Statens haverikommission
Swedish Accident Investigation Authority

Final report RL 2014:19e

Serious incident at Malmö Airport on January 10, 2014 involving the aircraft SE-LIS of the model Fokker F27 Mark 050, operated by Amapola Flyg AB.

File number L-04/14

2014-12-16

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring again, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available on SHK´s web site: www.havkom.se

(ISSN 1400-5719)

This document is a translation of the original Swedish report. In case of discrepancies between this translation and the Swedish original text, the Swedish text shall prevail in the interpretation of the report.

Postadress/Postal address	Besöksadress/Visitors	Telefon/Phone	Fax/Facsimile	E-post/E-mail	Internet
P.O. Box 12538 SE-102 29 Stockholm Sweden	Sveavägen 151 Stockholm	+46 8 508 862 00	+46 8 508 862 90	info@havkom.se	www.havkom.se

Statens haverikommission
Swedish Accident Investigation Authority

Contents

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring again, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

Investigations of aviation incidents are governed mainly by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and by the Accident Investigation Act (1990:712). The investigation is carried out in accordance with Annex 13 of the Chicago Convention.

The investigation

SHK was informed on January 10, 2014 that a serious incident involving one aircraft with the registration SE-LIS had occurred at Malmö Airport, Skåne county, on the same day at 01.44 hrs.

The incident has been investigated by SHK represented by Mr Jonas Bäckstrand, Chairperson, Mr Nicolas Seger, Investigator in Charge, Mr Christer Jeleborg, Technical Investigator (aviation), Mr Jens Olsson, Investigator behavioural science and Mr Urban Kjellberg, Investigator specializing in Fire and Rescue Services.

The investigation team of SHK was assisted by Mr Christer Magnusson and Mr Tomas Krave as experts specializing in sound and by Ms Liselotte Yregård as a medical expert.

Accredited representative has been Mr Guy Oomen from the Dutch Safety Board (the accident investigation authority in the Netherlands).

Mr Lars Kristiansson from the Swedish Transport Agency participated as an adviser.

The following organisations have been notified: the International Civil Aviation Organisation (ICAO), the European Aviation Safety Agency (EASA), the European Commission, the Dutch Safety Board and the Swedish Transport Agency.

Investigation material

Interviews have been conducted with the aircraft's commander and co-pilot.

A meeting with the interested parties was held on May 21 2014. At the meeting SHK presented the facts discovered during the investigation, available at the time.

Final report RL 2014:19e

Aircraft:	
Registration, type	SE-LIS, Fokker F27
Model	F27 Mark 050
Class, Airworthiness	Normal, Certificate of Airworthiness and Valid Airworthiness Review Certificate (ARC)[1]
Operator	Amapola Flyg AB
Time of occurrence	January 10, 2014, 01.44 hrs during darkness Note: All times are given in Swedish standard time (UTC + 1 hr)
Place	Malmö Airport, Skåne county, (position 5531,8N 01322,6E, 65 metres above sea level)
Type of flight	Commercial air transport
Weather	According to SMHI's analysis: wind around west 25 kts, gusts ca. 35, visibility 8-10 km, light rain, cloud 6-8/8 with base at 1 000 feet, temperature/dewpoint 5/3°C, QNH[2] 990 hPa, moderate turbulence between the ground and 3 000 feet
Persons on board:	2
crew members including cabin crew	2
passengers	None
Injuries to persons	None
Damage to aircraft	No damage
Other damage	None
Commander:	
Age, licence	44 years, ATPL (A)[3]
Total flying hours	6 583 hours, of which 5 332 hours on type
Flying hours previous 90 days	90 hours, of which all hours on type
Number of landings previous 90 days	42
Co-pilot:	
Age, licence	33 years, MPL (A) [4]
Total flying hours	1 720 hours, of which 1 153 hours on type
Flying hours previous 90 days	113 hours, of which all hours on type
Number of landings previous 90 days	62

[1] ARC (Airworthiness Review Certificate).
[2] QNH indicates barometric pressure adjusted to sea level.
[3] ATPL (A) (Airline Transport Pilot Licence Aeroplane).
[4] MPL (A) (Multi Pilot Licence Aeroplane).

SUMMARY

The incident occurred in connection with a commercial cargo flight at night from Sundsvall airport to Malmö Airport. The flight involved a cabin decompression and a veer-off to the side upon landing. There were no injuries and no damages.

SHK believes that it is extremely unlikely that the crew was subjected to hypoxia to such a degree that the flight operational tasks became neglected.

The crew had been subjected to an acute lack of sleep and probably to a cumulative lack of sleep as well.

Both planning and current conditions exceeded the operator's crosswind limitations for the aircraft.

The flight crew has not been offered medical examinations for employees in night work in accordance with the Swedish Work Environment Authority’s regulations.

Civil flight personnel in night work who are not offered a medical examination that has in view the medical suitability for working at night may constitute a potential aviation safety risk.

The incident was caused by the aircraft being suddenly subjected to a severe gust of wind during roll-out while maintaining thrust reversal.

Contributing factors were probably the crew's lack of sleep, which probably affected decision-making and attention, which in turn led to the landing being performed under conditions that exceeded the operator's crosswind limitations for the aircraft.

Safety recommendations

The Swedish Transport Agency is recommended to:

- examine, in consultation with EASA and the Swedish Work Environment Authority, the application of the Swedish Work Environment Authority's regulations and general advice (AFS 2005:6) on medical checks in working life and the Swedish Work Environment Authority's regulations (AFS 2005:20) on the medical examination of flight personnel in civil aviation regarding the employer's obligation to offer flight personnel within civil aviation in night work a medical examination for work environment reasons. *RL 2014:19 (R1)*

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Circumstances

The flight was a commercial cargo flight from Sundsvall Airport to Malmö Airport. The flight had been assigned the call sign APF9121.

The flight assignment on the night in question consisted of post conveyance. The take-off took place just before midnight, and the flight time to Malmö was calculated to one hour and 55 minutes. On board there was fuel for flying for about five hours and thirty minutes.

