Yaw problems on approach, Report on the Serious Incident at Bergen Airport Flesland (ENBR) ON 24 March 2003, involving SAS329, MD-81, LN-RMO, Operated By Scandinavian Airlines

Micro-summary: **This MD-81 experienced a yaw problem on approach.**

Event Date: **2003-03-24 at 1944 UTC**

Investigative Body: **Accident Investigation Board Norway (AIB), Norway**

Investigative Body's Web Site: **http://www.aibn.no/**

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Accident Investigation Board Norway

REPORT

SL Report: 48/2005

REPORT ON THE SERIOUS INCIDENT AT BERGEN AIRPORT FLESLAND (ENBR) ON 24 MARCH 2003, INVOLVING SAS329, MD-81, LN-RMO, OPERATED BY SCANDINAVIAN AIRLINES

SUBMITTED
December 2005

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REPORT ON THE SERIOUS INCIDENT AT BERGEN AIRPORT FLESLAND (ENBR) ON MONDAY 24 MARCH 2003, INVOLVING SAS329, MD-81, LN-RMO, OPERATED BY SCANDINAVIAN AIRLINES.

Designation of type:	McDonnell Douglas DC-9-81 (Boeing MD-81)
Registration:	LN-RMO
Owner:	Scandinavian Airlines
Operator:	Scandinavian Airlines
Crew:	2 cockpit + 3 cabin
Passengers:	107
Accident site:	Bergen airport Flesland, Norway (ENBR)
Accident time:	Monday 24 March 2003, at 2044 hrs.

All times given in this report are local times (UTC+1), unless otherwise stated.

NOTIFICATION

The Accident Investigation Board Norway (AIBN) was informed of the serious incident via a fax copy of an internal SAS Flight Occurrence Report and a report from the chief air traffic controller at Flesland TWR/APP. The incident was not reported to AIBN by the company as required by Norwegian Air Regulations BSL A 1-3.

SUMMARY

An MD-81, LN-RMO, with call sign SAS329 was on a scheduled flight from Oslo airport Gardermoen (ENGM) to Bergen airport Flesland (ENBR) with two pilots, three cabin attendants and 107 passengers on board. Due to low visibility at ENBR upon arrival, SAS329 entered a holding pattern north of ENBR. After 35 min in the holding pattern, visibility improved along RWY 35. The active runway (RWY) was changed from 17 to 35, and SAS329 was cleared for an ILS (Instrument Landing System) approach to RWY 35. The Commander was Pilot Flying (PF) and had planned to control the aircraft using the Autopilot (AP) down to 50 ft Radio Altitude (Rad alt) in accordance with SAS procedures.

The pilots obtained visual contact with the approach lights when passing minima, approximately 200 ft above the runway threshold level.

At approximately 100 ft above the threshold level (Rad alt) the aircraft drifted to the right. The Commander disengaged the AP and corrected to the left using left aileron control. During flare for landing, the Commander observed a leftward drift and corrected with a powerful right rudder input in order to yaw the aircraft's heading towards the RWY centre line. The aircraft touched down hard on the RH main landing gear with a leftward skid. The aircraft still had a velocity vector to the left and towards the RWY edge. The Commander corrected this by holding full right rudder to correct the path towards the RWY centre line. In the right turn from the RWY edge, the outer left main wheel collided with a RWY edge light that broke. The aircraft turned towards the centre line, and the remaining rollout and taxiing to parking was uneventful. The Commander reported to the TWR that they had landed on the left side of the RWY and asked for an inspection of RWY 35. Nothing unusual was observed. After shutdown, it was discovered that a main wheel tyre was damaged, and the Commander called the TWR and asked for a new RWY inspection. This time airport personnel found one broken RWY edge light on the left side of RWY 35. The Commander also informed TWR about a suspected bend on the localizer beam (LZZ).

The AIBN has investigated three previous serious incidents involving MD-80 aircraft from Scandinavian Airlines landing at ENBR. Two of the incidents occurred during landing on RWY 35 and one incident occurred on RWY 17. All incidents occurred during reduced visibility and in darkness.

Common factors leading to the three incidents on RWY 35 were:

- darkness,
- reduced visibility,
- the SAS policy of controlling the aircraft by autopilot down to a minimum certified height of 50 ft above the runway,
- a small bend on the localizer causing a slight rightward drift at around 100 ft radio altitude causing the flying pilot to disconnect the autopilot and make a manual correction, overcorrecting to the left causing a leftward drift and touchdown on the extreme left side of the runway.

Contributory factors leading to the incidents were:

- lack of updated Runway Visual Range (RVR)
- lack of runway centre line lights at ENBR
- the Norwegian policy of painting runway surface markings yellow instead of white as recommended by ICAO
- SAS procedure of not using landing lights in the event of reduced visibility

The AIBN considers that during such circumstances the Pilot Flying (PF) is led to believe that the aircraft is more offset than it really is and makes an over-correction. This takes place during flare and in each case the Commander decided that a continued landing was the safest course of action. In all incidents the Commander has salvaged the landing by use of full opposite rudder in order to steer the aircraft back onto the centre-line of the runway. The AIBN is not aware of any similar problems being reported by other operators. A significant finding is that SAS is the only operator flying into ENBR that controls the aircraft by autopilot below the Category I (CAT I) landing

minima at ENBR. The bend on the LLZ is well within the certification requirements for CAT I minima.

The AIBN has made 6 safety recommendations.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 SAS329 departed ENGM at 1900 hours, after a 10 min delay. On board were 2 pilots, 3 cabin attendants and 107 passengers.

1.1.2 It was the second round trip for the crew from ENGM to ENBR and back, and the third flight of the day. The crew was on its first working day in a five-day work period.

1.1.3 The flight arrived overhead ENBR at approximately 1945 hours. At that time, the meteorological visibility (VIS) and Runway Visual Range (RVR) were reported below the SAS operational minimum of 700 m for the active runway (RWY 17). RVR was reported to be 400 m along RWY 17.

1.1.4 SAS329 entered a holding pattern north of ENBR. After 35 min. in the holding pattern, visibility improved.

1.1.5 At 2020 hours, 24 minutes before landing, the RVR along RWY 35 was reported as 700 m with a wind velocity of 2-3 kt from the south-west. The active RWY was changed from RWY 17 to RWY 35, and SAS 329 was cleared for an Instrument Landing System approach to RWY 35 (ILS-35 approach procedure). Cf. Appendix 5.

1.1.6 The Commander was Pilot Flying (PF) and controlled the aircraft by means of the Autopilot (AP). He had planned an AP-coupled approach down to 50 ft radar altitude (Rad alt), in accordance with SAS procedure.

1.1.7 The pilots obtained visual contact with the approach lights when passing the approach minima, approximately 200 ft above RWY threshold level. However, the pilots estimated the visibility to be less than expected.

1.1.8 When passing approximately 100 ft above the threshold level (100 ft Rad. alt) the aircraft drifted to the right. The Commander disengaged the AP and made a manual correction to the left with left aileron input.

1.1.9 The First Officer, who was Pilot Not Flying (PNF), also noted the rightward drift. He made no comment to the Commander as he felt the Commander had made the proper corrections.

1.1.10 According to the transcript from the Flight Data Recorder (FDR), the aircraft was tracking correctly on the Localizer (LLZ) and Glide Slope (GS) beams all the way to touchdown.

1.1.11 During the flare for landing, the Commander observed a leftward drift of the aircraft and started to apply strong right rudder in order to swing the nose of the aircraft towards the RWY centre line.

1.1.12 The aircraft landed heavily on the right main landing gear, to the left of the centre-line marking. The aircraft was in a left skid and its velocity vector was pointing towards the left RWY edge. The landing time was 2044.

1.1.13 The Commander maintained full right rudder during the landing and gradually managed to swing the nose of the aircraft towards the RWY centre line.

1.1.14 During this turn, the outer left main (no. 1) wheel tyre collided with a RWY edge light, which was broken.

1.1.15 The rest of the rollout and taxing to parking was uneventful.

1.1.16 The Commander reported to the TWR that they had landed on the left side of the RWY and asked the TWR for a RWY inspection. The airport personnel did not observe anything out of order.

1.1.17 Shortly after that, damage to a left wheel tyre was reported to the TWR by the SAS maintenance crew. The Commander called the TWR and again requested a RWY inspection. This time the airport personnel did find a broken RWY edge light on the left side of RWY 35, just opposite the taxiway "D".

1.1.18 The Commander informed the TWR that in his opinion the "skew" landing was caused by a suspected bend on the LLZ beam.

1.2 Injuries

Injuries	Crew	Passengers	Other
Fatal			
Serious			
Minor/none	5	107	0

1.3 Damage to aircraft

The damage to the aircraft was limited to a deep slash in the left outboard main wheel tyre (wheel no. 1). No further damage was found on the aircraft or its systems. The wheel was replaced at ENBR. Cf. Appendix 1.

1.4 Other damage

One (1) runway edge light, located 700 m from the threshold on the left hand side of runway 35, was broken. Cf. Appendix 2.

1.5 Personnel information

1.5.1 Commander

1.5.1.1 The Commander, male 45 years old, had a valid ATPL A. His type rating (TR) and instrument rating (IR) were valid until 30 June 2003. The last Operational Proficiency Check (OPC, DC9-80/MD80/MD90) was performed on 1 December 2002. The Commander had a valid class 1 medical which expired 5 June 3003.

