFT CARGO COMPARTMENT INDEX		
LOAD IN KG	SECTION 1	SECTION 2
1 - 50	1	1
51 - 100	2	2
101 - 150	2	3
151 - 200	3	4
201 - 250	4	5
251 - 300	5	6
301 - 350	6	8
351 - 400	7	9
401 - 450	7	10
451 - 500	8	
501 - 550	9	
551 - 600	10	
601 - 650	11	
651 - 700	11	
701 - 750	12	
751 - 800	13	
801 - 850	14	
851 - 900	15	
MAX PR. SECTION	900	450
MAX TOT. WEIGHT	908 KG	

INDEX CORRECTIONS:
OBSERVER: −2
WARDROBE: −1

BALANCE CALCULATION	-	+	-	+
DOI		32,6		
CARGO SECTION 1		5		
CARGO SECTION 2		—		
OBSERVER	—			
WARDROBE	-1			
TOTAL	-1	37,6		
	↳ -	1	↳ -	
DLI		36,6		

NOTE:
THE BALANCE TABLE IS BASED ON THE PRINCIPLE THAT THE PASSENGERS ARE SEATED EVENLY THROUGHOUT THE CABIN



INDEX FORMULA:
Basic Index:

$$B.I. = \frac{A/C\ Weight\ (STA-408{,}2)}{10.000} + 50$$

Index of loaded items:

$$I.C. = \frac{Item\ Weight\ (STA-408{,}2)}{10.000}$$

REF. PSM 1-8-6

ISSUE NO. 6 - SEPT. - 13

Appendix C: Abstracts from some of the company's Normal Procedures valid in December 2010:

- *Approach, Landing, Preparation and Briefing*
- *Circling Approach*
- *Approach Briefing and Speeds*
- *Speed Corrections for Approach and Landing*
- *Wind Shear*
- *Missed Approach*
- *Deviation Calls, Different Phases of Flight*

2.4.7 Approach, Landing, Preparation and Briefing

2.4.7.1 General

Common basics for a successful approach are:

- Good descent planning.
- Careful consideration of approach charts.
- Accurate flying and good crew co-ordination
- Maintain altitude and a speed according to stabilized approach concept during the approach.
- If the aircraft tends to deviate from desired glide path or speed, correct this immediately by small power changes.

A precise approach technique is required not only to ensure safety during the approach itself, but also to bring the aircraft to a safe stop after touchdown. This is especially important on short runways or when adverse weather and/or runway condition exist.

- All relevant navigational aids shall be used and crosschecked in order to minimize the risk of let down/approach on an incorrect track or wrong runway.
- The power levers shall be operated by PF.
- The condition levers shall be operated by PNF upon order from PF.
- Gear and flaps shall be operated by PNF upon order from PF.
- PNF shall closely monitor airspeed during the approach.

When executing an instrument approach in weather close to minima, a high degree of precision is imperative.

- It is the duty of PNF to insist on a go-around and if necessary take over the controls if an approach is not stabilized at 500 ft AGL or 300 ft AGL at the latest on a circling approach.

The space available for corrections at low altitudes is limited.

- Steep correction turns close to ground should be avoided.

2.4.14.6 Circling Approach

2.4.14.6.1 General

Before a circling approach is commenced:

- Review the complete circling procedure, the missed approach procedure, and the use of navigation aids that can support the procedure.

During the approach, while descending to circling altitude the AFCS is used according to the procedures for non-precision or precision approach.

- During an ILS approach, after GS capture, use ALT to level off at circling altitude.
- When visual, select HDG mode to manoeuvre for a low circuit.
- Fly the approach to circling altitude with flaps 15 and gear down.
- At MDA or higher, turn L/R to position the aircraft onto a comfortable downwind.
- Adjust baseleg to roll out on final at minimum 300 ft on a normal glide path Flap 15 or 35. A special Briefing is required at some short fields.
- Reduce speed to cross the threshold at VREF

2.4.14.6.2 Circling Procedure

During circling the airplane shall be established in the approach configuration, Flap 15°, gear down and before landing checklist completed. Circling speed according to speed table (1,4 VS).

It is recommended to fly the circling procedure with Autopilot engaged until starting turn to base/final. Autoflight enables PF to maintain visual contact throughout the procedure while maintaining speed, altitude and attitude. PNF is responsible for monitoring instruments and call deviations from speed and briefed altitudes, position and distance.

2.4.10 Transition Level

The Transition Level checklist shall be complete latest when passing TL, if descending from Flight Level, or latest when commencing descent if cruise has been performed at altitude (QNH).

When passing Transition Level the following mandatory calls shall be given;

PNF call "TRANSITION LEVEL"

PF call "QNH........ ft. "

PNF call "SET AND CROSSCHECKED"

PNF Call; "CHECKLIST COMPLETE".

2.4.11 Approach

2.4.11.1 Approach Briefing and Speeds

Approaching destination, the crew shall re-evaluate the weather situation and if necessary recalculate the required landing distance.

Max recommended airspeed below 10.000 feet in TMA/Initial Approach is 235 knots (turbulence 180/190 knots), reducing to 210 knots on "base" before intercepting final course, reducing to 180 knots.

Established on inbound final course inside 10 NM from touchdown, a gradual reduction in airspeed and change in configuration will take place to be stabilized not later than 500 ft above minima, at target speed 1.4 V_S max. 1.4 V_S + 20 kts. Target speed at minima is 1.4 V_S for flaps 15. Target speed at threshold is V_{REF} for landing flaps.

2.4.11.2 Speed Corrections for Approach and Landing

Speeds shall be corrected as follows:

- Correct V_{REF} for wind by adding 5-10 kts, when max wind speed is above 10 kts.
- Correct V_{REF}, V_{FRI} and V_{FTO} when flying in Icing Conditions.
- Correct V_{REF} for malfunction.
- Decrease speed to V_{REF} at threshold when corrected for wind.
- If landing speed are corrected for icing or malfunction, it shall be reflected by the speed bug setting.
- If more than one correction is required, then only the largest correction shall apply.

2.4.11.3 Wind Shear

In case of reported severe wind shear or weather conditions where severe wind shear conditions are present.

- Do not approach and land,
- If possible, delay the approach until weather conditions improve, or proceed to an airport with more favourable weather conditions,

If weather conditions are such that wind shear conditions may be expected during approach and landing:

- Use the most favourable runway and/or approach sector.
- Use Flaps 15 for landing, runway length permitting.
- The PNF should monitor speed, rate of descent, pitch altitude, and power setting until the initiation of the flare.
- Do not make large power reductions until the beginning of the flare,

SPEED Briefing

- Decide and brief at an early stage on the maximum IAS that you will accept on short final in order to land. V_{REF} + 10 at runway edge should not give any trouble in stopping on a minimum runway length provided correct landing/stopping techniques are used.
- Landing distance increases dramatically if floating. Make a determined landing at the correct touchdown point.

- If a sudden, large airspeed increase is experienced on final approach, do not reduce power drastically. Very often, a drop in airspeed follows shortly after, due to windshear variations. In cases where this does not hold true, and the speed stays over the value that you have agreed upon in the approach briefing, a go-around must be made.

If inadvertently exposed to wind shear during approach causing speed loss and/or increased rate of descent:

- Simultaneously, select go around, disengaging the autopilot and if required, advance power levers to the mechanical stops to arrest descent.
- Increase the pitch altitude by rotating the aircraft smoothly and steadily to achieve V2.
- Trade speed for improved climb capability in order to prevent further altitude loss.
- Do not accelerate back to final approach speed.
- The stick shaker may activate at pitch attitudes lower than normal.
- Pitch attitude must be reduced just enough to silence the shaker.
- Do not change aircraft configuration until the vertical flight path is under control.
- Be prepared for penetration of additional areas of horizontal wind changes and /or vertical wind activity.

If wind shear has been experienced inform ATC.

2.4.11.4 Approach in Icing Conditions

Maintain minimum 160 knots during icing conditions while in clean configuration.

Make a normal approach with corrected VREF.

2.4.11.5 Automatic Approach

The PF should keep the autopilot engaged down to minimum altitude:

- In low visibility and contact close to MDA/DA/DH.

This applies as long as the aircraft is:

- Properly aligned on the localizer.
- Within 1 dot above/below glide slope.

If no contact MDA/DA/DH:

- Perform a missed approach without delay.

When flying automatic approaches below 1500 feet:

- Keep hands loosely on power levers and control wheel and feet on rudder pedals.

2.4.11.6 Manual Approach

Manual approaches may be flown if conditions are not marginal.

2.4.12 Stabilized Approach / Landing

All approaches shall be stabilized latest 500 feet above minimums in instrument meteorological conditions (IMC), and by 500 feet above airport elevation in visual meteorological conditions (VMC).

Max RPM shall be set latest when passing stabilized approach gate.

The aircraft shall be stabilized for landing when passing the runway threshold, for short field, runway edge.

The following actions are considered a procedure not disrupting the Stabilized Approach Concept:

- Selection of flap 35 for landing
- A change of the aircraft flight path to follow a PLASI/APAPI or PAPI.

2.4.12.1 Missed Approach

The missed approach can be flown either-conventionally (without FMS) or via FMS.

If the missed approach text states "FMS approved" then it should be flown via FMS. (After commanding "GEAR UP", PF shall command "SELECT LNAV". Then the command bar/autopilot can be used for the entire missed approach.)

PNF shall monitor conventional nav aids during missed approach.

2.4.12.2 Associated Calls

PNF shall actively use deviation calls, as required, to assist PF in meeting and maintaining the applicable stabilization criteria.

When arriving at the 500 gate, PNF shall verify that aircraft is Stabilized within approach criteria and call: **"Stabilized" and PF shall call; "Checked"**

Note: Small deviations from speed and sink rate are acceptable provided immediate corrections are made.

If the criteria are not met, an immediate Go-Around shall be executed.

PNF shall Call; "Go Around" and PF shall Call; "Go Around Set Power___ (TQ) Flap 15" and execute Go Around procedure.

If pitch angle is greater than 5 degrees at landing flare, a pitch call shall be given to inform the PF of corrective action. As an example, if the pitch angle is 6 degrees, PNF shall call "Pitch 6". PF shall call "Correcting".

If the stabilized criteria are not met, an immediate Go-Around shall be executed.No deviations are acceptable.

2.3.16 Deviation Calls, Different Phases of Flight

ACTION	PF	PNF	PURPOSE
Bank angle exceeds 30°.	"CORRECTING"	"BANK"	Bank awareness.
Any deviation from intended lateral or vertical flight path.	Explain why deviation is made.	Verify and accept deviation.	To ensure both pilots agree on the deviation.
Any improper FGC or FMS selection.	Correct the improper selection.	Bring attention of the improper selection made.	Mode awareness.
1 dot localizer or 5° VOR/NDB deviation.	"CORRECTING"	"TRACK"	Correct the deviation.
1 dot glide slope deviation.	"CORRECTING"	"ABOVE/BELOW GLIDE SLOPE"	Correct the deviation.
Altitude deviations ±100 ft	"CORRECTING"	"ALTITUDE ABOVE / BELOW"	Altitude awareness
Speed deviation ± 10 kts	"CORRECTING"	"SPEED HIGH / LOW"	Correct the deviation.
Briefed V_{REF} - 0 / +5 kts	"CORRECTING"	"SPEED HIGH / LOW"	Correct the deviation.
At 500ft above minimums and below	"GO AROUND, SET POWER....(TQ) FLAP 15"	If aircraft not within criteria for stabilized approach configuration. "GO AROUND "	To avoid aircraft continues flight outside criteria for stabilized approach.
PLASI deviation from 300 ft AGL to runway edge	"CORRECTING"	Pulses of white "above" or pulses of red "below": "ABOVE/BELOW PLASI"	To avoid unstabilized landing
Passing runway threshold, for short field; runway edge	"GO AROUND, SET POWER....(TQ) FLAP 15"	If aircraft not within criteria for stabilized landing configuration. "GO AROUND "	To avoid unstabilized landing.
Circling	"CORRECTING"	Call any deviation from speed/altitude.	To ensure correct flight path.

Appendix D: Abstracts from the company's Abnormal Procedures valid in December 2010

- Windshear/Terrain Recovery Procedure
- Stall and Stall Recovery Procedure

widerøe | CHAPTER 3 | ABNORMAL AND EMERGENCY PROCEDURES | 3.4-27 TLD 19 JUN 06

3.4.4.15 Windshear/Terrain Recovery Procedure

PF	PNF
Calls **"GO AROUND, FULL POWER"** Simultaneously: - Selects Go-around - Rotates aircraft to minimum go - around attitude or 1/10th of airspeed - Advances POWER levers towards 80%	Sets Condition Levers to MAX, sets power to certified torque, Calls **"CONDITION LEVERS, FULL POWER SET"** Monitors radar altitude and calls **"TERRAIN CLOSING"** if separation from the ground is still decreasing
If aircraft still closing on terrain	
Advances POWER levers to maximum available power Increases pitch attitude in increments to increase climb rate Minimum airspeed V_2 /V_{GA} If stick shaker occurs reduces pitch attitude to silence shaker	Monitors airspeed and terrain separation and provides callouts as appropriate
If aircraft climbing away from terrain	
Continues climb as required to avoid terrain Reduces power and pitch attitude to normal go-around values Continues with normal go-around or take-off procedure	Monitors radar altitude and baro altitude to determine when aircraft is safely clear of obstacles or terrain. Calls **"CLEAR OF TERRAIN"**

3.4.5 Stalls

Stall behavior is docile and the flight controls remain positive and effective throughout. While all stalls are preceded by buffet, the buffet margin prior to onset of the stall decreases as flap angle is increased. The stick shakers provide adequate stall warning in all configurations.

Stall recovery is prompt following relaxation of rearward pressure or application of gentle forward pressure on the control column. All 1g stalls are accompanied by nose-down pitch, the resultant height loss of which can be minimized by the prompt application of power prior to or following the pitch. Excessive forward movement of the column shall be avoided as this can add to the natural nose-down pitching motion and produce an excessively steep nose-down attitude during the recovery.

When performing intentional stalls for training purposes, the wings shall be held level throughout the stall by appropriate use of roll control and heading held fixed by appropriate use of rudder.

The greatest nose-high stall attitudes occur with zero flap, the stall attitude decreasing proportionately as flap angle is increased. Intentional power-on stalls should not be performed at power settings greater than those used during certification testing which is achieved with 37% torque and condition levers at MAX.

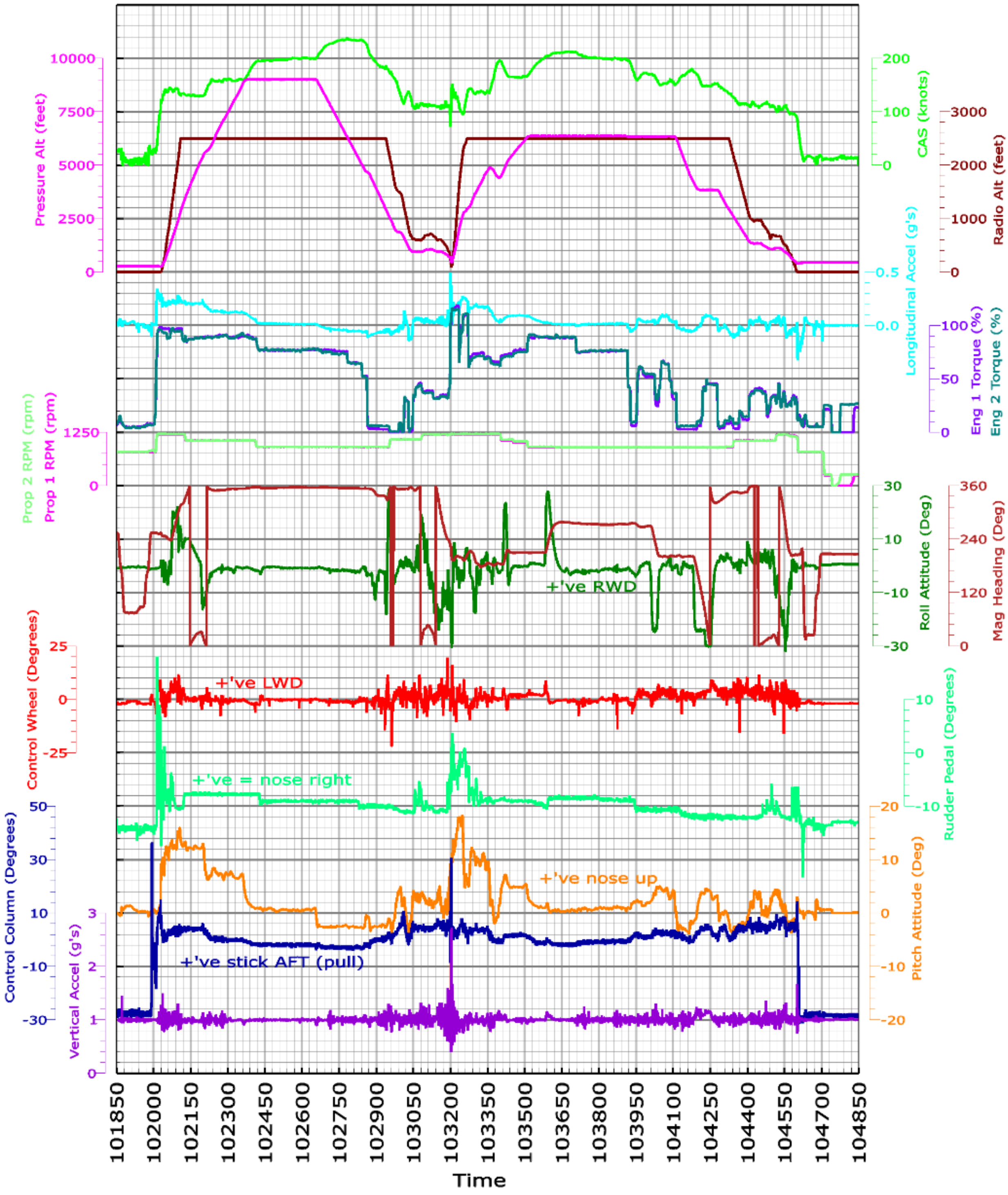
Recovery - Stall recovery will be initiated at stick shaker. Recovery is affected by a slight relaxation of rearward pressure on the control column while simultaneously applying "Full Power". If flaps are set to 35 they will immediately be selected to 15. With flaps at 5 or 15; accelerate to V_{FRI} before selecting flap to 0. During stall recovery, maintain altitude and adjust power so as not to exceed 140 kias.