The operational flight plan prepared by the crew indicated Gothenburg/Landvetter Airport as the alternate aerodrome and a minimum quantity of fuel corresponding to about two hours and 35 minutes of flight. The commander stated during an interview that the extra quantity of fuel had been motivated by the prevailing weather situation with very strong winds over southern Sweden. In the loadsheet, Stockholm/Arlanda had been stated as an alternative.

The company's flight crew members had access to a personal EFB[5] in the form of an Ipad. Among other things, the unit is used to display aeronautical charts and contains the company's flight manuals, calculation programs for take-off and landing performance and for mass and balance calculations.

The weather forecast for Malmö Airport that had been issued at 18.30 hrs stated the wind direction to be 280 degrees and the wind strength 25 knots with wind gusts of 45 knots as well as temporary rain showers. The corresponding forecast that was issued at 00.30 hrs, i.e. about 45 minutes after take-off, stated the wind direction to be 280 degrees and the wind strength 30 knots with wind gusts of 42 knots as well as temporary rain showers. The forecasted wind direction meant that the wind was largely across the runway, i.e. direct crosswind.

The operator's flight manual (OM-B[6]) stated a limitation, regarding the crosswind component on landing, of 30 knots for a dry runway and 25 knots for a wet runway. According to the manufacturer's flight manual (AOM[7]), the corresponding limitation is 33 knots for good braking action.

An ATS[8] flight plan had been filed for flight under Instrument Flight Rules. The aircraft was de-iced before take-off.

[5] EFB (Electronic Flight Bag) – Portable data unit containing flight operations programs and flight documentation.
[6] OM-B (Operations Manual B).
[7] AOM (Aircraft Operating Manual).
[8] ATS (Air Traffic Service).

1.1.2 History of the flight

The flight took off at 23.47 hrs. Take-off and climb to Flight Level 250, corresponding to about 7 600 metres, was performed according to normal procedures.

During the flight, the crew requested information regarding weather conditions at the destination airport, partly via air traffic control and partly via the crew of a sister aircraft. According to the CVR[9], the crew received information on the latest current weather according to METAR[10] at 00.56 hrs. The wind was stated to be 270 degrees, 25 knots and 39 knots in the gusts, and visibility to be 5 000 metres in moderate rain.

Shortly thereafter, when the aircraft was abeam Jönköping, the warning for cabin pressure altitude was activated. The crew made an emergency descent to Flight Level 80 and performed the measures according to the checklist for emergency descent and cabin decompression. According to the CVR, both the crew members had begun to use oxygen masks within two minutes of the warning being triggered.

At the crew's request to descend to Flight Level 80 or 90, air traffic control gave the clearance “descend to flight level 80” without any further information. Two and a half minutes later, air traffic control communicated “no traffic reported flight level 80”.

After this, the crew conducted an internal dialogue for just over ten minutes on the reduction of cabin pressure, which included reading the aircraft's operating manuals and performing an inspection of the cabin space.

At 01.23 hrs, the crew noted an ATIS[11] broadcast with the time stamp 00.20 (UTC time) which, among other things, contained information that runway 17 was in use, wet runway, wind 280 degrees 21 max 33 knots and visibility 9 km in light rain and mist. The commander has explained that the detail of the wet runway was not understood because of simultaneous communication on another frequency. After consultation with the co-pilot, the commander made the decision to use runway 35.

The crew carried out a briefing and subsequently commenced the approach and implemented the associated checklist. At 01.41 hrs, clearance was received to land on runway 35 with the wind stated to be 280 degrees 26 knots max 34. The landing clearance was

[9] CVR (Cockpit Voice Recorder), (see Section 1.11.2).
[10] METAR (Aviation routine weather report) – (in meteorological code).
[11] ATIS (Automatic Terminal Information Service).

acknowledged by the crew. The sound recordings also show that the crew received the wind data.

According to the crew, the approach and touchdown were performed without problems. Shortly after touchdown, the engines were reversed. When the speed reduced, the aircraft began to yaw to the left. The commander explained that he used the nose wheel steering to compensate the yawing tendency but that the nose wheel “probably went across”. Furthermore, he was unsure whether the brakes had been used.

The yaw continued towards the left, and the aircraft left the runway and stopped with the nose wheel and left main gear in the grass, with the right main gear on the asphalted runway shoulder. In connection with the excursion, the nose gear and left main gear each ploughed a furrow in the ground on the grass area with a depth corresponding to just under half the diameter of the wheels. See Figure 1.

Figure 1. The aircraft's position after the excursion. The picture was taken four hours after the incident.

The excursion was reported to the tower, which activated the crash alarm.

The crew shut down the engines, performed the normal checklist after landing and left the aircraft through the ordinary door.

The incident occurred at position 5531,8N 01322,6E, 65 metres above sea level.

1.1.3 Other

The commander has stated during interviews that he did not feel especially tired during the approach and landing.

1.2 Injuries to persons

	Crew members	Passengers	Total in the aircraft	Others
Fatal	-	-	0	-
Serious	-	-	0	-
Minor	-	-	0	Not applicable
None	2	-	2	Not applicable
Total	2	0	2	-

1.3 Damage to aircraft

No damage.

1.4 Other damage

None.

1.4.1 Environmental impact

No environmental impact.

1.5 Personnel information

1.5.1 The commander

The commander, was 45 years old and had a valid ATPL (A) licence with flight operational and medical eligibility. At the time the commander was PF[12].

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	5,8	11,1	90	6 583
This type	5,8	11,1	90	5 332

Number of landings this class/type previous 90 days: 42.
Type rating concluded on 9 May 2000.
Latest PC (proficiency check) conducted on 18 April 2013 on this type.

1.5.2 The co-pilot

The co-pilot, was 34 years old and had a valid MPL (A) licence with flight operational and medical eligibility. At the time the co-pilot was PM[13].

[12] PF (Pilot flying).
[13] PM (Pilot Monitoring).

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	5,8	11,1	113	1 720
This type	5,8	11,1	113	1 153

Number of landings this class/type previous 90 days: 62.
Type rating concluded on 19 December 2009.
Latest PC conducted on 27 August 2013 on this type.

1.5.3 The pilots' duty schedule

The crew was on duty for its fourth working period and its fifth working day. The duty in question began with check-in on January 9 at 16.50 hrs and was planned to end with check-out on January 10 at 02.00 hrs. The preceding duty ran between 03.25 hrs and 06.45 hrs on the morning of January 9.