1.5.1.2 The Commander reported for duty in the morning of the day of the incident. It was the third flight of day one in a five-day rotation period. The Commander had almost 3 days off prior to the incident day and felt well rested before starting on duty.

1.5.1.3 Commander's flying times

Flying experience	All types	On type
Last 24 hours	3:25	3:25
Last 3 days	3:25	3:25
Last 30 days	38	38
Last 90 days	Not specified	Not specified
Total	9,985	2,229

1.5.2 The First Officer

1.5.2.1 The First Officer, male 38 years old, had a valid CPL A and IR. His TR and IR were valid until 28 February 2004. His last Operational Proficiency Check (OPC, DC9-80/MD80/MD90) was performed on 23 January 2003. The First Officer had a valid class 1 medical licence which expired on 9 October 2003.

1.5.2.2 The First Officer reported for duty in the morning of the day of the incident. His flight duty on that particular day was the same as that of the Commander. The First Officer had almost 5 days off prior to the date of the incident and he felt well rested before starting to fly.

1.5.2.3 First Officer's flying times

Flying experience	All types	On type
Last 24 hours	3:25	3:25
Last 3 days	3:25	3:25
Last 30 days	48	48
Last 90 days	84	84
Total	2,762	579

1.6 Aircraft information

1.6.1 The aircraft was a McDonnell Douglas DC-9-81, S/N 53315, produced in 1991 by the McDonnell Douglas aircraft company. Its certificate of airworthiness was valid until 31 March 2004. The airframe had 24,380 flight hours and 22,362 cycles. Its last heavy maintenance (P 5) was performed on 27 November 2001, its last B check on 13 February 2003 and its last inspection (MSC/PFCN) was completed on 23 March 2003.

1.6.2 The aircraft engines were 2 (two) JT8D-217, (S/N L 716755 and R 725908).

1.6.3 The aircraft was airworthy and serviceable before the flight.

1.6.4 The aircraft take-off fuel load was 8,100 kg JET A-1. Estimated fuel burn was 2,100 kg for 45 min. After 1 hr holding, the aircraft landed with an estimated 3,500 kg of fuel onboard.

1.6.5 The aircraft mass and balance were within limits.

1.7 Meteorological information

1.7.1 Terminal Area Forecast (TAF)

TAF ENBR 241400Z 1524 VRB05KT 0500 FG VV002 TEMPO 1520 4000

TAF ENBR 241700Z 1803 VRB05KT 0500 FG VV002 PROB30 TEMPO 1803 2000 BR BKN003

1.7.2 Meteorological Aerodrome Report (METAR)

METAR ENBR 1850Z VRB01KT 0100 R17/0300FG VV001 02/01 Q1019 NOSIG=

METAR ENBR 1920Z VRB01KT 0100 R17/0400FG VV001 02/01 Q1019 NOSIG=

METAR ENBR 1950Z VRB01KT 0400 R35/0750FG VV001 02/01 Q1019 TEMPO 0200FG

1.8 Aids to navigation

Instrument Landing System (ILS) Category I (CAT I) for both runways (RWY 17/35).

ILS RWY 35: Glide path (GP) angle 3.0º. Glide path height over Threshold (THR) 56 ft. The ILS was approved and within limits down to the approved minimum.

Visual aids RWY 35: Precision Approach Path Indicator (PAPI) giving Minimum Pilot Eye Height over Threshold (MEHT) of 58 ft.

1.9 Communications

The communications between SAS329 and Flesland TWR (119.100 MHz) were performed according to standard procedures.

1.10 Aerodrome information

Name and location: Bergen airport Flesland, ENBR, N 60 17 37, E 005 13 05.

Height above sea level: 165 ft.

Aerodrome category for fire fighting: Category 7

Air Traffic Control (ATC) service: Approach control (APP) with Terminal Area Surveillance Radar (TAR), Tower control (TWR) and Ground Movement Control (GND).

Runway Designation: 17/35

Nominal RWY 35 magnetic heading (QFU): 353º

Length and width of surface: 2,990 m x 45 m.

Declared Landing Distance Available (LDA) RWY 35: 2,555 m.

Runway surfaces: Concrete and asphalt.

Slope RWY 35: +0.2% (average upslope).

Approach lights RWY 35: Calvet 420 m.

Threshold light RWY 35: High intensity green.

Lights RWY 35: High intensity white.

Markings RWY 35: Yellow (None ICAO std).

ILS CAT I for both runways.

Wind direction indicator: Lighted windsock.

Runway Visual Range (RVR) measurement: Transmissiometer not available (manual count by airport personnel of the number of visual runway lights).

1.11 Flight recorders

1.11.1 Flight Data Recorder (FDR)

The aircraft was equipped with an FDR type Honeywell, P/N 980-4100-DXUN. The FDR was not analysed by the company. As the incident was not notified and reported to the AIBN immediately as per BSL A 1-3 (Norwegian air regulations), the AIBN had no opportunity to request FDR removal.

1.11.2 Cockpit Voice Recorder (CVR)

The aircraft was equipped with a CVR type Honeywell, P/N 980-6020-001. The CVR was not analysed by the company. The CVR power supply was not shut off after the incident and the 30-minute continuous tape was overwritten.

1.11.3 Quick Access Recorder (QAR)

The aircraft was equipped with a QAR type Penny & Giles, P/N D51434-1. The AIBN has been given access to the QAR data by the company.

From the SAS internal incident report:

> *"At recorded 121 ft RH (radio height) the autopilot was engaged and tracked the ILS both in roll and pitch. At 86 ft RH the autopilot was recorded off. The disconnection has occurred between those heights.*

Recorded data show an a/c heading during the automatic part of the approach to be between 354.4º and 356.1º. Average is 355.2º. Nominal inbound track is 353º (no fractions stated). The a/c has a stable heading reference system (IRS).

After the autopilot disconnect a left wing down aileron input and a nose left rudder input is recorded. These inputs are present down to recorded 41 ft where the recorded bank angle is 5.6º left wing down. Maximum recorded value is 6.7º one second later.

The co-ordinated left turn brings the heading to a recorded 352.3º at 11 ft RH. No localizer deviation is recorded during the 6 seconds of co-ordinated left turn.

At recorded 34 ft RH the rudder input is reversed and reaches a recorded maximum of 10.7º nose right with the aircraft still airborne. The left aileron input is reduced; the bank angle is brought back to 2º left wing down.

At recorded touch down the heading is 360º and stays at that value during the first 8 seconds of the ground roll."

1.12 Aircraft and damage information

The outboard left wheel tyre was cut and had to be changed. Cf. Appendix 1.

1.13 Medical and pathological information

No blood samples were drawn from the crew after landing.

1.14 Fire

None.

1.15 Survival aspects

With the aircraft left wheels still on the hard runway surface, the risk of damage to the aircraft and personnel were low.

1.16 Tests and research

None.

1.17 Organisational and management information

The company has a JAR OPS 1 operating licence for scheduled domestic and international air traffic. At the time of the incident the company had 7,000 employees and operated 186 aeroplanes of the types Boeing MD-80, -81, -82, -83, -87, -90, Boeing 737-600, -700, -800, Bombardier DHC-8-400Q, Airbus 320, 330, 340, and Fokker 50.

The company has been, and still is, going through several organisational and management changes during the last few years. This has resulted in a reduction of management staff in the flight operations department at the headquarters in Stockholm, Sweden.

The company is divided into three separate national business areas. The crew of the incident aircraft belonged to the Norwegian business area and reported to the Chief Pilot at Oslo

airport Gardermoen (ENGM). Chief Pilot at ENGM reports to Flight Operations at the Head Office at Stockholm airport Arlanda. According to Norwegian regulations (BSL A 1-3) the incident should have been reported to AIBN, either directly by the Commander or through SAS Flight Operations.

1.18 Additional information

1.18.1 Previous incidents

1.18.1.1 *30 July 1995 (HSL RAP 06/95)*

MD-81, LN-RMM landed outside the runway edge at ENBR RWY 35 in a right bank damaging the right wing tip. The left wheel pair passed on the outside of two consecutive runway edge lights without hitting them.

