Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accident Investigation

Investigation Report

Identification

Type of Occurrence:	Serious incident
Date:	5 January 2009
Location:	Stuttgart Airport
Aircraft:	Transport aircraft
Manufacturer / Model:	Embraer EMB-145
Injuries to Persons:	No injuries
Damage to Aircraft:	Minor damage to airplane
Other Damage:	Minor damage to the airfield lighting
Source of Information:	Investigation by BFU staff
State File Number:	BFU EX001-09

Factual Information

History of the Flight

The aircraft was on a scheduled flight from Birmingham (UK) to Stuttgart. The crew stated that the approach had been performed according to all weather operation with precision landing aid (ILS), flight operations Cat II. The crew stated that they chose that procedure in order to be prepared for weather conditions possibly worse than those predicted. Beforehand, the crew had received the automatic information announcements for flight traffic at airports (ATIS), edition H, L, and M as well as the weather information for flying aircraft (VOLMET).

At 1524 hrs[1], the responsible air traffic control centre gave the aircraft the clearance for landing on runway 07. The female tower controller gave the aircraft the following information about the wind: 360°/5 kt. The Flight Data Recorder (FDR) data showed that the final approach was performed with a speed of approximately 127 kt (CAS). According to the Aircraft Operations Manual (AOM) flaps are to be set to 22° for landings in instrument approach CAT II “After Ice Encounter” and therefore were set to this position. The FDR recordings showed that the engine control levers had been set to idle nine seconds before touchdown. The runway threshold was crossed in an altitude of approx. 54 ft. The landing was performed by the female Pilot in Command (PIC). The aircraft touched down approx. 680 m behind the runway threshold at the level of taxiway H with a Computed Airspeed (CAS) of 118 kt at 1528 hrs. At that time, the engines ran with approx. 26% N1.

The ground spoilers were deployed automatically during touchdown. The crew described the braking action during the first phase of the landing as normal. The data showed that the aircraft oscillated around its vertical axis. The copilot noticed this, too. The female pilot in command tried to compensate these oscillations with cross controls.

The crew stated that they did not intend to use taxiways D and B, because these were partially covered with snow and ice and seemed to be too slippery. Moreover, their conditions had been described as “slippery” in the ATIS. For this reason, the brake was not operated to the maximum. After passing taxiway B, it was tried to brake harder again. The crew noticed a low braking action in this phase. The copilot stated that the female PIC actuated the brakes with a high amount of physical strength in this phase. Because he did not perceive a noticeable deceleration, he applied full force on the brake pedals as well. In the further course of deceleration it was insufficient to bring the aircraft to a stop at taxiway A.
The copilot stated to have actuated the parking brake, which is also used as emergency brake, in the last phase of rolling. Finally, the aircraft entered the paved surface of the Runway End Safety Area (RESA). The passengers left the aircraft via the passenger stairs.
The FDR data showed that the deceleration was approx. -0.1 g in the first section of the landing distance, and later approx. -0.05 g. Approximately 1,600 m behind the touchdown point, brake pressure dropped to zero and the deceleration values decreased accordingly. The brake pressure returned after approx. eight seconds, and

[1] All times local, unless otherwise stated

the aircraft decelerated more strongly. At that time, deceleration values of less than -0.1 g were reached again.
The Cockpit Voice Recorder (CVR) recordings showed that the copilot had noticed a low braking action shortly after the landing, which was confirmed by the female PIC:

Time after touchdown (s)	PIC	Copilot
9		*That doesn't feel like good braking action.*
11	*It doesn't actually. No. Pressing a bit harder.*	

The following further conversation was recorded:

20	*I might not go for that one. I might …*	
22		*Keep going*
24	*Keep going, yeah*	
33	*Keep going*	
35		*Keep going*
37		*Doesn't feel good at all*
39	*It doesn't*	
45		*Radio communication with ATC*
53	*Are you braking?*	

Approximately eight minutes after the landing, the female PIC gave the following assessment:
“I just ah I was braking and it seemed fine […] and then I started to brake again because we’d missed the turning. Because it said ‘braking action good, didn't it? - on the ATIS?”
The recording further showed that the crew noticed a strongly decreased braking action towards the end of the runway, and the copilot said that he pulled the emergency brake.

Personnel Information

Crew:

Female Pilot in Command (PIC):

The 52-year-old female PIC held an Airline Transport Pilot's License (ATPL (A)) first issued in 1993, valid until 24 June 2011. Her Class 1 Medical Certificate was valid until 1 June 2009. She held a valid type rating as PIC for the airplane EMB-135/145, valid until 30 November 2009, as well as the instrument rating. Her flight experience was:

Total:	approx. 9,500 hours
During the last 90 days:	112 hours
During the last 30 days:	33 hours
Total on the type:	approx. 6,000 hours

According to the operator, the PIC concluded a Learning Management System based winter ops training on 13 December 2008.

Copilot:

The 26-year-old pilot held a Commercial Pilot's License (CPL (A)) first issued on 1 October 2007, valid until 30 September 2012. His Class 1 Medical Certificate was valid until 1 June 2009. He had a type rating for the airplane EMB-145 valid until 31 January 2009. His flight experience was:

Total:	722 hours
During the last 90 days:	145 hours
During the last 30 days:	38 hours
Total on the type:	564 hours

According to the operator, the pilot concluded a Learning Management System based winter ops training on 8 December 2008.