The accumulated duty for the latest 7-day period amounted to 29 hours and 51 minutes.

The duty periods and rest periods were within prescribed limits.

1.6 Aircraft information

The aircraft is a twin-engined, high-wing turboprop aircraft intended for short- and medium-distance traffic. The aircraft has a length of 25.25 metres and a span of 29 metres and is fitted with a pressure cabin.

1.6.1 The aircraft

Aircraft	
TC-holder	Fokker Services B.V.
Type	Fokker F27/F27 Mark 050
Serial number	20152
Year of manufacture	1989
Gross mass, kg	Max authorised start/landing mass 20 820/20 030 current 17 223/16 024
Centre of gravity	Within permitted limits. 65 (forward/rear limit 57/89)
Total flying time, hrs	32 942
Flying time since latest inspection	13
Number of cycles	39 152
Type of fuel loaded before event	3 520 kg JET A-1

Engine		
TC-holder	Pratt and Whitney Canada Corp.	
Type	PW125B	
Number of engines	2	
Engine	No 1	No 2
Serial number	124053	124116
Total operating time, hrs	36 587	29 249
Operating time since latest inspection, hrs	4 896	547
Propeller		
TC-holder	Dowty Propellers	
Type	R352/6-123-F/1	
Propeller	No 1	No 2
Serial number	DRG103 94-89	DRG848 4-89
Total operating time, hrs	31 718	28 572
Operating time since overhaul, hrs	788	2 155
Open remarks	None	

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.2 *The pressurization and the oxygen systems*

During flight, the fuselage is normally pressurized in all spaces between the front and rear pressure bulkheads. An automatic system controls the outflow of air from the aircraft's pressurized cabin. The maximum permissible pressure differential of 5.45 PSI[14] allows a cabin pressure altitude of 6 000 feet when the aircraft is at an altitude of 25 000 feet.

If the cabin altitude exceeds 10 000 feet, the cabin altitude warning is activated, consisting of one audio and two visual warnings.

By each seat in the cockpit there is an oxygen mask that is designed so that it can be quickly put on and used.

1.6.3 *Flight controls*

The aircraft has primary flight controls for all control surfaces that are activated by means of control wheels and pedals via rod and cable systems. On the ground, the aircraft is manoeuvred in the yaw axis partly by means of the rudder through the pedals and partly by means of a tiller for each pilot that hydraulically activates the nose wheel steering.

[14] PSI (Pound force per square inch) – equivalent to about 0.07 bar.

In addition, manoeuvring in the yaw axis can be effectuated partly through asymmetric thrust from the engines' propellers and partly through asymmetric braking.

The thrust from the propellers is directed forward in normal flight and can also be directed backwards through thrust reversal, among other things in connection with landing in order to decelerate the aircraft.

The propellers' thrust is measured in the unit % TRQ[15]. The manufacturer has stated that a two-percent difference in TRQ between the right and left engines can result in an actual TRQ difference of four to five per cent, in part depending on rigging tolerances. Such a TRQ difference does not produce any noticeable movement in the yaw axis.

The manufacturer's flight manual states that rudder effectiveness decreases in connection with thrust reversal and that thrust reversal should be cancelled when the speed has reduced to about 60 knots. The manual further states that the cancelling of thrust reversal is intended to improve controllability at low speeds and that this should be done if problems arise with directional control.

1.6.4 *The aircraft´s vertical stabilizer and the weathervane effect*

When the wind hits the vertical stabilizer, a force arises that acts to turn the aircraft nose into the wind, see Figure 2 below.

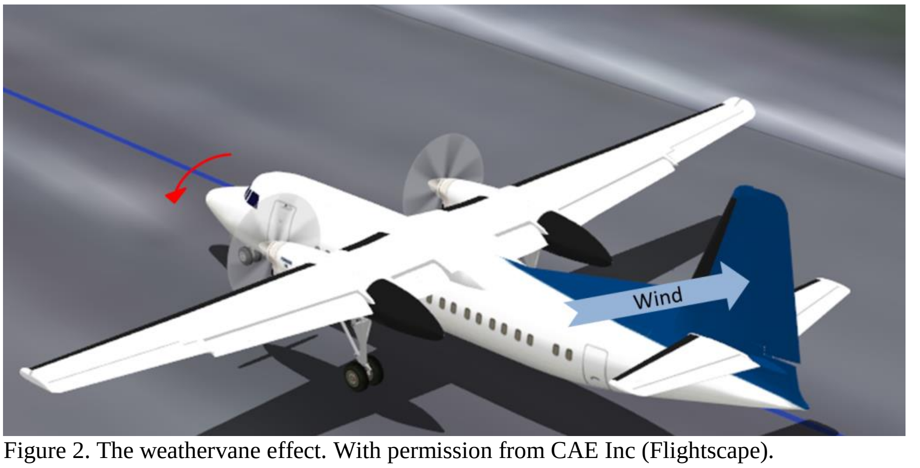

Figure 2. The weathervane effect. With permission from CAE Inc (Flightscape).

1.7 Meteorological information

According to SMHI's analysis: Wind around west 25 kts, gusts ca. 35, visibility 8-10 km, light rain, cloud 6-8/8 with base at 1 000 feet, temperature/dewpoint 5/3 °C, QNH 990 hPa, moderate turbulence between the ground and 3 000 feet.

[15] TRQ (Torque).

The weather forecasts for the airport that had been issued at 18.30 hrs and 00.30 hrs local time are given below in their original format (with UTC times):

TAF ESMS 091730Z 0918/1018 22020KT 9999 BKN020 TEMPO 0918/0922 24025G38KT 4000 SHRA BKN010 SCT015CB TEMPO 0922/1005 4000 SHRA BKN010 SCT015CB BECMG 0922/0924 28025G45KT BECMG 1002/1005 28018G28KT TEMPO 1005/1018 BKN010=

TAF ESMS 092330Z 1000/1024 28030G42KT 9999 BKN020 TEMPO 1000/1004 4000 SHRA BKN008 SCT015CB BECMG 1002/1005 28018G28KT TEMPO 1004/1012 BKN010 BECMG 1012/1014 27014KT TEMPO 1012/1024 4000 SHRA BKN008 SCT015CB=

The meaning of the forecasts regarding wind data and precipitation is described more closely in Section 1.1.1.