Based on data from the Quick Access Recorder (QAR) the HSL (AAIBN) report states:

> *"The recordings indicate a stabilised approach from approx. 100 ft above the decision height, down to the point at which the Commander initiated manual flying by disconnecting the Autopilot. The last recording with Autopilot engaged was at 116 ft radio altitude (RA) where the ailerons indicate 4º deflection for a left turn.*
>
> *The next recording is at 110 ft RA where the Autopilot was disengaged and the aileron deflection increased to 8º and the accompanied spoiler deflection to 4º. The rudder deflection was 1º to the left. The attitude indicated a 1º left bank and was increasing during the following recordings to approx. 11º left bank before the recordings indicated that a right bank was initiated.*
>
> *The aircraft's magnetic heading was 359º during several recordings with the Autopilot engaged, then 358º during three consecutive recordings, then 357º in one recording, 356º in the following four recordings, followed by 357º and 358º during the last two recordings with the Autopilot engaged. The heading stayed at 358º during the first three recordings with the Autopilot disengaged. The recording at 98 ft RA indicates a left bank of 4º and 6º. During the next two recordings down to 73 ft RA, the maximum indicated left bank was 12º. During the left turn the minimum recorded heading was 353º, three seconds before touch down. At 73 ft and 6 seconds before the landing, a correction to the right was initiated by a 3º left aileron down deflection. This deflection increased to 11º recorded one second before touch down resulting in a heading of 355º. The accompanied spoiler deflection was 7º (right bank). The rudder deflection was recorded at 20º right, increasing to maximum RANGE deflection of approx. 25º at touch down. At this time, the heading was 359º magnetic heading (Runway heading at the time was 355º). The aircraft touched down on the right main undercarriage with an attitude of 11º right bank.*
>
> *The recorded deflection on the LLZ needle from the decision height down to the Autopilot disconnect was 0.0 or 0.1 dot (fly right) until just before and after touch down when it reached a maximum of 0.7 dot (fly right).*
>
> *The recorded time from the decision height to touch down was 15 seconds."*

Based on that incident, the AAIBN issued two safety recommendations:

> *1. The CAA-N is requested to evaluate the need for changing the regulation for using both of the two ILS systems at the same time during operations on both runways in periods of marginal weather conditions (e.g. vertical and horizontal visibility below 300 ft/1 000 m) in order to limit the use of ILS to the active runway only.*
>
> *2. The airline company is requested to use the AAIBN report form NE-382 for submitting reports of serious incidents/accidents.*

Neither of the two safety recommendations were implemented.

Other actions taken after the 1995 incident:

CAA-N

An AIC B (Aeronautical Information Circular) was issued on 16 December 1996:

> *"With simultaneous use of ILS systems to more than one runway, it has sometimes been observed that the aircraft's ILS receivers have been disturbed by interference which has influenced their accuracy. This AIC is issued in order to inform commanders that they may request the ATC to switch off the ILS for the opposite runway if they consider this beneficial. ATC is obliged to comply with such a request unless this would limit the airport's capacity or come into conflict with other operational considerations."*

The company

After the incident in 1995, the company issued a 'note' on the ILS charts for ENBR:

> *"Auto coupled approach: Autopilot not to be used below DA due to unstable LLZ"*

That 'note' was in effect until October 1996 when it was removed by the company based on a review of approach procedures. It was decided that this 'note' was not required, and information on the approach charts should reflect the Norwegian AIP.

1.18.1.2 *23 September 1998 HSL BUL 36/99*

MD-81, SE-DIN landed on the left side of ENBR RWY 35 with the left wheel pair close to the runway edge lights. During the roll-out two runway edge lights were broken causing damage to both left wheel tyres.

An extract from the QAR included in the AAIBN report states:

> *"18 seconds before TD, LH aileron showed minus - 0.7 (lifting the wing). At 15 seconds before TD, LH aileron showed minus - 2.8, this initiated the right bank.*
>
> *14 seconds before TD at 161 ft (RA) the A/C started a RH bank on Autopilot peaking within 4 seconds to attitude 2.5º right. Then LH spoiler went from 0.0 to 3.2 out, and LH aileron went from - 2.1, trailing edge down, to 4.8, trailing edge up. This indicated that A/P already had started recovery to the left.*

10 seconds before TD, AP was disengaged and PF followed up manually the recovery to the left with a max. bank of - 9.5º at 34 ft (RA). Simultaneous LH aileron showed - 7.7 (RH turn), RH spoiler out to 5.9 and rudder position 3.0, increasing to the right. This arrested the LH bank almost to wing level at TD. Large rudder inputs brought the A/C back to inside the RWY edge lights.

Total time from aileron input to start right bank, and until LH bank was arrested at TD, 18 sec."

An inspection and control flight was performed by CAA-N on 18 August 1999. A report to the AAIBN dated 24 August 1999 stated:

"Inspection flight at Flesland LLZ 35.

On 18 August this year, the Inspection Flight Department performed an inspection flight on Flesland LLZ 35. The inspection was performed with the opposite LLZ 17 in normal operation. Attached are copies of recordings from approaches on transmitters 1 and 2. Calculations of data from the different segments are listed, as well as 'marker events' from the pilot's observations of other traffic during the approach. The conclusion is that the effect of the opposite LLZ is maximum 2-3 µA 'fly right' when the aircraft is passing 200 ft over the antenna system."

The AAIBN writes in the report that 2-3 µA results in an insignificant deviation on the LLZ needle on the cockpit instrument, and that full-scale needle deviation requires 150 µA.

After this second incident of landing on the left side of RWY 35 at ENBR, the company introduced intensive training for its pilots, focusing on reduced visibility on short final approach (CAT II and CAT III training).

The AAIBN commented on this training course that it is difficult to control an aircraft during such limited visibility conditions, even though the pilot initially considers the visibility to be sufficient. The conclusion was that an aborted landing would be preferable when the visibility becomes questionable on short final approach. Hence, the need for weather condition updates to the flight crew is vital for flight safety.

At the time of the incident, RVR measurements were performed manually by airport personnel counting the number of runway edge lights as observed from the airport inspection car on the runway. That meant that ATC was unable to update the RVR when an aircraft was on approach since no vehicles were allowed onto the runway.

At the time, the AAIBN had received information that a new ILS system was to be installed on RWY 35 at ENBR. The number of antenna elements was to be increased from 12 to 16. This improvement was expected to resolve the problem of the 'fly right' deviation when passing the antenna system.

Based on the information available at the time, the AAIBN did not issue any safety recommendations.

1.18.1.3 *10 December 2001 (HSL RAP 61/2002)*

MD-81, LN-ROO landed outside the right runway edge lights (west side of the RWY) at ENBR RWY 17. The left wheel pair collided with 3 runway edge lights, which were broken. During the collision, both left main wheel tyres were damaged. No other damage.

The seriousness of this incident was highlighted by the fact that the aircraft landed with both main landing gears outside the runway edge markings, with the right main landing gear 1.8 m from the edge of the hard surface of the runway.

The following has been extracted from the company incident report based on data from the QAR:

> *"At recorded 60 ft RH the aircraft enters the flare phase with a pitch attitude increase to 3.5º ANU (Aircraft Nose Up), which is reached at 35 ft RH. The pitch attitude remains at 3.5º until touchdown.*
>
> *LLZ No 1 data indicates the a/c being at the centre-line down to 29 ft RH (Radio Height). Heading 175º. Below 29 ft RH the deviation is 0.1 dot to the right.*
>
> *A left aileron input is recorded together with a right rudder input and the aircraft heading changes from 174º to 178º. The heading of 178º is maintained until touchdown.*
>
> *At 7 ft RH a rudder deflection of 3.1º to the left is recorded. The rudder deflection increases to 16.9º at touchdown and maximum-recorded value is 22.5º to the left three seconds after touchdown (the maximum available deflection to the left on the individual aircraft is 25.1º).*
>
> *Nose gear touchdown is recorded at 6 seconds after main gear touchdown. Aircraft heading at nose gear touchdown is 168º.*
>
> *Idle reverse is used during landing roll."*

Further from the company incident report:

> *"Measurements of RVR are made by an observer. The observer is positioned at the threshold on the centre-line. The observation height is the observer's eye height. Continuous measurement of RVR is only possible when there is a stop in the traffic flow. The procedure has been approved.*
>
> *The localizer for the opposite runway (RWY 35) was transmitting at the time the incident occurred. There is no approved procedure for shutting off the localizer for the opposite runway."*

The following has been extracted from the AAIBN report:

> *"....Both pilots were well acquainted with the airport. Experience had shown that there was a bend on the localizer beam near the decision height. A note on the approach chart about not using the autopilot below the decision height had been removed earlier. The Co-pilot who piloted the plane (Pilot Flying, PF), briefed the Commander that his intention was to keep the autopilot engaged until somewhat lower than the decision height. During the approach the A/P was not disengaged until approx. 90 ft over the threshold.*
>
> *The crew had the runway in sight during the whole approach. Then forward visibility was completely lost. The Co-pilot tried to complete the flare by reference to the runway surface, which was visible below the aircraft. During this manoeuvre, the*

aircraft drifted to the right. The Commander discovered this right drift and with a marked left rudder input he brought the aircraft back onto the runway. Three runway edge lights were run over.

The Commander assessed whether to abort the landing, but this option was felt to be more hazardous than continuing the roll-out.

.....

"Measurements of the visibility at Bergen Flesland airport are considered inconvenient and impractical. The method is demanding on personnel and constraining on the communications system. In addition, the measured values will not equal the actual values. Since Bergen Flesland airport periodically has fog conditions of this type, it is considered opportune to install modern fixed optical measurement equipment. The AAIBN considers the present arrangement to be an inconvenient method for measuring visibility and is therefore issuing a safety recommendation about this.

During this incident the crew had the runway in sight until the aircraft entered the flare phase. The average runway slope for runway 17 is 0.2%. For the first 609 m the slope is 1%. The AAIBN considers this to be a secondary causative factor for the deteriorating horizontal visibility in this area. In addition, the AAIBN believes that centre-line lighting would be of great value as a runway reference in conditions of marginal visibility. Hence, a safety recommendation is being issued to this effect.

