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Büro für Flugunfalluntersuchungen  
Bureau d'enquête sur les accidents d'aviation  
Ufficio d'inchiesta sugli infortuni aeronautici  
Uffizi d'investigaziun per accidents d'aviatica

Aircraft accident investigation bureau

# **Final Report No. 1901 by the Aircraft Accident Investigation Bureau**

concerning the serious incident  
to the aircraft Embraer 145 LR, I-EXME  
operated by Alitalia Express under flight number AZA 568  
on 3 August 2001  
at Zurich Airport

## Ursachen

Der schwere Vorfall ist darauf zurück zu führen, dass die Flugbesatzung nach einem unstabilierten Endanflug eine lange Landung mit überhöhter Geschwindigkeit auf einer nassen Piste durchführte und die Maschine auf dem verbleibenden Landebahnabschnitt nicht zum Stillstand bringen konnte.

Die Untersuchung hat folgende kausale Faktoren für den schweren Vorfall ermittelt:

- Die Flugbesatzung führte den Geschwindigkeitsabbau zu spät aus und wählte eine Konfiguration des Flugzeuges für die Landung, welche der Situation nicht angepasst war.
- Der Kommandant hinderte den Copiloten daran, den bereits eingeleiteten Durchstart weiterzuführen.
- Die Flugbesatzung führte trotz *hard warning* des GPWS, die auf einen unstabilierten Endanflug hinwies, keinen Durchstart aus.

Folgende Faktoren haben den Unfall möglicherweise begünstigt:

- Die Flugbesatzung verwendete die Radbremsen nicht optimal.
- Die Flugbesatzung drückte während des Ausrollvorgangs die Steuersäule deutlich nach vorne und verringerte damit die Wirkung der Radbremsen.

**General information regarding this report**

In accordance with the agreement on International Civil Aviation (ICAO Annex 13) the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

According to art. 24 of the Swiss Air Navigation Law the legal assessment of accident/incident causes and circumstances is no concern of the investigation.

The masculine form is used exclusively in this report regardless of gender for reasons of data protection.

If not otherwise stated, all times in this report are indicated in coordinated universal time (UTC) format. At the time of the serious incident, Central European Summer Time (CEST) applied as local time (LT) in Switzerland. The relation between LT, CEST and UTC is:  $LT = CEST = UTC + 2 \text{ h}$ .

The german-language version of this report is authoritative.

The Aircraft Accident Investigation Bureau (AAIB) of Switzerland would like to thank the authorities and other organizations for the given support throughout the investigation.

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Appendix 1: Chronological sequence of essential events

Appendix 2: Selected DFDR parameters

Appendix 3: The site of the incident

Appendix 4: Plot of Doppler weather radar of the FIT for 14:40 UTC

## Final Report

Owner	Alitalia Linee Aeree Italiane SpA, Rome (I)
Operator	Alitalia Express SpA, Rome (I)
Aircraft type	Embraer EMB 145 LR
Country of manufacture	Italy
Registration	I-EXME
Location	Zurich Airport, municipality of Kloten/ZH Elevation: 432 m AMSL 1417 ft AMSL
Date and time	3 August 2001 at 14:40 UTC

### Synopsis

#### Brief description

Flight number AZA 568 was assigned to a scheduled flight from the airport of Milan Malpensa (I) to Zurich Airport. On 3 August 2001 this connection was flown by the Embraer EMB 145 LR aircraft, registered as I-EXME, of the Alitalia Express airline. After an uneventful flight over the Alps, the crew made an instrument approach on runway 14 at Zurich Airport. The aircraft touched down in heavy rain between 1450 and 1650 m after the displaced threshold and overran the end of the runway by approximately 150 m. The 46 passengers and the three crew members were uninjured whereas the aircraft was slightly damaged.

#### Investigation

The serious incident took place on 3 August 2001 at 14:40 UTC. Swiss Air-Rescue (REGA) notified the Aircraft Accident Investigation Bureau (AAIB) at 14:50 UTC. The AAIB opened the investigation on 3 August 2001 at approximately 17:00 UTC at Zurich Airport and founded an investigation team comprising several experts. Italy, as the aircraft's country of registration, designated an authorised representative in accordance with Annex 13 of the International Civil Aviation Organisation agreement (ICAO Annex 13). Representatives of the airline and of the aircraft manufacturer cooperated with the investigation.

The serious incident is attributable to the fact that after an unstabilised final approach the flight crew made a long landing with excessive speed on a wet runway and were unable to bring the aircraft to a halt on the remaining section of runway.