Current weather for the aerodrome is called METAR and is issued every half hour. The following presents the METAR issued from 23.50 hrs until 00.20 hrs in their original format (with UTC times).

METAR ESMS 092250Z 26029G42KT 6000 BR BKN008 05/03 Q0986 RERA R17/29//95=

METAR ESMS 092320Z 27029G41KT 9999 -RA BKN009 04/02 Q0987 R17/29//95=

METAR ESMS 092350Z 27025G39KT 5000 RA BR BKN010 04/03 Q0988 R17/29//95=

METAR ESMS 100020Z 28023G33KT 9000 -RA BR BKN010 04/03 Q0989 R17/29//95=

An explanation of the weather information regarding wind data and precipitation is provided in Section 1.1.1 and relates to METAR ESMS 092350Z, which had been issued at 00.50 hrs local time.

Values for wind direction are given in relation to true north rounded to the nearest ten for TAF[16] and METAR.

The last group in each METAR states runway conditions and does not show any change. The group states that the main runway designated 17 is wet or has water patches that cover 51-100 % of the runway, without indication of water depth, and that the braking action is good.

SHK has examined recorded wind data from AWOS[17] for runway 35. The wind is measured by an anemometer placed about 50 metres to

[16] TAF (Terminal Aerodrome Forecast).
[17] AWOS (Automated Weather Observing System).

the right of the runway abeam the touchdown zone. The recorded wind direction at the time of landing was 280 degrees. The recorded two-minute average value for wind strength was 25 knots, and the ten-minute average value for maximum wind strength was 33 knots counted from the time of touchdown. Instantaneous wind has not been recorded.

The ATIS prior to the landing read as follows:

Malmö ATIS Foxtrot at 00:20, ILS approach runway 17, runway wet, transition level 60. Met report, wind 280 degrees, 21 knots, maximum 33, minimum 15 knots. Visibility 9 km, light rain mist. Cloud broken 1 000 feet, temperature 4, dew point 3, QNH 989 hPa, Malmö ATIS Foxtrot.

Values for wind direction are given in relation to magnetic north rounded to the nearest ten regarding ATIS and winds reported by the tower.

The incident occurred during darkness.

1.8 Aids to navigation

Runway 35 at Malmö Airport was equipped with an Instrument Landing System (ILS), a visual glide slope indicator at 3.0° (PAPI, Precision Approach Path Indicator), centre line lights, runway edge lights and visual runway markings.

1.9 Communications

SHK has examined the radio communication, both between the crew on the aircraft in question, a sister aircraft and air traffic control, and between the various actors involved in the measures after the incident, such as airport management, rescue services and ground vehicles.

Parts of radio communications concerning the incident are reproduced in Section 1.1.2.

1.10 Aerodrome information

The airport is listed as an approved instrument aerodrome according to AIP[18] Sweden.

The airport has one main runway designated runway 35 and 17, which indicates the magnetic bearing in tens of degrees. Runway 35 has a magnetic bearing of 349 degrees. The runway, which is covered with asphalt, has a length of 2 800 metres and a width of 45 metres.

[18] AIP – Aeronautical Information Publication (Aviation information of a permanent nature).

The strip has a length of 2 920 metres and a width of 300 metres. The strip encompasses the runway, runway shoulders, grass areas and parts of the taxiway system.

The runway's shoulders have a width of about seven metres and are asphalted.

1.11 Flight recorders

The aircraft was equipped with flight recorders that SHK has secured for readout and analysis. The units have subsequently been returned to the operator.

1.11.1 Flight Data Recorder (FDR[19])

The FDR was of the model FA2100 from L3 Communications with the serial number 000460872. The unit is digital and can store data for at least 25 hours.

The FDR in question does not record information on cabin pressure altitude, brakes or nose wheel steering.

The FDR was transported to SAAB AB in Linköping where data readout was performed under the supervision of SHK's Investigator in Charge. Binary data have then been converted into engineering units by means of the Dutch manufacturer's parameter list. The converted data have then been presented in the form of numerical values in table data, plots and in the form of an animation that is described in more detail in Section 1.16.

1.11.2 Cockpit Voice Recorder (CVR[20])

The CVR was of the model FA2100 from L3 Communications with the serial number 000460537. The unit is digital and has a recording time of up to two hours.

The CVR was transported to SAAB AB where data readout took place under the supervision of SHK's Investigator in Charge. Audio data have then been transferred to a digital medium and transcribed by means of the sound experts engaged by SHK.

The parts the information from the cockpit voice recorder concerning the incident are reproduced in Section 1.1.2.

1.12 Site of occurrence

The aircraft ran off runway 35 at Malmö Airport on the left side just over 100 metres after taxiway B. It has been possible to document the position by means of a GPS camera and by measurement of the wheel tracks in the grass.

[19] FDR (Flight Data Recorder).
[20] CVR (Cockpit Voice Recorder).

The grass area where the nose wheel and the left main gear left tracks constitutes the graded portion of the strip. According to the Swedish Transport Agency's Regulations and General Advice (TSFS 2010:132) on the design of runway systems and aprons at an airport, the strip's graded portion shall be constructed or prepared in such a way that reduces the risks of injury to a minimum for the aircraft the runway is intended for, if these unintentionally leave the runway.

1.13 Medical and pathological information

Both the commander and the co-pilot had valid medical certificates. Their latest aviation medical examinations were conducted in July 2013 and January 2014 respectively. After that no impairments of the crew members' state of health are known.

With the exception of the pilots' periods of wakefulness, nothing has emerged to indicate a reduced physical or mental condition before the flight.

1.13.1 Fatigue

Night work often entails a strain for the individual because it is more difficult to sleep during the day and work at night than the other way around.

Fatigue factors – general

Research and accident investigations have shown that fatigue is a significant and preventable cause of accidents in the transport sector.[21] Fatigue due to lack of sleep and disruptions of circadian rhythm can significantly impair the human capacity to function in terms of judgment and decision-making, attention and reaction time, wakefulness, memory and frame of mind. Such factors may in turn increase the risk of fatigue-related accidents/incidents and reduce operational safety margins.