At this time, the AAIBN will not make a decision on the simultaneous use of localizer transmitters for both runways. This problem has been discussed previously and has been dealt with by the proper authority. This is the third incident during a ten years period where the crew has lost visual reference during the flare. The AAIBN is referring to BUL 6/95 and 36/99 which deal with similar incidents. In BUL 6/95, the AAIBN issued a recommendation regarding the use of the localizer transmitters for both runways during marginal conditions…"

Based on that incident, the AAIBN issued two safety recommendations to the NCAA:

"to evaluate a requirement for installing a centre-line lighting system on runways 17/35 in order to improve the references during landing in reduced visibility (Recommendation no. 46/2002).

"to evaluate the requirement for installing a fixed modern optical (RVR) measurement system (Recommendation no. 47/2002).

The first recommendation was rejected due to cost considerations. Avinor did an evaluation of the cost vs considered value of centre line lights. The conclusion was that such installation would only marginally improve the RVR for an aircraft in a position over the runway edge lights. The second recommendation was accepted. A decision for installation of an automatic optical RVR system was taken in 2004, but was not yet installed in 2005, at time of report writing.

1.18.2 Scandinavian Airlines' evaluation flights at ENBR

1.18.2.1 After the incident in March 2003, Scandinavian Airlines and Luftfartsverket (now Avinor) performed evaluation flights at ENBR on 9 April 2003. Several automatic approaches were performed to RWY 17 and 35, including auto landings. The approaches and landings took place during daylight and in good visual conditions. The conclusion was that there were no offset LLZ problems but there was a slight dip on the GP to RWY 35. As a consequence the company has issued a note on the ILS approach chart informing the pilots that an automatic landing is not recommended due to a dip on the GP.

1.18.2.2 A closer look at the LLZ recordings show that there is a small deviation of the LLZ shortly before TD. There is a slight right deviation followed by a slight left deviation. This compares well with the incidents and may be the cause for the AP drift to the right at about 100 ft radio altitude. During autolandings the AP will correct back as the LLZ beam straightens out. Cf. Appendix 4.

1.18.3 Scandinavian Airlines' practice of reporting incidents and accidents to AIBN

1.18.3.1 According to Norwegian aviation law and civil aviation regulations (Bestemmelser for sivil luftfart, BSL A 1-3), air accidents and incidents must be notified and reported by the Commander or company to AIBN on specified forms (previously NE-382 and now NF-382). None of the four incidents were reported by Scandinavian Airlines in accordance with Norwegian BSL. After the incident in 1995, the AIBN issued a recommendation that the airline company should use the AIBN (HSL, Havarikommisjonen for sivil luftfart) report form NE-382 for reporting incidents/accidents. That recommendation was not accepted by the company and was not followed up by the NCAA. This recommendation is not formally closed.

1.18.3.2 The company claims that it cannot report in different ways to Sweden, Denmark and Norway, and that this is in agreement with the Scandinavian CAA Office in Stockholm, STK (Skandinaviska Tilsynskontor). The AIBN has obtained confirmation from the Norwegian Ministry of Transport and Communication (Samferdselsdepartementet, SD) that the NCAA had not been authorised to grant approval for this type of deviation from Norwegian aviation law and civil aviation regulations at the time of the incident.

1.18.3.3 The AIBN has been working with Scandinavian Airlines since 1995 regarding this issue. Finally, in 2004 the AIBN was informed by the company that future incidents and accidents will be reported according to BSL A 1-3 on the proper form NF-0382.

1.18.4 The AIBN has identified common factors during the four incidents at ENBR

1.18.4.1 *Darkness*

All the incidents occurred during the hours of darkness.

1.18.4.2 *Visibility conditions*

All the incidents occurred during reduced visibility conditions close to operating minima.

1.18.4.3 *Reported bend on the localizer with both localizer transmitters operating*

The AIBN has confirmed reports of a slight bend on the LLZ to RWY 17 and 35 at ENBR. The anomaly is believed to be caused by simultaneous operation of ILS-17 and ILS-35. The bend is within certification requirements.

At the present time there is a NOTAM at ENBR: ENBR/058/05 “Autopilot not to be used for ILS 35 inside 3 NM from threshold due to fluctuation”.

1.18.4.4 *Lack of automatic RVR measurement*

At the time of the incidents ENBR had not installed an automatic optical RVR measurement system (transmissiometer).

1.18.4.5 *Lack of centre line lighting system*

ENBR has no runway centre line lighting systems installed. These are installed at many of the larger European international airports.

1.18.4.6 *Use of autopilot below decision altitude*

Scandinavian Airlines' policy is to use autopilot down to a Minimum Use Height (MUH, minimum aircraft specific certified height) above runway, even when landing on CAT I runways. Most operators landing at ENBR, disengage autopilot when the runway environment becomes visible, or at the CAT I decision altitude at the latest.

SAS has the following comments regarding use of AP down to MUH:

> *“Generally using the autopilot down to MUH enhances flight safety in low visibility operations. In this case the procedure has been evaluated and test-flights have been performed by former FCP and former FTP. Their evaluation concluded that autoland was not to be recommended, which is now stated on BGO GAD. A warning is also stating: ”Low VIS conditions at Flesland, both RWYs, may induce problems during visual transition to a LDG. This is most likely caused by environmental factors combined with possible variations in ILS signals below minima. Unless positive visual references can be maintained at all times below minima, an immediate Go Around must be made. Autoland is not recommended due to dip in G/S below 50 ft””.*

Avinor has the following view on use of AP below MAPt (translated from Norwegian):

> “*To use coupled autopilot down to Pt C is to stay on the edge of ICAO’s intention regarding tolerances, and should be alarming. CAT 1 tolerance is probably based on that the aircraft should not use AP below MAPt. The argument for doing this VMC below MAPt will not exclude the possibility for an erroneous LLZ signal, either in the form of interference from the opposite LLZ, or that the ILS signals deviate from the nominal values.”*

1.18.4.7 *Commanders’ procedure of not using landing lights in conditions of darkness and reduced visibility*

SAS Commanders’ policy of not using the landing lights for landings in darkness in combination with reduced visibility, is based on the company’s recommendation in the Operations Manual Part A:

> *“Precipitation or drifting snow or sand in crosswind conditions may create a false impression of aircraft movement and thus the pilot may get an impression of no drift when in fact there is a considerable drift present. In these cases the use of landing lights is not recommended.”*

SAS states that there is no company recommendation regarding not to use landing lights in darkness and during CAT 1 landings.

1.18.4.8 *Norwegian policy of using yellow runway markings instead of the ICAO standard white*

Avinor (previously Luftfartsverket) has filed a deviation from ICAO Annex 14, which specifies use of white runway markings, due to occasional snow cover on the runway.

In the response to the draft report, it is commented that the safety enhancement of changing to ICAO standard white runway markings should be evaluated against cost, resources and timeframe.

1.18.4.9 *Commanders' decisions not to abort the landing*

In all four cases, the aircraft Commander decided that a continued landing was safer than an aborted landing.

SAS company states regarding its policy for Go Around:

> *"After these instances training has been performed in the simulator during two consecutive PC's where a go-around has been done as the aircraft drifted just before landing. Generally an effort is done during PC's to provoke a go-around when the Commander had made a commitment to land the aircraft."*

1.18.5 Accident involving SE-RDL, DC-9-83 at Londonderry/Eglinton Airport, UK, on 18 July 2003.

1.18.5.1 *Circumstances*

The accident happened to the same aircraft type and during similar circumstances as at ENBR, in darkness and low visibility. It was raining heavily and the Commander's windscreen wiper failed. The Commander decided that he still had sufficient visibility to complete the landing. Shortly before touch down (30-60 ft), when the Commander deselected the AP, the aircraft drifted right. It touched down hard (2G) to the right of centre line in a drift to the right. The aircraft continued the rollout with the aircraft's right main wheels and nose wheel outside of the hard RWY surface. A large portion of the rollout continued with the right main wheels outside the hard surface before the Commander was able to steer the aircraft back onto the RWY.

1.18.5.2 *Damage to the aircraft*

Damage occurred to all the main wheels, the right and left wing flaps, the underside of the fuselage and the fan stages of both engines.

1.18.5.3 *Use of Autopilot*

The Commanders' use of AP was according to SAS' procedures; to use the AP down to MUH of 50 ft.

1.18.6 Requirements for Instrument Landing Systems (ILS)

1.18.6.1 *BSL G (dated 3 December 2002)*

Para 33 (5) (translated from Norwegian):

"At installation of ILS to both runway ends the following applies:

a) ILS or LLZ/MKR/DME or combination thereof, as approach aids to both runways, shall be assured such that only ILS or LLZ to the runway in use is active at any one time.

a) CAA-N may allow deviation from letter a) when safety analysis has proven that both ILS's may be operational at the same time."

1.18.6.2 *ICAO Annex 10*

Chapter 3, para 3.1.2.7.1:

Recommendation.- At those locations where two separate ILS facilities serve opposite ends of a single runway and where a Facility Performance Category I-ILS is to be used for auto-coupled approaches and landings in visual conditions an interlock should ensure that only the localizer serving the approach direction in use radiates, providing the other localizer is not required for simultaneous operational use.

Note- If both localizers radiate there is a possibility of interference to the localizer signals in the threshold region. Additional guidance material is contained in 2.1.9 and 2.13 of Attachment C.

