Statens haverikommission
Swedish Accident Investigation Authority





Final Report RL 2017:05e

Serious incident at Vilhelmina Airport, Västerbotten County, on 6 April 2016 involving the aeroplane SE-LLO of model BAe ATP, operated by NextJet AB.

Reference no. L-35/16

5 April 2017

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. However, it is not the purpose of SHK investigations to apportion blame or liability, whether criminal, civil or administrative.

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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, as far as possible, determine both the sequence of events and the cause of the events, along with the damage and effects in general. An investigation shall provide the basis for decisions which are aimed at preventing similar events from happening in the future, or to limit the effects of such an event. At the same time the investigation provides a basis for an assessment of the operations performed by the public emergency services in connection with the event and, if there is a need for them, improvements to the emergency services.

SHK accident investigations thus aim to answer three questions: *What happened? Why did this happen? How can a similar event be avoided in future?*

SHK does not have any supervisory remit, nor is it charged with apportioning blame or liability with respect to damages. This means that issues concerning liability are neither investigated nor described in association with its investigations. Questions of blame, liability and damages are dealt with by the judicial system or, for example, by insurance companies.

Furthermore, SHK's remit does not include, aside from that part of the investigation that concerns the rescue operation, an investigation into how people transported to hospital have been treated there. Nor is there any investigation of the actions of society in the form of social care or crisis management subsequent to the event.

Investigations of aviation occurrences are governed primarily by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and the Swedish Accident Investigation Act (1990:712). Investigations are conducted in accordance with Annex 13 to the Chicago Convention.

The investigation

The Swedish Accident Investigation Authority was informed on 6 April 2016 that a serious incident involving an aeroplane with the registration SE-LLO had occurred at Vilhelmina Airport, Västerbotten County, that same day at 16:17 hrs.

The incident has been investigated by the Swedish Accident Investigation Authority, which is represented by Mikael Karanikas, Chair, Stefan Christensen, investigator in charge and operational investigator and Ola Olsson, technical investigator. Håkan Örtlund has participated in the investigation as an expert in performance issues.

Peter Coombs from the AAIB (Air Accidents Investigation Branch) has participated as an accredited representative of the United Kingdom.

Magnus Eneqvist has participated as an advisor for the Swedish Transport Agency.

Raluca-Maria Negoescu has participated as an advisor for the EASA.

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

Investigation material
Interviews have been conducted with the commander, the operator and personnel from Vilhelmina Airport.

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Aircraft:	
Registration, type	SE-LLO, BAe Systems ATP
Model	ATP
Class, airworthiness	Normal, Certificate of Airworthiness and valid ARC[1]
Serial number	2023
Holder	NextJet AB
Time of the occurrence	16:17 hrs in daylight Note: all times are given in Swedish daylight saving time (UTC[2] + 2 hrs)
Location	Vilhelmina Airport, Västerbotten County, (position 64º 34 43N, 016º 50 23E, 337 metres above mean sea level)
Type of flight	Commercial air transport
Weather	According to Metar at 16:20 hrs: wind 300 , 4 knots, visibility 1,400 metres in snow, runway visual range over 2,000 metres, temperature/dew point 0 /0° C, QNH[3] 990 hPa
Persons on board:	23
Crew including cabin	4
Passengers	19
Injuries to persons	No damage
Damage to the aircraft	Damage to right wing flap
Other damage	Damage to runway edge light
Commander:	
Age, licence	38 years, ATPL(A)[4]
Total flying hours	3 880 hours, of which 2 488 hours on type
Flying hours – last 90 days	123 hours, all on type
Number of landings – last 90 days	98
Co-pilot:	
Age, licence	31 years, CPL(A)[5]
Total flying hours	2 240 hours, of which 1 800 hours on type
Flying hours – last 90 days	77 hours, all on type
Number of landings – last 90 days	65

[1] ARC – Airworthiness Review Certificate.
[2] UTC – Coordinated Universal Time.
[3] QNH indicates barometric pressure adjusted to mean sea level.
[4]ATPL(A) – Airline Transport Pilot Licence, Aeroplane.
[5]CPL(A) – Commercial Pilot Licence, Aeroplane.

SUMMARY

The occurrence consists of two separate incidents, with the second having been a consequence of the first. The occurrence has therefore been described as *the first incident* and *the second incident*, respectively.

The first incident

The aeroplane, a BAe ATP from NextJet AB with the registration SE-LLO, took off from Hemavan Tärnaby Airport on a scheduled flight to Vilhelmina. There were 19 passengers and four crew members on board.

The plan was for the flight to continue on to Stockholm Arlanda Airport after a short stay on the ground in Vilhelmina. Due to the prevailing weather, the pilots were informed via radio from the airport in Vilhelmina that snow clearance of the runway had commenced.

The pilots commenced an ILS[6] approach to runway 28 in Vilhelmina. The visibility at the time was approximately 1,400 metres in snow with reported friction coefficients of 0.43, 0.45 and 0.42 and 0.5 cm (5 mm) of slush on the runway. Performance calculations were made using the lowest friction value of 0.42, but without corrections for contamination on the runway. According to the commander, the approach was normal and without deviations or problems. The approach was perceived early on to be stabilised and no major adjustments to attitude or engine power needed to be made. This is supported by recordings from the aeroplane's flight data recorder.

According to the commander, no deviations were perceived in the final phase of the approach in terms of flight controls, engine thrust or changes in the aeroplane's trim position. According to the commander, touchdown was at a normal speed on the centre line in the touchdown zone of the runway. Immediately after touchdown, the aeroplane drifted over to the right side of the runway and after a certain amount of ground roll outside the runway edge, was steered back towards the runway centre line again.

Measurements have shown that the aircraft's right pair of wheels left the asphalted section of the runway around 400 metres after the estimated touchdown point and rolled outside of the runway for a distance of 155 metres before it could be steered back onto the runway again. The wheels were at most 2.5 metres outside of the edge of the asphalt. Roughly 500 metres from the touchdown zone, the aeroplane's wheels hit one of the runway edge lights, which came loose from its fitting and was thrown to the side.

Data from the aeroplane's flight data recorder (FDR) revealed that the thrust during reversal of the engines after touchdown was not symmetrical. The thrust of the right engine was notably higher than that of the left engine. This caused a yawing moment to the right which could not be corrected by the crew. The incident was caused by the following factors:

[6] ILS – instrument landing system.

- Asymmetrical reverse thrust.
- The braking action was probably worse than what was indicated by the friction coefficients.

The second incident

When the aircraft taxied back after landing, the crew checked the wheel tracks and informed air traffic control that they had run off the runway and also damaged a runway edge light. Following the incident, the commander attempted to make contact with the company's technician, only to find that he had left the airport. The commander thus performed an inspection of the aircraft himself and detected no damage.

During their stay on the ground, the commander had a dialogue with one of the ramp service persons regarding the occurrence. At this time, the crew's perception of the incident changed and they did not believe they had run off the runway. This perception is however not consistent with the radio communications with the tower, the information provided by the ramp service person and the images taken directly after the incident.

The commander contacted the company's Head of Flight Operations to inform them about the occurrence. At this time, however, it was not reported that the aircraft had left the runway – only that it had "drifted far out towards the runway edge". The Head of Flight Operations thus had no objections to the flight continuing on to Stockholm Arlanda, according to plan.

However, it was established during an inspection the day after the occurrence that the aeroplane had suffered structural damage to the right wing flap, likely caused by the runway light being thrown up towards the underside of the wing when it was run over. SHK has established that the damaged wing flap – which had to be replaced – had cracks and other damage which likely affected the structural integrity of the unit. The aeroplane was thus not airworthy for the flights which were carried out following the landing in Vilhelmina. The incident was caused by the following factors:

- Continued flight was prioritised in the crew's assessment of the incident during landing.
- Shortcomings in the company's systematic safety management with regard to maintenance checks and inspections.

Safety recommendations

The EASA is recommended to:

- Introduce generic performance corrections for aeroplane operations on surfaces contaminated with slush or water. *(RL 2017:05e R1)*

- Review the feasibility of changing the method of reporting from airports in terms of friction coefficients, so that measured values are reported as unreliable under certain conditions. *(RL 2017:05e R2)*

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Circumstances

The aeroplane, a BAe ATP from NextJet AB (see Figure 1) with registration SE-LLO, took off from Hemavan Tärnaby Airport on a scheduled flight to Vilhelmina. The flight number was 2N773H and there were 19 passengers and four crew members on board.

The plan was for the flight to continue on to Stockholm Arlanda Airport after a short stay on the ground in Vilhelmina. Due to the prevailing weather, with incipient snowfall over the Vilhelmina area, the pilots were informed via radio from the airport in Vilhelmina that snow clearance of the runway had commenced.

Figure 1. The aircraft in question. Photo Joel Vogt.