Working continuously with a disrupted circadian rhythm may entail the building up of a certain accustomedness regarding the consequences of this. However, in practice, this usually means that it is easier for a person to become aware of when he/she will get tired, not that the fatigue itself can be worked off through experience.

The specific physiological factors that can cause fatigue are:

- the biological circadian rhythm (time of day/night),
- the length of the period of wakefulness,

[21] See e.g. Rosekind M.R. et al. Examining Fatigue Factors in Accident Investigations: Analysis of Guantanamo Bay Aviation Accident, Alertness Solutions, NASA Ames Research Center, National Transportation Safety Board.

- sleep (acute and cumulative sleep debt),
- sleep disorders.

The factors are additive so that fatigue at any given time is governed by the situation of the biological circadian rhythm, the length of the period of wakefulness and sleep obtained.

The biological circadian rhythm

The biological clock governs not only physiological activities such as body temperature and digestion, but also performance, wakefulness and frame of mind.

The biological clock is programmed for a lowest level of activity around 3 to 5 o'clock in the morning. It is a period of low activity, physiologically and functionally. Performance impairments may occur within a larger window from about 24 to 6 o'clock in the morning.

In the case in question, the incident occurred at 01.44 hrs in the morning.

Length of the period of wakefulness

The length of time someone is awake is another physiological factor that can affect performance and how fit and alert that person is. The length of the period of wakefulness is equal to the number of hours someone has been awake in one stretch. The relevant physiological factor is how long someone has been awake and not so much how long that person has worked during the waking period. In general, performance and alertness can be maintained for twelve hours of continuous wakefulness (the nature of the task at hand is, however, of great importance).

Sleep

The need of sleep for adult persons varies from about six to ten hours, but the average adult needs about seven to eight hours in order to perform optimally and be alert. Sleep loss is considered to be the total amount of sleep hours during a 24-hour period minus the number of hours of sleep normally needed. Studies show that two hours' sleep loss can result in a deterioration of performance and level of wakefulness.

Sleep loss built up over several days results in a cumulative sleep debt.

The crew's week of duty consisted of working periods that stretched over five 24-hour periods. All the working shifts were partially scheduled within the time interval 24-06.

Between the working periods were three rest periods. During the first rest period, the crew got 5-7 hours' sleep. Also during the second rest period, the crew got 5-7 hours of sleep and tried to sleep for further 2-3 hours in the evening before the third working period commenced.

During the third rest period, the commander slept for just over one hour, while the co-pilot slept for two to three hours.

The time period from 03.25 hrs the preceding night until the time of the incident (at 01.44 hrs) thus contained one and two to three hours' sleep respectively, which means that the crew was subjected to an acute sleep debt at the time of the incident.

Sleep disorders

Besides the length of sleep, the quality of sleep is important. Quality can be affected by the surrounding conditions, the time of day and sleep disorders of various kinds.

The commander has stated during interviews that he had disrupted sleep due to construction work at the hotel during the third rest period.

1.13.2 Regulations on medical examinations

Pilots and other personnel in civil aviation are covered by medical requirements established for reasons of aviation safety. Among other things, this means that pilots are to undergo regular aviation medical examinations. In Sweden, the Swedish Transport Agency issues regulations in the area.

For work environment reasons, the Swedish Work Environment Authority has issued regulations on the medical examination of flight personnel in civil aviation (AFS 2005:20). Furthermore, the Swedish Work Environment Authority has issued regulations and general advice on medical checks in working life (AFS 2005:6). These latter regulations apply to employees in general. They contain certain exceptions with respect to the length and placing of the working hours of flight personnel. However, flight personnel are also covered by the Swedish Work Environment Authority's requirement that employees in night work are to be offered regular medical examinations by their employer.

The medical examination shall at least include occupational history, disease history, relevant information on medication and social circumstances and physical routine status. The investigation shall otherwise include what is deemed to be relevant for elucidating whether the employee runs particular risks of ill health or accident through night work.

In this context, the time between 22 and 07 is counted as night work, though no longer than 7 hours. If employees normally perform at least three hours of their day's work at night or will probably complete at least 38% of their annual working hours at night, they shall be offered free medical examinations.

The Swedish Work Environment Authority's regulations in the area do not contain any requirement on fitness for service, i.e. a requirement for the employee to have undergone the health check in order to be allowed to continue working.

The Swedish Work Environment Authority's general advice on the application of the regulations (AFS 2005:6) on medical checks in working life states that the risks of fatigue due to lack of sleep consist in reduced attention and impaired judgment with the risk of accidents. Such risks are manifest with regard to the operation of vehicles.

According to the duty schedule for the past year, the crew in question mainly performed night work, but had not been offered any such health check.

The Swedish Transport Agency has communicated that it does not know how operators in civil aviation live up to the Swedish Work Environment Authority's regulations.

1.13.3 Hypoxia

Hypoxia is a state of oxygen deficiency in the blood, tissues and cells that is sufficient to cause an impairment of the body's functions. Hypoxia may, among other things, lead to drowsiness, fatigue, nausea and headache.

TUC (Time of Useful Consciousness)

In an aviation context, the term TUC refers to the period during which an individual adequately performs flight operational tasks with a deficient oxygen supply.

At a cabin pressure altitude of 25 000 feet, TUC is between three and five minutes, while TUC at 18 000 feet is between 20 and 30 minutes. These times decrease in the event of fatigue.[22]

1.14 Fire

There was no fire.

[22] Aviation Physiology, Federal Aviation Administration, Civil Aerospace Medical Institute

1.15 Survival aspects

1.15.1 Provisions on rescue services

Provisions on rescue services are found primarily in the Civil Protection Act (2003:778, Swedish abbrev. LSO) and the Civil Protection Ordinance (2003:789, Swedish abbrev. FSO).