3.1.2.7.2:

At locations where ILS facilities serving opposite ends of the same runway or different runways at the same airport use the same paired frequencies, an interlock shall ensure that only one facility shall radiate at a time. When switching from one ILS facility to another, radiation from both shall be suppressed for not less than 20 seconds."

Attachment C, para 2.1.9 Radiation by ILS localizers not in operational use

Severe interference with operational ILS localizer signals has been experienced in aircraft carrying out approaches to low levels at runways equipped with localizer facilities serving the reciprocal direction to the approach. Interference in aircraft overflying this localizer antenna system is caused by cross modulation due to signals radiated from the reciprocal approach localizer. Such interference, in the case of low level operations, could seriously affect approach or landing, and may prejudice safety. Chapter 3, 3.1.2.7, 3.1.2.7.1 and 3.1.2.7.2 specify the conditions under which radiation by localizers not in operational use may be permitted."

1.18.6.3 *Interlock of ILS equipment*

Avinor writes about Interlock (Norwegian "Forrigling"):

"Interlock of ILS equipment means that with opposite ILS's installed, the system not serving runway in use must be switched off. This practice has pros and cons, and Avinor has practised interlock only with ILS's which according to international ICAO standard may satisfy autoland requirements. In AAIBs report 1999/07

(Svalbard) the Norwegian practice of Interlock is questioned by issuing safety recommendation no 37/99: "The NCAA assesses the current policy of having all ground-based navigational aids running at all times with reference to the fact that the FMS of the Dornier 228 gave reasonable steering information on the ILS back beam"

Avinor's current policy is to use interlock only on ILS equipment which, according to the international ICAO standard, may be used for autolanding. ATC use of interlock will give less flexibility for a standardised traffic management.

Avinor has made a safety analysis and a survey among Norwegian operators regarding use of interlock. The general consensus is that use of interlock will restrict traffic flow and operators consider interlock as a negative option. They prefer to have the opposite ILS available for departure. Avinor also considers that use of interlock may introduce human error traps for the ATC controllers.

Avinor concludes:

"The advantage of interlock is that the ILS signals will be unaffected down to the runway. Without interlock a pulse of one second duration will affect the ILS by overflying the opposite LLZ at CAT II minima at 30 ft.

The disadvantage with interlock is that ILS is not available for departure and circling, in addition to the possibility of ATC by mistake may select the wrong ILS.

From the above evaluation and views from ATC and the airlines, the following conclusions may be made:

a. *Interlock will be in effect at Gardermoen (all runways) and Sola runway 18/36.*

b. *At Værnes runway 09/27 this will be discussed with SAS/Braathens and TWR.*

c. *At the rest of the airports with opposite ILS equipment interlock will not be implemented.*

Due to the small numbers of runways eligible for interlock, it is recommended that that BSL G 6-1, ch X, §33, item 5a. is changed as follows:

(5a) For ILS installations to both runways, the following applies:

ILS or LLZ/MKR/DME, or combination thereof, as equipment installed for, and with the proper quality suitable for automatic approach and landing, shall be arranged in such a way as only ILS or LLZ to runway in use is operating.

(5b) Dispensation based on a safety analysis may be deleted based on this report." (Avinor study).

1.18.6.4 *NOTAM at ENBR*

In 2005, Avinor issued a NOTAM for ENBR, valid from 4 February 2005 to 31 December 2005:

> *"NOTAM ENBR/0058/05 : "AUTOPILOT NOT TO BE USED FOR ILS35 INSIDE 3NM FM THR DUE TO FLUCTUATION."*

1.19 Useful or effective investigation techniques

AIBN has, by help of a RAPS (Recovery, Analysis and Presentation System) simulation of the QAR data from the aircraft, analysed the flight path of the aircraft during the approach and landing. This simulation confirms the aircraft right roll at about 100 ft above the runway, followed immediately by a left roll just before touch down. This simulation confirms the reports from the pilots and the slight anomaly seen on the evaluation flight data. (Cf. Appendix 4).

2. ANALYSIS

2.1 The sequence of events

Based on the four incidents at ENBR in general, and at RWY 35 in special, the AIBN considers that there were several causative factors in the incidents involving Scandinavian Airlines aircraft. Further, AIBN considers that these factors and combination of these, indicate weak safety barriers and led up to the serious incident involving LN-RMO (Ref. James Reason):

- The pilots were given acceptable RVR values for the active RWY by the TWR before commencing the approach. These values were not updated during the approach due to lack of automatic RVR measurement. Upon landing, the crew estimated the RVR to be lower than reported.

- The pilots received the runway approach lights and environment visual at MDA and decided that the conditions were acceptable for landing.

- The pilots used the recommended company procedure of using the autopilot down to 50 ft radio height.

- At approximately 100 ft radio height a slight right bend on the LLZ caused the autopilot to steer the aircraft slightly to the right of centreline.

- Due to the darkness, limited forward visibility and the lack of visual references, the PF was under the illusion that he was dangerously offset from the runway centre line and made a lateral correction.

- Due to optical illusions, the pilots made larger control corrections than required causing the aircraft to drift to the left. This leftward drift was not sensed immediately due to the 'black hole' effect caused by the lack of centre line lights, not using

landing lights, and the yellow runway markings on the black runway surface, which do not reflect light as well as white.

- The leftward drift was sensed at a late stage during the landing flare, and the pilots made a large right rudder input to steer the aircraft back towards the runway centre line.

- The Commander did not use the option of aborting the landing. In this, and the three other incidents, the Commanders felt that a continued landing was the safest option.

- The individual causative factors are listed under paras 2.2-2.10 below.

2.2 Darkness

2.2.1 The runway lighting system at ENBR satisfies the CAT I minimum requirements. However, AIBN considers that centre line lights would enhance safety when aircraft are landing during darkness and reduced visibility.

2.2.2 The combination of darkness, reduced visibility, lack of centre line lighting system, yellow runway markings and not using landing lights, creates the illusion that the pilots were dangerously offset from the centre line, forcing them to make last minute lateral corrections before the flare.

2.3 Visibility conditions

2.3.1 The combination of low visibility, darkness, lack of centre line lighting system, Commander's policy of not to use landing lights in reduced visibility, together with the yellow runway markings, are all contributory factors leading the pilots to overcorrect using manual lateral control inputs late in the landing phase.

2.3.2 SAS has explained to AIBN that the company does not have a policy of not using landing lights in darkness and during CAT 1 landings. Cf. 1.18.4.7. However, AIBN considers that the company's recommendation in OM Part A regarding not using the landing lights during precipitation or drifting snow or sand in crosswind conditions, is leading the Commanders not to use landing lights during all night landings in reduced visibility.

2.3.3 Combined with the lack of an automatic continuously measured RVR, the visibility may have changed since the last update given to the pilots before commencing the approach. This may mislead the crew and influence their actions.

2.4 Lack of automatic RVR measurement

2.4.1 The lack of a fixed modern automatic optical (RVR) measurement system is considered to be a significant contributory factor in all four incidents.

2.4.2 After the third incident in December 2001, the AIBN issued a safety recommendation to the NCAA to evaluate the requirement to install a fixed modern optical (RVR) measurement system. A decision to install such a system was taken in 2004 and installation was planned for 2005.

2.5 Reported bend on the localizer with both localizer transmitters operating

2.5.1 The AIBN has confirmed reports of a small bend on the LLZ on RWY 35. This bend is insignificant in relation to certification requirements for a CAT I operating minimum. The bend is located at approximately 100 ft radio height and is believed to be caused by interference from the opposite LLZ transmitter. In addition to the small bend on the LLZ, SAS' evaluation flights in April 2003 confirmed a minor dip on GP ILS-35.

2.5.2 This problem has been known since 1995 when the first incident occurred. Based on that incident, the AIBN issued a safety recommendation requesting the NCAA to assess the need to change the regulation concerning the simultaneous use of both ILS systems during operations on both runways, during periods of marginal weather conditions (e.g. vertical and horizontal visibility below 300 ft/1 000 m) in order to limit the use of ILS to the active runway only. The recommendation was not accepted in spite of ICAO Annex 10 recommendation. Cf. para 1.18.6.

2.5.3 The problem caused by the bend on the LLZ has no significance in relation to certification requirements for a CAT I ILS. It is not required to follow the LLZ below the published decision altitude. Continuing with the ILS below the operating minimum is not permitted without visual reference to the runway environment. The small anomaly with the LLZ, seems to exaggerate the problem if operators continue flying on autopilot past 100 ft radio height in darkness and low visibility.

2.5.4 After the first incident in 1995, the NCAA issued an AIC B (Aeronautical Information Circular) in December 1996, informing operators of the anomaly and encouraging pilots to request the TWR to manually switch off the opposite LLZ. Initially, this was done by some pilots, but as time went by the issue was forgotten.

2.5.5 The AIBN considers the anomaly to be a risk factor in combination with AP coupled approaches. Investigations have indicated that it is possible to eliminate the interference from the opposite LLZ by technical solution by use of interlock. It should not be left as an operational initiative on the part of the pilots, thereby leaving a latent human factor trap.