Snow clearance was estimated to take 15–20 minutes, which is why the aeroplane entered a holding pattern pending completion of the snow clearance. At around 16:10, the tower advised that snow clearance was completed and that the current friction coefficients had been measured at 0.43, 0.45 and 0.42 in the three zones of the runway and that the runway was covered with a layer of slush measuring 0.5 cm (5 mm).

1.1.2 Sequence of events

The pilots commenced an ILS[7] approach to runway 28. The visibility at the time was approx. 1,400 metres in snow, but the runway visual range (visibility along the runway's high-intensity lights) exceeded 2,000 metres. According to the commander, the approach was normal and without deviations or problems. The approach was perceived early on to be stabilised and no major adjustments to attitude or engine power needed to be made.

Contact with the high-intensity approach lights and runway edge lights, which were on at the time, was made at an early stage and well

[7] ILS – instrument landing system.

above the operating minima that applied to the approach. The commander explained that he did not perceive any deviations in the final phase of approach in terms of flight controls, engine thrust or changes in the aeroplane's trim position.

According to the commander, touchdown was with a normal speed on the centre line in the touchdown zone of the runway. Immediately after touchdown, the engines were put into reverse. At this stage, the aeroplane began to drift out towards and then over the right runway edge, and was able to be steered up onto the runway again only after a certain amount of ground roll.

Measurements taken by the airport personnel after the incident have shown that the aircraft's right pair of wheels left the asphalted section of the runway around 400 metres after the estimated touchdown point and rolled outside of the runway for a distance of 155 metres before it could be steered back onto the runway again.

The wheels were at most 2.5 metres outside of the edge of the asphalt. Roughly 500 metres from the touchdown zone, the aeroplane's wheels hit one of the runway edge lights, which came loose from its fitting and was thrown to the side. The crew reported to the tower via radio that they "were almost off the runway there".

When the aircraft taxied back after landing, the crew checked the wheel tracks and informed air traffic control that they had run off the runway and also damaged a runway edge light (see section 1.9). Following the incident, the commander attempted to make contact with the company's technician, only to find that he had left the airport. The commander thus performed a PW[8] inspection of the aircraft himself and detected no damage.

Immediately after the crew had reported the incident, a car with personnel from the airport was sent out to the area on the runway. The site of the incident was measured and documented using photographs of the tracks, among other things (see Figure 2).

[8] PW (pilot walk around) – inspection prior to flight, performed by the pilot.

Figure 2. Tracks of the aeroplane outside of the runway and the runway edge light that was run over. (The photo is taken opposite to the landing direction.) Photo: Vilhelmina Airport.

The commander contacted the company's Head of Flight Operations to inform him about the occurrence. After a discussion, during which the commander did not mention that they had run off the runway, the Head of Flight Operations had no objections to the flight continuing on to Stockholm Arlanda with passengers on board. Before take-off the runway friction was measured again. The values were almost the same (0,42; 0,40 and 0,42), but the depth of the slush had increased to 1 cm.

After landing in Stockholm, the commander wrote an operational report. However, the report contained no information regarding the aeroplane having run off the runway. This type of report is mandatory in the event of accidents and incidents and must also be forwarded to the Swedish Transport Agency. The incident occurred at position 64º 34 43N, 016º 50 23E, 337 metres above mean sea level.

1.1.3 Interviews

The commander

The commander explained that he was familiar with the airport and that he continuously flew the route in question. Cooperation in the cockpit with the commander's colleague, the co-pilot, had worked well and they had flown together on a number of occasions previously.

During the interview, the commander stated that the approach and landing were perceived as stabilised. After touchdown, the aeroplane drifted out towards the right runway edge. The commander, however, had no recollection of them having been outside the runway edge. He also explained that braking and steering were affected by the initial limited brake efficiency and the fact that the surface was perceived as very slippery.

The commander has no recollection of the radio transmissions made from the aircraft after the occurrence. During a conversation with a person working on the ramp, the commander asserted that at this time he had the perception that the aircraft had not been off the runway; just far out towards the edge. This perception had then been maintained in the telephone conversation with the Head of Flight Operations.

The reason the damage to the aeroplane's wing flap was not detected during the PW was, according to the interview, that the inspection was focused on potential damage to the aircraft's wheels and main landing gear.

The commander also mentioned that it was strange that the airport, after inspection of the site of the incident, had not informed the crew that the aeroplane was off the runway.

The co-pilot

Information provided by the co-pilot during the interview provides a similar picture of how the sequence of events was perceived. The pilot could not remember seeing the tracks at the site of the incident, nor that they had reported via radio that the incident had occurred.

The co-pilot does not have a clear perception of the subsequent sequence of events during their time on the ground as it was primarily the commander who handled the communication with the airport staff.

The ramp service person

SHK has received a written statement from the ramp service person who discussed what had occurred with the commander. This person had entered the cockpit in order to hand over certain operational documents. The ramp service person has the following recollection of the dialogue:

> *The commander said that they had left the runway and I responded, "Are you sure? It didn't look like that from where I was standing."*
>
> *So the commander responded, "Yes, we were off the runway!" And I said in return that that wasn't good.*

The ramp service person had not participated in the inspection of the site of the incident carried out by his colleagues. No other airport personnel submitted a report to the commander during the time the aeroplane was on the ground.

Airport personnel

At the time, both an AFIS[9] officer and the airport manager were on duty in the tower. After the crew reporting having run off the runway and even collided with a runway edge light, a vehicle was sent out immediately to inspect the site. This inspection confirmed the crew's information.

[9] AFIS – Aerodrome Flight Information Service.

No message regarding the inspection was sent via radio from the tower to the crew in the cockpit. According to the airport manager, this was not considered necessary as it was the crew themselves who had reported the incident.

The telephone conversations with the operator’s traffic administration office which followed were intended to ensure the upcoming flight had been approved by the company’s operational management. The airport personnel were not aware at this time that the crew no longer believed they had run off the runway.

The Head of Flight Operations

During an interview with the Head of Flight Operations, the telephone conversation mentioned by the commander was confirmed. The Head of Flight Operations did not receive information during the call regarding the aeroplane having left the runway. The commander had only reported that they had been far out towards the runway edge.

As nothing serious could thus be considered to have occurred, the Head of Flight Operations felt there was no reason to provide “approval” for onward flight; the conversation ended with the Head of Flight Operations having no objection to the flight continuing on to Stockholm Arlanda, according to plan.

1.2 Injuries to persons

	Crew members	Passengers	Total on board	Others
Fatal	-	-	0	-
Serious	-	-	0	-
Minor	-	-	0	Not applicable
None	4	19	23	Not applicable
Total	4	19	23	-

1.3 Damage to the aircraft

After the incident, damage was discovered in the trailing edge of the right side wing flap.

1.4 Other damage

During the incident, a runway edge light was damaged.

1.4.1 Environmental impact

No environmental impact.

1.5 Crew information

The commander was 38 years old and had a valid ATPL with the applicable operational and medical eligibility. At the time, the commander was PF[10].

Flying hours				
Last	24 hours	7 days	90 days	Total
All types	2.4	8.8	123.2	3880.1
Type in question	2.4	8.8	123.2	2488.1

Number of landings, type in question – last 90 days: 98.
Type rating conducted on 8 November 2011.
Latest PC[11] conducted on 2 February 2016 on BAe ATP.

The co-pilot was 31 years old and had a valid CPL with the applicable operational and medical eligibility. At the time, the co-pilot was PM[12].

Flying hours				
Last	24 hours	7 days	90 days	Total
All types	2.4	11	77	2 240.0
Type in question	2.4	11	77	1 800.0

Number of landings, type in question – last 90 days: 65.
Type rating conducted on 5 November 2012.
Latest PC conducted on 20 October 2015 on BAe ATP.

Cabin crew

Two persons.

1.5.2 The pilots' time on duty

The day of the incident was the first flying day on both of the pilots' schedules. Time on duty has been in accordance with the applicable provisions.

1.5.3 Other personnel involved

Not applicable

1.6 The aircraft

BAe ATP (Advanced Turbo-Prop) is a turboprop aircraft intended for short and medium-range flights. The aeroplane has 64–68 seats in the passenger version, but is used predominantly for air cargo. The model was developed from its predecessor, the HS 748.

Production of the BAe ATP ended in 1996 after only 64 examples were produced. All ATPs that are still airworthy are run by two

[10] PF (pilot flying) – the pilot who is manoeuvring the aircraft.
[11] PC – proficiency check.
[12] PM (pilot monitoring) – pilot who assists the PF.

Swedish operators. The aeroplane measures 26 x 30 metres (see Figure 3) and has a maximum take-off mass of 23,678 kilogrammes.