Female Air Traffic Controller:

The 25-year-old female air traffic controller had the license "Aerodrome Control with Radar", and she had ratings for all workplaces at the Aerodrome Control Stuttgart

since March 2006. Her working place at the time of the incident had the designation PL1 – Platzlotse 1 (aerodrome controller 1).

Aircraft Information

The EMB-145 is a low-wing aircraft with tricycle nose wheel landing gear. The airplane has 45 seats. Both engines are installed to the rear fuselage and are not equipped with thrust reversers.

Aircraft manufacturer:	**Embraer -** Empresa Brasileira de Aeronáutica SA
Type:	EMB-145EU
Serial number:	145 546
Year of manufacture:	2001
Maximum take-off mass:	19,990 kg
Maximum landing mass:	18,700 kg
Total flight time of cell:	14,392 hours
Overall cycles:	12,968
Type of engine:	AE3007/A1/1 / Rolls-Royce Corp. USA

The last follow-up certification of airworthiness was issued on 9 December 2008, valid until 18 December 2009. The last maintenance (A check) was concluded after 13,958 hours on 27 September 2008.

The Load Sheet indicated a take-off weight of 16,863 kg and a landing weight of 15,398 kg. Under consideration of fuel consumption, the crew had calculated a landing weight of 15,433 kg.

An investigation of the aircraft showed that the brake wear indicators did not show any undue wear of the brake pads. Further investigations at the aircraft operator did not show any indications for a malfunction of the braking system.

The braking system of the aircraft consists of two brake circuits operated by the hydraulic system of the aircraft. The brakes are controlled by the brake control unit and two brake control valves (inbound and outbound). The brake pressure is controlled

with the pedal actuating force. Furthermore, the brake pressure can be reduced depending on the inputs of the anti-skid system. The data stored in the FDR corresponded to the hydraulic pressure directly affecting the brakes.

According to the data of the Airplane Flight Manual Supplement-11 and JAR-OPS 1.520, the Landing Distance Required (LDR) should have been approximately 2,120 m for this flight.
The Aircraft Operations Manual – AOM part B7 (4.3.12 Contaminated Runways; 4.3.12.1 Introduction) states:
Except where stated otherwise, the limitations, procedures and information contained in other sections of this Manual remain applicable.
Only operations under the following settings may be made:

- *Only use T/O 1 thrust for take-off*
- *Only use Flaps 9° for take-off*
- *Only use static take-offs with the whole runway length available*
- *Only use Flap 45° for landings*

The airplane is equipped with an Engine Indication and Crew Alerting System (EICAS), displaying a total of 128 caution messages with different content for this aircraft.

Meteorological Information

There was snow flurry at Stuttgart Airport at the time of the incident. According to the Meteorological Aviation Report (METAR) Stuttgart, time of issue 1520 hrs (14:20 UTC), the following weather conditions prevailed:

Wind:	100° / 04 kt
Visibility:	1,800 m / (runway 07: 1,400 m)
Precipitation:	light snowfall
Clouds:	1-2 oktas in 500 ft; 8 oktas in 1,400 ft
Temperature:	- 3 °C
Dew point:	- 5 °C
Air pressure:	1,015 hPa
Further information:	Previous weather: Snowfall
Runway report:	Slush / Coverage extension 26% to 50% of the runway surface / good braking action

Other METARs had the following contents:
EDDS 051450Z 34004KT 1600 -SN SCT007 OVC014 M03/M05 Q1015 R07/6595 TEMPO 1400 SN=
EDDS 051420Z 01004KT 1800 R07/1400N -SN FEW005 OVC014 M03/M05 Q1015 RESN R07/6595 NOSIG=
EDDS 051350Z 36003KT 1400 R07/1200N SN FEW005 OVC009 M03/M05 Q1015 R07/6595 NOSIG=
EDDS 051320Z 01004KT 1300 R25/1200U SN SCT005 OVC009 M03/M04 Q1015 NOSIG=

The air traffic controller reported a wind direction of 360 degrees and a speed of five knots to the crew at the time of landing.
A SNOWTAM was issued on 5 January 2009 at 1430 hrs and at 1830 hrs. The first SNOWTAM described the runway coverage with 50% slush and the braking action as good (friction coefficient ≥ 0.4). The later issued SNOWTAM downgraded the braking action as “medium”. The runway condition was described as wet. Coverage of 100% was indicated.

The Deutscher Wetterdienst (German meteorological service provider, DWD) stated the data which was part of the above-mentioned METARs regarding the runway contamination and the SNOTAMs are based on information compiled by the airport operator and were made available to the DWD. This report did not contain any information as to the extent of the contamination. When the METAR was coded no one noticed the missing information.

Communications

Radio communications with the responsible ATC units were performed in the English language. The radio communication recordings were available for the investigation.