The investigation determined the following causal factors for the serious incident:

- The flight crew carried out the speed reduction to late and choosed an aircraft configuration for the landing which was not adapted to the actual situation.
- The commander prevented the copilot from continuing the go-around which had already been initiated.
- The flight crew did not carry out a go-around despite the ground proximity warning systems (GPWS) hard warning indicating an unstabilized final approach.

The following factors may have contributed to the serious incident:

- The flight crew did not make optimal use of the wheel brakes.
- During the landing roll, the flight crew pushed the control column forwards markedly, thereby reducing the effectiveness of the wheel brakes.

## 1 Factual Information

### 1.1 History of the flight

#### 1.1.1 General

For the following description of the history of the flight, the recordings of the cockpit voice recorder (CVR), digital flight data recorder (DFDR) and radiocommunications were used, as well as the statements of the flight crew.

Throughout the entire flight the copilot was pilot flying (PF) and the commander was pilot not flying (PNF).

The descent and approach were flown on autopilot up to an ILS-DME distance of 2.7 NM.

From take-off in Milan Malpensa on 3 August 2001 at 14:07 UTC to the start of the approach to Zurich, flight AZA 568 passed without any particular incidents.

#### 1.1.2 Preparation for the approach

Between 14:21:30 and 14:22:40 UTC the flight crew received the following ATIS<sup>1</sup> message:

*“Zurich Information TANGO: Landing runway 14, ILS approach, departure runway 28, Met report Zurich 1420 ZULU: wind 160 degrees, 4 knots, visibility 4000 m, rain, few 1000, scattered 2500, broken 5000, temperature 19, dew point 18, QNH 1017, tempo visibility 3000 m, transition level 50.*

*Speed limitation 240 kts, except on link route to RILAX. Taxiway KILO between runway two eight and taxiway BRAVO closed, taxiway HOTEL ONE closed.”*

At 14:24 UTC the commander went through this ATIS message again and stated to the copilot that he assessed the overall situation as presenting no problems.

Shortly after 14:26 UTC, the copilot explained to the commander how he wanted to make the approach. As part of this approach briefing he did not explicitly address the envisaged configuration of the aircraft for the approach and landing, merely mentioning in this context *“Alle 8 miglia, 4000 piedi, intercettiamo il glide...e...standard. - standard procedure after reaching glide path at 8 miles and 4000 feet.”* He also judged the landing distance available on runway 14 as sufficient. The crew were aware that I-EXME's reversers<sup>2</sup> were not available for technical reasons. According to the loadsheet, the current landing mass was 18 700 kg.

#### 1.1.3 Descent and commencement of the approach

In the descent to flight level (FL) 120, AZA 568 switched at 14:29:47 UTC from Zurich Radar air traffic control to Zurich Arrival West Sector (APW) approach control. The flight crew were informed that in order to intercept the runway 14 instrument landing system (ILS), a standard approach procedure KELIP 3E and radar vectoring were envisaged.

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<sup>1</sup> ATIS – automatic terminal information service – automated broadcast of landing and take-off information

<sup>2</sup> Reverser: device for reversing engine thrust



At 14:31:54 UTC, when flight AZA 568 passed FL 114 in its descent and was therefore still some 10 000 ft above the aerodrome, APW informed the flight crew that it should expect a flight path of 24 NM to touchdown. The aircraft was therefore approximately 2000 ft too high compared with an approach profile of 3°. The commander requested the copilot to descend as quickly as possible. A little later, the copilot reported that the aircraft was descending at a rate of 3000 ft/min and a faster descent was not possible.

The APW air traffic controller (ATCO) left the choice of speed to the crew, by instructing at 14:32:32: *“Alitalia five six eight, speed for the time being at your discretion.”* To this the commander replied that the aircraft was currently flying at 240 KIAS<sup>3</sup> and would maintain this speed: *“We are two four zero and we’ll maintain, Alitalia 568.”*

At 14:33:12 UTC, passing FL 80 in descent, the copilot ordered the flaps to be set to 9° to increase the aircraft’s resistance. In this phase the airspeed was 245 KIAS and the rate of descent was about 2500 ft/min.

After flight level 60 had been reached at 14:34:48 UTC, flight AZA 568 was instructed at 14:35:04 UTC to descend to 4000 ft AMSL<sup>4</sup>: *“Alitalia five six eight, descent to 4000 feet, QNH<sup>5</sup> one zero one seven”*. At 14:35:24 UTC the aircraft left FL 60 and the crew set reference atmospheric pressure QNH to 1017 hPa on both altimeters. The commander then carried out the approach check and in the process mentioned: *“heavy raining ... se ben ricordo... - heavy rain.... If I recall correctly”*.