2.5.6 Based on these investigations, AIBN considers that AP coupled approaches below CAT 1 minimum should not be performed unless the ILS to the opposite runway is interlocked. Avinor has informed AIBN that use of interlock at Norwegian airports will be limited to ENGM (all runways) and ENZV runway 18/36. ENVA runway 09/27 will be evaluated for interlock. Cf. 1.18.6.3.

2.5.7 AIBN considers that AIP Norway should specify which airport ILS's are interlocked and which are prohibited from automatic approaches and landings.

2.6 Lack of centre line lighting system

2.6.1 The AIBN believes that the lack of a centre line lighting system is a significant contributory factor in all four incidents. Cf. 2.2.

2.6.2 After the third incident in December 2001, the AIBN issued a safety recommendation to CAA-N to evaluate the requirement for installing a centre line lighting system to improve references when landing in reduced visibility. This recommendation was rejected on cost considerations. AIBN considers a centre line lighting system to be a significant safety enhancement.

2.6.3 Avinor rejected the AIBN recommendation SL 46/2002 on the grounds it would not be cost-effective. Cf. 1.18.1.3. The conclusion is based on the assumption that the aircraft is positioned above the runway edge lights, and that the theoretical increase in RVR based on centre line lights would only be a few metres. Further, the evaluation was based on one incident where a crew lost forward visibility during the flare in ground fog landing on runway 17. AIBN considers that with centre line lights available, the crew most likely would have been able to correct the right hand drift at an earlier stage and hence prevented the aircraft from drifting to the runway edge. The crew had the black runway in front of the aircraft in sight, but had no lateral references. AIBN argues that the benefit of centre line lights is not to improve the RVR, but to help pilots to keep lateral orientation in relation to runway centre line during low visibility in darkness. The three landing incidents on runway 35 illustrate the benefit of runway centre line lights even further. The three incidents were very similar. The crew had the runway lights visually from the DA. However, the aircraft drifted to the right caused by the LLZ and autopilot. The lack of visual cues with only a few runway edge lights available caused an optical illusion to the crew resulting in the PF to over control the aircraft during the landing flare. AIBN considers that runway centre line lights would have helped the crew to keep correct orientation in relation to the runway centre line and prevented the over controlling during the landing.

2.7 Use of autopilot below decision altitude

2.7.1 The AIBN considers the company's policy, of using the autopilot below the CAT I operating minima at ENBR, in combination with simultaneous use of reciprocal approach localizers, to be a causative factor for the landing incidents. The latent condition with a bend on the LLZ is considered by AIBN to be most problematic when flying on autopilot in darkness with reduced visibility. Such a procedure is normally considered to be a safe procedure provided only the approach localizer is operational at the time (Cf. 1.18.6.2). Most operators flying into ENBR are disengaging the autopilot at the operating minimum at the latest. The remaining landing segment is flown manually with visual reference to the runway lights/environment. On the other hand, AIBN will not rule out the possibility of pilots making the same mistake by following the offset LLZ when flying manually during difficult landing conditions.

2.7.2 After the first incident in 1995, the company issued a 'note' on the ILS charts for ENBR prohibiting use of the autopilot below DA, due to an unstable LLZ. The 'note' was withdrawn in October 1996 after a company review. It was decided that the 'note' was no longer required, and information on the approach charts should reflect the respective country's AIP. AIBN considers the 'note' to be of great value to the pilots reviewing the approach procedures, giving them a reminder to disconnect the AP at the operating minimum.

2.7.3 The company's argument for using the autopilot below DA is that the autopilot will maintain the aircraft on the LLZ and GP down to 50 ft radio height and thus protect the pilots from a tendency to "tuck under" in "black hole effect" conditions.

2.7.4 After the incident on 24 March 2003, SAS made some evaluation flights on 9 April 2003, using AP and performed autolandings. The results indicated that the AP tracked the LLZ beam and steered the aircraft to a touch down slightly left of centre line, but within acceptable tolerances. Based on the evaluation, SAS revised the approach charts to include a note that autolandings are not recommended due to a dip in the GP. The evaluation recordings also indicate that there is a slight bend on the LLZ shortly before TD. This

deviation is small and within the certification requirements. A continuous AP-coupled approach would steer the aircraft first to the right and then back to the centre line again shortly before touchdown. This may explain why the aircraft touched down to the left of centre line during the auto landing evaluation.

2.7.5 The autopilot steers the aircraft slightly to the right at approximately 100 ft radio height. Due to the limited visual references available, AIBN believes the PF may be under the illusion that he/she is dangerously offset from the centre line. He/she makes a manual correction - effectively an overcorrection - and the aircraft ends up on the opposite side of the runway. The manual correction comes at the most critical time when the pilot is starting the flare for landing. Hence, there is no time available to make a counter-correction before the aircraft touches down with a leftward drift. The only way the pilot flying can make a control correction at that time is to use right rudder to steer the aircraft back onto the centre line of the runway.

2.7.6 SAS claims that similar, but less severe offset approaches, have been experienced with Boeing 737 aircraft. Hence, AIBN will not rule out the possibility of experiencing similar circumstances when flying manually in darkness and reduced visibility. AIBN believes the installation of centre line lights at ENBR would increase the safety margins significantly.

2.7.7 Avinor has issued a Notam for ENBR which is valid to 31 December 2005. Cf. 1.18.6.4. AIBN considers this action as a temporary action and recommends that Avinor seeks an acceptable permanent solution which should be published in AIP Norway.

2.8 Commanders' policy of not using landing lights during conditions of darkness and reduced visibility

2.8.1 The company's Commanders' policy of not using the landing lights when landing in darkness in combination with reduced visibility is considered by AIBN to be another contributory factor. The combination of yellow runway markings instead of white markings on a dark asphalt surface and the lack of centre line lights, means that the pilots lack sufficient references to line up the aircraft properly for landing. SAS has explained to AIBN that the company does not have a general policy of not using landing lights in darkness and during CAT 1 approaches. Cf. 1.18.4.7.

2.8.2 AIBN considers that the company's recommendation regarding non-use of landing lights during precipitation or drifting snow or sand in crosswind conditions, to lead the commanders not to use landing lights during limited visibility conditions. AIBN considers that CAT 1 landings are based on visual references to the runway and hence the use of landing lights should be beneficial. CAT I minima are based on visual references to the runway environment from the decision point. Hence, the visibility should be sufficient to continue the landing even with landing lights on.

2.9 Norwegian use of yellow runway markings instead of the ICAO recommended white

2.9.1 Luftfartsverket (now Avinor) has filed a deviation from ICAO Annex 14, which specifies the use of white runway markings on the basis of occasional snow cover on the runway. The theory is that yellow markings on a black surface are more visible than white markings under winter conditions.

2.9.2. Norway is the only country in the world to have filed such a deviation regarding runway markings. Countries like Sweden, Finland, Canada, USA, Japan and Russia, which all

permit operations on snow-contaminated runways, use ICAO standard white runway markings. In this respect it is also worth mentioning that European road standard uses white markings. Sweden is an example in this respect. AIBN has not seen any scientific evidence that supports the theory that yellow runway markings enhance aviation safety. On the contrary, AIBN has received information from pilots claiming the opposite.

2.9.3 The AIBN does not agree with this deviation and considers white markings in general to be more effective than yellow. When there is snow or ice on the runway, the markings are not visible anyway and pilots are forced to judge the approximate location of the centre line from other references. Another consideration is that ICAO and JAR OPS recommendations specify that airports should try to keep the runway surfaces clear of most contamination. Yellow markings may contribute to undermine this recommendation.

2.9.4 During the review of this draft report AIBN received comments regarding cost and timeframe for changing from yellow to white painting of Norwegian runways. AIBN considers that repainting may be implemented during the regular maintenance work. This would imply that during the transition period some airports will have yellow and some will have white markings. This is the present situation experienced by pilots flying between Norway and other Scandinavian countries and should not present a significant safety problem during the transition period.

2.10 Commander's decision not to abort the landing

2.10.1 In all four cases, the aircraft Commander decided not to abort the landing. After each incident, the company has informed its pilots that a go-around should be initiated whenever the crew is in doubt regarding the safety of continuing the landing. This is a general challenge in the airline industry. Several investigations have shown that it is a difficult decision for a flight crew to abort a landing during the flare phase.

2.10.2 The AIBN investigations show that in the four incidents at ENBR, each of the commanders felt that a go-around would be less safe than a continued landing. AIBN considers that, in general, a go-around would have been the proper action. However, a go-around must be initiated before the power levers are retarded to idle. With a touch-down heading offset from the runway heading, the required spool-up time for the engines may make it more hazardous to perform a go-around during the flare or on the runway rather than continuing the landing process.

2.10.3 AIBN considered issuing a safety recommendation regarding a review of the company's CRM training related to unstabilised landings and late go-arounds. SAS has informed AIBN that such action was implemented after the last incident. Based on this information, AIBN considers that this safety issue has been corrected. Cf. 1.18.4.9.

3 CONCLUSIONS

3.1 The crew

3.1.1 The crew were qualified and well rested before the flight.

3.1.2 The Commander decided that a continued landing was safer than an aborted landing.

3.2 The aircraft

3.2.1 The aircraft was certified with mass and balance within limits.

3.2.2 The aircraft AP is certified down to 50 ft radio height.

3.2.3 The DC-9/MD-80 series aircraft is the only type of aircraft involved in known landing incidents at ENBR.

3.3 Weather and lighting conditions

3.3.1 The weather was acceptable for landing.

3.3.2 The RVR was above, but close to the operating minimum.

3.3.3 It was dark.

3.4 The airport

3.4.1 Bergen airport Flesland is equipped with ILS CAT I for RWY 17/35.

3.4.2 The LLZ for RWY 17/35 has a bend at approximately 100 ft radio height with simultaneous operation of both ILS-systems (Latent condition).