According to Chapter 1, Section 2, first paragraph of LSO, the term “rescue services” denotes the rescue operations for which central government or municipalities shall be responsible in the event of accidents and imminent danger of accidents in order to prevent and limit injury to persons and damage to property and the environment. Central government is responsible for mountain rescue services, air rescue services, sea rescue services, environmental rescue services at sea, and rescue services in case of the emission of radioactive substances and for searching for missing persons in certain cases. In other cases, the municipality concerned is responsible for the rescue services (Chapter 3, Section 7, LSO).

1.15.2 The rescue operation

The air traffic controller in the tower at Malmö Airport was informed by the crew at 01.44 hrs that the aircraft had ended up at the side of the runway. A crash alarm was immediately triggered from the tower in accordance with the applicable checklist.

The airport's rescue services reached the aircraft at 01.46 hrs, and the rescue services from Svedala municipality arrived about twelve minutes later. An ambulance and the police also arrived at the scene. It was not necessary to perform any rescue operation as the crew was unharmed and there was no damage to the aircraft.

The ELT[23] of type ELT96 Cobham was not activated during the incident.

1.16 Tests and research

1.16.1 Wind limitations regarding flight planning

According to the operator's manual, the destination airport shall be considered to be below minimum values for landing if the forecast winds exceed the aircraft's limitations for crosswind. This means that the fuel on board shall be sufficient to reach two alternate aerodromes with prescribed weather minima. When the forecast states gusty winds, the average wind speed plus 50% of the wind gust factor shall be used to calculate the wind strength.

[23] ELT (Emergency Locator Transmitter).

The forecast that was in force before take-off indicated, among other things, "BECMG 0922/0924 28025G45KT", which meant that the average wind speed applicable to the time of landing was 25 knots and the wind gust factor 20 knots (45 – 25 knots). 50% of the wind gust factor is 10 knots, which is to be added to the average wind, giving a total forecast wind of 35 knots.

The crosswind component on the destination's landing runway is obtained with the formula below:

349° – 276° = 73° ⇒ sin 73° x 35 = 33.5 knots, where:

- 349 degrees is the runway's magnetic bearing,
- 276 degrees is the wind direction converted into magnetic bearing from true bearing (wind directions in forecasts are stated with true bearing),
- 73 degrees is the wind's angle of incidence relative to the runway's bearing and
- 35 is the total forecast wind.

The forecasted wind exceeded the aircraft's crosswind limitations that are established by the operator for both a dry and wet runway.

1.16.2 Operational crosswind limitations and procedures

The operator's manual states the crosswind limitation to be 30 knots on a dry runway and 25 knots for a wet runway. A wet runway is defined as being that the runway's surface is covered with water to a depth of less than three millimetres or that there is sufficient moisture on the surface to cause it to appear reflective, but without significant areas of standing water.

The operator's manual states, in conformity with the manufacturer's manual, that rudder effectiveness decreases in connection with thrust reversal and that thrust reversal should be cancelled when the speed has reduced to about 60 knots. The same manual also states that thrust reversal should be reduced or cancelled if problems arise with directional control.

During the incident in question, the runway was wet according to the ATIS broadcast, and the latest reported wind from the tower was stated to be 280 degrees, 26 knots, max 34 knots (reported wind is given in degrees magnetic).

The crosswind component is then:

349°-280° = 69° ⟹ sin 69° x 34 = 31.7 knots

The current wind exceeded the operator's crosswind limitations for the aircraft both for a dry and a wet runway.

1.16.3 Reference friction measurement

At the request of SHK, the airport operator has performed a reference friction measurement on the main runway.

The purpose of the measurement was to investigate whether the runway had an abnormally low friction coefficient when it was wet. A low friction coefficient results in inferior friction between the aircraft's tyres and the surface, which impairs both steering and braking characteristics.

The reference measurement was performed with a SARSYS SFH (Surface Friction tester High Pressure). A new measuring tyre was mounted and calibrated before the measurement.

The measurement was performed by means of the measuring vehicle depositing 1 mm of water in front of the measuring wheel. The measurement took place at 97 km/h, 5 metres on each side of the centre line and was started about 300 metres into the runway to allow for acceleration and braking. The total measurement length on each side was 2 200 metres. (Measurement at too low speeds, <60 km/h, can give incorrect values.) The surfacing on the runway was the same as during the incident. New lines have been painted in the spring, but these have not been passed at the time of measurement.

The lowest measurement value was a friction coefficient of 0.62. Good braking action exists from the friction coefficient 0.40 (the higher the coefficient, the better the friction and hence the better the braking action).

1.16.4 FDR data

Table data, plots and animation

Table data and corresponding plots show that the touchdown and the initial roll-out took place in connection with the centre line with an indicated speed of 95 knots and a heading of about 345 degrees. Thrust reversal was initiated soon thereafter at an indicated speed of 90 knots. At about 60 knots, the highest recorded torque value during thrust reversal was achieved, TRQ 59 % and 58 % for the left and right engines, respectively. See Figure 3 below.