About 30 seconds later, I-EXME received an instruction to turn right on heading 110°. At the same time, flight AZA 568 was cleared for an ILS approach on runway 14: *“Alitalia five six eight, right heading one one zero, cleared ILS one four, report established”*.

#### 1.1.4 Final approach

During the attempt to turn onto the localizer and to follow it, at 14:36:30 UTC the aircraft crossed the localizer at an ILS-DME<sup>6</sup> distance of 9.5 NM from the landing threshold. At this time the autopilot switched to localizer captured mode. In this phase, the commander noted that the flight management system (FMS) was indicating a south-westerly wind of 30 kt. Finally, I-EXME turned from the east at a speed of 210 KIAS onto the localizer. A little later, at 14:37:00 UTC, at an ILS-DME distance of 7.5 NM, the aircraft intercepted the glide path at a speed of 225 KIAS from above and the autopilot switched to glide slope captured mode.

At 14:37:24 UTC the commander noted that the aircraft should be at 3400 feet at an ILS-DME distance of 6 NM. However, it seemed, that it was actually flying 200 feet too low: *“... 6 miglia, 3400...siamo bassi! \*\*\*<sup>7</sup>! 6 miglia 3.2 siamo 200 sotto – 6 miles, 3400... We are low! \*\*\*! 6 miles 3.2 we’re 200 under”* At this

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<sup>3</sup> KIAS – knots indicated airspeed (kt)

<sup>4</sup> ft AMSL – feet above mean sea level

<sup>5</sup> QNH – atmospheric pressure reduced to sea level, calculated using the values and properties of the ICAO standard atmosphere

<sup>6</sup> DME – distance measuring equipment

<sup>7</sup> Expressions which constitute a spontaneous personal assessment of the current situation as well as personal utterances without any direct relation to the incident are identified by \*\*\*\*\*

time, AZA 568 was approximately 5.8 NM from the glide path transmitter at a height of 3170 ft in relation to the QNH of 1017 hPa.

At 14:37:30 UTC, the commander reported to APW *“Fully established one four, Alitalia five six eight”* and eight seconds later the aircraft reached the localizer from the east. At 14:37:32 APW instructed the crew to switch to the Zurich Aerodrome Control (ADC) frequency – *“Zurich Tower”*: *“Alitalia five six eight, number one, tower one one eight one, good bye”*.

When I-EXME flew over the Stadlerberg at 14:37:37 UTC at an ILS-DME distance of 5 NM, the audio warning *“LANDING GEAR”* was triggered. The crew subsequently lowered the landing gear at 220 KIAS and at a DME distance of 4.1 NM.

The aircraft was at an ILS-DME distance of 3.7 NM, at an altitude of 2540 ft with reference to the QNH of 1017 hPa when the commander noticed at 14:37:53 UTC: *“4 miglia 2730,...200 sotto ancora! – 4 miles 2730,...still 200 under!”*

At 14:37:58 UTC the commander made contact with Zurich Tower: *“Zurich grüezi, Alitalia five six eight fully established one four”*. Immediately afterwards, he received landing clearance together with the current wind: *“Alitalia five six eight, Zurich Tower, good afternoon, cleared to land runway one four, wind one niner zero degrees, four knots”*.

At 14:38:09 UTC, at an ILS-DME distance of 2.7 NM and at a height of 2220 ft AMSL or 820 ft AAL<sup>8</sup> a warning from the ground proximity warning system (GPWS) sounded for five seconds, *“TOO LOW, TERRAIN”*, because the flaps were only set to 9°.

At the same time the commander confirmed the landing clearance.

At 14:38:12 UTC the copilot reacted to the *“TOO LOW TERRAIN”* warning, said *“Riattacco – Go-around”*, switched off the autopilot, altered the pitch of 1° attitude nose down (AND) by pulling on the control column to 5.8° attitude nose up (ANU) and pushed the engine power lever forward. The commander interrupted this go-around with the words *“No, Andiamo sotto!– No, we’re going down!”* and ordered the flaps to be set at 22°. The commander simultaneously pointed out that it would be possible to land with flaps set at 22°: *“Male che va, andiamo giù con flaps a 22...”*.