3.4.3 The GP to RWY 35 has a dip close to touchdown. Consequently auto-landings are not recommended (Latent condition).

3.4.4 The airport does not have RWY centre line lights (Latent condition).

3.4.5 The airport did not have an automatic RVR measuring device at the time of the incident (Latent condition).

3.4.6 The airport runway surface markings are yellow instead of the ICAO standard white markings (Latent condition).

3.5 The procedures

3.5.1 Scandinavian Airlines' policy is to use the AP below the CAT I DA and down to 50 ft radio height. This procedure will normally enhance safety, but in combination with the special circumstances at ENBR, the procedure becomes a risk factor (Latent condition).

3.5.2 SAS Commanders' procedure of not using landing lights in darkness and reduced visibility when landing on CAT I runways is not supported by AIBN. This is particularly the case when landing at ENBR, which has neither RWY centre line lights, nor white runway markings (Latent condition).

4 SAFETY RECOMMENDATIONS

Based on this serious incident, the AIBN issues the following safety recommendations:

Simultaneous operation of RWY 17/35 LLZ transmitters may be causing interference from the opposite LLZ signal. CAA-N should consider to review the Norwegian requirements for ILS equipment and use of interlock. (SL recommendation no. 50/2005).

Based on the present NOTAM at ENBR regarding not using autopilot inside 3 NM on ILS 35, Avinor should consider to publish in AIP Norway any restrictions on automatic approaches and landings by use of the ILS equipment at Bergen airport Flesland. (SL recommendation no. 51/2005).

Based on investigations of four landing incidents at ENBR, AIBN considers that the installation of centre line lighting systems will improve the flight safety level during landings at ENBR. CAA-N should consider to evaluate the requirement for RWY centre line lighting system at ENBR. (SL recommendation no. 52/2005).

Norway is the only country in the world using yellow runway markings. AIBN has not seen any scientific evidence supporting the Norwegian policy of using yellow runway markings. CAA-N should consider to evaluate the requirement for adhering to ICAO standard white runway surface markings in Norway. (SL recommendation no. 53/2005).

Scandinavian Airlines has experienced four landing incidents at ENBR involving the use of AP down to the MUH. SAS should consider to re-evaluate the procedure of using the autopilot below CAT 1 minimum at ENBR. (SL recommendation no. 54/2005).

SAS Commanders' policy is not to use landing lights in darkness and reduced visibility in drifting fog or precipitation. SAS should consider to re-evaluate the wording in OM Part A to clarify when use of landing lights are not recommended and when it may be beneficial. (SL recommendation no. 55/2005).

REFERENCE

Reason, J.: Managing the Risks of Organizational Accidents, Ashgate 1997, London.

APPENDICES

1 Picture of the damaged aircraft tyre.

2 Picture of the damaged runway edge light.

3 Touch down and aircraft ground track.

4 SAS evaluation flight recordings - approach to runway 35 at ENBR.

5 SAS approach chart ENBR ILS-35

ABBREVIATIONS

AAIBN	Aircraft Accident Investigation Board Norway (pre AIBN)
AIBN	Accident Investigation Board Norway
AAIBN BUL	AAIBN Bulletin
A/C	Aircraft
AIC	Aeronautical Information Circular
AP	Autopilot
APP	Approach control
ATC	Air Traffic Control
ATPL A	Airline Transport Pilot Licence Airplane
ANU	Aircraft Nose Up
BSL	Bestemmelser for sivil luftfart (civil aviation regulations)
CAA-N	Civil Aviation Authority-Norway
CAT I	Category I ILS
CPL A	Commercial Pilot Licence Airplane
CVR	Cockpit Voice Recorder
DA	Decision Altitude
DH	Decision Height
ENBR	Bergen airport Flesland
ENGM	Oslo airport Gardermoen
FDR	Flight Data Recorder
GND	Ground control
GP	Glide Path
GS	Glide Slope
HSL	Havarikommisjonen for sivil luftfart (AAIBN, Aircraft Accident Investigation Board Norway)
HSL BUL	HSL Bulletin

HSLB	Havarikommisjonen for sivil luftfart og jernbane (AIBN, Accident Investigation Board Norway)
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
IR	Instrument Rating
IRS	Inertial Reference System
JAR OPS	Joint Aviation Regulations Operations
JET A-1	Jet fuel
LDA	Landing Distance Available
LH	Left Hand
LLZ	Localizer
MEHT	Minimum Eye Height above Threshold
METAR	Meteorological Aerodrome Report
MUH	Minimum Use Height (Autopilot)
OPC	Operational Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PNF	Pilot Not Flying
QAR	Quick Access Recorder
QFU	Runway magnetic heading
RA	Radio Altitude
RH	Right Hand
RVR	Runway Visual Range
RWY	Runway
SAS	Scandinavian Airlines System
SD	Samferdselsdepartementet (Norway’s Ministry of Transport and Communications)
TAF	Terminal Area Forecast

TAR	Terminal Area Surveillance Radar
TD	Touch Down
THR	Runway Threshold
TWR	Tower control
TR	Type Rating
VIS	Meteorological Visibility

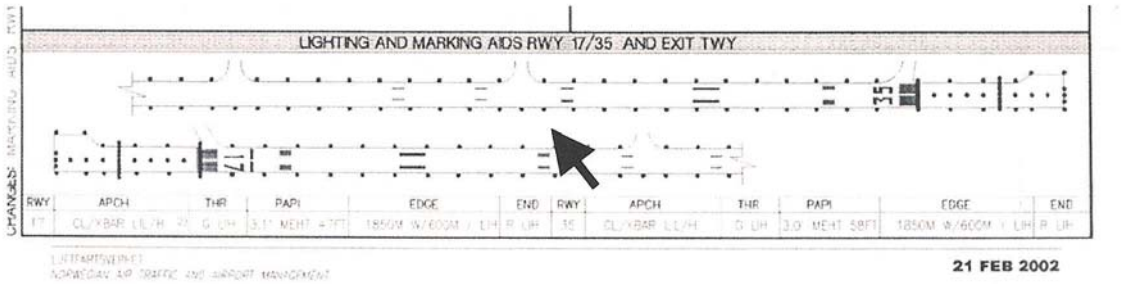
ACCIDENT INVESTIGATION BOARD NORWAY (AIBN)