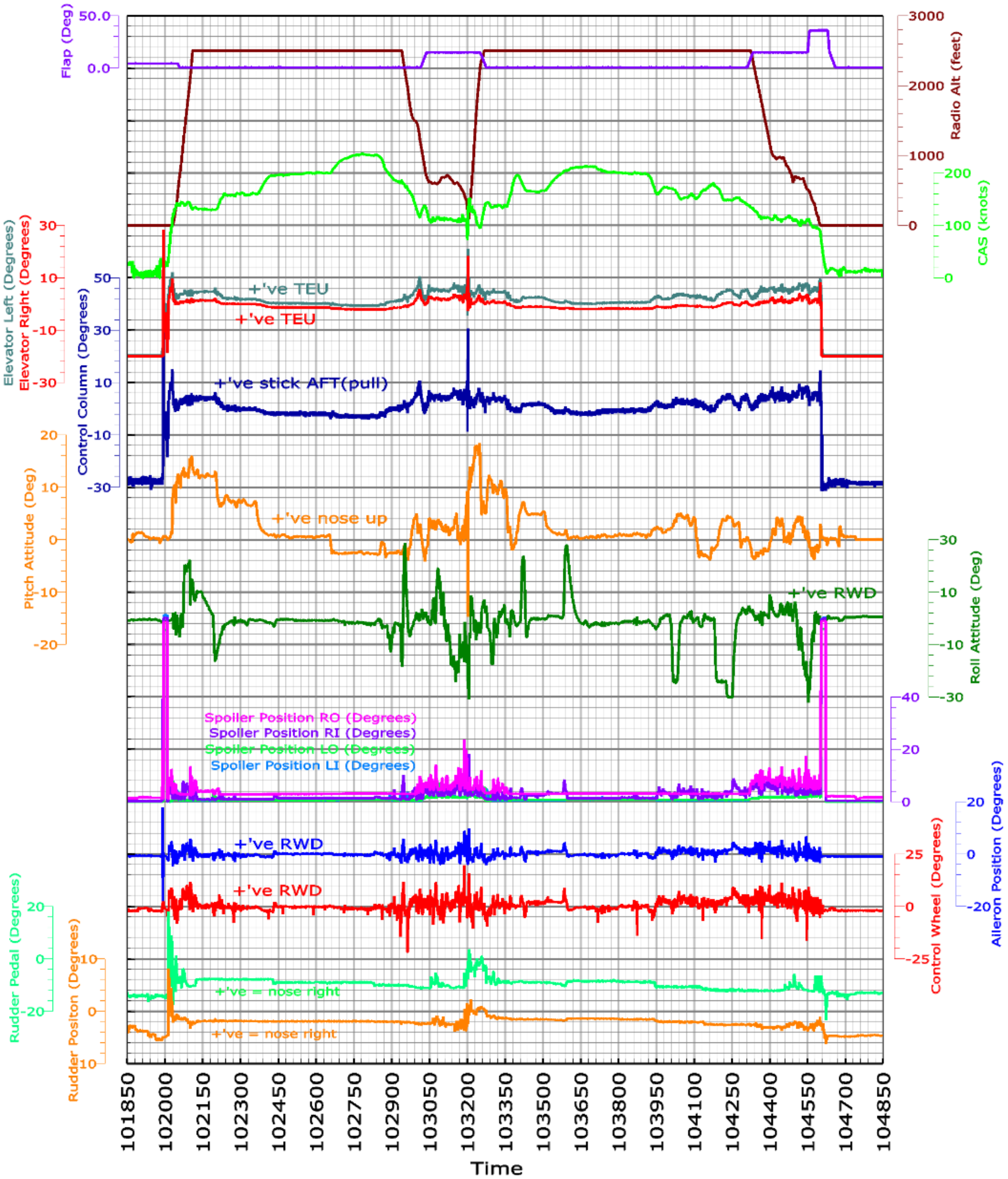
3.4.5.1 Stall Recovery Procedure

Crew Coordination:

PF	PNF
AT STICK SHAKER, SIMULTANEOUSLY: ● Relax Back Pressure ● Press GA button and Advance power towards 80% ● Call "GO-AROUND, FULL POWER, FLAP 15" CAUTION DO NOT OVER-TORQUE, PNF IS RESPONSIBLE FOR SETTING GO-AROUND POWER	Sets condition levers to max, sets power to certified torque, and selects flap to 15. Call; "CONDITION LEVERS, FULL POWER FLAP 15 CHECKED" CAUTION IF FLAP ALREADY SET AT 15 OR LESS, LEAVE AS SELECTED.
● Call "GEAR UP, SELECT HDG"	Observe positive rate: ● Call "POSITIVE RATE" Selects landing gear lever Up. Selects (Hdg mode) and confirms. When gear is confirmed up, Call; "GEAR UP CHECKED, HDG SELECTED"
At a minimum speed of VFRI: ● Call; "FLAPS 0" Commands "SET .....FT ALT SEL"	Confirms speed VFRI or above. Selects flaps to 0 Selects and calls "... FT SET ALT SEL" When flaps checked at zero Call; "FLAP 0 CHECKED"
Commands "SELECT IAS VFTO" ● Call; "CLIMB POWER" **Note:** As the aircraft accelerates adjust power so as not to exceed 140 KIAS.	Select IAS VFTO and confirms. Call "IAS xxx SELECTED" Set Climb Power ● Call; "CLIMB POWER SET"

Appendix E: FDR data for the flight from Bodø to Leknes




Flap (Deg)
Radio Alt (feet)
CAS (knots)
Elevator Left (Degrees)
Elevator Right (Degrees)
+'ve TEU
+'ve TEU
Control Column (Degrees)
+'ve stick AFT(pull)
Pitch Attitude (Deg)
+'ve nose up
Roll Attitude (Deg)
+'ve RWD
Spoiler Position RO (Degrees)
Spoiler Position RI (Degrees)
Spoiler Position LO (Degrees)
Spoiler Position LI (Degrees)
+'ve RWD
+'ve RWD
Control Wheel (Degrees)
Aileron Position (Degrees)
Rudder Pedal (Degrees)
Rudder Positon (Degrees)
+'ve = nose right
+'ve = nose right
Time

FLYMEDISINSK INSTITUTT

Analyse av hendelsene under Widerøes rute 814 fra Bodø Lufthavn til Svolvær Lufthavn Helle 2.desember 2010

En rapport for Statens Havarikommisjon for Transport

Jannicke Sandvik, Anthony Sverre Wagstaff & Jørn Brede Stangnes

10.02.2016

Etter forespørsel fra Statens Havarikommisjon for Transport har Flymedisinsk Institutt foretatt en analyse av hendelsene under Widerøes rute 814 fra Bodø Lufthavn til Svolvær Lufthavn Helle 2. desember 2010 med henblikk på mulige sanseillusjoner involvert. I rapporten kvantifiseres grad av kreftenes påvirkning av sanseapparatet under hendelsen. Det vurderes hvordan disse kreftene kunne påvirket begge piloter. I tillegg vurderes i hvilken grad det i litteraturen er dokumentert sammenheng mellom piloters henholdsvis erfaring og fatigue (tretthet) og opplevelsen av sanseillusjoner. Til slutt er det gitt eksempler på lignende hendelser. Analysen er gjennomført på basis av aktuell litteratur, data fra flyets flight data recorder, utskrift av besetningsmedlemmenes beskrivelser av hendelsene, kartutsnitt over flyplassen og området samt opplysninger om vær og lysforhold. Analysen viser at forholdene lå til rette for å oppleve en somatogravisk illusjon, men om besetningen faktisk opplevde dette, og i hvilken grad det eventuelt påvirket flygingen, kan ikke fastslås sikkert.

Innholdsfortegnelse

Analyse av hendelsene under Widerøes rute 814 fra Bodø Lufthavn til Svolvær Lufthavn Helle 2. desember 2010

Innledning

Etter forespørsel fra Statens Havarikommisjon for Transport (SHT) har Flymedisinsk Institutt (FMI) foretatt en analyse av hendelsene under Widerøes rute 814 fra Bodø Lufthavn til Svolvær Lufthavn Helle 2. desember 2010. Oppdraget var å vurdere hvorvidt sanseillusjoner kan ha vært en medvirkende faktor til hendelsen.

SHT ønsket at FMI skulle vurdere hvorvidt sanseillusjoner kunne vært involvert i hendelsene under Widerøes rute 814 fra Bodø Lufthavn til Svolvær Lufthavn Helle 2. desember 2010. Herunder var det ønsket at FMI skulle:

a) kvantifisere grad av påvirkning av sanseapparatet ved den sterke akselerasjonen
b) vise hvordan disse kreftene kunne påvirket både *pilot flying* (PF) og *pilot monitoring* (PM)
c) vurdere i hvilken grad det i litteraturen er dokumentert sammenheng mellom piloters erfaring og opplevelsen av sanseillusjoner
d) vurdere i hvilken grad det i litteraturen er dokumentert sammenheng mellom piloters fatigue (tretthet) og opplevelsen av sanseillusjoner
e) gi eksempler på lignende hendelser

Analysen er gjennomført på basis av litteratur om sanseillusjoner, data fra flyets *flight data recorder* (FDR), utskrift av besetningsmedlemmenes beskrivelser av hendelsene, kartutsnitt over flyplassen og området samt opplysninger om vær og lysforhold.

For nærmere beskrivelser av hendelsesforløp, vitneutsagn, data fra FDR-data, værforhold mv. henvises det til SHTs egen rapport om hendelsen.

Sanseillusjoner

Menneskets sanseapparat er tilpasset livet på jordoverflaten, hvor orientering i rommet opprettholdes av det visuelle systemet (syn), det vestibulære systemet (balanseorgan) og det somatosensoriske systemet (hud-, ledd- og muskelsanser) på en samordnet måte. Under flyging utsettes kroppen for høye hastigheter, akselerasjonskrefter, uvante bevegelser og posisjoner, samt at synsinntrykkene er annerledes enn på bakken. Når en pilot mangler visuelle referanser, det vil si ikke kan se horisonten klart, er han/hun avhengig av det vestibulære og det somatosensoriske systemet for å orientere seg. Under de spesielle forholdene som råder under flyging fungerer imidlertid ikke disse sansene optimalt og kan gi feilaktig informasjon om sin eller flyets posisjon og bevegelse relativt til bakken (McGrath, Rupert & Guedry, 2003). Fenomenet kalles *spatial disorientation* (North Atlantic Treaty Organization, Research and Technology Organisation (NATO RTO), 2008), eller sanseillusjoner på norsk, og er en naturlig følge av det normale sanseapparatets reaksjon på stimuli det ikke er tilpasset.

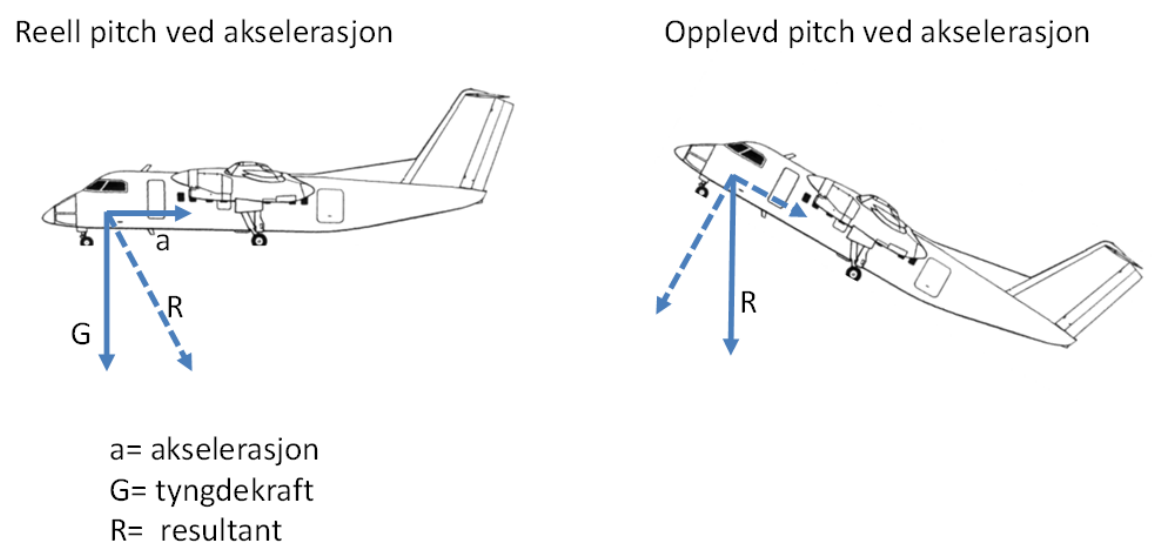
Man skiller vanligvis mellom 2 typer sanseillusjoner. Type 1 sanseillusjoner er illusjoner som går uoppdaget, dvs at piloten ikke er klar over at han eller hun ikke har et riktig bilde av sin og flyets posisjon og stilling i luften. Type 2 sanseillusjoner opptrer når piloten er oppmerksom på illusjonen, og ved hjelp av visuelle referanser og flyets instrumenter er klar over at den gir et feilaktig bilde.

Det finnes en rekke ulike sanseillusjoner, både visuelle og vestibulære. Ved visuelle illusjoner er det synsinntrykk, og hjernens tolkning av disse, som fører til illusjonen, mens balanseorgan og det somatosensoriske system gir grunnlag for de vestibulære illusjonene. I noen illusjoner kan en kombinasjon av disse spille inn.

Hendelsen med Widerøes rute 814 peker i retning av en særskilt type sanseillusjon og rapporten vil i det følgende beskrive denne nærmere, samt en illusjon til som anses å kunne være relevant.

Somatogravisk illusjon

En somatogravisk illusjon oppstår ved at det er en falsk persepsjon (oppfatning) av egen/flyets orientering grunnet en kraftvektor som virker i en annen retning og/eller styrke enn den vanlige gravitasjonskraften (vertikalt ned mot bakken). Når flyet akselererer presses piloten bakover mot seteryggen. I fravær av visuelle referanser utenfra oppleves denne kraften mot seteryggen og tyngdekraften som én kraft (resultantkraft), noe piloten oppfatter som vertikalen (rett ned som tyngdekraften) (Benson & Rollin Stott, 2006, Cheung, 2004). Piloten får dermed en følelse av å være tiltet (i Figur 1 beskrevet som «*pitch*») bakover og at flyets nese peker oppover mer enn det som faktisk er tilfellet (se figur 1). Det motsatte er tilfellet ved deselerasjon.



Figur 1: Resultantkraft og opplevd *pitch* (nesestilling) i en somatogravisk illusjon

Paradokset med denne illusjonen er at eventuelle justeringer av nesestilling som piloten måtte forsøke å gjøre, skaper liten endring i følelsen av nese opp. Dersom piloten retter nesen nedover, vil flyet akselerere, noe som igjen øker følelsen av nese opp (Benson & Rollin Stott, 2006, Cheung, 2004). Dersom piloten derimot retter nesen mer opp, ville akselerasjonskraften forover reduseres, siden mer motorkraft ville kreves for å klatre. Dette kan igjen resultere i at man oppfatter lite endring i nesestilling fordi den reduserte illusoriske oppfattelsen av nesestilling oppveier følelsen av reell endring av nesestilling (Benson & Rollin Stott, 2006). Det er kjent fra flere hendelser i luftfarten at en somatogravisk illusjon kan ha påvirket piloten til å senke nesen på flyet og ført til, eller medvirket til, ulykker (Department of Transport, Air Accidents Investigation Branch, 2010; Armentrout, Holland, O'Toole & Ercoline, 2001; Bureau of Air Safety Investigation (BASI), 1991).

Oculogravisk illusjon

De samme uvanlige kraftmiljøene som skaper somatograviske illusjoner kan også skape illusjoner med visuelle komponenter. Disse såkalte oculogravisk illusjoner kan også sees på som den visuelle komponenten av somatogravisk illusjoner (Benson & Rollin Stott, 2006).

For eksempel vil en pilot som opplever en somatogravisk illusjon under akselerasjon også kunne oppleve at objekter i synsfeltet synes å bevege seg oppover, som for eksempel særlig cockpitbelysning (Previc, 2004), men også singulære lyspunkt utenfor cockpit. Piloten kan tolke oppoverbevegelsen i synsfeltet som en endring i flyets stilling, og følelsen av nese opp intensiveres (Benson & Rollin Stott, 2006). Dette er paradoksalt fordi objekter utenfor cockpit faktisk beveger seg nedover i synsfeltet når flyets nese beveger seg oppover (Cheung, 2004).

Slike illusjoner oppstår sjelden når det finnes veldefinerte, eksterne visuelle referanser, men for eksempel nattestid, når kun noen få stjerner eller isolerte lys er synlige, for eksempel, kan de lett skape problemer for piloters situasjonsoppfattelse (Benson & Rollin Stott, 2006).

Erfaring og sanseillusjoner

Litteraturen er noe uklar på hvordan flyerfaring påvirker sannsynligheten for å oppleve sanseillusjoner (McGrath et al., 2003). Noen sammenhenger er imidlertid påvist. Tribukait og Eiken (2012) fant i en undersøkelse at ikke-piloter, i større grad enn piloter, undervurderte tilt, både i *roll* og *pitch*, under akselerasjon i sving. De mente at piloter lærer seg å la signalene fra buegangene dominere over de otolittiske [1]signalene, noe som gjør dem bedre til å vurdere *nesestilling*.

Når hodet beveger seg i én retning skal en refleks gjøre at øynene beveger seg i motsatt retning for å stabilisere bildet midt på netthinnen. Lee, Kim & Park (2004) fant at piloter hadde mer utviklet refleks enn ikke-piloter, men fant ikke signifikante forskjeller mellom piloter med ulike erfaringsnivå. Forskerne fant at bedringen i refleksen fant sted allerede etter 20 timer flyskole, noe som antyder at bedringen skjer raskt og ikke endres videre med mer erfaring.

I en simulatorundersøkelse fant Previc et al. (2007) at mer erfarne piloter hadde en marginal tendens til å oppdage flere situasjoner hvor deres opplevelse av situasjonen var i konflikt med instrumentene (Type 2 sanseillusjon fremfor Type 1), men at de ble mer påvirket av enkelte illusjoner enn mindre erfarne piloter. I en undersøkelse av en ekstrem somatogravisk situasjon førte flygererfaring ikke til prestasjonsforskjeller mellom forsøkspersoner (Cohen et al. i Newman, Lawson, Rupert & McGrath, 2012).

Det synes å være stor enighet om at piloter ikke er immune mot sanseillusjoner, og at sannsynligheten for at enhver pilot, uavhengig av erfaring, vil oppleve sanseillusjoner i løpet av sin

[1] Otolitter er del av det vestibulære systemet; det ene balanseorganet i det indre øret.

flykarriere, er stor (Newman, 2007, Air Accident Investigation Unit Ireland, 2011). Ulike undersøkelser viser at 78-100% av militære piloter rapporterer å oppleve sanseillusjoner (*spatial disorientation*) i noen grad i karrieren (LeDuc et al., 1999). Bramble (2008) gjennomgikk en rekke (7) hendelser og flyulykker som er assosiert med SD, og fant at det var fartøysjefen, altså ofte den mest erfarne piloten, som fløy flyet i seks av de syv tilfellene. En gjennomgang av US Navy ulykker viser at den typiske «sanseillusjons-ulykkes-piloten» ikke er en uerfaren flyger (McGrath et al., 2003). Dette tyder på at erfaring ikke i stor grad verner mot sanseillusjoner. I litteraturen har enkelte spesielt nevnt at piloter med instrument-utsjekk ikke er immune mot den somatograviske illusjonen (Transport Safety Board of Canada, 1997), og at erfarne og uerfarne piloter er like mottakelige for denne illusjonen (Transport Safety Board of Canada, 1997; Wolfe & Cramer, 1970 i Cheung, 2004).

Det faktum at alle piloter opplever sanseillusjoner synes intuitivt riktig ettersom sanseillusjoner er naturlige reaksjoner for sanseapparatet og hjernefunksjonen vår på «unaturlige» stimuli, og dette lar seg ikke enkelt forandre. På tross av dette synes enigheten stor om at sanseillusjons-trening er nyttig (NATO RTO, 2008). Treningen vil i liten grad endre sanseapparat og hjernefunksjon slik at illusjoner ikke oppstår, men gjennom å gjenkjenne risikofaktorer og å modifisere sin atferd i henhold til situasjonen kan piloten redusere risikoen for sanseillusjoner. Sanseillusjonstrening og økt bevisstgjøring på og forståelse av problematikken rundt sanseillusjoner, kan gjøre det lettere å oppdage en illusjon (gjøre Type 1 sanseillusjoner om til Type 2) og gjøre piloten bedre i stand til å vite hvordan han eller hun skal respondere når illusjoner oppstår (Bramble, 2008). Trening kan også gjøre piloter dyktigere på gjenoppretting til normal stilling.