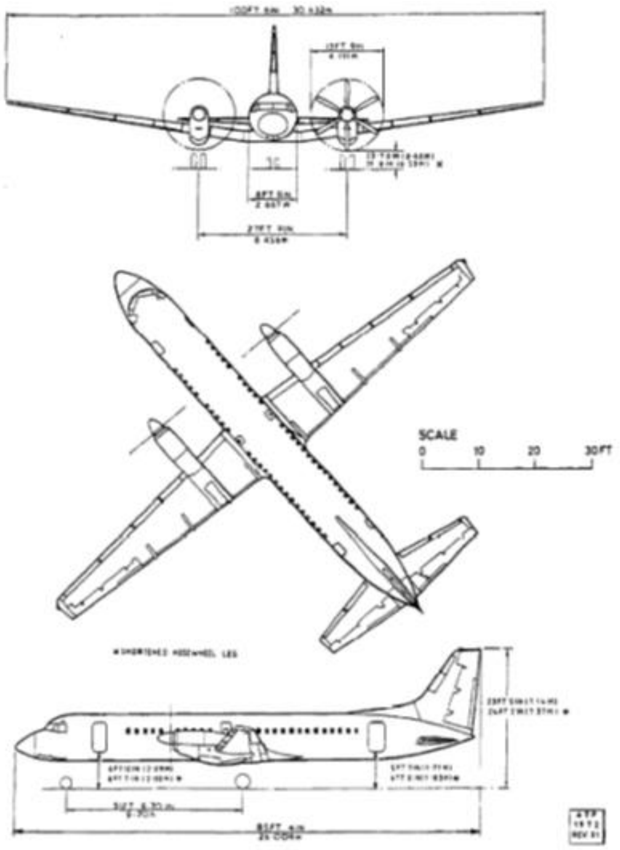

Figure 3. Three-view drawing of the BAe ATP. Source: BAe AFM[13].

1.6.1 General

Type certificate holder	BAe Systems (Operations) Ltd
Model	BAe ATP
Serial number	2023
Year of manufacture	1989
Gross mass (kg)	Max. authorised takeoff/landing mass 23,678/23,133, actual 19,137/18,764
Centre of gravity	Within limits.
Total flying time, hours	31,389
Flying time since last periodic inspection (hours)	25
Number of cycles	38,614
Type of fuel loaded prior to the occurrence	Jet A-1

Engine	
Type certificate holder	Pratt and Whitney Canada Corp.
Type	PW 126
Number of engines	Two

[13] AFM – aeroplane flight manual

Engine	No. 1	No. 2
Serial number	PCE12 4389	PCE12 421
Total operating time (hours)	23 120	21 355
Operating time since last overhaul	2,702	1 718

Propeller		
Type certificate holder	Hamilton Standard Division	
Type	6/5500/F	
Propeller	No. 1	No. 2
Serial number	4A424-952	4A424-871
Total operating time (hours)	11 360	11 361
Operating time since overhaul (hours)	3,904	2 794

Deferred remarks

No remarks relevant to the occurrence have been found in the aeroplane's logbook.

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

1.6.2 *Damage to the aeroplane*

The damage to the aeroplane that was discovered was localised to the trailing edge of the inner part of the right wing flap. The damage consisted of cracks and a deformation of the flap plate measuring roughly 290 x 180 mm. The underside of the plate was indented by approximately 25 mm and a bulge of some 8 mm was detected on the top side (see Figure 4).

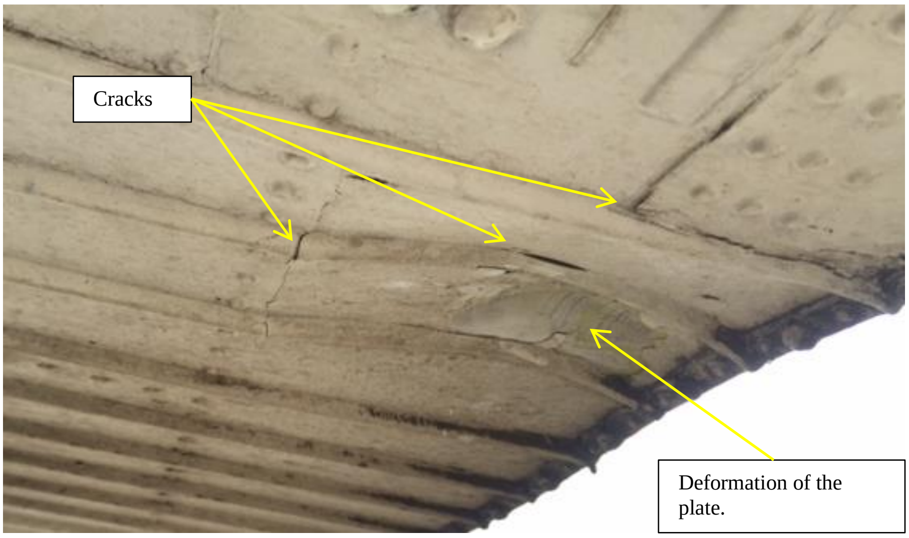

Figure 4. The underside of the damaged wing flap. Photo: NextJet AB.

The damage was localised to an area on the inner part of the wing flap that is located behind the right engine nacelle and above the right main landing gear (see Figure 5).

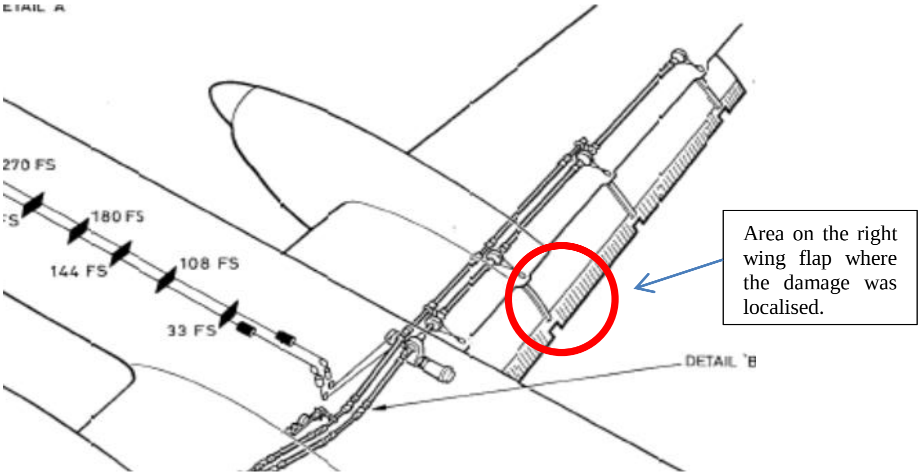

Figure 5. Section of the BAe ATP. Source: AFM.

The damaged flap was not found to be in a repairable state; it was removed from the wing and a new flap unit mounted. The damage established could not be investigated by SHK as the part was destroyed after the flap was replaced. It is therefore not possible to determine with any certainty just how deep into the aircraft's structure these cracks went, or if some of the cracks stopped at the paint layer.

1.6.3 Description of parts or systems significant to the occurrence

The flap system

The ATP's flap system is conventional, of the Fowler type and consists of one flap unit per wing. This means that the lower trailing edge of the inner section of the wings can be lowered into different angles. The flaps are normally used during takeoff and landing. Because the curvature of the wing increases when using the flaps, there is an increase in lift, which allows the wings to maintain lift at lower speeds.

When using the flap, the wing's resistance also increases due to the higher aerodynamic forces. The system is manoeuvred via a control lever in the cockpit through which angles of 7, 15, 20 and 29 degrees can be selected. According to the operator, the normal flap position for landing – even on short runways – is 20 degrees.

Steering and brakes

The aeroplane is equipped with a hydraulic system for steering the nose-wheel. The system is manoeuvred via a wheel on the left side of the cockpit and is normally only used at speeds below 80 knots. During landing, this is managed by means of calling out "80 knots", whereby the left-hand pilot activates the nose-wheel steering.

At speeds in excess of 80 knots, the aeroplane is steered using the rudder. The aeroplane's disc brakes on the main wheels are also hydraulic and are manoeuvred by pressing down on the upper side of the rudder pedals. According to information from the commander, the brakes' effectiveness increases when warming up after a number of "pumps".

Reverse thrust

The aeroplane's engines can be set to reverse thrust. This system is only used on ground and is intended to reduce the speed during landing or in the event of an aborted takeoff, for example. During landing, reverse thrust may not be initiated until the nose-wheel has touched the ground.

The system is controlled by means of the angle of the propeller blades being changed from the normal thrust position, where the air is forced backwards, to a position in which the air is forced forward and creates a braking effect. Reverse thrust is activated by means of a separate control on the power levers being moved backwards.

In previous investigations of SHK[14] with the same aircraft model, British Aerospace ATP, some deviations regarding engine control settings (rigging) have been identified. Problems of this nature can lead to asymmetric engine thrust with the power levers in equal position.

1.6.4 Performance regulations

General

In accordance with the provisions of Commission Regulation (EU) 965/2012, the requisite performance calculations are to be made prior to each landing. These calculations are made in order to ensure a safe landing with regard to the aeroplane's mass and configuration, the prevailing weather conditions and the dimensions, surface condition and elevation of the runway in question. Annex 1 to the regulation also specifies that a runway is to be considered contaminated if more than 3 mm of water, slush or snow (converted value) is covering at least 25 per cent of the runway surface.