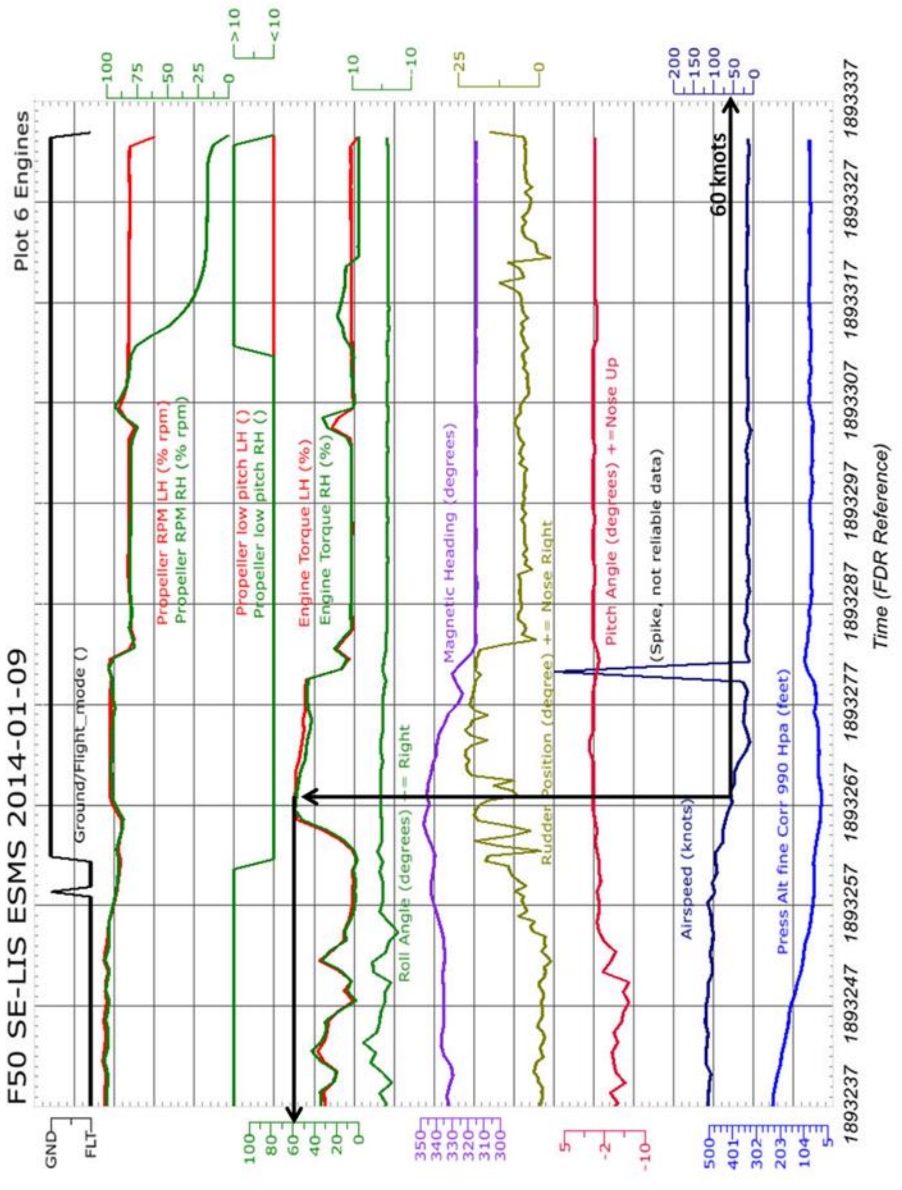

Figure 3. FDR plot during the last 100 seconds of the sequence of events.

When roughly abeam taxiway B, the heading began to change to the left; the recorded indicated speed was 40 knots, and TRQ during thrust reversal was 56% and 51% respectively - see Figure 4 below. Throughout the sequence of thrust reversal, the rpm of the propellers was just over 95% Np, which according to the manufacturer corresponds to full thrust reversal. In connection with the left yaw, the left engine had about 4 to 7% higher TRQ values than the right engine, which according to the manufacturer leads to the possibility of a noticeable movement occurring in the yaw axis.

Figure 4. Screen dump from animation. With permission from CAE Inc (Flightscape).

The change of heading continued towards the left to 325 degrees to momentarily change towards the right to 329 degrees. The heading subsequently changed back to the left at the same time as the aircraft left the runway and thrust reversal was reduced. The aircraft's heading at standstill was 315 degrees.

1.16.5 Previous incidents

SHK has examined a bulletin, 4/2010, from the UK Air Accidents Investigation Branch (AAIB) describing a similar incident that occurred in 2009. The aircraft, which was of the same type, went off the runway to the left at Ronaldsway Airport, Isle of Man, in connection with landing in crosswind from the left.

In its synopsis, AAIB writes: "Selection of a high reverse power setting while landing on a wet runway, in a crosswind which was close to the maximum demonstrated limit, resulted in the aircraft departing from the paved surface. No injuries or damage resulted."

1.17 Organisational and management information

Amapola Flyg AB is a commercial aviation company that principally operates cargo flights within Sweden.

The company has a valid operating permit issued by the Swedish Transport Agency.

1.18 Additional information

1.18.1 Air traffic control´s clearance and phraseology

According to Dhb ANS[24] Section 2, Chap. 1, subsection 3, the tasks of air traffic control include, among other things:

- Preventing collisions between aircraft in relation to one another.
- Giving advice and information of importance to the safety and efficiency of aviation.

In the case in question, the aircraft was cleared at the crew's request down to Flight Level 80, which is in uncontrolled airspace south of Jönköping's terminal area. The initial clearance contained no traffic information. “No traffic reported flight level 80” was communicated first after the aircraft had come down to Flight Level 80. Air traffic control also gave no information to the crew that the aircraft was leaving controlled airspace.

1.18.2 Measures taken by the operator after the incident

The operator has communicated that, among others, the following measures have been taken in response to the incident:

- Information has gone out to the flight crews regarding the incident and the risks of thrust reversal in crosswind situations.
- Recurrent theoretical knowledge tests regarding the company's publications will be introduced.
- All flight crew members shall be offered a medical examination in accordance with the Swedish Work Environment Authority's regulations for employees in night work.
- The conditions for a disruption-free environment during rest periods shall be reviewed.

1.19 Special methods of investigation

Not applicable.

[24] Dhb ANS – Operations Manual for Air Navigation Services.

2. ANALYSIS

2.1 Circumstances

2.1.1 General

No deficiencies have emerged with regard to the crew's knowledge and experience that give reason to suppose that they should not have the ability to handle a flight and landing under the circumstances in question in a safe manner. SHK has therefore chosen to investigate whether there might be any other factors that could have adversely affected the crew's ability during the flight.

2.1.2 The crew´s lack of sleep

SHK has found that the crew had been subjected to an acute lack of sleep and probably also a cumulative lack of sleep during the last flight period. Besides this, the point in time of the incident falls next to the time window in which the body's biological clock is programmed for the lowest level of activity, when it is known that the level of human performance is reduced.

Admittedly, the commander has stated in the interviews that he “did not feel especially tired during the approach and landing”.

SHK cannot establish with certainty that the crew's lack of sleep affected the sequence of events. However, the time of day together with the lack of sleep make it likely that some temporary impairment of cognitive functions contributed to an overall deterioration in performance capacity during the flight in question.