Fatigue og sanseillusjoner

I litteraturen hevdes det at *fatigue,* eller tretthet, øker mottakeligheten for sanseillusjoner som den somatograviske illusjon (BASI, 1991). Likevel kjenner man ikke mange studier som direkte knytter tretthet med sannsynlighet for sanseillusjoner, og de man kjenner til gir heller ikke entydige svar (Previc et al., 2007). Mange studier viser imidlertid at tretthet virker negativt inn på en rekke menneskelige funksjoner som har betydning for piloten og hans eller hennes orientering og prestasjoner i luften.

Både balanseorganene, hørselen og det somatosensoriske systemet gir sensorisk input under flyging, men pilotens orientering er i stor grad et produkt av det visuelle systemet. Mange studier har demonstrert at tretthet kan påvirke det visuelle systemet negativt (LeDuc et al., 1999; Russo et al., 2005), for eksempel i form av visuelle forstyrrelser og illusjoner, som sløret syn, dobbeltsyn, feilaktig dybdepersepsjon og forvrengninger av form og størrelse (LeDuc et al., 1999) eller tunnelsyn (Rogé et al., 2003 i Russo et al., 2005). I tillegg har studier vist dårligere motoriske synsfunksjoner ved tretthet (Previc et al., 2007). Eksempler er økt forekomst av nystagmus [2](LeDuc et al., 1999), dårligere reaksjoner i pupillstørrelse, tregere øyebevegelser og vanskeligheter med å fokusere (De Gennaro, 2001 i Russo et al., 2005). Slike visuelle svekkelser rammer funksjoner som er viktige for orientering i luften (Previc, 2007), og kan følgelig trolig indusere desorientering eller sanseillusjoner (LeDuc et al., 1999).

[2] Når hodet beveger seg sender balanseorganet beskjed til øynene om å bevege seg for å stabilisere synsfeltet, men når balanseorganet er preget av feilaktige inntrykk, så kan øynenes rykkvise bevegelse skape problemer i forhold til å få et stabilt bilde; nystagmus.

Tretthet påvirker også andre funksjoner enn synet, og som er knyttet til situasjonsbevissthet og tredimensjonell orientering. For eksempel er det vist at tretthet fører til redusert oppmerksomhet, økt reaksjonstid, redusert tenningsnivå og årvåkenhet (BASI, 1991; Kjellberg, 1977, Krueger, 1989 i LeDuc et al. 1999; Russo et al., 2005; Weeks, McAuliffe, DuRussel, & Pasquina, 2010) og konsentrasjon (Kjellberg, 1977, Krueger, 1989 i LeDuc et al., 1999), hukommelsesproblemer og reduserte kognitive evner (Belmont, Agar & Azouvi, 2009; Rabinowitz et al., 2009; Ray, 1990 i Weeks et al., 2010), redusert fysisk prestasjon (Belmont et al., 2009 i Weeks et al., 2010), dårligere selv-monitorering (BASI, 1991), samt dårligere evne til å dele oppmerksomhet mellom ulike oppgaver og å ekstrahere meningsfylt informasjon fra for eksempel flyinstrumenter (Bramble, 2008).

Tretthet har generelt sammenheng med dårligere flyprestasjoner (BASI, 1991; Previc et al., 2007), for eksempel i form av mindre presis flyging og lengre tid for å gjenopprette normal stilling på flyet (LeDuc et al., 1999), da spesielt i tette flyformasjoner, under instrumentflyging eller ved komplekse innflyginger (i Russo et al., 2005).

Negative effekter av tretthet er påvist etter søvndeprivasjon; for eksempel etter henholdsvis 19 timer (Russo et al., 2005) og 30 timer (LeDuc et al., 1999) sammenhengende våkenhet. Belenky et al. (2003 i Russo et al., 2005) observerte effekter hos personer som hadde sovet henholdsvis 3, 5 og 7 timer pr. natt over 7 netter, og Dinges et el. (1997 i Russo et al., 2005) fant effekter hos personer som hadde sovet 4-5 timer pr. natt i to netter.

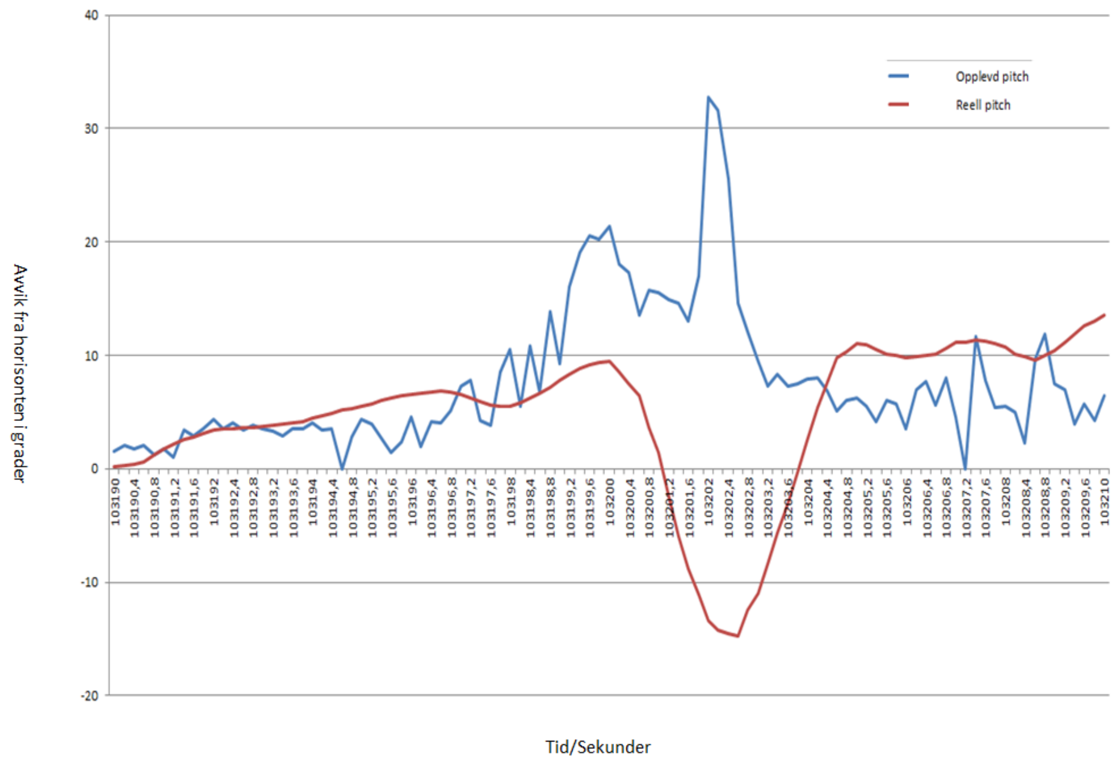
Ulykkesstatistikk viser at sanseillusjons-ulykker skjer oftere skjer ved nattflyging, og oftere ved lengre flyginger (Previc et al., 2007). I en gjennomgang av flyulykker fant Mortimer og Kenneth (2000) at 9 % av ulykkene som involverte tretthet, også involverte sanseillusjoner (Mortimer & Kenneth, 2000). Litteraturen viser imidlertid i liten grad direkte årsaksmessige sammenhenger mellom tretthet og sanseillusjoner, men de påviste effektene av tretthet resulterer i suboptimal prestasjon. Dette vil trolig ha betydning både for sannsynligheten for redusert situasjonsbevissthet og opplevelse av sanseillusjoner, samt evne til å rette opp situasjonen effektivt (Newman, 2007). Det er derfor sannsynlig å anta at tretthet kan øke risikoen for sanseillusjoner (BASI, 1991; LeDuc et al., 1999; Previc, 2007).

Analyse av hendelsene under Widerøes rute 814 fra Bodø Lufthavn til Svolvær Lufthavn Helle 2. desember 2010

Rapporten beskriver flere sanseillusjoner som kunne ha forekommet under den type forhold som WIF 814 var ute for, og viser noe av kompleksiteten og mangfoldet av sanseillusjoner som kan forekomme i tilsynelatende ganske like situasjoner. I den påfølgende analysen er den somatograviske illusjon tillagt mest vekt ettersom SHT i sitt oppdrag spesifikt ønsket en kvantifisering av kraftpåvirkningen forbundet med den kraftige akselerasjonen under en spesifikk periode i hendelsen (ca. sekund 103200-103205).

FMI har valgt å bruke en enkel modell for å vise kraftpåvirkningen under hendelsen. Variabler som flyets krengning, pilotens hodeposisjon mv. er utelatt, selv om de kan ha hatt innvirkning på de opplevde kreftene. Dette er utelatt fordi disse variablene kompliserer bildet og/eller medfører usikkerhet da aktuell hodeposisjon kun ville vært basert på antakelser og ikke nøyaktige data. For å kvantifisere kraftpåvirkningen er resultantkraften (R, se figur 1) beregnet for hele det aktuelle tidsrommet (sekund 103190-103210). Beregningen, ved hjelp av trigonometriske metoder, baserer seg på FDR-data om longitudinell akselerasjon, G(x), og vertikal akselerasjon, G(z). Professor i matematikk ved Universitetet i Oslo, Nils Henrik Risebro, har kvalitetssikret beregningene.

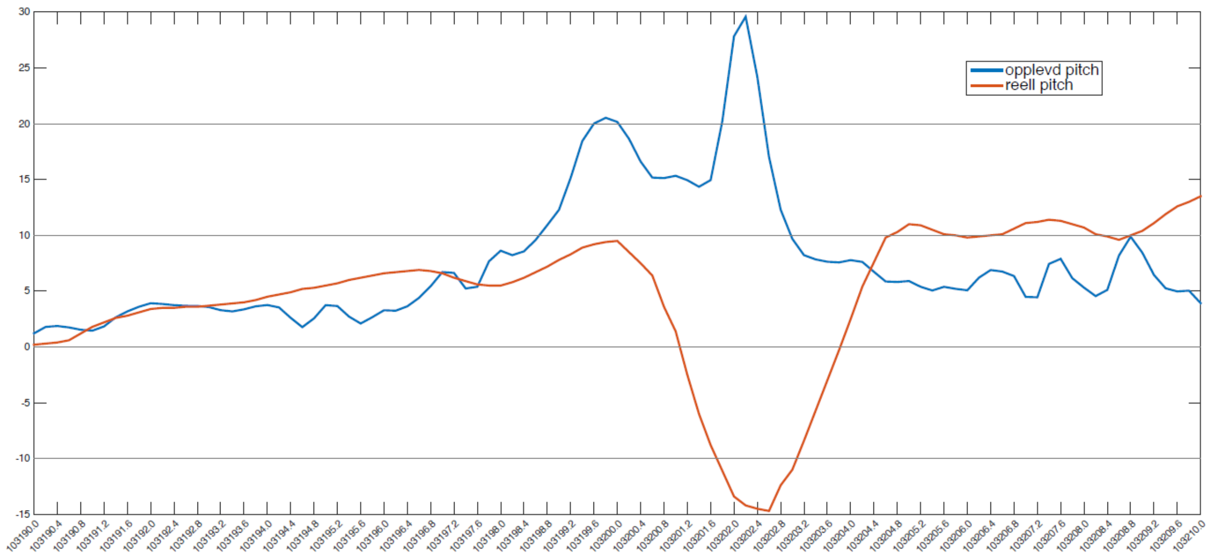
Figur 2 viser WIF814s reelle nesestilling, hentet fra FDR-data, (rød linje) sammen med den beregnede resultantkraften (blå linje) (se figur 1). Resultantkraften kan kalles opplevd *pitch*, altså hvordan pilotene kan ha opplevd flyets nesestilling basert på de krefter det var utsatt for.



Figur 2: Reell pitch (nesestilling) versus opplevd pitch (resultantkraften) i grader avvik fra horisonten (0).

Ettersom opplevd nesestilling dels bestemmes av vertikal akselerasjon G(z), som igjen påvirkes av turbulens, er kurven for opplevd nesestilling i denne modellen svært ujevn. For bedre å illustrere den underliggende tendensen i kreftene, er de samme data fremstilt med et glidende vektet gjennomsnitt i figur 3 (Fourierkurve[3]).

[3] Det glidende gjennomsnittet (fourierkurven) er utarbeidet av Professor i matematikk ved Universitetet i Oslo, Nils Henrik Risebro.



Figur 3: Glidende gjennomsnitt (Fourier-kurve): reell pitch (nesestilling) versus opplevd pitch (resultantkraften) i grader avvik fra horisonten (0).

I figur 2 og 3 ser vi at den beregnede resultantkraften viser opplevd nesestilling opp under hele hendelsen, med en økning i opplevd nesestilling opp like før, og spesielt mens, flyets nese faktisk vendte nedover. Flyets reelle nesestilling sank fra like etter øyeblikket hvor flyets stikke ble beveget forover (sekund 103199), og var på det laveste på ca. -14,5˚. Samtidig økte resultantkraften til nese opp med ca. 29,9˚ på det høyeste (sekund 103202).

Beregningene viser altså en noe høyere opplevd nesestilling enn det som var tilfellet før stikka ble beveget fremover. Det er usikkert om denne opplevde kraftpåvirkningen var stor og langvarig nok til å ha påvirket PF til å bevege stikka forover. I den påfølgende fasen, mens flyet akselererte med nesen ned mot havoverflaten (sekund 103200-103202), er derimot kraftpåvirkningen, og forskjellen mellom mulig opplevd og reell nesestilling så stor, at det er sannsynlig at en somatogravisk illusjon kan ha inntruffet. Dette kan ha påvirket PF til å ha holdt flyets nese lavere enn han ville med gode visuelle referanser.

Pilotene har i intervjuene ikke direkte beskrevet at de følte at de hadde nesestilling opp på dette tidspunktet. PF har beskrevet hendelsen slik: «Det første unormale jeg registrerer er at flyet rister litt, og så faller ned. I hvert fall får vi sug i magen, og det jeg gjør da er å dytte ned nesen, frem med stikken og gir på power [...] Når jeg drar opp igjen, så får jeg stick shaker [...] dyttet godt på med power og dro flyet ut [...] og lå lavt for å bygge opp speed». PF har også uttalt at «jeg så jo på instrumentene for å justere, men det var mer at jeg følte hvor jeg hadde flyet sånn fysisk». Dette antyder at han kjente etter flyets bevegelser og kan ha brukt dette som referanse for flygningen sin, noe som ville gjøre ham mer mottakelig for å oppleve en illusjon. PF sa at han følte han hadde kontroll på flyet da PM overtok kontrollene og at han holdt flyet nede for å øke farten og å unngå *stick shaker*. I følge SHT skjedde dette trolig i sekund 103201,3, mens flyet fortsatt hadde nesen ned og høyden fortsatt sank. Illusjonen kan ha gjort at han ikke var klar over flyets lave posisjon og stilling, og at han ikke ville holdt flyet nede på den måten dersom han var klar over dette. I hvilken grad dette faktisk påvirket PF og hans flyging kan ikke fastslås sikkert, men kreftene som kan skape en somatogravisk illusjon var til stede i det aktuelle tidsrom.

PM sin oppgave under sirklingen var å følge med på instrumentene. Dersom PM fulgte med på flyinstrumentene da kreftene og forholdene medvirket til at illusjoner kunne oppstå, ville han hatt visuelle referanser som kunne korrigere andre, feilaktige sanseinntrykk. Han ville derfor trolig i mindre grad vært preget av illusjonskreftene. Han kunne også ha opplevd en illusjon i noen grad, men han ville trolig vært oppmerksom på at egen opplevelse ikke stemte med instrumentene, så det ville vært en Type 2 sanseillusjon (oppdaget). Dette forhindrer at man handler på bakgrunn av illusjonen.

Figur 3 med det glidende gjennomsnittet[4] ble inkludert for å redusere synligheten av variasjonene grunnet turbulens og lignende, og heller få frem den underliggende tendensen i kreftene. Imidlertid kan turbulensen ha innvirket på opplevelsen av en eventuell illusjon, både direkte og gjennom opplevd arbeidsbelastning. Her har en imidlertid ikke tilgjengelig kunnskap til å kunne vurdere om turbulens har vært en faktor for illusjonen.

Sanseillusjoner, som den somatograviske, oppstår stort sett i fravær av gode visuelle referanser. Hendelsen med WIF814 skjedde i mørke med overskyet vær og regn eller hagl. Vitnene er usikre på om det var snø på bakken, men utsagnene tyder på at det uansett ikke var nok snø til å gjøre bakken synlig under sirkling.

PF uttalte at «…jeg ser ingenting, det er helt svart, det eneste vi ser er jo lys [...] som står på disse her høydene på extended center line», og PM har uttalt at nesen droppet og da så han «rett ned i svarte havet». Pilotene kunne i ulike perioder av innflygingen se sirklingslys, hinderlys, lysene på flyplassen og kanskje noe lys fra enkelte boliger i området. Kartutsnitt over området og flyplassen viser at det er lite bebyggelse og lys i området. Besetningens utsagn i intervjuene tyder på at de ikke kunne skjelne konturer i terrenget eller mellom land og sjø, de hadde altså ikke en synlig horisont. De enkeltstående lyspunktene de kunne se er ikke nok til å gi gode visuelle referanser og dermed motvirke en sanseillusjon. De kan faktisk bidra til å skape eller forsterke sanseillusjoner, som tidligere nevnt.

Når de *pitchet* nesen ned ville lysene ha beveget seg oppover i cockpitvinduet, men hvis de følte seg *pitch up* eller *level* på grunn av en somatogravisk illusjon, så kunne en oculogravisk illusjon samtidig, tilsynelatende, føre lyset oppover i synsfeltet. PF snakket om de røde hinderlysene: «…jeg observerte at de her røde lysene på land, som var til høyre, at de steg, da. Høyere enn normalt for en innflyging, og det var ikke fordi jeg banket til høyre, men for at vi da datt ned». Dette kan ha vært en oculogravisk illusjon, som bidro til å forsterke den somatograviske illusjonen, men det er vanskelig å fastslå sikkert.

PF hadde første dag på jobb av en arbeidsperiode på syv dager. Han hadde vært våken og i aktivitet i rundt 13 timer, og på arbeid i omtrent fire timer da hendelsen inntraff og har uttalt at han var noe trett og sliten. Tretthetsnivået til PF synes ikke å ha vært ekstremt høyt, men det kan ha påvirket situasjonsbevisstheten hans negativt og potensielt gjort ham noe mer utsatt for å oppleve sanseillusjoner, og potensielt også i dårligere stand til å innhente situasjonen når den oppstod.

Flygererfaring verner i liten grad mot muligheten for å oppleve sanseillusjoner, men kan bidra til å håndtere eventuelle sanseillusjoner bedre. De to pilotene i cockpit under rute WIF 814 hadde ulikt

[4] I et glidende gjennomsnitt (Fourierkurve) er de høyfrekvente komponentene dempet.

erfaringsnivå, men begge ansees å være erfarne piloter. Fartøysjefen, den mest erfarne, var PF (med ca. 8600 flytimer, hvorav ca. 5500 t. på aktuell type). Styrmannen,PM, hadde ca. 4000 flytimer hvorav ca. 3000 t. på aktuell type på hendelsestidspunktet. Pilotenes erfaringsnivå anses derfor ikke å ha hatt stor relevans for hendelsen med WIF 814.

Eksempler på lignende hendelser

Newman (2007) skriver at inntil ⅓ av alle flyulykker har sanseillusjoner som en årsak. I litteraturen finnes mange eksempler på ulykker hvor somatogravisk illusjon anses å være en viktig årsaksfaktor. Under følger en kort gjennomgang av noen av disse relevante hendelsene/ulykkene.

U.S. Air Force C-5 Galaxy

En U.S. Air Force C-5 Galaxy ble utsatt for en nestenulykke under en natt-innflyging over sjø. PF påbegynte innflygingen sent, noe som resulterte i høy fart og høyde initielt, hvorpå han deselererte. Besetningen oppdaget samtidig en *slat*-feil, som også satte steilingsvarslings-systemet ut av spill. Mens besetningen fokuserte på *slat*-feilen klatret flyet mens det deselererte med ca. 3,4 fot/sekund. Dette var nok til å kunne gi besetningen en feilaktig følelse av nese ned på ca. 6˚(somatogravisk illusjon).