Aerodrome Information

Stuttgart Airport is an international airport. A runway in the direction 074°/254° with a length of 3,345 m and a width of 45 m is available. The LDA of runway 07, published in the Aeronautical Information Publication Germany (AIP), is 3,045 m.

Winter service had been performed in the time from 1400 hrs to 1426 hrs on the runway and the adjacent taxiways. Two measuring runs for checking the friction coefficient were performed at 1416 hrs. The following average values were measured on the individual runway sections: A: 87, B: 84 and C: 89[2]. Section A was located at the western end of the runway.
Two further measuring runs were performed immediately after the incident, at 1534 hrs. The following average values were measured: Runway section A: 46, B: 38 and C: 51. In the last quarter of section A and in the first half of section B, the values were constantly below 40.
All measurement runs were performed with a Vammas AEC Skiddometer, system BV 11. According to the statement of the Airport Ground Operations Manager, the next measuring run was scheduled approximately one hour after the last snow removal. An earlier check was considered unnecessary, because the runway had been sprayed and a relative long, trouble-free use could be expected under the given conditions. There were no further statements from pilots of previously landed aircraft about a reduced braking action. Thus, he did not see the necessity of a measuring run ahead of schedule. He stated that the runway was covered with a light layer of snow of 2 - 3 mm.
In the rear area of the runway around taxiway A, a semi-circular area of approximately 40 meters had not been completely cleared of snow.

The ATIS reports from 14:06 (H) until 14:09 UTC (M) issued the following information about the condition of the runway:
Approx. 14:06 K
Information Kilo special metreport one four zero five expect ILS approach runway in use zero seven runway conditions braking action good snow removal in progress apron and taxiways partly slippery
TL60 010/3 1600m -SN FEW/500 OVC/1200 -3/-5 1015 29.97 Trend TEMP 1400m SN OVC/900
Approx. 14:08 L
Information Lima special metreport one four zero six expect ILS approach runway in use zero seven runway conditions braking action good snow removal in progress apron and taxiways partly slippery
TL60 010/3 1600m -SN FEW/500 OVC/1200 -3/-5 1015 29.97 Trend TEMP 1400m SN OVC/900

[2] Indications for this device in %

Approx. 14:09 M
Information Mike special metreport one four zero eight expect ILS approach runway in use zero seven runway conditions baking action good snow removal in progress apron and taxiways partly slippery
TL60 020/3 1600m -SN FEW/500 OVC/1200 -3/-5 1015 29.97 Trend TEMP 1400m SN OVC/900
The crew stated that they heard these reports as well as weather information for flying aircraft (VOLMET) from 13:20 UTC, and incorporated this information into the preparation for landing.
Five aircraft had landed after the last snow removal. The female air traffic controller stated that no crew reported decreased braking action.

Flight Recorders

A Flight Data Recorder (Honeywell, SSFDR, P/N 980-4700-042) and a Cockpit Voice Recorder (Honeywell, SSCVR, P/N: 980-6022-001) were installed in the aircraft. Both recorders were evaluated. A Caution Message was recorded on the FDR 36 seconds after the landing, for which no further information was recorded.

Wreckage and Impact Information

After passing taxiway A, the aircraft came to rest on the paved area outside the runway, thereby changing direction by about. 25° to the left. A touchdown point on the runway could not be detected. One light of the runway lighting was torn out of its fixture and lay in the immediate vicinity of the main landing gear.
The outer tire of the left main landing gear showed a crack with a length of approx. 30 cm and a depth of 10 mm. All tires of the main landing gear showed skid marks. The marks showed a skidding direction of approximately 25° relative to the longitudinal axis of the aircraft.

Fire

There was no fire.

Tests and Research

In 1995, the Canadian Aviation Authority started the “Joint Winter Runway Friction Measurement Program” in co-operation with other aviation organizations. As a result of this program, extensive information on the reliability of existing measuring methods was established. Furthermore, the basics for the development of the International Runway Friction Index (IRFI) were established.

Organisational and Management Information

According to their own statement, the airline does not have any further guidelines for winter operation for the aircraft Embraer-145 beyond the requirements in part A and B7 of the Operations Manual. Part B7, 2.4.12 Landing on Wet or Slippery Runways stipulates additional procedures for landings under these conditions. It prohibits the use of the emergency brake.

ICAO Annex 14, Appendix A, item 6 (Determining and expressing the friction characteristics of snow- and ice-covered paved surfaces) describes how the measuring of the braking action shall be performed and how the measuring results are classified. The following table has been published as a relation between the measured friction coefficient and a word code:

Measured braking action	Estimated braking action	Code
0.40 and above	Good	5
0.39–0.36	Medium to good	4
0.35–0.30	Medium	3
0.29–0.26	Medium to poor	2
0.25 and below	Poor	1

Furthermore, the following information on the use of these values is given in ICAO Annex 14:
6.6 The table below with associated descriptive terms was developed from friction data collected only in compacted snow and ice and should not therefore be taken to be absolute values applicable in all conditions. If the surface is affected by snow or ice and the braking action is reported as “good”, pilots should not expect to find con-

ditions as good as on a clean dry runway (where the available friction may well be greater than that needed in any case). The value "good" is a comparative value and is intended to mean that aeroplanes should not experience directional control or braking difficulties, especially when landing.