2.1.3 Planning of the flight

The flight was planned with Gothenburg/Landvetter as an alternate aerodrome according to the operational flight plan and with Stockholm/Arlanda as an alternate aerodrome according to the ATS flight plan. However, according to the operator's rules for planning minima, Malmö Airport would be considered closed with reference to the current weather forecast, which meant that two alternatives were to be stated in the operational flight plan. The quantity of fuel that was on board at take-off covered, with a margin, what was needed to reach Stockholm/Arlanda via Gothenburg/Landvetter, which means that the conditions for operational planning with two alternatives existed.

The fact that the flight was not planned with two alternatives may be a result of the impaired functional capacity regarding judgment, decision-making and attention caused by lack of sleep.

2.2 The flight towards Malmö

2.2.1 The cabin decompression

During the flight towards Malmö, a cabin decompression arose, which was handled in accordance with the operator's checklists and procedures. Since the crew had begun to use oxygen masks within less than two minutes from when the warning was triggered, SHK believes that it is extremely unlikely that the crew was subjected to hypoxia to such a degree that the flight operational tasks became neglected. This is also confirmed by the fact that the procedures for emergency descent were carried out in an adequate manner.

2.2.2 The clearance to Flight Level 80

Air traffic control's clearance down to Flight Level 80, which is below area-type controlled airspace, was given by air traffic control without any additional information. Two and a half minutes later, the information "No traffic reported flight level 80" was given.

SHK is of the opinion that it would have been appropriate for air traffic control to have provided information about reported traffic in conjunction with the initial clearance to Flight Level 80 and to have provided information that the aircraft was leaving controlled airspace.

2.2.3 Weather follow-up

Throughout the flight, the crew sought continuous information on weather conditions at the destination airport. Some parts of that information caused the crew to assume that the wind strength would abate, while other parts indicated that the wind situation could exceed the aircraft's operational limitations.

The detail that the runway was wet was never understood. This can be explained partly by the crew's attention being reduced as a result of a lack of sleep and partly by simultaneous communication on another frequency having impaired the audibility of that information.

2.3 The landing and excursion

2.3.1 The landing

Taking into consideration the wind's gustiness, the approach and the landing were performed in a normal manner. The commander was the one manoeuvring the aircraft.

2.3.2 The roll-out, thrust reversal and excursion

The initial part of the roll-out took place close to the runway's centre line.

The yaw to the left was probably caused by a combination of a wind gust in connection with the fact that thrust reversal was still activated at a speed far below what was recommended.

The thrust reversal was asymmetric with a higher TRQ value on the left engine, which may have further contributed to the left yaw.

2.3.3 The evacuation and rescue operation

The crew was able to leave the aircraft through the main door, and the rescue services were on site in about two minutes. The communication between involved actors functioned excellently. The scenario during this phase proceeded optimally and without damage/injury to either aircraft or crew, which shows that the strip's bearing resistance and design had functioned as intended with regard to the deceleration of the aircraft.

2.4 Medical examinations

There are two different types of medical examination for flight personnel in civil aviation; those that are prescribed by the Swedish Transport Agency for reasons of aviation safety and those that are prescribed by the Swedish Work Environment Authority for work environment reasons. The provisions on how the different examinations are to be carried out, and what they are to include, differ. Among other things, this means that the circumstance of pilots regularly undergoing the medical examinations prescribed by the Swedish Transport Agency does not necessarily entail that the Swedish Work Environment Authority's requirements for medical examinations are also met.

The Swedish Transport Agency only exercises supervision over medical examinations that have been prescribed for reasons of aviation safety and does not know how operators in civil aviation live up to the Swedish Work Environment Authority's regulations.

SHK's investigation of how the regulations on medical checks for night-working personnel are applied has been made against the background of an individual incident. However, there are indications that the Swedish Work Environment Authority's regulations are generally not known or applied with reference to flight personnel. On the other hand, the rules appear to be applied to a greater extent for ground personnel employed within civil aviation.

SHK shares the Swedish Work Environment Authority's view that the risks of fatigue due to lack of sleep consist in reduced attention and impaired judgment with the risk of accidents and that such risks are manifest with regard to the operation of vehicles.

The fact that personnel within civil aviation who are in night work are not offered a medical examination in accordance with the Swedish Work Environment Authority's regulations may therefore constitute an aviation safety risk because an employee who is not suited for night work thereby misses out on the opportunity to have his/her suitability tested voluntarily.

SHK is therefore of the opinion that it would be desirable for the Swedish Transport Agency, in consultation with EASA and the Swedish Work Environment Authority, to review the rules and regulations and their application.

3. CONCLUSIONS

3.1 Findings

a) The crew was qualified to perform the flight.
b) The aircraft had a Certificate of Airworthiness and valid ARC.
c) The crew had been subjected to an acute lack of sleep and probably to a cumulative lack of sleep as well.
d) A cabin decompression occurred during the flight.
e) The crew had no awareness of the prevailing condition that the runway was wet.
f) Both planning and current conditions exceeded the operator's crosswind limitations for the aircraft.
g) The thrust reversal was active in the speed range below 60 knots.

3.2 Factors as to Cause and Contributing Factors

The incident was caused by the aircraft being suddenly subjected to a severe gust of wind during roll-out while maintaining thrust reversal.

Contributing factors were probably the crew's lack of sleep, which probably affected decision-making and attention, which in turn led to the landing being performed under conditions that exceeded the operator's crosswind limitations for the aircraft.

3.3 Factors as to Risk

Civil flight personnel in night work who are not offered a medical examination that has in view the medical suitability for working at night may constitute a potential aviation safety risk.

4. SAFETY RECOMMENDATIONS

The Swedish Transport Agency is recommended to:

- examine, in consultation with EASA and the Swedish Work Environment Authority, the application of the Swedish Work Environment Authority's regulations and general advice (AFS 2005:6) on medical checks in working life and the Swedish Work Environment Authority's regulations (AFS 2005:20) on the medical examination of flight personnel in civil aviation regarding the employer's obligation to offer flight personnel within civil aviation in night work a medical examination for work environment reasons. *RL 2014:19 (R1)*

The Swedish Accident Investigation Authority respectfully requests to receive, **by March 16, 2015** at the latest, information regarding measures taken in response to the recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Jonas Bäckstrand Nicolas Seger