Flyet havnet deretter i et skylag og PF var sen med å iverksette god instrumentskanning. Kommunikasjonsproblemer om bord førte til at *flaps* ikke ble satt til riktig landingsstilling og at anmodning om nedstigning ikke ble etterfulgt. Farten de holdt var riktig for den antatte full *flaps*-stillingen, men for sakte for den faktiske flaps-konfigurasjonen. Det betød at det krevdes mye større angrepsvinkel enn vanlig for å fly *level*. På dette tidspunktet oppdaget PM at de hadde nesen 10˚ opp, men illusjonen om nese ned var så sterk at besetningen trodde at begge *Inertial Navigation Systems* (INS) viste feil. De kontrollerte således ikke nesestilling og fokuserte på det antatte INS-problemet. Flyet fortsatte derfor å klatre, og følgelig sank farten mens flyet rettet nesen mer og mer opp. Deselerasjonen og nese opp-posisjonen motvirket hverandre i forhold til å gi pilotene nesestillings-referanser, så de kjente trolig lite til nesestillingen på tross av at den på dette tidspunktet var på over 20˚.

PM oppdaget så at farten sank og ba piloten akselerere, deretter å sette nesen ned, men på dette tidspunktet steilet flyet i 4900 fots høyde med angrepsvinkel på over 30˚, nesestilling på over 20˚ opp og fart på 55 knop. Flyet mistet da høyde, krenget 60 grader til høyre, 95˚ venstre og 95˚ høyre igjen. Ved 2700 fots høyde gjorde aerodynamiske krefter at den tidligere *slat*-feilen ble rettet, og steilingsvarslings-systemet koblet inn og advarte om steiling. Det var først på dette tidspunktet at pilotene virkelig forstod hvor alvorlig situasjonen var og iverksatte *stall recovery*. De innhentet situasjonen 773 fot over havet. I etterkant trodde besetningen at det bare hadde vært en *windshear*-situasjon de hadde opplevd i forbindelse med skyene de hadde flydd inn i.

Flybesetningen på tre piloter og to maskinister hadde flydd flyet et langt strekk over de siste seks dagene og vært på vakt i nesten 21 timer, med minimal hvile underveis, da hendelsen fant sted, og flybesetningens tretthet ble beskrevet som sterkt medvirkende i hendelsen. Det var lite konversasjon i cockpit og dårlig *crew resource management*. Slat-feilen distraherte besetningen og førte til kanalisert oppmerksomhet, dårligere situasjonsbevissthet og trolig opplevelsen av en somatogravisk illusjon (Armentrout et al., 2006).

Eurocopter EC225 LP Super Puma, Nordsjøen 18. februar 2009

Et Super Puma helikopter skulle lande på helikopterplatformen på en oljerigg i Nordsjøen i mørke med noe dårlig sikt, men traff sjøen like ved plattformen. Helikopteret skulle gjøre en 90 graders venstresving inn for å kunne lande. Autopilot var aktivert slik at PF kunne se ut av cockpit mot plattformen. PM assisterte med informasjon fra værradaren, og så i blant ut mot plattformen.

De steg ned fra 400 til 300 fot, men entret et skydekke og klatret derfor inntil de igjen kunne se plattformen. PF deaktiverte autopiloten, og fokuserte på plattformen, noe som førte til lite kapasitet igjen til instrumentskanning. I venstresvingen overvåket PM instrumentene og informerte piloten om fart og nedstigning. PF spurte om PM kunne se plattformen, noe som trolig skiftet PMs oppmerksomhet bort fra instrumentene. De la da ikke merke til at helikopteret mistet høyde raskt og akselererte de siste 50 sekundene.

Besetningen var begge opptatt av å identifisere helikopterplattformen og var ikke oppmerksom på den stadige nedstigningen eller stigende nesestillingen og den påfølgende fartsreduksjonen. Uten synlig horisont, og med få og forvirrende visuelle referanser (tåke eller lavt skydekke forårsaket forvirrende reflekser og dårligere visuelle referanser fra plattformbelysningen), var det vanskelig å oppdage helikopterets endring i stilling. Helikopteret kunne fortsatt å føles *level*, på tross av en nesestilling på 22,5˚ opp på det meste (somatogravisk illusjon).

Denne somatograviske illusjonen ble forsterket av en oculogravisk illusjon. PF rettet helikopterets nese stadig mer oppover de siste 20 sekundene. Effekten av dette var trolig at plattformen beholdt riktig plassering i vindusruten, og synsbildet lignet bildet ved en normal, stabil innflygingsvinkel (oculogravisk illusjon) helt inntil de siste fem sekundene, hvor *pitch*-raten økte og innflygingsvinkelen ville sett ut til å bli høy og rask (DTAIB, 2010).

Etterforskningen konkluderte med at besetningens oppfatning av helikopterets posisjon og stilling i forhold til plattformen mot slutten av innflygingen var feil fordi begge piloter var fokusert på plattformen og ikke instrumentene. De hadde mistet situasjonsbevisstheten, trolig grunnet oculogravisk og somatogravisk illusjon (DTAIB, 2010).

Beech King Air E 90, Wondai Queensland, 26. juli 1990

En Beech King Air E 90 styrtet like etter en tilsynelatende normal avgang fra Wondai flyplass i 1990. Det var en klar, mørk natt uten måneskinn eller synlig horisont. Piloten måtte umiddelbart etter avgang bytte fra eksterne visuelle referanser (rullebane og rullebanelys) til instrumentflyging. Akselerasjonen under og etter avgang ville ha gitt besetningen en følelse av større grad av nese opp enn det som var tilfellet (somatogravisk illusjon), og det fantes ikke visuelle referanser for å rette opp dette inntrykket. Beregninger viste at flyet gjennomsnittlig akselererte med 8,79 fot/sekund (0,275 G) fra flyet lettet til det traff bakken 600 m. bortenfor enden av rullebanen. Dette ville vært nok til å skape en følelse av nese opp på omtrent 15,3˚.

Etterforskningen konkluderte med at besetningen hadde vært utsatt for en somatogravisk illusjon i forbindelse med avgang. Det var også antatt at tretthet og stress kunne ha påvirket hendelsen, ettersom PF hadde vært våken i 15 timer og på jobb i åtte timer da ulykken inntraff og selv om det ikke var tegn til stress i tiden før ulykken, viste det seg at piloten hadde opplevd flere ting i perioden som potensielt kunne ført til stress (BASI, 1991).

Gulf Air Flight Airbus 320-212, 23. august 2000

En Airbus 320-212 var på vei til Bahrain International Airport i mørke, men styrtet i sjøen 3 km. fra flyplassen kort tid etter å ha initiert en go-around etter andre landingsforsøk. Besetningen initierte *take-off/go-around*-kraft på motoren, og flyet steg slakt. Mens flyet akselererte utløstes varselsystemet for *flap over-speed*. PF beveget så stikka fremover, og flyets nesestilling endret seg fra ca. 5˚ nese opp til ca. 15,5˚ nese ned, de steg saktere/vertikal akselerasjon sank og farten økte, samtidig med at Ground Proximity Warning System ble utløst. Kapteinen ba om «*flaps up*». Deretter beveget han stikka til bak nøytral posisjon, med maks bakover-utslag på 11,7˚, men bakoverbevegelsen av stikka vedvarte ikke, og påfølgende bevegelser overgikk aldri 50% av full bakover-utslag.

En analyse gjennomført av Naval Aerospace Medical Research Laboratory konkluderte med at ulykken skyldtes en somatogravisk illusjon, med følelse av nese opp på 12˚ når reell nesestilling var 5˚ opp (Rupert, McGrath & Guedry, n.d.).

De ovenfor beskrevne hendelser og ulykker viser at somatograviske illusjoner ikke er uvanlige, og at de har vært en medvirkende årsak til flere hendelser og ulykker, slik den også kan ha vært involvert i hendelsen med WIF 814 i 2010. I de ovennevnte fire eksemplene endte tre med at flyet havararte og to med fatale konsekvenser.

Konklusjon

FMI ble bedt om å kvantifisere grad av påvirkning av sanseapparatet ved den sterke akselerasjonen under hendelsen med WIF 814 under sirklingen til ENSH, vise hvordan kreftene kunne påvirket både *pilot flying* (PF) og *pilot monitoring* (PM), vurdere i hvilken grad det i litteraturen er dokumentert sammenheng mellom henholdsvis piloters erfaring og *fatigue* (tretthet) og opplevelsen av sanseillusjoner, samt gi eksempler på lignende hendelser.

Disse analysene ble gjennomført på basis av litteratur om sanseillusjoner, FDR-data, utskrift av besetningsmedlemmenes beskrivelser av hendelsene, kartutsnitt over flyplassen og området samt opplysninger om vær og lysforhold.

Tidligere havarirapporter viser mange eksempler hvor man har konkludert med at en somatogravisk illusjon har vært årsak, i alle fall en medvirkende årsak, til hendelsen eller ulykken.

FMI sine beregninger av resultantkraft, det vil si potensielt opplevd nesestilling (*pitch*), under hendelsen med WIF814 2. desember 2010 viser at forholdene lå til rette for at PF kan ha opplevd en somatogravisk illusjon. Opplevd nesestilling var opp under hele hendelsen, med en økende tendens like før, og spesielt mens, flyets nese faktisk vendte nedover. Kraftpåvirkningen før stikkebevegelsen var trolig ikke stor og langvarig nok til alene å ha påvirket PF til å bevege stikka forover. Kraftpåvirkningen mens flyet akselererte med nesen ned mot havoverflaten, var sterkere, og det er sannsynlig at en somatogravisk illusjon kan ha inntruffet. Dette ville komplisert gjenopprettingen av flyet, og kan ha påvirket PF til å holde nesen lavere enn han hadde gjort med gode visuelle referanser.

Styrmannens oppfattelse av situasjonen ville sannsynligvis i mindre grad vært preget av illusjonskreftene, da han hovedsakelig hadde fokus på flyinstrumentene.

Litteraturen antyder at tretthet (*fatigue*) potensielt gjør en pilot mer utsatt for sanseillusjoner. Under hendelsen med WIF814 2. desember 2010 var PF etter eget utsagn noe preget av tretthet, og det kan derfor ikke utelukkes at dette kan ha gjort ham mer utsatt for sanseillusjoner.

Litteraturen antyder videre at flygererfaring ikke i særlig grad kan verne mot å oppleve sanseillusjoner, men kan potensielt bidra til bedre gjenoppretting (*recovery*). Pilotenes erfaring under WIF 814 anses ikke å ha vært avgjørende for om de opplevde en sanseillusjon.

Referanser

Armentrout, J. J., Holland, D. A., O'Toole, K. J. & Ercoline, W. R. (2006). Fatigue and related human factors in the near crash of a large military aircraft. *Aviation, Space and Environmental Medicine, 77*, 963-970.

Benson, A. J. & Rollin Stott, J. R (2006). Spatial disorientation in flight. I D. J. Rainford & D. P. Gradwell (Eds.), *Ernsting's Aviation Medicine* (4th ed., pp. 433-458). London: Hodder Arnold.

Bramble, W. J. (2008, October). Spatial disorientation accidents in large commercial airplanes: Case studies and countermeasures. In *61st annual International Air Safety Summit*. Paper presented at the summit of the Flight Safety Foundation, International Federation of Airworthiness & International Air Transport Association, Honolulu, HI, October 2008.

Bureau of Air Safety Investigation (1991). Accident investigation report. *Beech King Air E 90 VH-LFH, Wondai Queensland, 26 July 1990* (BASI Report B7901/1047).

Cheung, B. (2004). Nonvisual illusions in flight. I F. H. Previc & W. R Ercoline (Eds.) *Spatial disorientation in aviation*. *Progress in Astronautics and Aeronautics, 203*, pp. 283 – 321. Reston, VA: American Institute of Astronautics and Aeronautics.

Department for Transport, Air Accidents Investigation Branch (2010). *Report of the accident to Eurocopter EC225 LP Super Puma, G-REDU near the Eastern Through Area Project /ETAP), Central Production Facility Platform in the North Sea on 18 Febuary 2009* (Aircraft Accident Report 1/2011).

LeDuc, P. A., Riley, D., Hoffman, S. M., Brock, M. E., Norman, D., Johnson, P.A. et al. (1999). *The effects of sleep deprivation on spatial disorientation* (US Army Aeromedical Research Laboratory, Report No. 2000-09).

Lee, M. Y., Kim, M. S. & Park, B. R. (2004). Adaptation of the horizontal vestibular reflex in pilots. *The Laryngoscope, 114*, 897-902.

McGrath, B. J., Rupert, A. H., and Guedry, F. E. (2003). *Analysis of spatial disorientation mishaps in the US Navy, Spatial disorientation in military vehicles: Causes, consequences and cures* (RTO-MP-086, 2003, pp. 10-1 to 10-12).

Mortimer, R. G. & Kenneth, Q. G. (2000). Physical and psychological impairments of pilots in U.S. aviation crashes. In *International Ergonomics Association/Human Factors and Ergonomics Society Congress*.

North Atlantic Treaty Organization, Research and Technology Organisation (2008). *Spatial disorientation training –Demonstration and avoidance* (TG-039, RTO Technical Report, TR-HFM-118, AC/323 (HFM-118)TP/206)).

Newman, D. G. (2007). *An overview of spatial disorientation as a factor in aviation accidents and incidents* (ASTB Transport Safety Investigation Report, Aviation Research and Analysis Report –B2007/0063).

Newman, M. C., Lawson, B. D., Rupert, A. H., McGrath, B. J. (2012, August). The role of perceptual modeling in the understanding of spatial disorientation during flight and ground-based simulator training. *American Institute of Aeronautics and Astronautics on Guidance, Navigation and Control*. In *American Institute of Aeronautics and Astronautics conference on Guidance, Navigation and Control*. Paper presented at the conference of the American Institute of Aeronautics, Minneapolis, MN.

Previc, F. H. (2004). Visual illusions in flight. I F. H. Previc & W. R Ercoline (Eds.) *Spatial disorientation in aviation*. *Progress in Astronautics and Aeronautics, 203*, pp. 283 – 321. Reston, VA: American Institute of Astronautics and Aeronautics.

Previc, F. H., Ercoline, W. R., Evans, R. H., Dillon, N., Lopez, N., Dulaz, C.M. et al. (2007). Simulator-induced spatial disorientation: Effects of age, sleep deprivation, and type of conflict. *Aviation, Space and Environmental Medicine, 78*, 470-477.

Rupert, A. H., McGrath, B. J. & Guedry, F.E. (n.d.). Gulf Air flight GF-072 Perceptual study, 23 August 2000, Gulf Air Airbus A320-212 (A40-EK), Night landing.

Russo, M., Sing, H., Kendall, A. Johnson, D., Santiago, S., Escolas, S. et al. (2005). Visual perception, flight performance, and reaction time impairments in military pilots during 26 hours of continuous wake: Implications for automates workload control systems as fatigue management tools. In *Strategies to maintain combat readiness during extended employments –A human systems approach* (Paper 27, pp. 27-1 – 27-16 RTO-MP-HFM-124). Neuilly-sur-Seine, France: North Atlantic Treaty Organization, Research and Technology Organisation

Tribukait, A. & Eiken, O. (2012). Flight experience and the perception of pitch angular displacements in a gondola centrifuge. *Aviation, Space, and Environmental Medicine*, *83*, 496-503.

Weeks, S. R., McAuliffe, C. L., DuRussel, D. & Pasquina, P. F. (2010). Physiological and psychological fatigue in extreme conditions: The military example. *American Academy of Physical Medicine and Rehabilitaion*, *2*, 438-441.

Final report on SD analysis of incident with DHC-8 at Svolvær Airport Helle, Norway 2 December 2010

Memorandum

Kampweg 5
3769 DE Soesterberg
P.O. Box 23
3769 ZG Soesterberg
The Netherlands

www.tno.nl

T +31 88 866 15 00
F +31 34 635 39 77

To

From
E.L. Groen, J.G.H. Bos, M.M.J. Houben, J.E. Bos

Subject
Final report on SD analysis of incident with DHC-8 at Svolvær Airport Helle, Norway 2 December 2010

Date
2 February 2016

Our reference
TNO-2016-0100293386

Contact

1 Introduction

The Accident Investigation Board Norway (AIBN) requested TNO to assess the possible role of vestibular illusions in a serious flight incident, using the Spatial Disorientation Identification Tool (SDiT). This analysis tool was recently developed by TNO and Boeing, and presented at the International Society of Air Safety Investigators (Mumaw et al, 2015).

The SDiT takes in text files containing the time histories of flight data, and visualizes how a pilot supposedly perceives the motion and orientation of the aircraft. The tool's computations are based on a contemporary perception model, consisting of mathematical representations of the sensory dynamics involved in human perception of self-motion and – orientation (Bos & Bles, 2002). The SDiT identifies two categories of vestibular illusions that occur in-flight: 1) the "somatogravic illusion", resulting from ambiguities between linear accelerations and attitude; and the "somatogyral illusion", resulting from erroneous perception of aircraft rotations. Special types of the somatogyral illusion include sub-threshold (angular) motion, and the post-roll illusion (Nooij and Groen, 2011).

2 Assumptions, boundary conditions

The SDiT assumes that there is a lack of external visual references, due to darkness or Instrument Meteorological Conditions (IMC), and the pilot is not effectively using cockpit instruments. Furthermore, the tool does not take into account pilot's head movements which may induce Coriolis-related disorientation during constant rate turns. Information on visual cues and head movements are not available in flight data recordings.

3 Input variables

The input variables include: 1) x-, y-, and z-components of the specific force, i.e. the vector sum of linear inertial acceleration and gravitational acceleration; 2) x-, y- and z- Euler angles, which are used to compute 3-D angular velocity. The initial aircraft orientation is derived from the Euler angles at the first data sample, where upright is defined as (0,0,+9.81). The input variables are resampled at 100 Hz (irrespective the original sample rate of the FDR data).

Date
2 February 2016

Our reference
TNO-2016-0100293386

Page
2/4

4 SDiT analysis of the incident

The incident involved a Bombardier DHC-8, and occurred in December 2010 at 18:18 hr near the Svolvær airport Helle (Norway). A detailed description of the incident can be found in the preliminary report of the AIBN (2015). Important here is that the incident took place in complete darkness, hence there was no visual horizon.

Figure 1 shows a screenshot of the SDiT during the analysis of the incident. The various parts of the screen are explained in the caption. Note that the current SDiT always resets the time to t=0s for the first sample. The animation is being paused at t=11.2s, corresponding to about 103202 where the aircraft reached maximum pitch down attitude.