The runway in Vilhelmina has limited dimensions. The landing distance available (LDA) on runway 28 is 1,260 metres, and its width is 30 metres. These conditions mean that calculations must usually be made prior to landing for the model of aeroplane in question in order for necessary safety margins to be maintained – taking into account both the length and width of the runway. This is especially important in the winter as an aircraft's braking and steering capacity can be considerably impaired due to contamination of the runway surface.

[14] See SHK report RL 2007:11e.

The data used by the operator for this calculation has been produced by an external company that provides performance data to operators. The material is presented in a way that allows pilots to be able to quickly find the limitations for takeoff or landing at a specific airport, taking into account the prevailing conditions at a given time.

The planning of required landing distance works in such a way that in the event of a wet runway, 15 per cent is to be added to the required distance calculated for a dry runway. The performance data provider has advised that with the friction coefficient of 0.42 used in the calculations, the runway should be considered to be wet.

When calculating landing performance on contaminated runways, specific calculations should be carried out. The required landing distance must then be increased in accordance with the corrections for snow, water or slush – of varying thickness – which should be found in the aeroplane flight manual (AFM). The calculated value may however never be below the calculated distance for a wet runway. For landing on contaminated runways, the manufacturer has to provide performance data with instructions regarding the use of anti-skid, reverse thrust and any other braking devices.

The calculated value gives a required landing distance for a given mass. Inverted, the calculation can be used to calculate the maximum permitted mass for landing on a specific runway.

The company that provides performance data to the operator has stated that data in the aeroplane's AFM is inadequate with regard to landing on snow, water or slush. SHK has had an external expert examine the conditions for performance calculations on the aeroplane type in question (see section 1.16.3).

EASA has published the European Plan for Aviation Safety (EPAS), 2017 - 2021. One of the scopes and objectives is to reduce the number of runway excursions in fixed-wing commercial operation.

The safety actions related to runway safety cover, inter alia, the introduction of on board technology to provide information to the pilot on remaining runway left available, aeroplane performance and prediction of wind shear.

EPAS is also fostering the implementation of the European Plan for the Prevention of Runway Excursions (EAPPRE) which addresses several recommendations to the operators related to the landing phase.

Calculations during landing

The operator has compiled calculation bases for performance in its RPM (route performance manual), which contains both general rules and specific landing cards for different airports.

During the landing in question, the crew had made calculations of the maximum landing mass and the maximum permissible crosswind, taking into account the friction coefficient of 0.42. According to the operator’s manual, this friction value corresponds to a braking value of *GOOD*. The calculations showed that under the prevailing conditions, landing on runway 28 could be carried out with the aeroplane’s mass at the time. In accordance with the performance data used by the operator, the fact that the runway was contaminated with 5 mm of slush did not need to be taken into account during the landing.

Calculation data that take into account the width of the runway at airports are found in the company's OM-B.[15] These limitations encompass only the maximum permitted crosswind with regard to the actual runway friction for different runway widths. During the landing in question, however, the crosswind component was negligible, which is why it was not necessary to make any corrections. See Figure 6.

The Commander is strongly advised to limit the crosswind for take off and landing as follows:

CROSSWIND LIMIT Braking Action	Width of Runway 45 m	40 m	30 m
Dry runway	34 kts	34 kts	25 kts
Wet runway	25 kts	25 kts	15 kts
0.40 or above	25 kts	20kts	15 kts
0.39	24 kts	19kts	14kts
0.38	23 kts	18kts	13kts
0.37	22 kts	17kts	12kts
0.36	21kts	16kts	11kts
0.35	20kts	15kts	10kts
0.34	19kts	14kts	9kts
0.33	18kts	13kts	8kts
0.32	17kts	12kts	7kts
0.31	16kts	11kts	6kts
0.30	15kts	10kts	5kts
0.29	14kts	9kts	4kts
0.28	13kts	8kts	3kts
0.27	12kts	7kts	2kts
0.26	11kts	6kts	1kts
0.25	10kts	5kts	0
0.24	9kts	4kts	
0.23	8kts	3kts	
0.22	7kts	2kts	
0.21	6kts	1kts	
0.20	5kts	0	
0.19	4kts		
0.18	3kts		
0.17	2kts		
0.16	1kts		
0.15	0		

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NOTE: Take-Off and Landing with reported braking action below 0.15 on 45 m width, 0.20 on 40m width and 0.25 on 30m width of runway is not allowed.

Figure 6. Extract from the operator’s OM-B concerning wind limitations for different runway widths.

For example, it is clear from the table that at a reported friction coefficient of 0.30, which is a relatively normal value during the winter, the maximum crosswind component for takeoff and landing at Vilhelmina Airport is 5 knots.

1.6.5 *Measurement of friction*

[15] OM-B (operations manual) – the operator’s fight manual for the aeroplane model in question.

The friction value on a runway is to be reported for every third of the runway seen from the threshold with the lowest runway number. The measured friction coefficient corresponds to the estimated braking effect and codes 5–1 and 9 in accordance with the table in Figure 7:

Code	Measured friction coefficient	Estimated braking action
5	0.40 and more	GOOD
4	0.39 – 0.36	MEDIUM to GOOD
3	0.35 – 0.30	MEDIUM
2	0.29 – 0.26	MEDIUM to POOR
1	0.25 and below	POOR
9	unreliable	UNRELIABLE

Figure 7. Braking action. Sources: ICAO Airport Service Manual, Doc 9137, Chapter 6 and TSFS 2010:137, regulation on airport data.

1.6.6 Aquaplanning

Aquaplaning can impair both the braking capacity and directional control of an aircraft on the ground. Important factors for the emergence of aquaplaning are speed, gas pressure in the tyre and the texture of the runway surface. Three types of aquaplaning (hydroplaning) can occur; viscous, dynamic and aquaplaning as a result of viscous or dynamic aquaplaning if a film of water or slush vapour arises under a stationary tyre.

Viscous aquaplaning can arise with a depth of slush or water less than 0.025 mm, while dynamic aquaplaning can arise with a minimum slush or water depth of 0.25 – 0.76 mm, depending on whether the tyres are worn or new. An empirically based formula for calculation of the speed at which dynamic aquaplaning arises for a stationary wheel has been developed by the UK accident investigation authority AAIB, among others. The formula is expressed as $9\sqrt{p}$, where p is the gas pressure in the tyre expressed in psi (pounds per square inch).

The steering and braking capability at an aeroplane when aquaplaning occurs is solely a result of the relationship between the aeroplane tyres and the condition of the surface.

1.6.7 Checks of the aeroplane

Pilot walk around inspection (PW)

Prior to each flight, the aeroplane must be inspected with regard to external damage or other faults and deviations from normal status. This inspection is performed by one of the pilots in accordance with a special check-list. Section 2, point 12 of the operator's OM-B contains instructions to check the flaps, ailerons and wings for damage:

> *Check flaps, aileron & wing are free from damage.*

After the incident at Vilhelmina airport five flights were performed with the aircraft, with a total flight time of 4 hours and 32 minutes.

For all of these flights, PW inspections were carried out without the damage to the right wing flap being detected.

Daily checks

Daily checks are a maintenance measure that is part of the aircraft's established maintenance programme and – depending the manufacturer's instructions – are performed at set time intervals, e.g. every 48 or 72 hours. The name "daily checks" does not mean that they are carried out every day – this is a remnant of tradition, from a time when the interval between inspections was shorter.

These inspections are performed regularly and consist of a more extensive maintenance check of the aircraft than the aforementioned PW. The maintenance check is normally carried out by a type-rated technician and is noted in the aircraft's logbook.

In the morning of the day after the incident – 7 April – a daily check of the aircraft was carried out by a technician at Stockholm/Arlanda airport. The damage to the wing flap was not noted during this maintenance check. It was not until late that same day – after four additional flights – that the damage was discovered and the aeroplane was taken out of service for repair.

Maintenance check following runway excursion

At SHK's request, the type certificate holder BAe Systems has issued a statement regarding maintenance checks performed following a runway excursion such as the one which now occurred. According to Chapter 4 of the ATP's AMM[16], an unscheduled maintenance check shall be performed after a heavy landing.

BAe equates a runway excursion as a heavy landing and recommends that this maintenance check be carried out before the aeroplane is returned to service. This type of maintenance may only be performed by a type-rated technician.

1.7 Meteorological information

Wind 300, 4 knots, visibility 1,400 metres in snow, runway visual range over 2,000 metres, temperature/dew point 0 /0° C, QNH 990 hPa

1.8 Aids to navigation

No faults or malfunctions in the aids to navigation at the airport have been reported. During the approach in question, outer locator NV, ILS, DME[17] and PAPI[18] were used.

[16] AMM – aircraft maintenance manual.
[17] DME (distance measuring equipment) – system for measuring the distance from an aeroplane to a ground station.
[18] PAPI (precision approach path indicator) – visual light system for correct approach angle towards the runway's touchdown zone.