The Aeronautical Information Publication Germany (AIP) AD 1.2, Snow Plan, publishes the following information about the removal of snow on the movement areas of German airports:

6. Frequency of measuring
If runways are covered completely or partially with snow, slush and/or ice, the braking coefficient is determined by at least one measuring per day. Additional measuring will be performed if a change of the braking action can be expected due to weather conditions as e. g. precipitation or temperature change, or by order of the local air traffic control centre.

The winter service at Stuttgart Airport was regulated in Service Instruction D No. 43 of the operator dated 1 October 2007. The tasks of Airport Ground Operations Services and of the responsible Airport Ground Operations Manager (VL 1-1) are defined in section 3.2. Among other things, it is stipulated that the information "Snow removal in progress; apron and taxiways partly slippery; taxi with caution" is added to the ATIS at the start of winter service.
It was further stipulated, among other things, that at the end of a checking tour the condition of the operations surfaces is be reported to the control tower. The measured brake coefficients are transmitted as "Estimated braking action". The relations stated in ICAO Annex 14 shall serve as references points. There are no criteria when and to which level further downgrades of the estimated braking action are to be carried out.
This service instruction includes specifications as to when further measuring runs for the determination of the brake coefficient have to be performed:
1. on the runway, when the result of the checking tour or the weather conditions suggest a brake coefficient of 0.35 or worse
2. on the runway, in case of beginning accumulation of slush or snow
3. on the runway, if winter service was performed on it
4. on all relevant movement areas, if an aircraft went astray or hit an obstacle, even if there is no subjective correlation to winter weather conditions.

The Airport Ground Operations Manager stated that pilot messages were used in the decision-making process in particular during ongoing flight operations. As long as operation flows without any reports on restrictions, normally no friction measuring run is conducted in order to not interfere with traffic. As soon as there are first signs of a deterioration of braking values, a friction measuring run is undertaken.

Additional Information

The following restrictions on the use of the device are stated in a bulletin of the manufacturer of the Vammas AEC Skiddometer, System BV 11:
A decelerometer or a diagonal braked vehicle should not be used in deep loose show or slush.

Analysis

General:

Both pilots held the appropriate licenses and ratings for flight operation. The female PIC was very experienced given her flying experience on the type of about 6,000 hours and a total flying experience of about 9,500 hours.
With 722 hours of total flying experience and 564 hours of flying experience on the type, the copilot had significantly less experience. Based on his remarks concerning the braking action in the first phase of the landing the assessment can be made that he noticed the reduced braking action more distinctly and noticed the problem earlier than the female PIC.
The airplane was properly registered for air traffic. Due to the results of the investigation of the braking system performed after the incident and missing entries on the EICAS it can be assumed that the braking systems worked properly without any malfunction. It is highly probable that the Caution Message displayed after 36 seconds can be assigned to the Caution Message ENG NO T/O DATA, which did not have an impact on the further course of events. The marks visible on the tires, with a direction of exclusively 25° (approx.), showed that they blocked only at the end of the runway. There was no interim blocking on the runway.
The available data do not allow any statements about the reaction and the function of the anti-skid system.

The weather conditions at the airport were sufficient for flight operation and for landing. The wind came from lateral direction with 70°. However, due to the low wind speed of five knots, its influence can be rated as low.

Flight Operation:

The crew stated that category 2 (Cat II) was chosen for the instrument approach due to the expected weather. The necessity of a Cat II landing cannot be derived from the weather information of the ATIS messages, because the visibility and the base of cloud were significantly above limit values. Furthermore, ATIS did not state that Cat.II operation was active at Stuttgart Airport at that time. With the decision to land according to Cat II procedure, the AOM specified flap position 22° instead of 45° normally used for landing. In contradiction to this, flap position 45° was specified for landings on contaminated runways. Would the flaps have been set to 45° it would have resulted in a shorter landing distance.
The decision of the crew to conduct a Cat II landing including the requirement to set the flaps to 22° resulted in an extended landing distance although there was no need for it.
In general, the crew could select the landing category for the ILS approach. Nevertheless, a critical estimation of the weather situation at Stuttgart Airport which was reported with snowfall could have resulted in a waiving of the Cat II landing.

The approach was stabilized, thus corresponding to the AOM specifications with respect to the configuration of the aircraft. According to the AOM a landing speed of 124 kt CAS was specified and adhered to with a speed of 127 kt CAS. Touchdown took place within the touchdown zone with a distance of approx. 680 m to the runway threshold. This distance corresponds to a distance of approx. 265 meters to the position of the glide-path antenna and can thus be rated as normal.
The FDR shows movements of approx. 6° around the vertical axis and opposing inputs to the rudder pedals after the touchdown. This yawing shows that the crew experienced directional control difficulties during landing. An effective use of the brakes was impaired under these conditions. The data show that the oscillations around the vertical axis were minimized initially with reduced and later complete interruption of braking pressure.
During the interview the crew stated that the braking action was normal in the first section of the runway. The CVR recordings, however, show that the crew detected a

reduced braking action already immediately after the touchdown. This factor, however, was not considered any further with the result that the aircraft was not braked with the maximum possible deceleration.
The crew stated that they did not intend to use taxiways C and B, because these were partially covered with snow and seemed to have a layer of ice. The crew further stated that the ATIS information about the taxiway conditions had supported this decision.
The remarks of the crew to let the airplane keep on rolling (“keep going”), the comments on the braking pressure and the deceleration recorded by the FDR prove this intention. The decision not to brake for approx. eight seconds in the area of passing taxiway B resulted in a further extension of the landing run. This used up the last reserves.