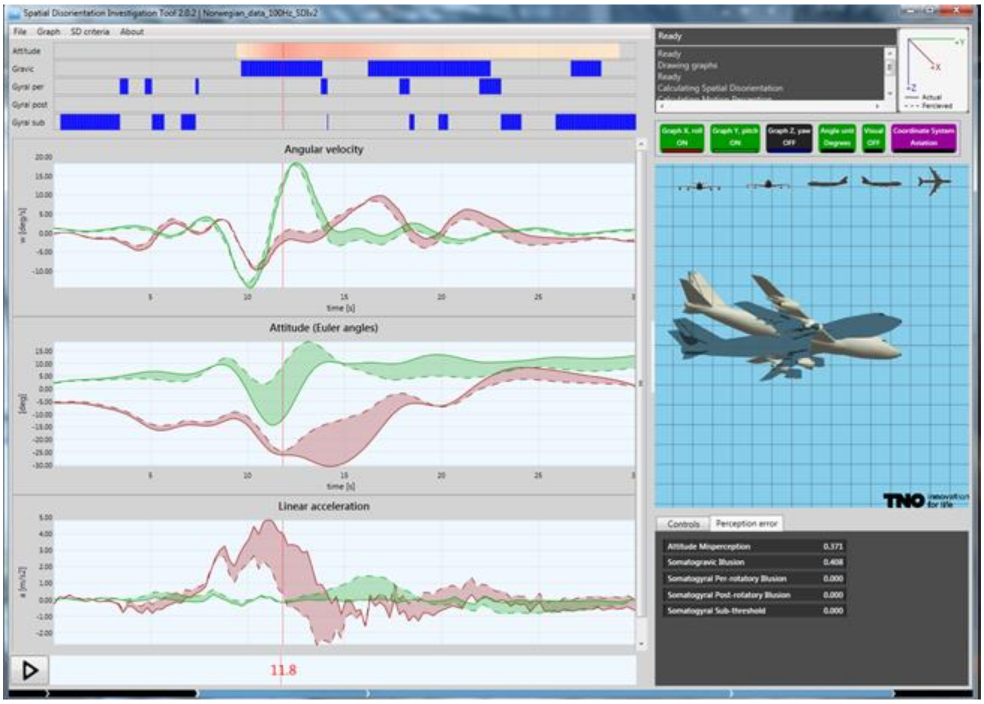


Figure 1. Screenshot of incident analysis with the SDiT. **Upper panel**: SD tracks showing the identified vestibular illusions. Attitude=attitude misperception; Gravic=somatogravic illusion; Gyral per=somatogyral illusion during turn; Gyral post=somatogyral illusion after turn; Gyral sub=sub-threshold rotation. **Bottom panel**: time histories of actual (solid lines) and perceived (dashed lines) aircraft attitude (upper) and linear acceleration (lower). The shaded areas indicate the perceptual mismatch. Red: motions in the x-axis (roll rotation resp. longitudinal acceleration); Green: motions in the y-axis (pitch rotation resp. lateral acceleration). Motions in z-axis (yaw rotation and vertical acceleration) are not shown.

The blue and orange SD tracks in the upper panel of Figure 1 show various SD events. The three tracks labelled with “Gyral” indicate that the aircraft’s angular motion was not always being perceived at all (“Gyral sub”), or alternatively, the perceived angular rate was below the actual rate due to the dynamics of the semicircular canals (“Gyral per”). Looking at the shaded areas in the time history of angular velocity, the error in the perception of angular velocity was only minor. Therefore it is likely that the somatogyral effects were not an issue in this case.

The “Attitude” track, however, shows that there was misleading vestibular feedback about the aircraft’s attitude for most of the manoeuvre. Looking at the corresponding time history (middle plot), there are substantial discrepancies in the perceived pitch attitude (green shaded area), as well as in the perceived angle of bank (red shaded area). The latter is due to the presence of lateral accelerations, which indicates that the flight was uncoordinated.

According Appendix C in the AIBN report, there was reason to believe that the pilot flying experienced a somatogravic illusion in the pitch plane. For this reason, we have limited the analysis of the somatogravic illusion to the pitch plane only. Hence, whereas the Attitude track in Figure 1 reflects the combined error in perceived pitch and roll, the “Gravic” track only reflects the error in perceived pitch.

According to vestibular literature, humans can perceive self-tilt (i.e. deviations from an upright posture) between 0.6 and 6.8 deg (Gundry, 1978; Fitzpatrick 1994; Janssen et al. 2011). This shows that there is no “absolute” threshold for the perception of self-tilt, as is true for human perception in general. We have chosen 6.0 deg as default criterion for the somatogravic illusion (Table 1), which is in the upper region of the above-mentioned range. This means that the computed mismatch in perceived pitch must exceed 6.0 deg to be labelled as somatogravic illusion. The rationale for choosing a rather high threshold is that motion perception in the dynamic environment of an aircraft will be more “noisy” than in the controlled conditions of a vestibular laboratory.

With a criterion of 6.0 deg, there appear two episodes of the somatogravic illusion (in pitch). The first episode (9.9 - 13.7 sec) seems related to the strong longitudinal acceleration up to about 5.0 m/s^2 (red trace in lower time history), resulting in a perceived nose-high attitude while the aircraft was in fact oriented nose-down. In fact, the illusion intensified during the pitching down motion. The illusion reached a maximum value of about 17 deg, which is well above the known perception thresholds. The second episode (16.9 - 21.9 sec) seems related to a sustained deceleration along the longitudinal axis of about -1.0 m/s^2, resulting in a lower perceived pitch attitude than actual. The illusion reached a maximum of about 7 deg in this episode.

The time history of attitude also shows a slight over-pitch sensation when the aircraft reached maximum pitch-up attitude (around 8.7 sec), but this perception error remained below the 6.0 deg threshold that we assumed for the somatogravic illusion.

Table 1. Parameter settings for the SD analysis.

Parameter	Value
Attitude mismatch	6 deg
Somatogravic threshold	6 deg
Somatogyral threshold	3 deg/s

5 Conclusion

The SDiT analysis identified two phases in the recorded flight profile where the vestibular inputs gave rise to a somatogravic illusion in the pitch plane (assuming that no visual information was available). In particular the first phase may have induced a strong perception of nose-high attitude, while the actual attitude was nose-down. The illusion (i.e., the mismatch between perceived and actual pitch attitude) even intensified due to the forward acceleration that resulted from the nose-down action. When the pilot flying based his control behaviour on this erroneous perception, this would result in stronger pitch forward inputs.

Although the time histories also showed a slight over-pitch sensation when the pitch down input starts, it seems too small to be identified as a somatogravic illusion. Therefore it is more likely that the decision to push the nose down was due to the flight condition (e.g., low airspeed), and not on a false pitch sensation.

The data showed that the flight was uncoordinated at that time, which resulted in errors in the perceived angle of bank. We have not further addressed this in the current analysis.

6 References

AIBN (2015) Preliminary report on serious aviation incident at Svolvaer airport Helle, Norway 2 December 2010 involving Bombardier DHC-8-103, LN-WIU operated by Wideroes Flyveselskap AS 21.08.2015. [Downloaded at January 12, 2016].

Bos, J.E., Bles, W. (2002) Theoretical considerations on canal-otolith interaction and an observer model. Biological Cybernetics 86, pp. 191-207.

Fitzpatrick, B., McCloskey, D.I. (1994) Proprioceptive, visual and vestibular thresholds for the perception of sway during standing in humans, The Journal of Physiology 478, pp. 173–186.

Gundry, A.J. (1978) Thresholds of perception for periodic linear motion, Aviation Space and Environmental Medicine 49, pp. 679–686.

Janssen, M. Lauvenberg, M. Van der Ven, W. Bloebaum, T. Kingma, H. (2011) Perception threshold for tilt, Otology & Neurotology 32, pp. 818–825.

Nooij, S.A.E., Groen, E.L. (2011) Rolling into spatial disorientation: simulator demonstration of the post-roll (Gillingham) illusion. Aviation, space, and environmental medicine 82 (5), pp. 505-512.

Mumaw, R., Groen, E., Fucke, L., Anderson, R., Bos, J., Houben, M. (2015) “A New Tool for Analyzing the Potential Influence of Vestibular Illusions,” Conference paper, International Society of Air Safety Investigators, Augsburg, Germany.

FLYMEDISINSK INSTITUTT

Utredning av visuell sirkling i mørke inn til rullebane 19 ved Svolvær Lufthavn Helle

En rapport for Statens Havarikommisjon for Transport

Jannicke Sandvik, Jørn Brede Stangnes & Anthony Sverre Wagstaff

12.02.2016

Etter forespørsel fra Statens Havarikommisjon for Transport har Flymedisinsk Institutt (FMI) foretatt en utredning av potensielle faremomenter av perseptuell art ved visuell sirkling i mørke inn til rullebane 19 ved Svolvær Lufthavn Helle. Dagens situasjon ønskes sammenlignet med situasjonen i 2010, da en alvorlig luftfartshendelse fant sted her med Widerøes rute 814. FMI har delt sirklingsrunden i tre soner. Vurdert på bakgrunn av mottatt informasjon anses risikoen for sanseillusjoner relativt lav i sone A og sone C. I sone B anses det fortsatt ikke å være tilstrekkelige visuelle referanser eller hjelpemidler til å kunne motvirke sanseillusjoner som kan påvirke flygingen. Mulige tiltak for å redusere restrisikoen foreslås.

Innhold

Utredning av visuell sirkling i mørke inn til rullebane 19 Svolvær Lufthavn Helle

Bakgrunn

2. desember 2010 skjedde det en alvorlig luftfartshendelse med Widerøes rute 814 fra Bodø Lufthavn under sirklingen inn til Svolvær Lufthavn Helle (ENSH). Statens Havarikommisjon for Transport (SHT) gir følgende korte sammendrag av hendelsen: «Like før flyet skulle svinge inn på finalen droppet hastigheten betydelig, og flyet begynte å riste. Til tross for at det ble gitt full motorkraft, fortsatte både hastigheten og høyden å avta. Nesepartiet ble senket og steiling avverget, men i det påfølgende opptrekket ble høyden over sjøen svært lav (25 m over sjøen ifølge registrerte data fra radiohøydemåleren). Det ble benyttet full motorkraft og opptrekket var så kraftig at flyet ble utsatt for høy g-belastning» (Statens Havarikommisjon for Transport, 2015). For mer informasjon, se SHT sin rapport om hendelsen.

Etter forespørsel fra SHT har Flymedisinsk Institutt (FMI) foretatt en utredning av potensielle faremomenter ved visuell sirkling i mørke inn til rullebane 19 ved ENSH. FMI er bedt om å beskrive risikofaktorene slik de var 2. desember 2010, tidspunktet for hendelsen med WIF 814, og å sammenligne med situasjonen pr. dags dato, ettersom det er tilkommet endringer i flyplassbelysning og innflygingsprosedyrer etter 2010.

FMI har avgrenset sin utredning til kun å se på risikoen ved sirklingen i lys av perseptuelle forhold, det vil si forhold som har med sanseoppfattelse å gjøre.

Metode

FMI legger til grunn følgende dokumenter som SHT har gjort tilgjengelig for oss, i tillegg til informasjon mottatt gjennom samtaler med SHT: Innflygingskart til ENSH pr. 11. februar 2011 (se vedlegg 1), innflygingskart til ENSH pr. 20. februar 2015 (se vedlegg 2), kart over området (se vedlegg 3 og 4), Widerøes *Airport briefing* (se vedlegg 5) Luftfartstilsynets godkjenning av Widerøes søknad om ny sirklingsrunde RWY 19 ENSH, 8. november 2011 (se vedlegg 6) og *Aeronautical Information Publication* (AIP) Norge; Visual approach chart – ICAO, pr. 15. Januar 2009 (vedlegg 7). FMI baserer altså vurderingene av forholdene i 2010 på Widerøes innflygingskart fra 11. februar 2011 og forholdene pr. dags dato på innflygingskartet fra 20. februar 2015, da det er dette vi har mottatt som grunnlag. Når det i utredningen refereres til forholdene i 2010 er det altså snakk om forholdene pr. 11.02.11, og når det snakkes om forholdene i dag, er det altså pr. 20.02.11. Dersom det er skjedd endringer etter 20.02.15 eller mellom 02.12.10 og 11.02.11, er disse ikke hensyntatt i utredningen.

FMI har videre hatt en samtale med Lufthavnsjefen ved ENSH for å avklare forhold rundt belysningen tilknyttet flyplassen. FMI har også hatt tilgang til transkripsjoner fra intervjuer med besetningen under hendelsen om bord WIF 814 i 2010. Videre er FMI sin rapport med analyse av eventuelle sanseillusjoner i hendelsen 02.12.10. også lagt til grunn i påfølgende utredning (Sandvik, Wagstaff & Stangnes, 2016).

For å få et bedre inntrykk av forholdene rundt sirklingen, har FMI, ved en *human factors* spesialist og en flyoperativ vært i Dash 8-100/300 Full Flight Simulator på CAE Training Centre i Oslo (hendelsesflyet var et Bombardier Inc. DHC-8-103). Sammen med representanter fra SHT og Widerøes Head of Training og Chief Flight Instructor Special Operations, fløy vi sirklingsrunden til ENSH i flere ganger. Flygningene i simulatoren ble gjort med lysforhold og med værsettinger mest mulig tilsvarende hendelsen i 2010. Her fikk vi også diskutert med treningsavdelingen hvordan Widerøe flyr sirklingen i Svolvær.

Human factors spesialist og flyoperativ fra FMI var også med en Widerøe rute fra Bodø til Svolvær Lufthavn i DHC-8 25. november 2015. Flygningen ble gjort i mørke, men lysforholdene var bedre enn under hendelsen ettersom det var fullmåne. Det var sludd/snø, men lite vind, og vindretningen tilsa sirkling til rullebane 19. Under denne flygningen satt human factors spesialisten på klappsete i cockpit. I forbindelse med denne turen var det også drøftinger om de operative forhold og Widerøes praksis tilknyttet innflygingen med en erfaren Widerøe-pilot på den aktuelle flytypen og –strekningen.

Det ble også foretatt sirkling/innflyging til flyplassen i mørke 3 ganger med Luftforsvarets Bell 412 helikopter. Dette for å sikre en grundig gjennomgang av de visuelle forholdene ved innflygingen.

Sansemessige forhold ved flyging

Menneskets behov knyttet til visuell orientering

Synsapparatet er bygget opp med to ulike «synssystemer»; skarpsynet og perifersynet. Perifersynet benyttes til vanlig til å avgjøre vår orientering, stort sett uten at vi er bevisst hvilke visuelle referanser som er benyttet. Skarpsynet benytter vi til gjenkjenning og identifisering av objekter. Når man flyr med gode visuelle referanser og klart definert horisont, benytter piloten perifersynet til å orientere seg, og dette krever lite bevisst prosessering. Når gode visuelle referanser ikke er tilgjengelig for perifersynet, som når man flyr i skyer eller i mørke, må piloten bruke instrumentene sine for å orientere seg. Dette krever bruk av skarpsynet, og derigjennom også mer prosessering i hjernen (skanning, lesing og tolkning). Selv om erfaring med instrumentflyging gjør at dette etter hvert kan gjøres mer automatisk, så er det fortsatt en «unaturlig» måte for et menneske å orientere seg, og dermed mer sensitivt for feil. Derfor er det mer sannsynlig å oppleve desorientering og sanseillusjoner under IMC enn i god VMC (Benson, 2006).

Visuelle referanser i perifersynet gjør at piloten kan oppfatte endringer i stilling i luften i *pitch* og *roll*. Avstandbedømmelse er en kompleks kombinasjon av en rekke ulike forhold som også inkluderer form og farge på ulike deler av terreng, størrelsesreferanse til kjente objekter, og perspektivfølelse. For nøyaktig avstandsbedømmelse, som høyde og avstand til flyplass og lignende er derfor piloter avhengig av flyinstrumenter (Benson, 2006).

I praksis er det ikke alltid man får dekket de fysiologiske behovene fullt ut når man flyr. Dette er gjerne tilfellet i korte tidsrom i overgangen mellom visuell flyging og instrumentflyging, eksempelvis når man tar av inn i skyer. Det kan også være tilfellet når man flyr visuell sirkling når det er så mørkt at man ikke har en skikkelig horisont å orientere etter, slik som var tilfellet under hendelsen med WIF 814. Man kan ha minne om horisonten en kort stund og til dels klare å orientere etter dette, kanskje sammen med et mentalt bilde av området, men dette medfører risiko da hjernen uansett skaper et mentalt bilde selv uten tilstrekkelige rådata. Dersom det er turbulens i området, som ofte er tilfellet ved sirkling til ENSH, vil man ikke kunne bevare et korrekt slikt minne på grunn av endringer i flyets stilling – enten reelt, eller opplevd.

Ved utførelse av prosedyren for *precision circling* RWY 19 ENSH i mørke og/eller dårlig sikt, vil det ofte kunne være forhold hvor det ikke gir en tydelig horisont. For trygg flyging trenger flyger enten å ha en tydelig horisont eller å være godt etablert på instrumenter. Hvis flyger ikke har en tydelig horisont og heller ikke er godt etablert på instrumentene i cockpit kan sanseillusjoner lettere føre til risikofylte situasjoner.

I det følgende beskrives noen av de sanseillusjonene som kan forekomme under sirkling i mørke.

Sanseillusjoner

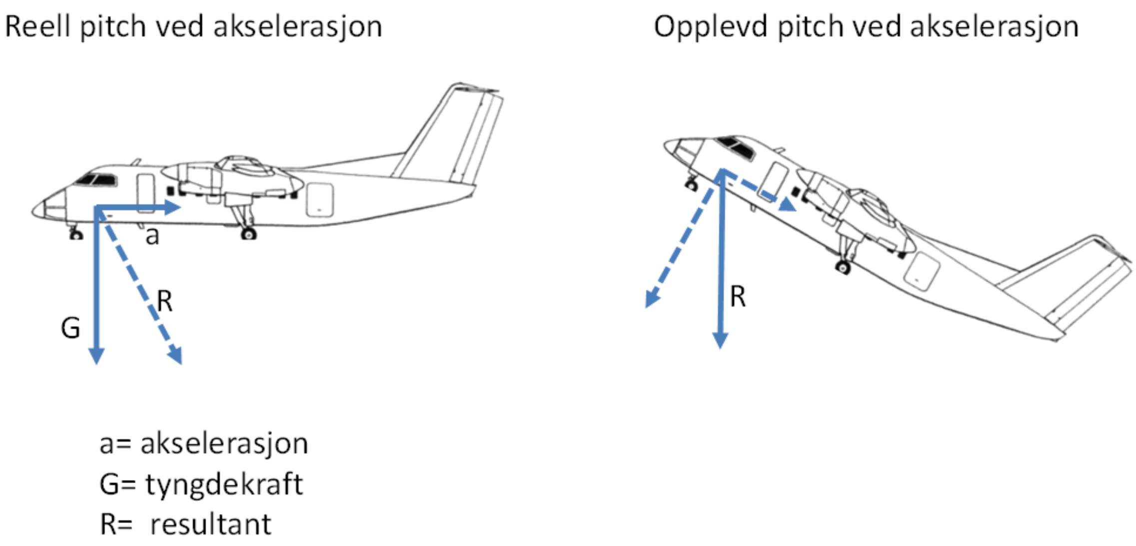
Menneskets sanseapparat er tilpasset livet på jordoverflaten, hvor orientering i rommet opprettholdes av det visuelle systemet (syn), det vestibulære systemet (balanseorgan) og det somatosensoriske systemet (hud-, ledd- og muskelsanser) på en samordnet måte. Under flyging utsettes kroppen for høye hastigheter, akselerasjonskrefter, uvante bevegelser og posisjoner, samt at synsinntrykkene er annerledes enn på bakken. Når en pilot mangler visuelle referanser, det vil si ikke kan se horisonten klart, er han/hun avhengig av det vestibulære og det somatosensoriske systemet for å orientere seg. Under de spesielle forholdene som råder under flyging fungerer imidlertid ikke disse sansene optimalt og kan gi feilaktig informasjon om sin eller flyets posisjon og bevegelse relativt til bakken (McGrath, Rupert & Guedry, 2003). Fenomenet kalles *spatial disorientation* (North Atlantic Treaty Organization, Research and Technology Organisation (NATO RTO), 2008), eller sanseillusjoner på norsk, og er en naturlig følge av det normale sanseapparatets reaksjon på stimuli det ikke er tilpasset.

Man skiller vanligvis mellom 2 typer sanseillusjoner. Type 1 sanseillusjoner er illusjoner som går uoppdaget, det vil si at piloten ikke er klar over at han eller hun ikke har et riktig bilde av sin og flyets posisjon og stilling i luften. Type 2 sanseillusjoner opptrer når piloten er oppmerksom på illusjonen, og ved hjelp av visuelle referanser og flyets instrumenter er klar over at den gir et feilaktig bilde.