Lillestrøm, 19 December 2005

APPENDIX 1 LN-RMO

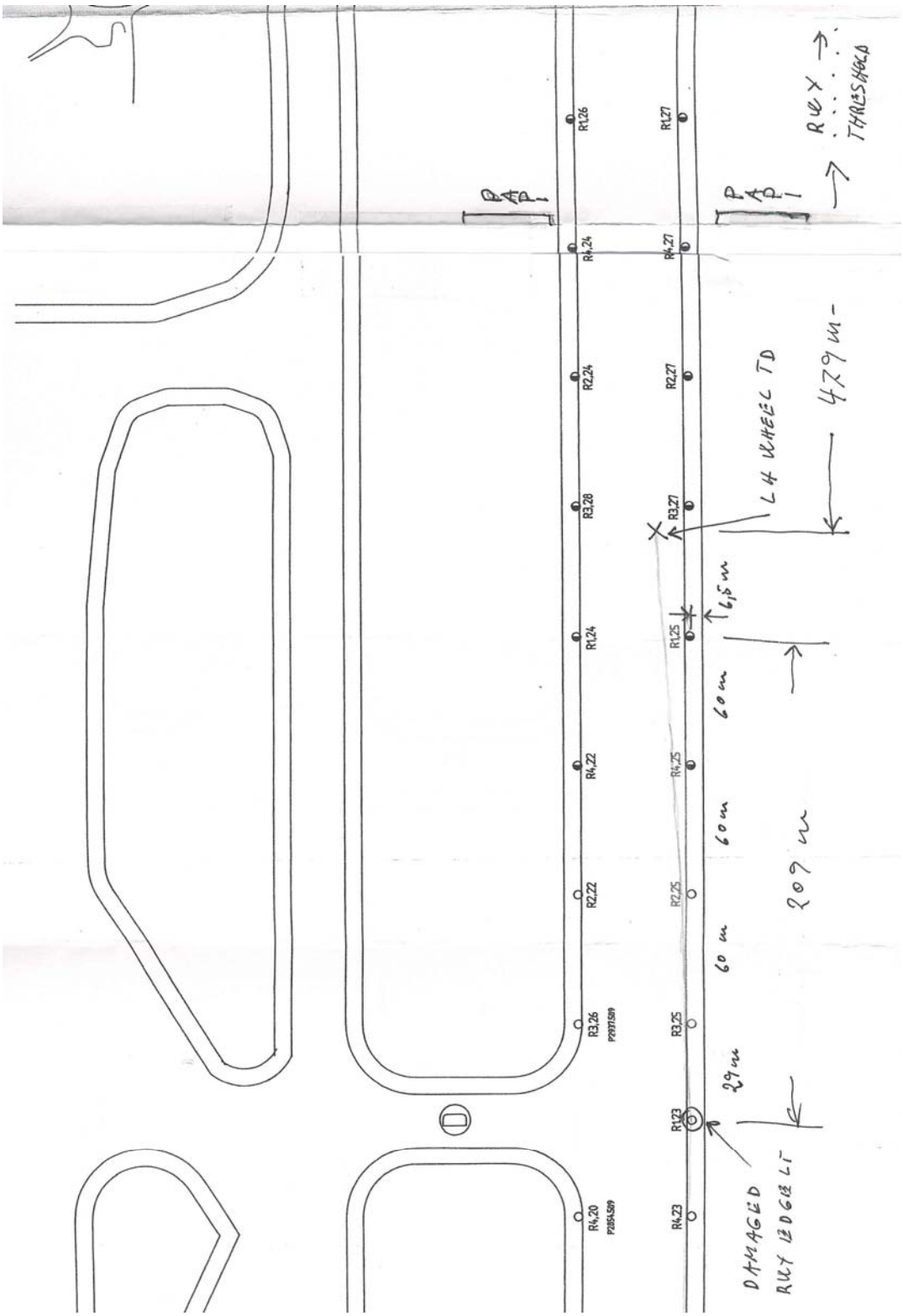
Damaged aircraft tires

APPENDIX 2 LN-RMO

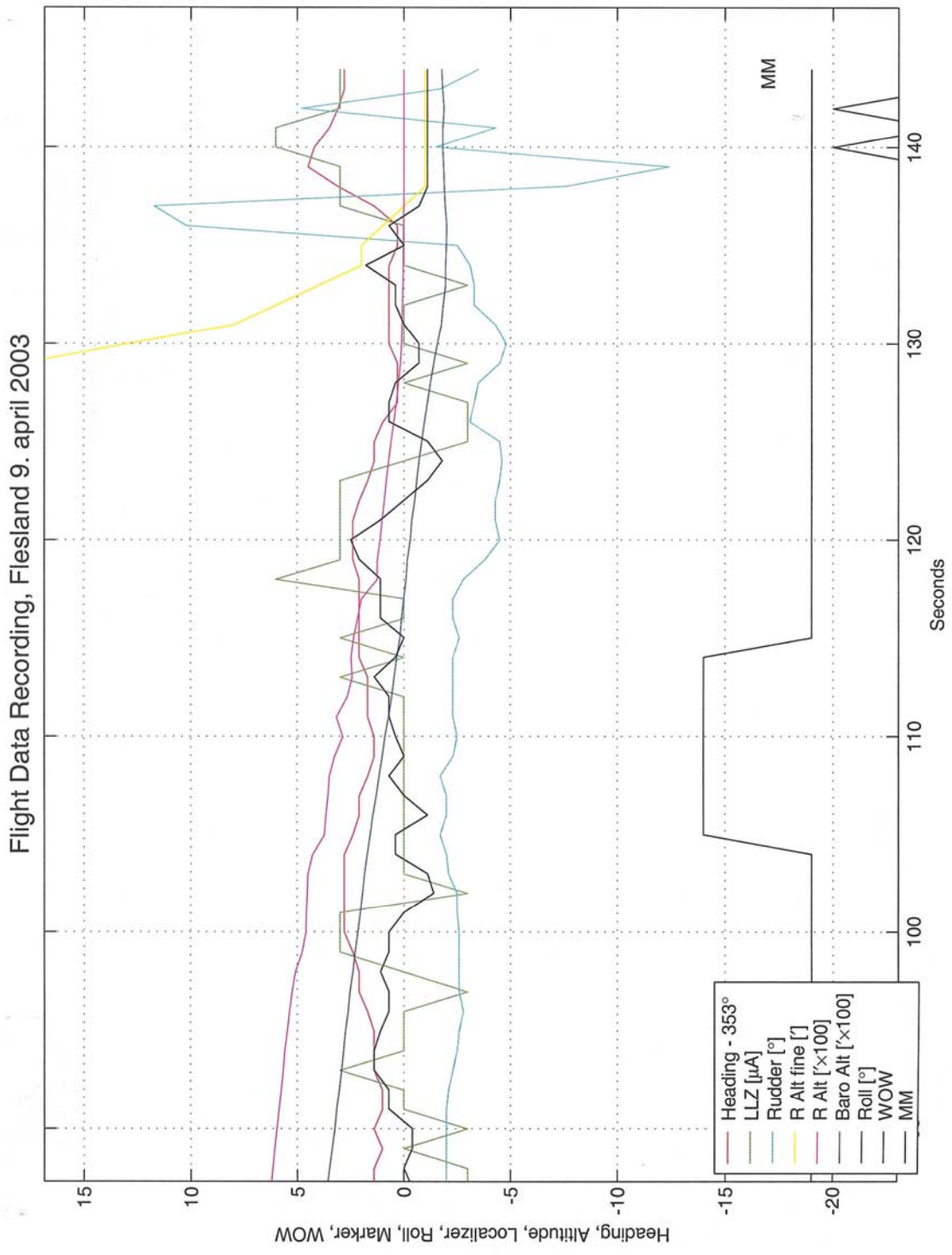


Damaged runway edge light

APPENDIX 3 LN-RMO

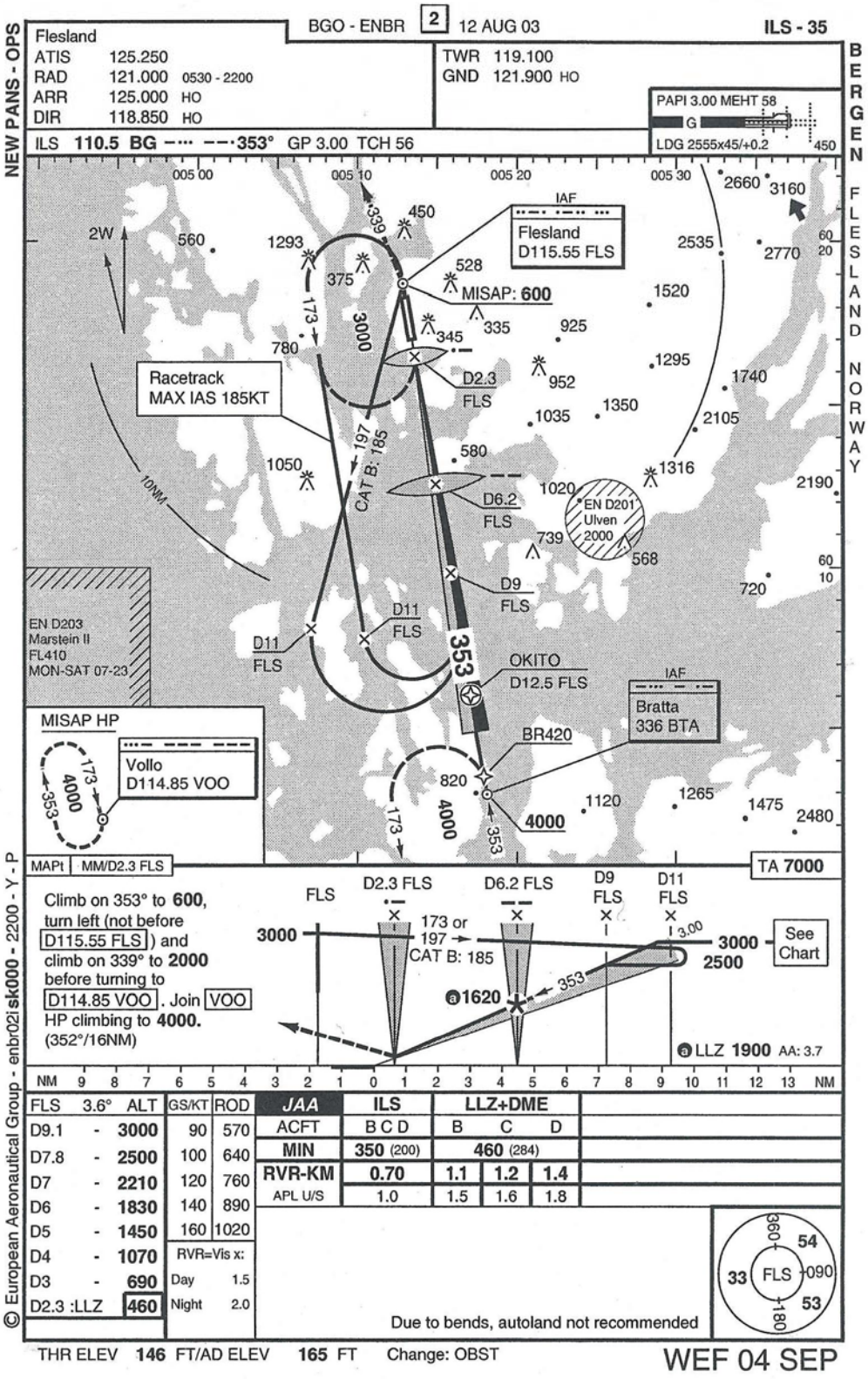


Touch down and aircraft ground track



SAS evaluation flight recordings

APPENDIX 5 LN-RMO



Scandinavian Airlines approach chart ENBR ILS-35