The brake was pushed down harder in the last section of the runway. This resulted in a deceleration of approx. 0.1 g which then increased further. It can be assumed that now the brake was pushed down with maximum power, and that the achieved deceleration corresponded to the maximum possible deceleration values on this section of the runway. However, this deceleration did not meet the crew’s expectations. The deceleration value was not high enough to not overshoot the end of the runway. Shortly before overshooting the runway, the emergency brake was pulled which inactivated the anti-skid system, so that the aircraft started skidding and became uncontrollable. The marks on the tires confirmed that the aircraft finally skidded with 25° across the runway. The actuation of the emergency brake was not in accordance with the OPS B7, 2.4.12 Landing on Wet or Slippery Runways, Item 8.

Based on the calculations computed with the factors stated in JAR-OPS the Landing Distance Required (LDR) would have been sufficient to come to a complete stop on the runway.
All the allowances stated in JAR OPS take into account every deviation during the conduct of the flight. Furthermore, there was an additional reserve of about 925 m until the end of the runway available beyond the, according to JAR OPS, calculated LDR.
Based on the actual speed during touchdown and the then remaining distance to the end of the runway, an average deceleration of 0.08 g would have been sufficient to safely come to a complete stop on the runway. These deceleration values were indeed reached during the first 20 seconds of rollout but were not maintained for rea-

sons already mentioned.

The mean deceleration value in the time period between 49 seconds and 60 seconds after touchdown was approx. 0.12 g which is comparatively low. However, with a consistent deceleration of 0.12 g after touchdown approx. 750 meters of reserve would have been available.

The inconsistent braking of the aircraft in the first rollout phase and the interruption of braking in the area of taxiways B and C resulted in the extension of the rollout distance.

Influence of the ATIS Message on the Action of the Crew and Special Provisions for Winter Operation:

During flight planning the crew did not have the SNOTAM and METAR of 1520 hrs available to them. Therefore, the crew could only use the weather information (e.g. METARs) available at the time of the flight planning and the ATIS information for their decision. But this information did not provide any data regarding the contamination of the runway.

The statements of the crew and the CVR recordings approx. eight minutes after the landing showed that they had considered the ATIS information for their actions. In particular, the decision not to use taxiways D and B was supported, according to their own statements, by the information about their condition (“partially slippery”). The publication of the information “braking action good” similarly resulted in the fact that a reduced braking action at the end of the runway was not considered. Therefore, the aircraft was not forcefully brought to a complete stop or decelerated to a very low speed.

However, the crew did not take into account other present signs for the worsening condition of the runway. There was continuous snowfall at Stuttgart Airport and the runway was covered with a thin but visible layer of snow. This runway condition suggested a limited braking action. Since the estimation “braking action good” was broadcast by ATIS at 1409 UTC, already 20 minutes prior to the landing, it could have been assumed that the conditions had deteriorated since then. Moreover, the reduced braking action detected during the first rollout phase should have been con-

sidered for all further actions.

The operator had not established special provisions for winter operation. There were no special procedures in case a reduced braking action was broadcast. Possibly received information estimating a braking action less than “good” would generally not have resulted in a different conduct of the flight.

Winter Service at Stuttgart Airport:

The snow removal from the runway in the time period between 1400 hrs and 1426 hrs and the subsequent measuring run showed that the runway was sufficiently prepared for operation. The five aircraft which landed before the incident occurred did not report any braking action deterioration. In the further course of events, the continuous light snowfall should have been regarded as a sign for deteriorating conditions.
The transmitted messages about the condition of the movement surfaces (SNOWTAM and METAR) were contradictory. The braking action assessment “good” published in a first SNOWTAM cannot be correct in case of 50% slush coverage. This was also true for the contradictory information in the METAR regarding the runway contamination and the braking action. Opposed to this, the second SNOWTAM classifies the braking action on wet runway as “medium” and thus much worse whereas conditions are actually much better. These differences suggest uncertainties with respect to the classification and the description of the runway condition by the responsible personnel.
Although the measuring run conducted shortly after the incident showed values which would correspond to a formal classification of „good“, these values cannot be used for an assessment of the actually existing braking action. Under certain conditions, especially in case of slush and wet snow, the braking action measuring equipment cannot deliver values reflecting the real condition. The BFU has already addressed this fact in earlier investigations. Moreover, ICAO Annex 14, Attachment A-6 and AIP Germany AD 1.2 item 11 indicate limitations with respect to the use on contaminated surfaces. Furthermore, there are publications describing this inaccuracy (see the results of the Joint Winter Runway Friction Measurement Program, among others**)**. According to manufacturer information, the used measuring device AEC Skiddometer, System BV 11, does not supply reliable values when used on slush.
The snow lying on the runway at the time of the incident had fallen onto a surface