Det finnes en rekke ulike sanseillusjoner, både visuelle og vestibulære. Ved visuelle illusjoner er det synsinntrykk, og hjernens tolkning av disse, som fører til illusjonen, mens balanseorgan og det somatosensoriske system gir grunnlag for de vestibulære illusjonene. I noen illusjoner kan en kombinasjon av disse spille inn. Nedenfor følger en enkel forklaring på de vanligste sansillusjoner som anses som mest relevante ved sirkling i mørke til ENSH.

Somatogravisk illusjon

En somatogravisk illusjon oppstår ved at det er en falsk persepsjon (oppfatning) av egen/flyets orientering grunnet en kraftvektor som virker i en annen retning og/eller styrke enn den vanlige gravitasjonskraften (vertikalt ned mot bakken). Når flyet akselererer presses piloten bakover mot seteryggen. I fravær av visuelle referanser utenfra oppleves denne kraften mot seteryggen og tyngdekraften som én kraft (resultantkraft), noe piloten oppfatter som vertikalen (rett ned som tyngdekraften) (Benson & Rollin Stott, 2006, Cheung, 2004). Piloten får dermed en følelse av å være tiltet (i Figur 1 beskrevet som «*pitch*») bakover og at flyets nese peker oppover mer enn det som faktisk er tilfellet (se figur 1). Det motsatte er tilfellet ved deselerasjon.



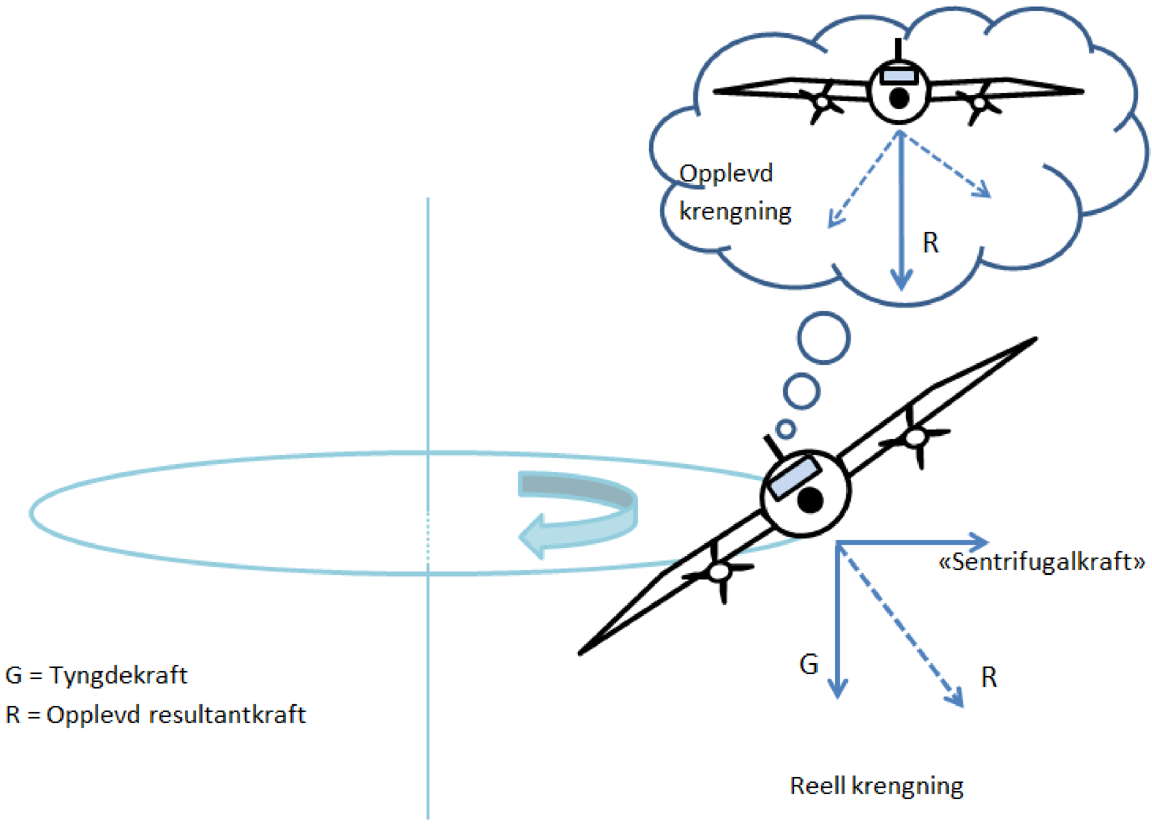
Figur 1: Resultantkraft og opplevd *pitch* (nesestilling) i en somatogravisk illusjon

Paradokset med denne illusjonen er at eventuelle justeringer av nesestilling som piloten måtte forsøke å gjøre, skaper liten endring i følelsen av nese opp. Dersom piloten retter nesen nedover, vil flyet akselerere, noe som igjen øker følelsen av nese opp (Benson & Rollin Stott, 2006, Cheung, 2004). Dersom piloten derimot retter nesen mer opp, ville akselerasjonskraften forover reduseres, siden mer motorkraft ville kreves for å klatre. Dette kan igjen resultere i at man oppfatter lite endring i nesestilling fordi den reduserte illusoriske oppfattelsen av nesestilling oppveier følelsen av reell endring av nesestilling (Benson & Rollin Stott, 2006). Det er kjent fra flere hendelser i luftfarten at en somatogravisk illusjon kan ha påvirket piloten til å senke nesen på flyet og ført til, eller medvirket til, ulykker (Department of Transport, Air Accidents Investigation Branch, 2010; Armentrout, Holland, O'Toole & Ercoline, 2001; Bureau of Air Safety Investigation (BASI), 1991).

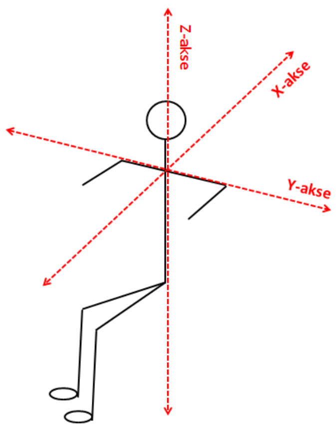
«G-excess» illusjon

Krengning og hodeposisjon kan også gi opphav til sanseillusjoner. I en sving kan hodebevegelser i *pitch*, *roll* eller *yaw* indusere feilaktige opplevelser av flyets stilling. Forholdet mellom ulike hodebevegelser og resulterende opplevelse av egen eller flyets stilling er uklart i litteraturen og kan variere i ulike situasjoner og mellom ulike personer.

Videre vil tyngdekraften i en koordinert sving virke vertikalt rett ned mot bakken, mens sentripetalkraften virker innover i svingen. Motkraften, sentrifugalkraften, oppleves som en kraft som virker utover. Resultanten av disse to virker på skrå nedover og utover fra svingen (se figur 2), og er i samsvar med pilotens z-akse (se figur 3).



Figur 2: Resultantkraften i koordinert sving og feilaktig oppfatning av rett stilling.



Figur 3: Pilotens x-, y- og z-akse

Piloten vil kunne føle at flyets stilling er horisontal ettersom signalene fra balanseorganene og de kinestetiske referansene (hud-ledd- og muskelsanser) tilsvarer de på bakken (Benson & Rollin Stott, 2006). Uten tilstrekkelige visuelle referanser kan dette resultere i at piloten øker flyets krengningsvinkel (Cheung, 2004, Newman, 2007).

Oculogravisk illusjon

Det finnes også sanseillusjoner hvor visuelle forhold gir feilaktige oppfatninger av flyets posisjon. De samme uvanlige kraftmiljøene som skaper somatograviske illusjoner kan også skape illusjoner med visuelle komponenter. Disse såkalte oculograviske illusjoner kan også sees på som den visuelle komponenten av somatograviske illusjoner (Benson & Rollin Stott, 2006).

For eksempel vil en pilot som opplever en somatogravisk illusjon under akselerasjon også kunne oppleve at objekter i synsfeltet synes å bevege seg oppover, som for eksempel særlig cockpitbelysning (Previc, 2004), men også singulære lyspunkt utenfor cockpit. Piloten kan tolke oppoverbevegelsen i synsfeltet som en endring i flyets stilling og følelsen av nese opp intensiveres (Benson & Rollin Stott, 2006). Dette er paradoksalt fordi objekter utenfor cockpit faktisk beveger seg nedover i synsfeltet når flyets nese beveger seg oppover (Cheung, 2004).

«Elevator» illusjon

En endring i styrke på kraftvektoren, som ved vertikal akselerasjon, eksempelvis turbulens, vil i tillegg til følelsen av henholdsvis oppover- eller nedoverbevegelse, gi inntrykk av en tilsynelatende bevegelse i synsfeltet og følelsen av endring av flyets nesestilling, såkalt *elevator* illusjon (Benson & Rollin Stott, 2006).

Autokinetisk illusjon

Autokinetisk illusjon er en annen illusjon som kan oppstå når man kun har enkelte lys å forholde seg til i et ellers mørkt synsfelt. Etter å ha fokusert noen sekunder på et slikt enkelt lys, vil øynene begynne å gjøre små bevegelser. Dette gjør at lyset ser ut til å bevege seg, og dette kan av en pilot tolkes som endringer av flyets stilling (Previc, 2004).

Slike illusjoner oppstår sjelden når det finnes veldefinerte, eksterne visuelle referanser, men for eksempel nattestid, når kun noen få stjerner eller isolerte lys er synlige, for eksempel, kan de lett skape problemer for piloters situasjonsoppfattelse (Benson & Rollin Stott, 2006).

«Black hole» illusjon

Generelt er flyging om natten, spesielt under innflygingsfasen, knyttet til noen ekstra utfordringer for piloter. En såkalt *black hole approach* illusjon kan forekomme under innflyging på natt over vann eller i uopplyst terreng inn mot en opplyst rullebane uten synlig horisont. Uten andre visuelle referanser enn rullebanelysene kan piloten få en feilaktig oppfatning av rullebanens plassering, helning, bredde eller høyde i forhold til det omkringliggende terreng, og følgelig plassere flyet feil i forhold til rullebanen (Federal Aviation Administration, n.d.).

Beskrivelse av forholdene ved Svolvær Lufthavn Helle

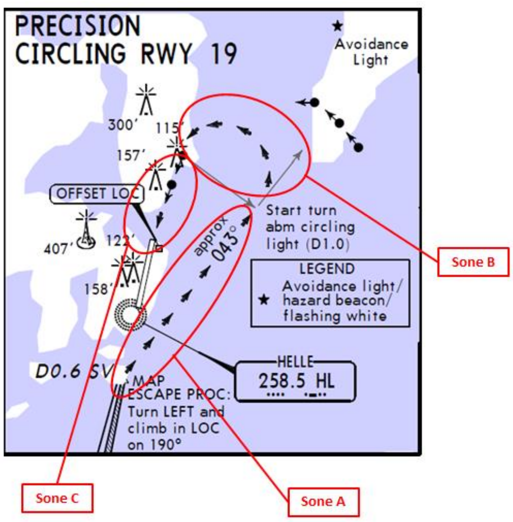
De foregående sanseillusjonene er et utvalg av de illusjoner som en flyger vil kunne oppleve ved innflyging i mørke til ENSH. I den videre utredningen er sirklingsrunden delt inn i tre ulike soner, sone A, B og C. Risikonivået i de ulike sonene beskrives, både slik de vurderes å ha vært i 2010 og slik de vurderes å være pr. i dag. Avslutningsvis foreslås måter for potensielt å redusere risikoen i sonene.

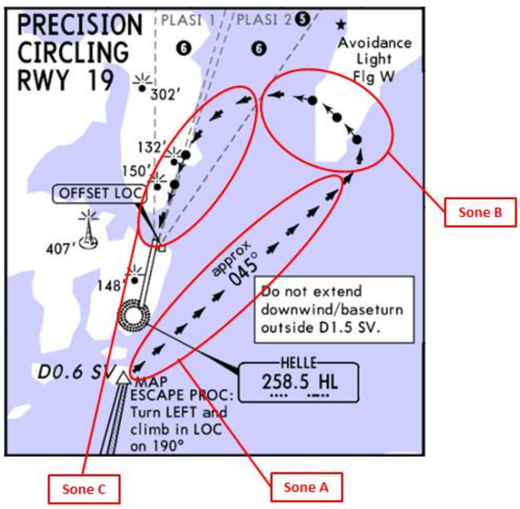
Værforhold ved Svolvær Lufthavn Helle

ENSH ligger ytterst i Austnesfjorden i Lofoten med fjell vest, nord og øst for flyplassen (se vedlegg 4). Ettersom flyplassen ligger på ca. 68˚N er det mørketid på vinteren, og derfor ofte mørkt under innflyging. Beliggenhet gjør flyplassen utsatt for vind, spesielt i vinterhalvåret. Fremherskende vindretning er fra SV. Særskilte vindrestriksjoner gjelder for variabel vind i sektoren 240˚- 340˚. Da kan det være moderat, og i blant, sterk turbulens under sirkling, og det er registrert til dels sterke *downdrafts* på finalen til rullebane 19. Ved SV-NV vind over 20 knop kan *windshear/eddies* forekomme på kort finale til samme rullebane (vedlegg 5).

Sirklingsrunden til rullebane 19 ved Svolvær Lufthavn Helle

Som nevnt baserer FMI vurderingene av forholdene i 2010 på Widerøes innflygingskart fra 11. februar 2011 og forholdene pr. dags dato på innflygingskartet fra 20. februar 2015 (se figur 4 og 5 samt vedlegg 1 og 2.





Figur 4: Innflygingskart SHL pr. 11. feb. 2011 **Figur 5: Innflygingskart SHL pr. 20. feb. 2015**

Det synes å være noen uoverensstemmelser mellom ulike informasjonskilder FMI har mottatt om flyplassforholdene. Det er uklart hvilken farge hinderlyset ca. 3,5 km. nordøst for flyplassen hadde i 2010, men dette anses ikke som avgjørende for analysen.

Widerøes innflygingskart (vedlegg 1) og AIP pr. 15.01.2009 (vedlegg 7) er ikke like hva gjelder sirklingslys. AIP viser ett sirklingslys nord for rullebanen og to sirklingslys nordøst for flyplassen, mens Widerøe sitt kart viser to sirklingslys nord for rullebanen og tre nordøst for flyplassen. I følge Lufthavnsjefen ved ENSH har sirklingslysene nordøst for flyplassen vært der siden 2008. De skal ha blitt endret sent i 2010 fra *white flashing* til å kunne være *white flashing* og/eller *yellow steady*, ut i fra lysforholdene. Det var Widerøe som ba om dette fordi *white flashing* var vanskelig å se på dagtid, mens *yellow steady* synes bedre da. Lysinnstillingen endres fra tårnet (Lufthavnsjefen ved ENSH, personlig kommunikasjon, 26. januar 2016). Det er usikkert hvorvidt denne endringen inntraff før eller etter hendelsen med WIF 814, men det anses ikke som avgjørende i forhold til vurderingene, da dette dreide seg om å gjøre lysene mer synlige på dagtid, og utredningen gjelder sirkling i mørke.

Det var PLASI, *Pulse Light Approach Slope Indicator*, på ENSH i 2010. FMI legger til grunn at PLASI i 2010 var lik som den merket PLASI 1 på innflygingskartet fra 2015.

Sone A
Sone A strekker seg fra *missed approach point* (MAP) og til det punkt hvor man begynner svingen tilbake mot rullebanen. I 2010 var kursen 043˚ på sone A-strekket, og startpunktet for svingen var på tvers av (*abeam*) sirklingslysene nord for rullebanen (DME 1.0) (se vedlegg 1). I dag er kursen 045˚, og svingen må startes på en slik måte at man ikke kommer utenfor DME 1.5 SV på *downwind* eller i *base*-svingen (se vedlegg 2).

I sone A har pilotene begynt visuell flyging (*precision circling*). Flygingen går på stødig kurs og jevn høyde (minimum 580 fot), normalt koblet på autopilot. Selv om flygingen er visuell er det naturlig at det meste av flygingen foregår med referanse til instrumentene, samtidig som *pilot flying* (PF) også vil beholde visuell kontakt med rullebanen og sirklingslysene rett frem. I denne sonen vil flygingen være nokså stabil, uten store pilotinduserte akselerasjoner/deselerasjoner, svinger eller stigning/nedstigning.

I sone A vil man i hovedsak ha vinden mer eller mindre bakfra. Det kan være en del turbulens på strekningen, og man kan oppleve vindkast bakfra, som vil gi plutselig akselerasjon. En slik akselerasjon kan bidra til en opplevelse av en somatogravisk sanseillusjon.

Det har vært en kursendring på +2˚på sone A-strekket mellom 2010 og i dag. Punktet for start av sving (og sone B) er endret fra å være på tvers av (*abeam*) sirklingslysene nord for rullebanen til slik at man overflyr de tre sirklingslysene nordøst av flyplassen, nær Oddvær (se vedlegg 2 og 3). Tilsynelatende blir sone A lenger med den nye prosedyren, men punktet for å starte sving er avhengig av vindstyrken.

Sterke vindkast og turbulens kan gi noe risiko for sanseillusjoner i sone A. Ettersom flygingen, både nå og tidligere, normalt foregår på jevn fart, kurs og høyde, gir eventuell manglende horisont og eksterne visuelle referanser imidlertid relativt lav risiko for sanseillusjoner. Det antas derfor at risikoen er omtrent den samme nå som i 2010. Autopilot og gode instrumentprosedyrer vil føre til en relativt godt kontrollerbar situasjon i denne sonen.

Sone B
Sone B starter der svingen inn på *base* begynner og strekker seg til det punkt hvor piloten har PLASI i sikte og kan følge denne. I 2010 startet svingen på et bestemt punkt, på tvers av (*abeam*) det nordligste av de to sirklingslysene nord for rullebanen. Man entret ikke PLASI før man var omtrent på landingsretningen og svingen var avsluttet. Nedstigning måtte da skje i svingen for at man ikke skulle komme for høyt inn på finalen (se vedlegg 1).

I dag er det ikke spesifisert et eksakt startpunkt for sving, men spesifisert at man skal følge sirklingslysene, slik det fremgår i Luftfartstilsynets godkjenning av sirkling til Svolvær av 8. november 2011 (se vedlegg 2 og 6), og ikke skal ha *downwind/baseturn* utenfor D 1.5 SV. Punktet for start av sving blir da lenger ut og kursen er litt endret, slik får man en større svingradius. I tillegg finnes nå en sekundær PLASI som er 18˚*offset* fra rullebanen. Man ser da PLASI etter færre grader gjennomført sving enn i 2010, og man flyr altså en mindre del av svingen uten gode referanser. Fordi man kommer innenfor PLASI lenger nord for rullebanen enn tidligere kan det også holdes en større høyde gjennom svingen uten å komme for høyt på finalen.

Sone B karakteriseres, både i dag og i 2010, av en gjennomgående sving med større eller mindre grad av gjennomsynkning/nedstigning hvor krengningen vil variere for å hindre at flyet drifter for langt mot nord. De nye sirklingslysene nær Oddvær nordøst for rullebanen kan bidra til å hindre at man havner for langt nord, men de er ikke nok til å gi visuelle referanser å orientere etter. Enkeltlys kan ikke benyttes til orientering da de ikke kan gi korrekt oppfattelse av flyets stilling i luften (*attitude*) og referanser som avstand/høyde. Fokusering på enkeltlys kan føre til sanseillusjoner som den autokinetiske.

PF vil i denne sonen veksle oppmerksomheten mellom utvendige referanser (rullebanelys, hinderlys og sirklingslys) og instrumenter. Utvendige referanser benyttes til å orientere seg og for å oppdage PLASI så tidlig som mulig. Flygingen vil i hovedsak ikke foregå ved hjelp av instrumenter, men med visuelle referanser. Dette øker risiko enn i sone B.