1.9 Radio communications

The radio communications between the aeroplane and the AFIS personnel in the tower at Vilhelmina Airport have been obtained. The communication between the aeroplane and the tower during landing and prior to the onward flight to Stockholm Arlanda is found in the table in Figure 8.

AFIS in the tower (T):	NextJet 773 Hotel, landing 18	
NextJet 2N773H (773):		Ah, thank you. It was really slippery on the runway you know. We were on … We were almost off the runway there. Can you … Wait, we'll see if we were off the runway there. You'll probably have to get a new braking value before we leave in any case. We have 773 …
T:	Absolutely, 773	
773:		And Vilhelmina information 773 Helge. We left the runway a bit with one … with the right wheel. We ran over those lights for you … 773 Hotel.
T:	NextJet 773 Hotel, understood.	
T:	NextJet 773 Hotel Vilhelmina information?	
773:		773 Hotel here.
T:	One question: Seeing as you were off the runway, are you contacting your OP about that?	
773:		Yes, we are, and we have (*name*) the technician here. He'll come out and have a look as well, 773 Hotel
T:	Okay great. Understood 773.	
773:		Hey, I don't know where (inaudible) went, but can you contact them and say

		that we're ready for deicing? Just go when they're ready, 773 Hotel.
T:	And (*name*), has he already been here?	
773:		No he'd already left so we … he's not coming, 773.
T:	773 understood, but don't you think you need to have that checked?	
773:		No the captain went out and took a look; it was … he didn't see anything – it was only on the wheel if anything, but there was nothing so it seems fine, 773.
T:	773	

Figure 8. Printout of radio communications. Source: Vilhelmina Airport.

1.10 Aerodrome information

1.10.1 General

The airport had valid status to the Swedish IAIP[19]. Snow clearance is performed using snow ploughs and sweepers. Measurement of friction is done using a BV 11 Skiddometer 43. The measurement equipment was calibrated on 9 December 2015.

The airport's operations manual states that the measured values for runway friction can be misleading. This applies, among other things, to equipment of type BV 11 when measuring runways covered with wet snow or slush if the measurement speed is lower than 95 km/h. On such occasions, the measured values are to be regarded as unreliable.

With respect to other reporting of friction coefficients, the airport adheres to the Swedish Transport Agency's regulations (TSFS 2010:37). Provided there is approved and functioning measurement equipment at the airport, there are no restrictions in these regulations regarding the reporting of friction coefficients in conditions with slush on the runway.

1.10.2 Communication between ground staff and the crew

When the aeroplane had taxied to the apron, there was some communication between the crew and ground staff and between the crew and the AFIS personnel in the tower. This communication was

[19] IAIP – Integrated Aeronautical Information Package

supplemented with some recorded telephone conversations from the AFIS personnel to the company's operations office – OP. An extract from the telephone conversations is found in the table in Figure 9 below.

AFIS in the tower (T)	Hi, it's (*name*), Vilhelmina tower	
NextJet's traffic administration office (OP)		Hi
T	Hi, did the crew contact you?	
OP		Erm yes, regarding the fact that they went off the runway a bit.
T	Yep. Now (*name*) was supposed to look at that, but he'd already gone. Apparently they made the assessment themselves that they could go; is it okay?	
OP		Yes I think so; I just have to double-check. I think he was going to call the Head of Flight Operations there and just double-check with him first.
T	Can you check that and call back so that we don't give someone the green light and things go wrong?	
OP		Yes I hope that he's called him, because otherwise he won't get to leave will he. That's exactly what he said to me two minutes ago.
T	Yes, exactly. Yes, but can you just double-check that?	
OP		Absolutely.
T	And call back?	

Figure 9. Printout of recorded telephone conversation. Source: Vilhelmina Airport.

A response was received from OP after a minute or so, with confirmation that they had checked with the Head of Flight Operations and that "it was fine for them to continue with the onward flight".

1.11 Flight recorders

1.11.1 Flight data recorders

The aeroplane was equipped with both a flight data recorder (FDR) and a quick access recorder (QAR). The QAR is primarily intended for technical readouts and fault detection, but records the same number of parameters as the FDR. The unit – of model L3 Communications with item number QAR200-02-00 and serial number 000588159 – was removed from the aircraft and sent to the AAIB[20] in the United Kingdom in order for the content to be reviewed.

The parameters which were of interest to the investigation have been recorded and were readable. SHK has studied all recorded parameters that affected the approach and landing on runway 28. The results of this part of the investigation reveal very small variations with regard to rate of descent, speed and heading during the approach.

According to the QAR data, the speed when passing a height of 50 feet was 107 knots, compared with the reference speed (V_{REF}) of 104 knots that applied to the approach. The engine power was reduced gradually from approx. 20 % at a height of 50 feet, down to approx. 10 % upon touchdown on the runway, which took place at a speed of some 99 knots. The aeroplane's changes of heading on the final 10 seconds prior to touchdown varied within 1.5°, with only very small rudder deflections recorded.

The parameters that SHK chose to look at in more detail have been compiled in the graphic in Figure 10. It can be established that reverse thrust was applied approx. 5 seconds after touchdown but that the power was asymmetrical, with the right engine producing more thrust. The difference (Δ) in engine power was 13 % at approx. 8 seconds after touchdown. At this time, a change in heading of some 5° to the right is observed, meaning the aeroplane yawed towards the right runway edge.

At the same time as the aircraft was yawing towards the right runway edge – beginning essentially at the same time the yaw began – sharp displacements of opposite rudder were recorded. Brakes, throttle position and nose-wheel steering are not in the list of recorded parameters.

[20] AAIB – Air Accidents Investigation Branch.

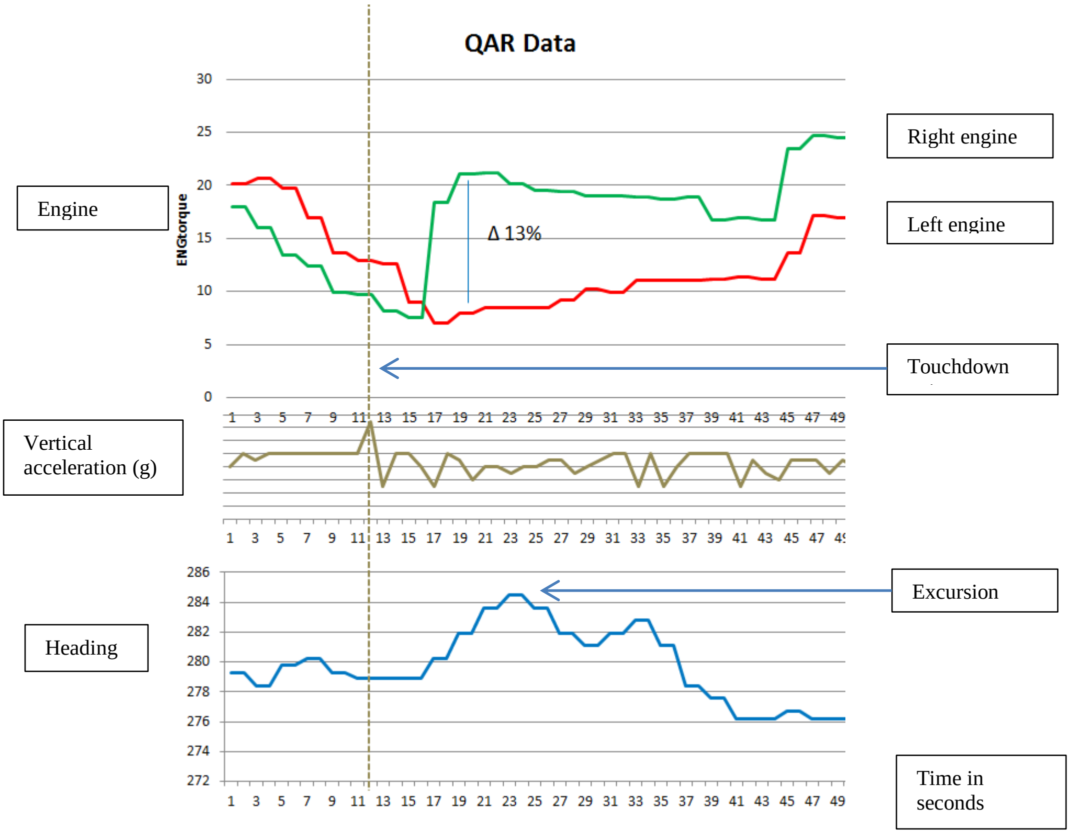

Figure 10. Graphic showing certain parameters from the FDR.

1.11.2 Cockpit voice recorder (CVR[21])

The CVR of model Fairchild with item number 93A100-83 and serial number 60672 could not be read as the content was recorded over during the subsequent flight.

1.12 Site of the occurrence

Vilhelmina Airport is owned and operated by Vilhelmina Municipality. Runway 10/28 is positioned in an east–westerly direction and has the dimensions 1,502 x 30 metres, where the threshold of runway 28 is displaced, giving an available runway length for landing of 1,260 metres (see Figure 11).