which had been treated with de-icing fluid shortly before. Due to the relatively high outside temperature, it can be assumed that the snow was not dry and behaved similar to slush.
After all, the aircraft deceleration values reached in the last phase of the rollout showed a comparatively low deceleration given the maximum pressure on the brake. Therefore, the conclusion can be drawn that at the time of the incident braking action on the runway did not meet the classification “good” any longer.
The classification of the braking action as „good“ after the snow removal at approx. 1400 hrs was justified because the values measured then had an average of 0.87. The classification inaccuracies described above were irrelevant because no slush had been detected on the runway.
After the snow removal at 1400 hrs, the Airport Ground Operations Manager was responsible to determine the time for the next measuring run and then, if necessary, to arrange for another snow removal. The Service Instruction D No. 43 of Flughafen Stuttgart GmbH include instructions to conduct measuring runs whenever the weather conditions suggested a braking coefficient of 0.35 or less or when slush or snow begins to accumulate. These criteria give a certain range to the responsible person. Due to the fact that the previously landed aircraft did not report any problems with braking action on the runway, the decision to conduct the next measuring run at approx. 1530 hrs was within this range. The measured braking coefficient of the runway was never below 0.35 even after the incident. The accumulation of snow had just begun, too. Under the concrete conditions at the time of the incident, the Airport Ground Operations Manager had utilised the existing scope of the Service Instruction and had planned, according to his own statement, to conduct another measuring run at the approximate time of the incident.
Critical consideration of further marginal conditions, e. g. temperatures around freezing point and the fact that the last aircraft had landed already 20 minutes before the incident, ought to have led to an earlier measuring run.
The value of 0.35 indicated in the Service Instruction D No. 43 is too low and does not consider the differences for different types of contamination. The investigation results mentioned above have shown that a braking coefficient of 0.35 measured on contaminated surfaces already leads to a significantly reduced braking action which would require a classification far below “good” on contaminated surfaces. The term „beginning accumulation“ is not unambiguous, because it implies that measuring runs would have to be conducted all the time during continuous snowfall and the differences of the various kinds of accumulations are not considered.

The ATIS information on braking action (braking action good) did not reflect the real situation at the time of the incident. The continuous snowfall was not promptly incorporated into the ATIS broadcast. The procedures established at Stuttgart Airport make provisions for the correction of the ATIS reports only after measuring runs. Thus, providing pilots with updated and timely information on runway conditions is not possible. Updated information on the braking action actually to be expected would have been helpful for the pending decisions of the crew.
The evaluation of the deceleration values shows that in the rear part of the runway where the snow was not completely removed, braking action did not become worse, but instead better. It can be assumed that the freshly fallen snow had a better braking action than the slush in the remaining part of the runway. Thus, the incomplete snow removal did not contribute to the course of the incident.

Conclusions

Findings:

- The crew's decision to perform the approach according to the rules for all weather operation with precision landing aid (ILS), flight operations Cat II, that means to set the flaps to 22°, could not be justified by the prevailing weather.
- The necessity to set the flaps to 22° extended the landing distance.
- The approach was stabilized and corresponded to the specifications in the AOM.
- The touchdown occurred in the rear area of the touchdown zone.
- The aircraft was not braked with the maximum possible deceleration.
- The interruption of the aircraft's braking process for approx. eight seconds resulted in a further extension of the braking distance.
- The braking action on the runway was reduced and did not correspond any longer to the classification "good".
- The condition of the runway would have allowed a complete braking process after touchdown.
- The braking action information in the ATIS did not correspond any longer to the prevailing conditions on the runway at the time of the incident.
- The copilot actuated the emergency brake at the end of the rollout distance. Thus the anti-skid system was deactivated.
- The crew did not use the rapid exit taxiways because due to snow and ice contamination they did not seem suited for taxing.

Causes:

The serious incident was caused by the fact that the crew did not brake the aircraft consistently down to a safe speed.
The fact that the braking action on the runway did not correspond with the classification “good” and that this information had not been transmitted to the crew, contributed to this situation.

Safety Recommendations

Safety Recommendation No 03/2012:

The Flughafen Stuttgart GmbH should develop procedures permitting a timely and flexible transmission of the prospective braking action to the responsible air traffic control centre.

Safety Recommendation No 04/2012:

The Flughafen Stuttgart GmbH should modify the Service Instruction D No. 43 so that the prevailing weather conditions are taken into account when decisions regarding measurement runs are made.
When runways are contaminated additional corrections, which take the inaccuracy of the measuring method into account, should be made when classifying the friction coefficients.

Safety Recommendation No 05/2012:
The operator should extend the instruction of the crews with respect to winter operation so that indications on a possibly reduced braking action are recognized and considered for the planning of the landing.