Risikoen for å oppleve enkelte sanseillusjoner øker med økt krengning og G-krefter. Det samme gjelder for akselerasjon/deselerasjon og stigning/nedstigning. Det at PF veksler blikket mellom utvendige referanser og instrumenter fører til hodebevegelser, som i sin tur øker risikoen for å oppleve sanseillusjoner. I tillegg tar det et øyeblikk for hjernen å bearbeide og gjenkjenne informasjon hver gang man flytter blikket inn eller ut, slik at man har korte øyeblikk hvor man er uten faste, sikre referanserammer. Dette er også med og øker sannsynligheten for å oppleve sanseillusjoner. Eksempler på sanseillusjoner som kan forekomme i sone B er somatogravisk, oculogravisk, *g-excess* og *black hole* illusjon.

Det er ofte turbulens i sirklingsområdet, og når man nærmer seg fjellene nordvest og nordøst for flyplassen (se vedlegg 4) kan vindretningen skifte retning innenfor korte tidsrom. *Downdrafts*, *eddies* og *windshear* kan oppleves, særlig mot slutten av sone B. Denne typen værfenomener vil kunne bidra til å øke arbeidsbelastningen og påvirke sannsynligheten for å oppleve sanseillusjoner. Disse forholdene kan ha vært medvirkende under hendelsen med WIF 814 i 2010.

Siden radius på svingen, i følge innflygingskartene, er økt i dag sammenlignet med 2010 vil det generelt være behov for mindre krengning i svingen nå. I tillegg flyr man en mindre del av svingen før man treffer PLASI i dag. Risikoen forbundet med svingen og krengning anses derfor å være redusert etter 2010. Det reduserte behovet for nedstigning i svingen vil også kunne bidra til å redusere risiko. Startpunktet på svingen er endret fra et fast punkt i 2010 til et punkt som må bedømmes av piloten ut i fra de rådende vindforhold i dag. Denne menneskelige vurderingen anses isolert sett som en mulig økt risiko.

I sin søknad om den nye sirklingsrunden (godkjent 8. november 2011, se vedlegg 2 og 6) legger Widerøe til grunn «en beregningsmetode om hinderfri område ved sirkling med foreskrevet trekk langs sirklingslys» og «at sikkerheten blir større i svingområdet som blir utvidet og at sluttinnlegg til bane 19 blir tidligere enn før». Selskapet legger også til grunn at «PLASI intercept kan foregå i 500 ft» (se vedlegg 6). FMI oppfatter det slik at pilotene normalt ikke flyr over sirklingslysene, men starter svingen tidligere og benytter sirklingslysene mer som en linje de holder seg innenfor. Fordelen med den nye prosedyren for sirkling kan da reduseres fordi praksisen krever noe mer krengning for å holde seg innenfor sirklingslysene enn om prosedyren ble fulgt slik den er beskrevet i søknaden og godkjenningen. FMI har også inntrykk av at pilotene foretar nedstigning i svingen og entrer PLASI med lavere høyde enn de 500 fot som godkjenningen legger opp til.

Ulike risikoer er fortsatt til stede, men den totale risikoen i sone B anses å være lavere i dag enn i 2010.

Sone C

Sone C strekker seg fra det punktet hvor man entrer PLASI og frem til rullebanen. I sone C benyttes visuell innflyging for å lande. Det betyr at PF i hovedsak vil føre flyet ved hjelp av utvendige referanser med enkelte blikk inn i cockpit for å sjekke instrumentene.

Flyet vil også i sone C ofte være utsatt for krefter i form av omskiftende vind, turbulens, *windshear* og *eddies*. Som nevnt, kan slike forhold bidra til å øke arbeidsbelastning, og det påvirker sannsynligheten for å oppleve sanseillusjoner. Det samme kan PF sine hodebevegelser og veksling av blikket mellom utvendige referanser og instrumenter gjøre, som nevnt under sone B. Eksempler på sanseillusjoner som kan forekomme i sone B er somatograviske, oculograviske, *g-excess* og *black hole* illusjoner.

I 2010 var det singel PLASI som gjorde at man måtte være tilnærmet etablert på landingskursen for å treffe PLASI. Ettersom svingen i sone B hadde mindre svingradius var man også nærmere rullebanen når man entret PLASI, og man måtte således ha en lavere høyde på dette tidspunktet. Risikoen for å komme for høyt inn på finalen kunne medføre at piloten måtte benytte en brattere nedstigning enn normalt. Dette medfører et noe høyere stressnivå og et noe annerledes synsbilde av rullebanen, som igjen kan øke sannsynligheten noe for å oppleve sanseillusjoner.

I dag er det dobbel PLASI (offset PLASI) som gjør at man kommer innenfor PLASI opptil 30˚ før landingskursen. Ettersom svingen (sone B) startes på et senere punkt i dag enn i 2010 blir svingradiusen større, og PLASI kan dermed følges fra en større utgangshøyde. Det vil si at man entrer PLASI på et punkt høyere og lenger vekk fra rullebanen nå enn i 2010. I sin søknad vedrørende den nye (godkjente) sirklingsrunden la Widerøe til grunn at man kunne entre PLASI i en høyde på 500 fot (se vedlegg 6). Sone C er således lenger i dag enn i 2010. Med en lengre sone C hvor man kommer innenfor PLASI på et tidligere tidspunkt og i en større høyde enn i 2010, antas sone C å ha en redusert risiko nå sammenlignet med i 2010.

Oppsummering av risiko i 2010 versus i dag

I sone A er risikoen omtrent den samme nå som i 2010 med en relativt lav risiko for sanseillusjoner. Den totale risikoen i sone B anses å være lavere i dag enn i 2010, men sonen anses å ha den største risikoen av de tre for å oppleve sanseillusjoner. Sone C involverer noe risiko for å oppleve sanseillusjoner, men risikoen vurderes å være redusert nå sammenlignet med i 2010. Faren for å oppleve sanseillusjoner under visuell sirkling (*precision circling*) i mørke til rullebane 19 på ENSH er til stede, men totalt sett anses risikoen redusert ved bruk av prosedyren slik den er beskrevet i vedlegg 2 og 6 i 2015 sammenlignet med prosedyre i 2010 (vedlegg 1).

Mulige tiltak som vil kunne forbedre risikobildet i forhold til sanseillusjoner

Risiko ved sirklingsprosedyren (*precision cirkling*) inn til rullebane 19 ved ENSH synes i dag å være hovedsakelig knyttet til følgende faktorer:

- Sirklingsprosedyren defineres og utføres som en visuell flyging (*precision cirkling*) selv om det i mange tilfeller ikke finnes en definert og synlig horisont som referanse
- Risikoen for å oppleve sanseillusjoner, spesielt i svingen i sone B
- Værforhold som dårlig sikt, sterk vind, turbulens og *windshear/eddies* kan påvirke muligheten for å oppleve sanseillusjoner

Værforholdene rundt flyplassen er det lite å gjøre med, men det finnes flere mulige metoder, både teknologiske og av prosedyremessig art, for potensielt å redusere risikoen under sirkling til rullebane 19 ved ENSH. Tiltak kan deles i tre grupper:

1. Tilrettelegge for instrumentflyging helt frem til PLASI er synlig
2. Tilrettelegge for eksterne referanser som muliggjør trygg visuell flyging frem til PLASI er synlig
3. Forbedring av prosedyrer og trening

I det følgende foreslås noen teknologiske muligheter for å redusere risikoen for sanseillusjoner i dette og lignende scenarioer. Imidlertid presiserer vi at FMI ikke har tilstrekkelig kompetanse på slik teknologi for å anslå gjennomførbarhet og tekniske ulemper. Forslagene er kun basert på menneskets fysiologiske forutsetninger for å kunne orientere seg og for å minimalisere risiko for sanseillusjoner. Det er også viktig å være oppmerksom på at ny teknologi, samtidig som den løser enkelte sansemessige utfordringer, også kan skape nye utfordringer.

Tilrettelegging for instrumentflyging helt frem til PLASI er synlig

Tilrettelegging for instrumentflyging også i sving vil kunne bidra til at PF vil kunne holde konstante instrumentprosedyrer helt frem til sone C. GPS-basert innflygingsteknologi skal kunne gjøre dette mulig. Med en slik løsning er det viktig at displaysystemer ivaretar god situasjonsbevissthet i forhold til høyde, hastighet, svingradius og krengning, i tillegg til en god horisont.

Nye innflygingsmetoder hvor prosedyren ligger inne i flyets autopilotsystem, vil kunne redusere arbeidsbelastning og dermed gjøre at piloten har mer kapasitet til å følge med på eventuelle avvikende forhold som kan oppstå, eksempelvis sanseillusjoner. Imidlertid vil ikke autopilotsystemet ha autoritet nok til å kunne følge prosedyren gjennom hele svingen ved urolige og ekstreme vindforhold slik at piloten da vil måtte overta kontrollen av flyet selv (Chief Flight Instructor Special Operations, personlig kommunikasjon, 27. januar 2016).

En annen løsning som vil kunne bidra til lettere instrumentflyging er et *head-up display*. *Head-up displayet* vil gjøre en kunstig horisont og andre viktige data lett tilgjengelig i synsfeltet. Behovet for å veksle blikket blir da mindre, og medfølgende hodebevegelser reduseres.

Disse løsningene ville kunne gi bedre visuelle referanser for flygingen og redusere risikoen under *precision circling* generelt, og spesielt kunne redusere risikoen for sanseillusjoner i sone B.

Tilrettelegging for eksterne referanser som muliggjør trygg visuell flyging frem til PLASI er synlig

Det er mulig å konstruere lyskilder på bakkenivå som gir mer informasjon og et større grunnlag for høyde- og horisontbedømmelse enn de få sirklings- og hinderlysene som finnes i dag gjør. Slike løsninger er kjent både fra skipsfart (overrettmerker, sektorbelysning) og luftfart ved innflyging av helikopter til skip. En slik type løsning vil kunne redusere risikoen i sone B og C av sirklingsrunden.

Forbedring av prosedyrer og trening

Å forstå hvordan sanseapparatet virker, hvordan og under hvilke forhold sanseillusjoner oppstår gir økt bevissthet rundt problematikken og kan gjøre at piloter tar forbehold for å forsøke å unngå illusjoner eller oppdager sanseillusjonene (Type 2 sanseillusjoner). Opplæring om sanseillusjoner sammen med riktig trening i simulator vil kunne redusere risiko for sanseillusjoner, selv om denne risikoen aldri vil kunne fjernes helt. Denne type opplæring bør skje for alle piloter, både under flyopplæring og gjennom karrieren.

FMI er oppmerksom på at Widerøe i den senere tid har hatt større fokus på og er kommet i gang med sanseillusjonstrening i simulator (Chief Flight Instructor Special Operations, personlig kommunikasjon, 27. januar 2016).

Under en sirklingsprosedyre hvor piloten må veksle oppmerksomheten mellom å se ut og se på instrumentene, er gode *cockpit voice* prosedyrer nødvendige. Dersom PF får jevnlig får opplest viktige indikasjoner (for eksempel høyde og fart) gjennom svingen fra *downwind* til finalen av *pilot monitoring* (PM), uavhengig av om parameterne er innenfor eller utenfor det normale, vil det være til hjelp for PF i forhold til å opprettholde god situasjonsbevissthet. En slik muntlig instrumentavlesning kan til en viss grad kompensere for utilstrekkelige visuelle referanser. Rollene til henholdsvis PF og PM må også være klart definerte, og trent i simulator.

Det at flyet får endret fart, *attitude* og høyde kan skje raskt og krever rask kompensasjon for å unngå uhell i en slik sirkling. Prosedyren med at PM sier «*check speed*», hvorpå PF må veksle blikket til instrumentene, skanne, lese og tolke farten –om den er for høy eller lav- er tidkrevende og skaper mentale utfordringer. En kontinuerlig avlesning ved bestemte intervaller vil gi en bedre forståelse og muliggjøre raskere justering til riktige parameter.

Konklusjon

Ut fra den informasjonen Flymedisinsk institutt har mottatt som grunnlag anses risikonivået for sanseillusjoner som relativt lavt i sone A og sone C i 2010. Risikoen anses å ha vært større i sone B. Det var også i sone B at hendelsen med WIF 814 skjedde i 2010.

Risikoen i dag anses også å være relativt lav i sone A og sone C. Flyging i sone B medfører fortsatt større risiko enn i de andre sonene. Når det er mørkt og/eller lav sikt i sone B vurderes det dit hen at det fortsatt ikke finnes tilstrekkelige visuelle referanser eller hjelpemidler til å kunne motvirke sanseillusjoner. Det finnes derfor en restrisiko.

FMI har foreslått noen potensielle tiltak, både prosedyremessige og av teknologisk art, som kan bidra til å senke restrisikoen. Bevisstgjøring og undervisning om sanseillusjoner, sanseillusjonstrening i simulator, samt videreutvikling av prosedyrer vil kunne redusere risikoen. Innføring av teknologiske løsninger vil potensielt kunne føre til ytterligere reduksjon av restrisiko.

Referanser

Armentrout, J. J., Holland, D. A., O'Toole, K. J. & Ercoline, W. R. (2006). Fatigue and related human factors in the near crash of a large military aircraft. *Aviation, Space and Environmental Medicine, 77*, 963-970.

Benson, A. J. (2006). Spatial disorientation in flight. I D. J. Rainford & D. P. Gradwell (Eds.), Ernsting's Aviation Medicine (4th ed., pp. 433-458). London: Hodder Arnold.

Benson, A. J. & Rollin Stott, J. R (2006). Spatial disorientation in flight. I D. J. Rainford & D. P. Gradwell (Eds.), *Ernsting's Aviation Medicine* (4th ed., pp. 433-458). London: Hodder Arnold.

Bramble, W. J. (2008, October). Spatial disorientation accidents in large commercial airplanes: Case studies and countermeasures. In *61st annual International Air Safety Summit*. Paper presented at the summit of the Flight Safety Foundation, International Federation of Airworthiness & International Air Transport Association, Honolulu, HI, October 2008.

Bureau of Air Safety Investigation (1991). Accident investigation report. *Beech King Air E 90 VH-LFH, Wondai Queensland, 26 July 1990* (BASI Report B7901/1047).

Cheung, B. (2004). Nonvisual illusions in flight. I F. H. Previc & W. R Ercoline (Eds.) *Spatial disorientation in aviation*. *Progress in Astronautics and Aeronautics, 203*, pp. 283 – 321. Reston, VA: American Institute of Astronautics and Aeronautics.

Department for Transport, Air Accidents Investigation Branch (2010). *Report of the accident to Eurocopter EC225 LP Super Puma, G-REDU near the Eastern Through Area Project /ETAP), Central Production Facility Platform in the North Sea on 18 Febuary 2009* (Aircraft Accident Report 1/2011).

European Union (2012). Standardised European Rules of the Air. L 281/2 Official Journal of the European Union 13.10.2012, Article 2. Retrieved Febuary 2, 2016 from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ%3AL%3A2012%3A281%3A0001%3A0066%3

AEN%3APDF.. Regulation Commission implementing regulation (EU) No 923/2012 of 26 September 2012 laying down the common rules of the air and operational provisions regarding services and procedures in air navigation and amending Implementing Regulation (EU) No 1035/2011 and Regulations (EC) No 1265/2007, (EC) No 1794/2006, (EC) No 730/2006, (EC) No 1033/2006 and (EU) No 255/2010.

Federal Aviation Administration (n.d.). *Spatial disorientation –Visual illusions*. [Brochure] Retrieved August 3, 2015 from https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/spatiald_visillus.pdf

Sandvik, J., Wagstaff, A. S. & Stangnes, J. B., 2016. *Analyse av hendelsene under Widerøes rute 814 fra Bodø Lufthavn til Svolvær Lufthavn Helle 2. desember 2010 –En rapport for Statens Havarikommisjon for Transport.* Unpublished manuscript, Flymedisinsk Institutt.

LeDuc, P. A., Riley, D., Hoffman, S. M., Brock, M. E., Norman, D., Johnson, P.A. et al. (1999). *The effects of sleep deprivation on spatial disorientation* (US Army Aeromedical Research Laboratory, Report No. 2000-09).

Lee, M. Y., Kim, M. S. & Park, B. R. (2004). Adaptation of the horizontal vestibular reflex in pilots. *The Laryngoscope, 114*, 897-902.

Luftfartstilsynet (2014). Luftfartstilsynets VFR Guide (2014). [Brochure] Retrieved Febuary 3, 2016 from http://easa.europa.eu/essi/egast/wp-content/uploads/2014/05/VFR+Guide+2014.pdf. Bodø, Norge: Luftfartstilsynet.

McGrath, B. J., Rupert, A. H., and Guedry, F. E. (2003). *Analysis of spatial disorientation mishaps in the US Navy, Spatial disorientation in military vehicles: Causes, consequences and cures* (RTO-MP-086, 2003, pp. 10-1 to 10-12).

Mortimer, R. G. & Kenneth, Q. G. (2000). Physical and psychological impairments of pilots in U.S. aviation crashes. In *International Ergonomics Association/Human Factors and Ergonomics Society Congress*.

North Atlantic Treaty Organization, Research and Technology Organisation (2008). *Spatial disorientation training –Demonstration and avoidance* (TG-039, RTO Technical Report, TR-HFM-118, AC/323 (HFM-118)TP/206)).

Newman, D. G. (2007). *An overview of spatial disorientation as a factor in aviation accidents and incidents* (ASTB Transport Safety Investigation Report, Aviation Research and Analysis Report –B2007/0063).

Newman, M. C., Lawson, B. D., Rupert, A. H., McGrath, B. J. (2012, August). The role of perceptual modeling in the understanding of spatial disorientation during flight and ground-based simulator training. *American Institute of Aeronautics and Astronautics on Guidance, Navigation and Control*. In *American Institute of Aeronautics and Astronautics conference on Guidance, Navigation and Control*. Paper presented at the conference of the American Institute of Aeronautics, Minneapolis, MN.

Previc, F. H. (2004). Visual illusions in flight. I F. H. Previc & W. R Ercoline (Eds.) *Spatial disorientation in aviation*. *Progress in Astronautics and Aeronautics, 203*, pp. 283 – 321. Reston, VA: American Institute of Astronautics and Aeronautics.

Previc, F. H., Ercoline, W. R., Evans, R. H., Dillon, N., Lopez, N., Dulaz, C.M. et al. (2007). Simulator-induced spatial disorientation: Effects of age, sleep deprivation, and type of conflict. *Aviation, Space and Environmental Medicine, 78*, 470-477.

Rupert, A. H., McGrath, B. J. & Guedry, F.E. (n.d.). Gulf Air flight GF-072 Perceptual study, 23 August 2000, Gulf Air Airbus A320-212 (A40-EK), Night landing.