[21] CVR – cockpit voice recorder.

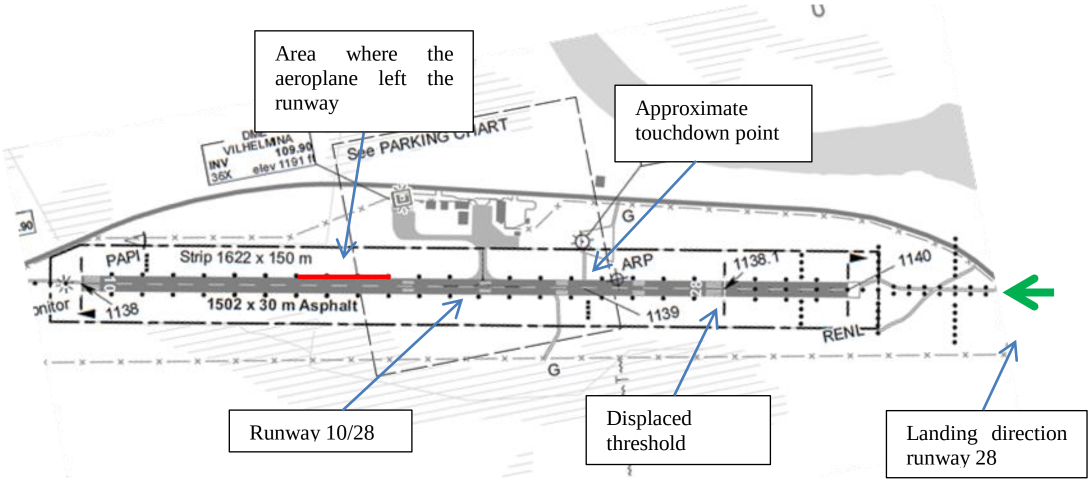

Figure 11. Vilhelmina Airport. Picture from the IAIP.

The airport is classed as an instrument aerodrome and is equipped with high-intensity runway edge and approach lights and has the approach aids ILS and DME on runway 28. The runway has no centre line lighting.

1.13 Medical and pathological information

Nothing has emerged that points to the pilots' mental or physical condition having been impaired prior to or during the flight.

1.14 Fire

Not applicable.

1.15 Survival aspects

1.15.1 Rescue operation

Not applicable.

The emergency locator transmitter (ELT[22]) of type Kannad 406 AP was not activated during the occurrence.

1.16 Tests and research

1.16.1 Limitations when operating on certain runways

There are no general requirements on runway length and width in relation to different classes and sizes of aeroplanes. The required runway length is regulated by the requirements for performance calculations, and the required runway width is primarily governed by the guidelines that are to be included in the operator's operations manual (see section 1.6.4).

The provisions which regulate operations at aerodromes can be found in Commission Regulation (EU) 965/2012, where what constitutes an

[22] ELT – emergency locator transmitter.

adequate aerodrome in CAT.OP.MPA.107 and the aerodrome operating minima in CAT.OP.MPA.110, which are to be stipulated by the operator, are defined.

These provisions compiled in chapter 8.1.2.2 of the operator's operations manual (OM-A), where the company's policy is set out. Operations may only be carried out at airports which fulfil the requirements for performance safety, instrument approach aids, fire and rescue services and certain service functions.

1.16.2 Snow clearance at airports

For additional information regarding snow clearance at Swedish airports, please refer to SHK's report RL 2017:20.

1.16.3 Investigation of performance conditions

SHK has engaged Håkan Örtlund Production AB to investigate the conditions for performance calculations pertaining to the aeroplane type in question, BAe ATP. The assignment has essentially entailed checking applicable regulations (see section 1.6.4) and information in the aeroplane's AFM and how these basic conditions have been converted to performance data in the operator's manuals.

The fundamental rules for calculations can be found under Subpart C 'Aircraft Performance and Operating Limitations' section 1 'Aeroplanes' (CAT.POL) of Commission Regulation (EU) 965/2012. Limitations for crosswind can be found in the manufacturer's AFM. An appendix to the AFM (Attachment 4) states that water or slush with a thickness exceeding 3 mm may have an adverse effect on landing performance. Under such conditions, aquaplaning *is likely to occur*, with associated problems in terms of the aeroplane's braking and steering capacity. The information in this appendix only serves as a guideline, however, and does not constitute a mandatory basis for corrections the performance calculations.

Chapter 17 of the operator's RPM contains instructions for operations on *slippery* runways. This states that under the following conditions, landing should be avoided:

- During tailwind conditions.
- On contaminated runways, whenever possible.

The operator's RPM contains information on aquaplaning and different types of contamination. There is however no information regarding the reliability of reported friction conditions in connection with slush and temperatures around 0°C. According to GM1 ADR.OPS.A005 'Condition of the movement area and related facilities', measured friction values can be unreliable, for example in conditions with slush on the runway.

Conclusions from the investigation of performance conditions can be summarised as follows:

- The performance manual used by the operator has been drawn up in accordance with applicable provisions (EASA OPS) and instructions from the aeroplane's type certificate holder (AFM).
- The AFM lacks specific bases on which to calculate corrections when landing on contaminated surfaces. Only advisory information is available with regard to the increased risk of aquaplaning.
- The landing in Vilhelmina was performed in accordance with the limitations in the performance manual concerning crosswind and required runway length for the actual landing mass of 18,800 kilos.
- In terms of the definition in the operator's manual, the prevailing conditions on the runway mean that the friction could be converted to the braking value of *GOOD* without any other corrections.
- The operator's manual lacks instructions for the crew with regard to the interpretation of friction coefficients when landing on runways contaminated with water or slush.

1.17 Organisational and management information

The airline NextJet was founded in 2002 and primarily conducts domestic scheduled flights to over 20 destinations. In addition to scheduled flights, it the airline also operates charter flights, stretching all across Europe. The company operates 14 turboprop aircraft and its head office is registered in Husum.

In addition to the BAe ATP, the company also operates the aeroplane model SAAB 340.

1.17.1 Supervision

According to the provisions of Commission Regulation (EU) 965/2012, the national supervisory authority shall conduct regular supervision of operations conducted by the operator that require an Air Operator Certificate (AOC) in accordance with the provisions for CAT[23].

In Sweden, this supervision takes the form of regular oversight inspections, VK1 and VK2, conducted by the Swedish Transport Agency. The major inspection, VK1, involves a review of the entire company’s operations. The inspections are conducted every 12–24 months, depending on the level of risk established for the operations. The smaller inspection, VK2, is an intermediate, less extensive inspection that is normally conducted every 12 months.

[23] CAT – commercial air transport.

1.17.2 Action taken

As a result of the incident that occurred during the landing in Vilhelmina, the operator has taken the following action:

- The airport has been upgraded to category C in difficulty rating in the operator's internal classification which, among other things, means that pilots have to undergo special training before they can fly to this airport.
- The simulator programme has been supplemented with information concerning operations on slippery runways.
- This subject has been covered in the annual "Winter Operation Information" sent out to all pilots.

1.18 Deviations

Based on the ICAO Safety Management Manual, deviations from aviation safety standards and routines can be broadly described as follows.

Deviations from regulations or established procedures constitute examples of human behaviours that are present in most operations. Many of these deviations occur on account of unrealistic targets or production conditions.

As a result of this, people can create shortcuts or their own solutions to be able to complete an assignment. Such actions are often rooted in the desire and motivation to carry out the assignment and to do a good job. Such behaviour is more rarely a result of carelessness or negligence.

Some deviations are created spontaneously in situations where people are faced with unexpected or unplanned decisions, possibly together with time pressure or a high workload. On these occasions, people can, against their better judgement, deviate from rules and norms – but usually with the conviction that the deviation will not lead to any consequences.

Another form of deviation, which commonly involves more individuals or groups, can arise when there are recurrent problems or difficulties in performing the work while at the same time following the stipulated procedures and rules. In such circumstances, routine deviations can arise where the deviation eventually becomes "*the normal way to do business*" – i.e. a procedure which becomes accepted over time – without the individual regarding the procedure as a real deviation.

One possible cause of these deviations that is sometimes overlooked is the operator's responsibility for the balance between production and aviation safety. The operations of smaller airlines, which sometimes have limited resources, occasionally border on what would be considered a deviation.

An air operator's aviation safety work is not decisively a matter of creating an environment in which no mistakes are made, but rather of effectively and purposefully identifying and capturing deviations from the established standard within operations and managing them so as to avoid the occurrence of aviation safety deficiencies.

In order to attain these goals, the operator's safety management tool, the safety management system (SMS) must constitute a natural component in all activities carried out as part of the company's production, within both operational and technical areas.

The deviations which nevertheless appear within these activities must be identified by the operator's compliance monitoring system (CMS) in order to systematically and continuously maintain a high level of safety.