Investigator in Charge:	Thomas Karge
Assistance:	Dieter Ritschel, Hans-Werner Hempelmann
Flight performance:	Klaus Himmler

Appendices

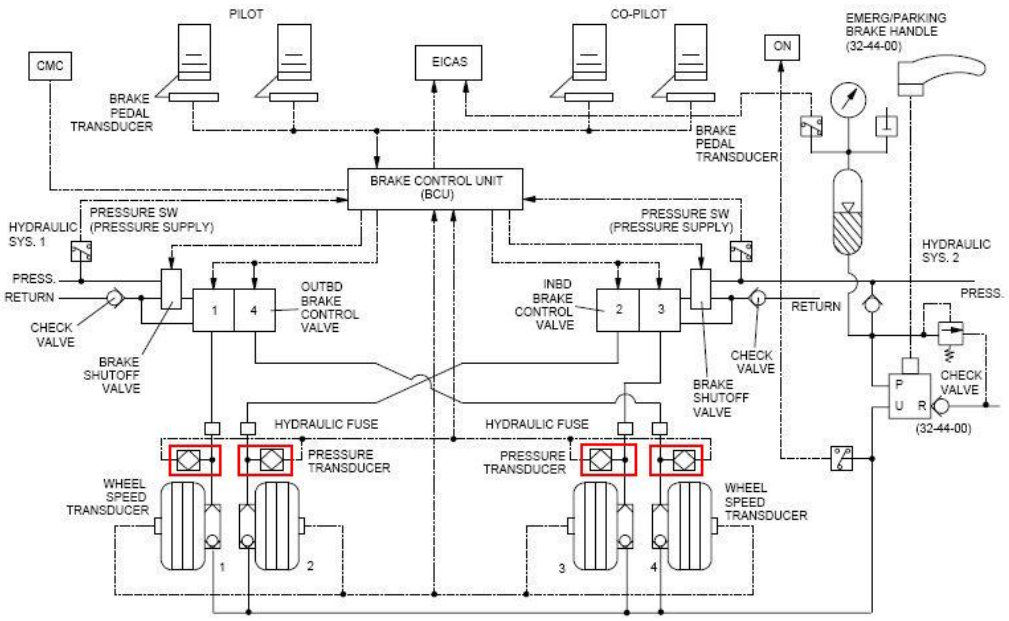
Overview photo towards the end of runway 07 Photo: BFU