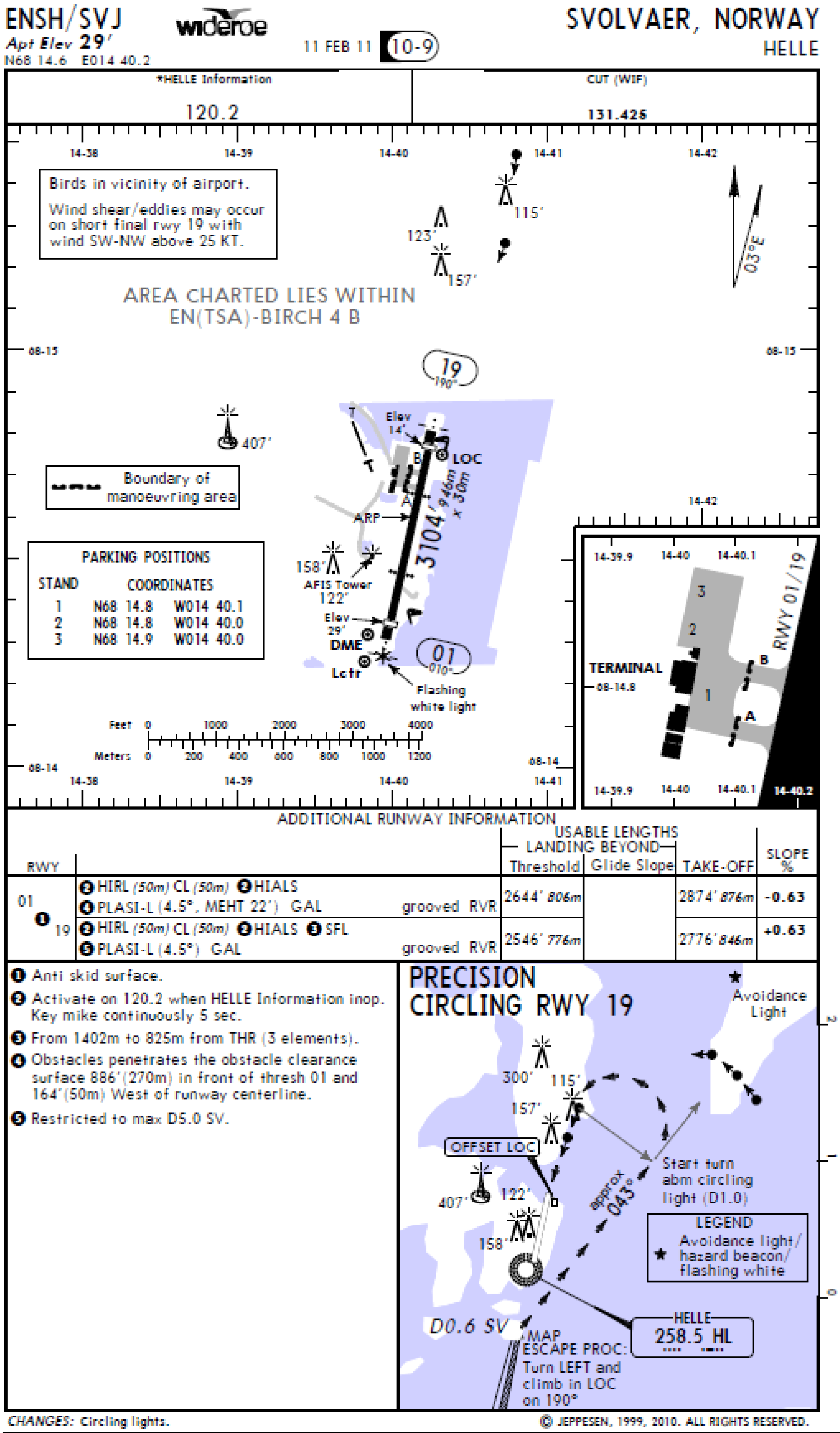
Russo, M., Sing, H., Kendall, A. Johnson, D., Santiago, S., Escolas, S. et al. (2005). Visual perception, flight performance, and reaction time impairments in military pilots during 26 hours of continuous wake: Implications for automates workload control systems as fatigue management tools. In *Strategies to maintain combat readiness during extended employments –A human systems approach* (Paper 27, pp. 27-1 – 27-16 RTO-MP-HFM-124). Neuilly-sur-Seine, France: North Atlantic Treaty Organization, Research and Technology Organisation

Statens Havarikommisjon for Transport (2015). Undersøkelse av alvorlig luftfartshendelse ved Svolvær lufthavn Helle –Sammendrag. Retrieved Febuary 1, 2016 from Statens Havarikommisjon for Transport website: http://www.aibn.no/Luftfart/Undersokelser/15-12

Tribukait, A. & Eiken, O. (2012). Flight experience and the perception of pitch angular displacements in a gondola centrifuge. *Aviation, Space, and Environmental Medicine*, *83*, 496-503.

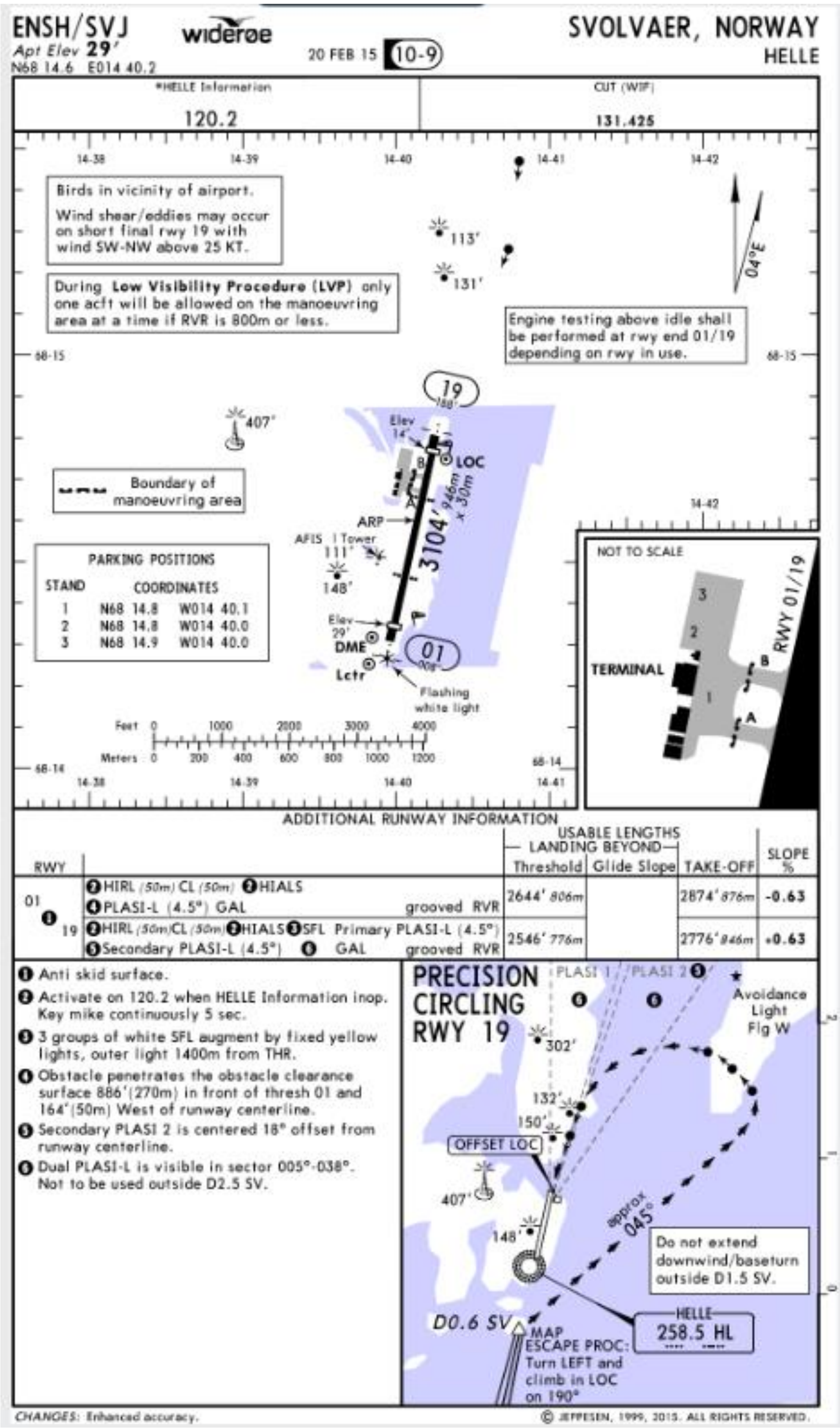
Weeks, S. R., McAuliffe, C. L., DuRussel, D. & Pasquina, P. F. (2010). Physiological and psychological fatigue in extreme conditions: The military example. *American Academy of Physical Medicine and Rehabilitaion*, *2*, 438-441.

Vedlegg 1: Widerøe sitt innflygingskart for Svolvær Lufthavn Helle (ENSH) pr. 11. februar 2011

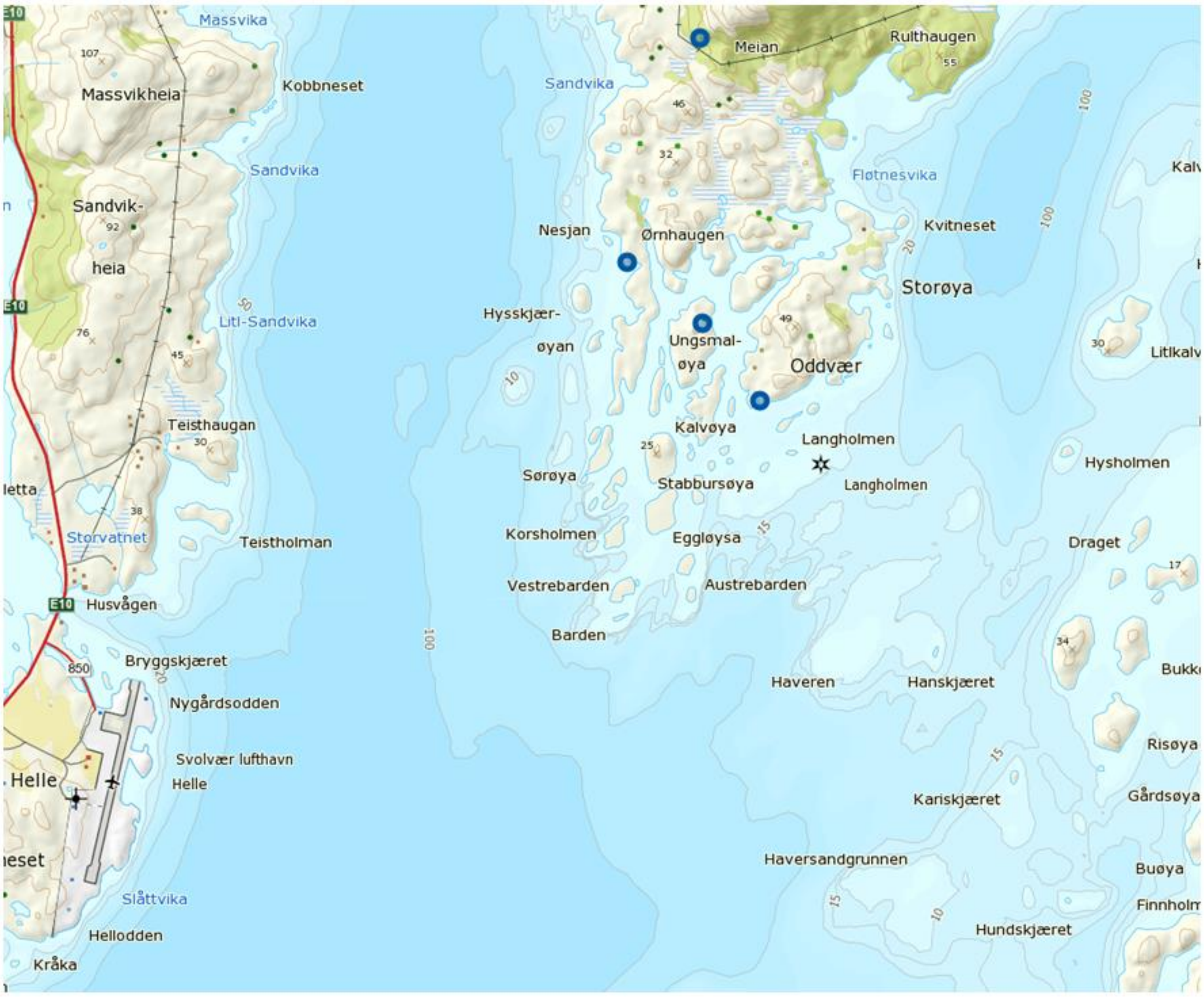


Flymedisinsk Institutt

Vedlegg 2: Widerøe sitt innflygingskart for Svolvær Lufthavn Helle (ENSH) pr. 20. februar 2015



Vedlegg 3: Kart over området rundt Svolvær Lufthavn Helle (ENSH)



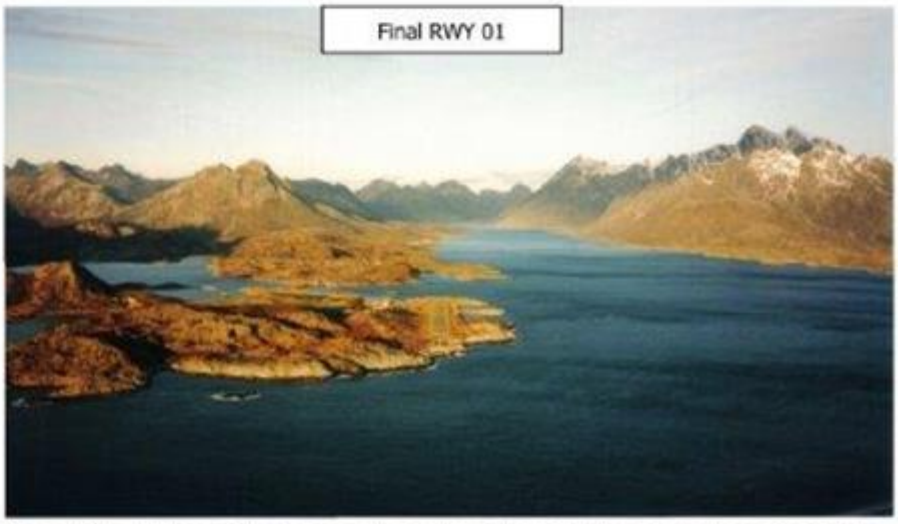
Vedlegg 4: Kart over området rundt Svolvær Lufthavn Helle (ENSH) og omegn

Vedlegg 5: Widerøes Airport Briefing pr. 30. september 2014

widerøe 30 SEP 14 | 10-01 | **AIRPORT BRIEFING**

Airport Category **C**

SVOLVÆR
HELLE, ENSH/SVJ



Svolvær Lufthavn, Helle ligger på E-siden av en halvøy nær strandlinjen med småkupert nærterreng og med sjø på alle kanter unntatt mot W-NW. På avstand omkranses flyplassen av relativte høye fjell i sektoren W-NE. Plassen ligger ca. 6 KM fra Svolvær sentrum.

RESTRICTION:

The following restrictions apply for approach and landing:
Variable wind within sector 240°-340°

- Max wind speed 25 kts including gust within 2 minutes (variable means when there is variation in direction of 60° or more).

Take-off RWY 01: OBST 150 ft., 800M N of RWY must be visible at brake release.

CAUTION:

- When wind exceeds 20 kts from NW, be aware of wind shear/eddies/downdrafts on short final to RWY 01.
- Wind shear/eddies may occur on short final RWY 19 with wind SW-NW above 20 kts.
- Downslope RWY 01.

AIRPORT CATEGORY C

Risk factors: Wx, turbulence, mountainous terrain, approach to one RWY only, special missed approach procedure (25° bank/flap 15°)/course reversion, tight circling procedure, black hole effect, special CLP RWY 01(immediate turn), AFIS.

SPECIAL BRIEFING:

- Recommended circling altitudes for continuous descent to RWY 19.
- Escape Procedure in marginal Wx.

Issue No. 8

widerøe 30 SEP 14

10-02

AIRPORT BRIEFING

SVOLVÆR
HELLE, ENSH/SVJ

ESCAPE PROCEDURES:

RWY 01: Start immediate climb and follow CLP 01.
Circling RWY 19:

- On downwind or on base to final: Start immediate Left climbing turn towards HL and follow CLP 19.
- On final, start immediate climb and follow CLP 19

VÆR

Flyplassens beliggenhet gjør den utsatt for vind, spesielt i vinterhalvåret. Statistikk viser at fremherskende vindretning er fra SW men når vindstyrken er 30 kts. eller sterkere, er også sektorene NE og E fremtredende.
Det er variabel vind fra W og NW over 20 kts som skaper de største operasjonelle problemer, spesielt ved landing da W og NW høydevind gir variabel bakkevind. Særskilte vindrestriksjoner gjelder for variabel vind i sektoren 240°-340°. Under slike forhold er det moderat og i blant sterk turbulens under siste del av innflygingen til bane 01 og under sirkling. Det er registrert til dels sterke downdrafts på finalen til begge baner under slike forhold. E og NE vinder forekommer oftest i sommermånedene og kan gi noe turbulens under innflygingen. SW-lig vind er relativt stabil, hva angår styrke og retning.

Med SW-vind får en som oftest en heving av skybasen over plassen, mens det kan være lavere skybaser mot S, E og N. Med vind fra S-lig kant får en dannelse av stratus mot fjellene nord for plassen, men avstanden er så stor at dette vanligvis ikke er til hinder for sirkling NE for flyplassen.

Lav stratus/tåke forekommer oftest vår/sommer. Plassen er noe beskyttet mot havtåke fra NW. Adveksjonståke kommer som oftest inn fra sektor SW-S sen kveld eller natt, og løses opp om morgenen/formiddagen.

Flymedisinsk Institutt

Vedlegg 6: Luftfartstilsynets godkjenning av Widerøes søknad om ny sirklingsrunde RWY 19 ENSH, 8. november 2011

Luftfartstilsynet
Civil Aviation Authority - Norway

Widerøe's Flyveselskap AS
Postboks 247
8001 BODØ

Vår saksbehandler:	Vår referanse:	Vår dato:
Leif Sandham	201100042-5/400/LSA	8. november 2011
Telefon direkte:	Deres referanse:	Deres dato:
98 26 17 77	Jens Gjerlev	31.oktober 2(

OPERATIV
... 10/11-2011
BEH.: Per-Arild / Yngve / Jens

Widerøe's Flyveselskap AS – selskapets søknad om sirkling til Svolvær lufthavn, Helle

Luftfartstilsynet viser til selskapets brev av 31.oktober 2011 saksnr. 20110042-3 og brev av 31.oktober 2011 saksnr. 201100042-4 vedr. sirkling til bane 19, og selskapsspesifikke innflygning til bane 01, med høyresving på DME 0.6 NM ved avbrutt innflyging.

Selskapet vil benytte en beregningsmetode om hinderfri område ved sirkling med forskrevet trekk langs sirklingslys som settes til total bredde av 1 km på hver side av trekk, og at de innerste 500 m er primærområde med full hinderklarering, og de ytterste 500 m er sekundærområdet med gradvis mindre hinderklarering.

Metoden som er brukt blir kalt Grimsrud rapport fra 1991 og som avviker fra Doc 8168 Appendix til kapittel 7 og selskapet legger til grunn at flysikkerheten økes ved å benytte denne metode i forhold til de nye sirklingslys til bane 19.

Selskapet legger også til grunn at sikkerheten blir større i svingområdet som blir utvidet og at sluttinnlegg til bane 19 blir tidligere enn før.
Selskapet legger også til grunn at PLASI intercept kan foregå i 500 ft.
Selskapets MDA for bane 19 settes til 500ft. idet OCA for området er beregnet til 485ft.

Selskapet vil beholde dagens selskapsspesifikke innflyging til bane 01 med Missed Approach på 0.6 NM og etterfulgt høyresving.

Luftfartstilsynet har behandlet saken og aksepter selskapets prosedyrer for sirkling til bane 19 ved Svolvær lufthavn, og vi aksepter også selskapsspesifikke innflyging til bane 01 og at eventuell Missed Approach starter på 0.6 NM med høyre turn.

Luftfartstilsynets avgjørelse kan innfor forvaltningslovens bestemmelser ankes til Samferdselsdepartementet innen 3 uker, og anken sendes gjennom Luftfartstilsynet.

Kjell Klevan
seksjonssjef fly
Operativ avdeling

Leif Sandham
flyoperativ inspektør

Vedlegg 7: Aeronautical Information Publication Norge; Visual approach chart – ICAO, pr. 15. Januar 2009