2. ANALYSIS

2.1 The first incident

2.1.1 Planning of the flight

On the day of the accident, there were snow showers in the area in question. The planned flight was part of the company's normal route network and can be said to constitute a familiar feature of the pilots' daily routines. The pilots had flown together previously and cooperation in the cockpit went very smoothly.

Vilhelmina was also a familiar airport for the crew, where particular attention was accorded to performance planning due to the short runway and the limited runway width. At the time of the landing in question, the crew was informed that there would be a minor delay because snow clearance was taking place. In connection with this, they were also advised that the runway was covered in slush.

The calculations made indicated that the landing would not be limited by the prevailing conditions, despite a 5 mm layer of slush on the runway, which can be explained by the fact that the performance data available to the pilots did not include this particular condition as a factor to take into account in the calculations.

2.1.2 Approach and landing

The data from the flight data recorder (QAR) that was analysed reveals that only minor corrections of heading, speed and engine power were made during the approach and up to the point of touchdown. No major deviations from the ILS system's glide path and localiser have been established.

The 50 feet height was passed at a speed of 107 knots, i.e. with a minor overspeed of 3 knots. The speed then reduced to approx. 99 knots at touchdown. SHK can thereby establish that the approach was stabilised down to an altitude of 50 feet, below 50 feet, and down to the touchdown point on the runway.

2.1.3 Touchdown

The rudder deflection was largely constant during approach and during the phase from 50 feet and down to the point of touchdown. The aeroplane's heading was held without any major rudder corrections during the first five seconds after touchdown.

The point at which reversing commenced – approx. five seconds after touchdown – may be assumed to correspond to the time between the main wheel's contact with the surface and the landing of the nose-wheel. At the time reverse thrust was initiated, the following occurrences were recorded: The engine power was asymmetrical, the heading changed to the right and opposite rudder was applied.

The reason for the asymmetric reverse thrust has not been clarified. In previous investigations of SHK have, however, some deviations when setting the engine controls (rigging) been identified, which may cause the reverse thrust to be asymmetric with equal position on the power levers.

Given there was no crosswind and that no other external disturbances have been established, there is a high probability that the change in heading to the right – out towards the right runway edge, after touchdown – was caused by the asymmetrical engine power.

2.1.4 Landing roll

The limited runway width of 30 metres means that the distance from the outer edge of the landing gears' respective pairs of wheels to the runway edge is some 10 metres when the aeroplane is on the runway centre line.

At the same time as reverse thrust was initiated, a change in heading of approx. 1° per second was registered. This change, which was largely linear, meant that the 10-metre margin to the runway edge was reduced to zero within a window of approx. 6 seconds, measured to the point at which the aeroplane's right pair of wheels passed over the runway edge.

If the reverse thrust is higher on one side, this creates a greater braking force on this side. This results in a moment which acts to turn the aircraft to the side. The rudder deflection registered during the same period of time was insufficient to compensate for the increased yawing moment.

Considering the prevailing conditions, SHK considers it highly likely that the aeroplane was subjected to aquaplaning in the initial stage of the landing roll. This affected both steering and braking capacity to an unknown degree and has likely had a negative impact on the sequence of events at the time of the excursion.

If braking had commenced during this stage, this would likely have had a limited effect due to the friction in the slush being in all probability very low, and the fact that the brakes, according to information from the pilot, not having maximum effect at the low braking temperature prevailing at the time of the first “pumps” of the pedals.

The nose-wheel steering is not intended for use at speeds of over 80 knots. Any attempts to change heading using the nose-wheel steering would at any rate probably have had no effect considering the prevailing friction conditions in the slush on the runway.

It can also be discussed why the crew did not reduce the reverse thrust when the yaw to the right occurred. SHK sees two potential reasons for this action not being taken:

- The crew did not notice that the reverse thrust was asymmetrical
- The short runway meant that the crew could not afford to forgo the braking effect of reverse thrust, which was independent of the condition of the surface.

When the aeroplane passed over the runway edge and continued to roll outside of the runway for a distance of 155 metres, the speed had reduced to 60 knots and the change in heading discontinued. The low speed, combined with the fact that the brakes' effectiveness had likely increased by this point, meant that the aeroplane could be steered back up onto the runway.

SHK has no information regarding how much of the runway remained when the crew managed to bring the aeroplane to a stop. Apart from the asymmetrical reverse thrust, the limited visibility in the snowfall and the lack of centre line lights on the runway may also have had an impact on the sequence of events.

2.1.5 Performance data

At the time of landing, the runway was covered with 5 mm of slush (see Figure 12). The performance data used at the time of the incident show that the crew had not made any corrections for the contaminated runway; they based their calculations solely on the reported friction coefficients. Contact with the operator and performance data provider has revealed that this was consistent with the data used in the operator's manuals.

Figure 12. Runway 10/28 soon after the incident. Photo: Vilhelmina Airport

According to SHK, however, this procedure is not fully consistent with the provisions of Regulation (EU) 965/2012, which requires that performance calculations take into account whether or not the runway is contaminated with slush.

The provisions of the regulation are intended to increase the safety margins in the event of landings performed on surfaces where the measured friction coefficients cannot always be considered reliable due to contamination. In the present case, this was also confirmed by the crew's comments after landing that "*it was very slippery on the runway*".

Apart from the braking and steering capacity which could not be accurately assessed, the risk of aquaplaning should also be taken into account when determining necessary corrections on a runway that is covered with a layer of slush.

2.1.6 Overall picture

The external investigation supports SHK's opinion concerning the potentially increased risks in connection with landing on contaminated runways. In the present case, the operator has partially noted the risks in its performance manual by stating that landings on contaminated surfaces should be avoided whenever possible.

At the same time, the type certificate holder points out in an appendix to the AFM that there is a high risk of aquaplaning when landing on contaminated surfaces. The EASA also points out in GM1 ADR.OPS.A.005 that friction measurements can be unreliable in the event of various forms (snow, slush or ice or frost) of contamination on the runway.

It can however be established that there is a lack of specific provisions on the handling of situations under certain runway conditions in governing documents (Commission Regulation (EU) 965/2012). Instead, the AFM of the model of aeroplane in question is considered to provide all data necessary in order to take into account any limitations in operations involving contaminated surfaces when performing calculations.

Overall, these circumstances can result in situations that are both contradictory and difficult to interpret. Information about landings with a certain model of aeroplane on contaminated runways can, for example, be accompanied a large number of warnings, but lack specific data for how any limitations are to be taken into account in calculations.

The consequences of this are that, as in the case of the landing in Vilhelmina, the aeroplane may be approaching a narrow and short runway, covered in a more or less floating layer of slush, with a reported braking action of GOOD (0.42) as the only basis on which to make a calculation.

As these noteworthy circumstances do not, however, entail a formal deviation from the applicable regulations, SHK is of the opinion that there are weaknesses in the fundamental regulatory framework, the intention of which is to ensure there are adequate margins when landing. The regulations currently applicable result in an unreasonable amount of responsibility being placed on the commander with regard to decisions concerning whether or not a landing is to be performed on a contaminated surface.

A clearer regulatory framework would mean better decision-making support for crews in situations that are difficult to assess. For example, it could be expressed that braking action is to always be assessed as *POOR* in circumstances where there are slush and water of a certain thickness under critical temperature conditions.

An aeroplane that risks aquaplaning when landing on surfaces that are contaminated with slush or water has, according to SHK, only very limited use of any measured friction coefficients.

In parallel with such grounds for assessment, the airport's reporting of friction coefficients in similar conditions can be reviewed. Measured friction values for aeroplanes should, under certain meteorological conditions in combination with runway contamination, be supplemented with the information that the values may be unreliable. This would also make it easier for the crew to plan any performance limitations for the impending landing.

The European Plan for Aviation Safety (EPAS) and the European Plan for the Prevention of Runway Excursions (EAPPRE) include future actions which are promoting an increased level of landing safety.

As far as SHK has noted, the planned measures do not take into account all parts of what SHK has described above as a concept for safe landings on contaminated surfaces.

2.2 The second incident

2.2.1 Taxiing in and the ground stop

Dialogue with the tower

The recorded communication reveals that when the aeroplane had turned around after its landing roll and taxied back, the crew noted the wheel tracks outside of the runway edge and the runway edge light they had run over. This was reported via radio to the tower (see section 1.9). The crew's information was immediately checked by airport personnel, who went out to the scene of the incident. On this occasion, the area was documented photographically and the wheel tracks were measured.

The crew's information regarding the events following the excursion – i.e. that they had not perceived that the plane to be off the runway and that this was confirmed by the airport personnel after investigating the runway – are not consistent with the audio recordings of the communication with the tower, the information provided by the airport personnel and the images taken immediately after the incident.

Dialogue with the ramp service person

The commander thus first stated that he perceived that the aircraft had been off the runway. He has subsequently changed his opinion, saying that he received confirmation from the ramp service person that this was not the case. However, this information is not consistent with the statement from the ramp service person.

According to the latter, the conversation was primarily about the fact that he was not a direct witness to the occurrence and that he had not been out at the site of the incident. According to the ramp service person, the conversation also involved the commander stating that his perception at the time was that the aircraft was outside of the runway during the landing.