Overview photo towards end of runway 25 at 1612 hrs Photo: BFU

Skid marks on the right main landing gear Photo: BFU

Brake system diagram

Source: Aircraft manufacturer



BRAKE SYSTEM - SCHEMATIC

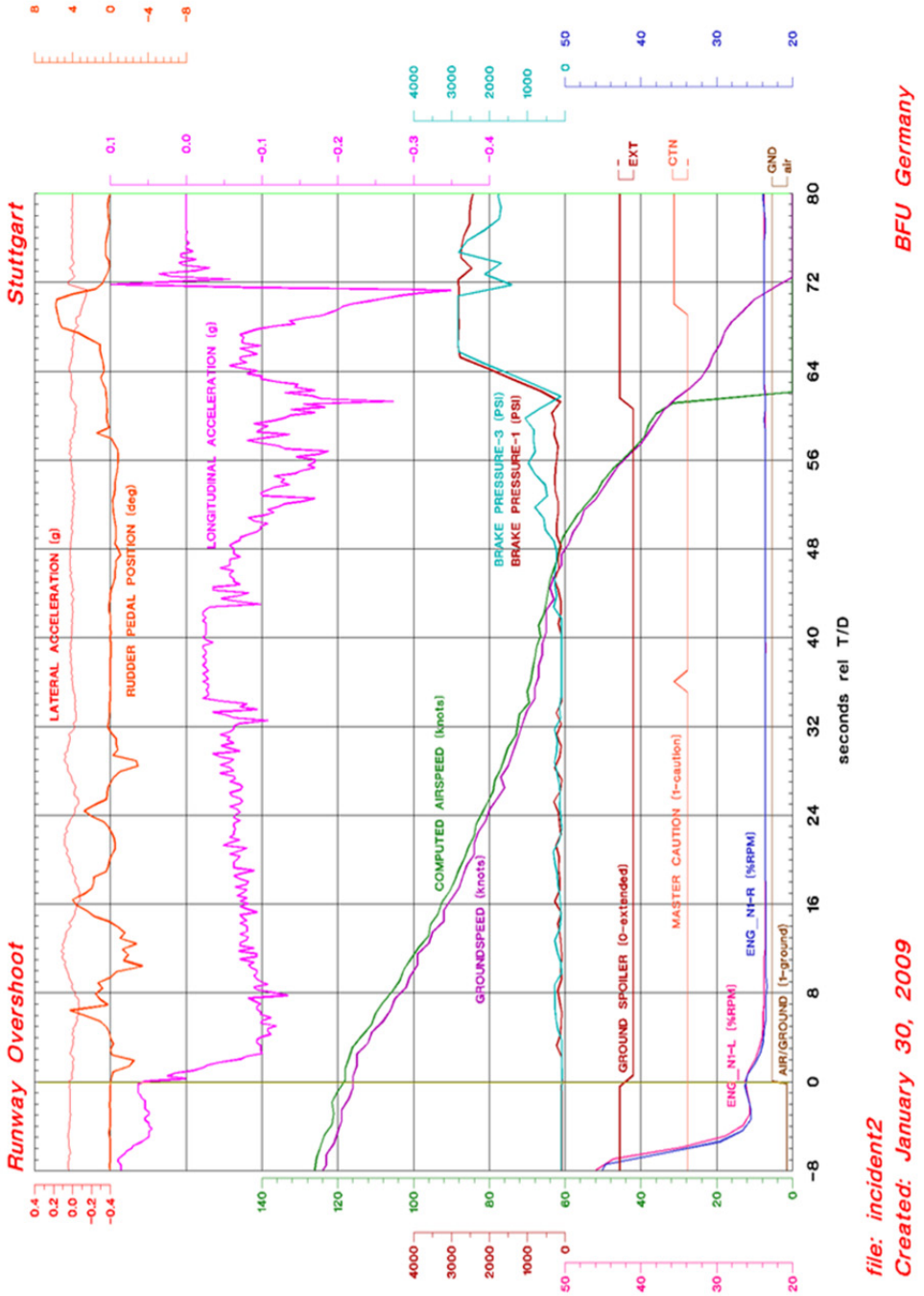


Diagram of selected parameters (from the F D R)

Source: BFU

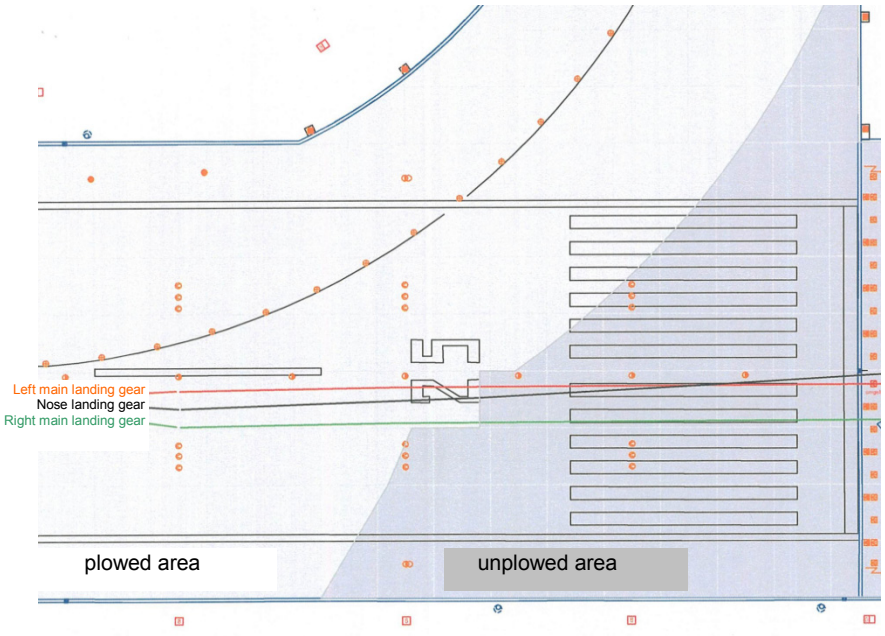


Illustration of the unplowed area at the end of the runway Source: Stuttgart Airport

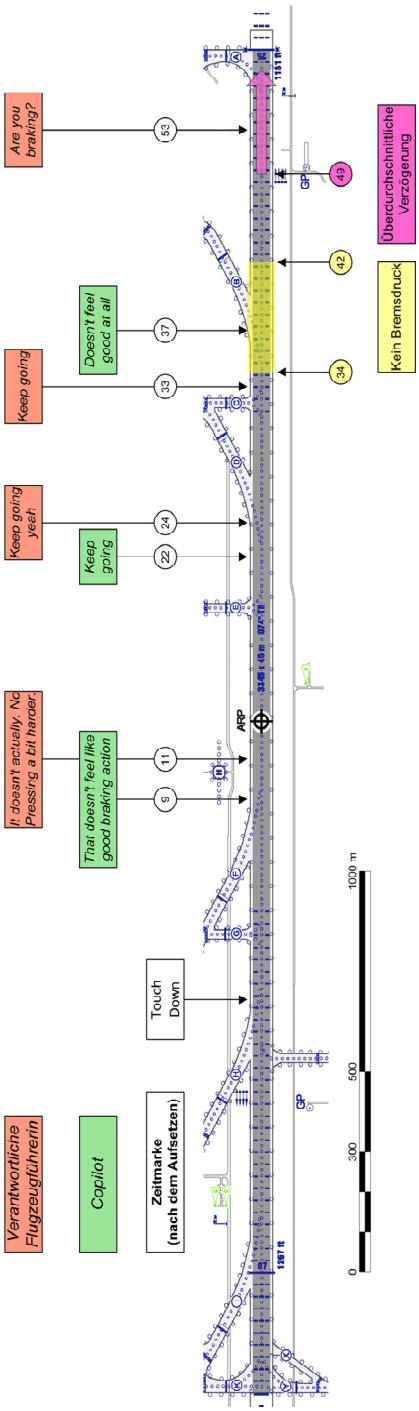


Illustration of the crew's comments and selected parameters from the F D R in relation to the position on the runway (Map: AIP-DFS)

This investigation was conducted in accordance with

the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.

the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FlUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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