Conversation with the Head of Flight Operations

The commander has stated that his decision to continue the flight on to Stockholm following the incident was supported by the company's Head of Flight Operations. However, information from the interview with the Head of Flight Operations suggests that during the conversation, he was not provided with a full account of the incident.

The commander had only reported that they had been far out towards the runway edge during the landing. The Head of Flight Operations therefore had not given any permission for – or felt he would have had any reason to “approve” – the onward flight.

Dialogue with the airport

The commander has stated that he never received a report from the airport personnel's inspection of the scene of the incident immediately after the occurrence and thereby came to the conclusion that the aeroplane had never been off the runway.

During interviews with the airport personnel, however, it has been discovered that it was not considered necessary to submit a report to the commander as it was the crew that reported the incident and so the reasonable conclusion was that he must have been aware of it.

The action that followed, whereby the personnel in the tower checked with the company's traffic administration office regarding the all-clear signal for onward flight, may be considered an ambition on the part of the airport management partly to ensure the correct information had reached the company and partly to ensure the airport did not contribute to the incidence of a flight which did not comply with applicable regulations.

Even if the airport did not have the authority to influence the operational decisions regarding execution of a flight, SHK notes that the conversations which took place – all of which via a recorded telephone line – contributed to the gathering of facts in connection with the investigation of this occurrence.

2.2.2 Damage to the aircraft

There is a high probability that the damage to the aeroplane's right wing flap was caused during the collision with the runway edge light at the time of the excursion. The deformation in the plate is localised to an area above and just behind the right main landing gear.

It may be considered highly unlikely that this damage could have occurred in another manner and at a later point in time – but before the discovery of the damage at Arlanda.

There has been no opportunity to perform a more in-depth investigation of the damage, which is why a specific assessment of the severity of the damage has not been possible. According to SHK, however, deformations and cracks in the aeroplane's structure constitute a type of damage that must always be considered serious.

In the present case, the damage was localised to the right wing flap, which constitutes a vital part of the aeroplane's flight control system. This part of the aeroplane's structure is subjected to strong aerodynamic forces every time it is deployed during flight, whereby the strain on the unit and its attachments increases. This can also entail the risk of the existing damage increasing in terms of their scope or spread.

SHK is unable to assess the level of the increased risks to aviation safety that the flights conducted with the damaged wing flap may have entailed. However, it has been possible to conclude that the aeroplane cannot be considered to have been airworthy during the five flights that followed the incident.

2.2.3 Inspections of the aeroplane

Pilot walk around inspection (PW)

After the incident, five PW inspections were conducted, i.e. performed by means of pilots walking around the aeroplane and looking for any damage or other discrepancies. The damage to the aeroplane was not discovered on any of these occasions, despite the fact that such inspections are intended to discover damage of this exact nature.

Collisions with birds or objects, leakage, etc. are normally defects which can arise – or which may have arisen – within a shorter time perspective, for example during the previous flight.

It has not been possible to discern the reason why the damage was not discovered during the inspection which took place immediately after the incident. However, it is possible that the inspection was focused to such a great extent on damage to the wheels or landing gear that other parts of the aeroplane did not receive appropriate checks.

Nevertheless, regardless of the conditions under which a PW inspection is performed, it is of the utmost importance to the maintenance of aviation safety that it is performed in accordance with the check-lists issued by the type certificate holder that are included in the operator's documentation. If the inspection had been carried out in accordance with the check-list, the damage to the flap would likely have been discovered.

A PW is not a flight or calendar-scheduled inspection and is not included in the aeroplane's set maintenance programme. The fact that the damage was not discovered during the ground stop in Vilhelmina – nor during the following four flights – indicates shortcomings in the operator's systematic safety management with respect to training and monitoring of how these inspections are carried out.

Daily checks

During the daily check carried out on the morning of 7 April (the day after the incident), the damage was not discovered by the technician who carried out the inspection of the aeroplane.

SHK considers it remarkable that the damage to the aeroplane was not identified on this occasion. The deformations were visible both on the underside and the top-side of the flap section in the area behind the right engine nacelle (see Figure 13). The cracks that had arisen in the structure of the flap were clearly visible, without the need for any methods other than a visual inspection.

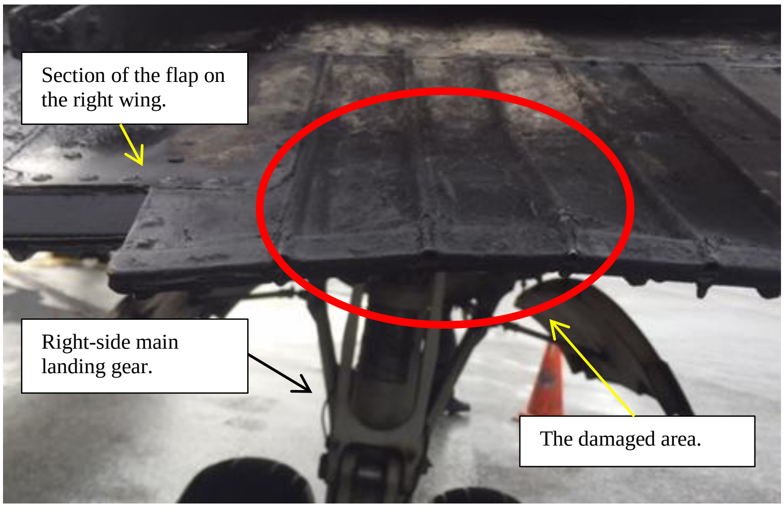

Figure 13. Upper side of the right wing flap. Photo: NextJet AB.

According to SHK, the inability to detect the damage that was later ascertained gives the impression that there are shortcomings in the operator's application of the aeroplane's established maintenance programme.

Maintenance check following runway excursion

According to the recordings of the communication between the aeroplane and the tower, it can be ascertained that the crew's intentions after the incident were that the operator's on-site technician would perform a maintenance check of the aeroplane. However, he had left the airport.

SHK's perception is that this indicates that the commander was to some extent aware that a maintenance check of the aeroplane was necessary following the incident.

The commander's decision to perform an inspection, a PW, himself is not consistent with the regulations that the type certificate holder recommends be complied with in the event of occurrences such as the one in question.

2.3 The operator’s systematic safety work

In conjunction with the investigation, SHK has established a number of deviations:

- Failure to report a serious incident,
- Incomplete PW inspections,
- Deviations from instructions and routines during daily checks.

Deviations as these described above can be seen as a measure of how successful the operator's systematic safety management is. Commitment, guidance and communication with the intention of achieving functional systematic safety management must come from the operator's senior management.

In the present case, the crew's actions in connection with takeoff from Vilhelmina were likely governed by a situation-induced deviation, potentially amplified by workload or time shortage, where they deviated from rules and norms.

The deviations that took place in terms of technical inspections are of a specific nature. The operator's system for managing these checks – performed by both pilots and technicians – cannot be considered to have fulfilled the requirements of an acceptable level of aviation safety.

The procedures that have developed – especially with regard to inspections performed by pilots – may, by extension, mean that personnel gain the perception that such procedures are a routine deviation that is acceptable.

The operator's CMS has not been able to identify these shortcomings in the organisation's safety management system, which can be interpreted as an organisation-dependent deviation on the operator's part.

3. CONCLUSIONS

3.1 Findings

a) The pilots were qualified to perform the flight in question.
b) The aeroplane had a Certificate of Airworthiness and valid ARC.
c) The aeroplane was not airworthy during the five flights following the incident.
d) The aeroplane ran off the runway during landing and rolled outside of the runway for a distance of 155 metres.
e) The aeroplane's right main wheel collided with a runway edge light.
f) The engines' reverse thrust was asymmetrical.
g) The runway was contaminated with a 5 mm layer of slush at the time of the landing.
h) No corrections were made for the contamination on the runway.
i) The incident was not correctly reported.
j) No technical inspection was performed following the incident.
k) Structural damage to the right wing flap was established.
l) The damage was not detected during five PW inspections.
m) The damage was not detected during a daily check.

3.2 Causes

The first incident was caused by:

- Asymmetrical reverse thrust.
- The braking action was probably worse than what was indicated by the friction coefficients.

The second incident was caused by:

- Continued flight was prioritised in the crew's assessment of the incident during landing.
- Shortcomings in the company's systematic safety management with regard to maintenance checks and inspections.

4. SAFETY RECOMMENDATIONS

The EASA is recommended to:

- Introduce generic performance corrections for aeroplane operations on surfaces contaminated with slush or water. *(RL 2017:0e R1)*
- Review the feasibility of changing the method of reporting from airports in terms of friction coefficients, so that measured values are reported as unreliable under certain conditions. *(RL 2017:05e R1)*

The Swedish Accident Investigation Authority respectfully requests to receive, **by 5 July 2017 at the latest**, information regarding action taken in response to the safety recommendations that have been issued in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas Stefan Christensen