During the last 8 NM of the final approach, the ground speed averaged 227 kt. Between 6 and 2 NM ILS-DME distance, I-EXME flew through a zone of heavy rain (cf. Appendix 4). At the edge of this rain zone, the DFDR briefly indicated a maximum tailwind component of approximately 40 kt. This tailwind component reduced to zero over the remaining flight path to the landing threshold.

Up to an ILS-DME distance of 2.3 NM from the runway threshold, I-EXME's speed was in excess of 200 KIAS. In this phase the crew had set power values on both engines which were clearly above the idling setting of 34% N1<sup>9</sup> and were up to about 64% N1. During the copilot's go-around attempt, the engines were briefly run up to 81% N1.

At 14:38:24 UTC the aircraft was still 1.8 NM from the landing threshold. It was about 370 feet above the glide path because of the go-around which was initiated and subsequently aborted. Its speed at this time was about 190 KIAS. At an

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<sup>8</sup> ft AAL – feet above aerodrome level

<sup>9</sup> % N1: rotation of the low-pressure compressor and turbine compared with its nominal rotation speed

ILS-DME distance of 1.2 NM and a height of 650 ft AAL, the flaps were finally set to 22°.

### 1.1.5 Landing

A few seconds after the synthetic voice of the ground proximity warning system (GPWS) had issued the message *"FIVE HUNDRED"*, from 14:38:46 UTC to 14:38:53 UTC the GPWS warning *"SINKRATE, SINKRATE"* sounded. After an interruption of two seconds, the warning sounded again and at 14:38:59 UTC AZA 568 flew over landing threshold 14 at a radar altitude of 186 ft. At this time the aircraft's speed was 178 KIAS and 55% N1 power was set on both engines. In this phase the sink rate was up to 1740 ft/min and from 14:38:58 UTC for several seconds the GPWS issued the warnings *"PULL UP, PULL UP"* and then again *"SINKRATE, SINKRATE"*.

At 14:38:59 UTC the copilot asked the commander to switch on the wipers, because heavy rain was evidently affecting visibility.

Eighteen seconds after flying over the landing threshold and between 1500 and 1700 m before the end of the runway, I-EXME touched down on the wet runway 14 with flaps set in the 22° position and at a speed of 167 KIAS. The crew tried to bring the aircraft to a halt on the remaining section of runway using the wheel brakes. The reversers could not be used for technical reasons. Finally, the aircraft was still travelling too fast to be able to vacate the runway via taxiway H3. On a heading of about 170° and a track of approximately 160° I-EXME skidded over the southern shoulder of taxiway H3 onto the grass and came to rest after approximately 150 m on a road within the aerodrome perimeter.

When it had come to a halt, the commander informed the cabin crew and the copilot handled radio communications with Zurich Tower. It was possible to leave the aircraft normally.

The 47 passengers and the three crew members were uninjured.

Swiss coordinates of the final position of the aircraft: 685 075/257 035, elevation 432 m AMSL corresponding to 1417 ft AMSL

National map of Switzerland 1:25,000, sheet No. 1071, Bülach

## 1.2 Injuries to persons

Injuries	Crew	Passengers	Third parties
fatal	---	---	---
serious	---	---	---
slight/none	3	47	

## 1.3 Damage to the aircraft

The aircraft was slightly damaged.

## 1.4 Other damage

There was minor damage to the ground.

## 1.5 Personnel information

### 1.5.1 Commander

Person	Italian citizen, born 1963
Flight duty times	Rest time: 11 hours Start of duty: 10:55 UTC Flight duty time at the time of the incident: 3:45 hours
Licence	<i>Brevetto e licenza di pilota civile 3° grado</i> - corresponding to an airline transport pilot's licence, issued by the Ministero dei Trasporti e Navigazione, Direzione Generale dell'Aviazione Civile, Servizio Navigazione Aereo, Italy, valid until 31.12.2002
Ratings	Type rating Embraer EMB 145 LR as pilot in command Type rating ATR 42/72 as pilot in command Type rating Cessna 500 Type rating Jetstream BA31 Radiotelephony International RTI
Instrument ratings	Embraer EMB 135/145, last extended on 12.02.2001
Last simulator check	with Alitalia Express on 24.06.2001
Last line check	with Alitalia Express on 05.06.2001
Medical certificate	Last periodic examination on 12.2.2001
Flying experience	8300 hours total
on the type involved in the incident	468:30 hours
during the last 90 days	150 hours
of which on the type involved in the incident	150 hours
during the last three days	6:27 hours
of which on the type involved in the incident	6:27 hours
on the day of the incident	0:33 hours
of which on the type involved in the incident	0:33 hours
Conversion to the aircraft type involved in the incident	September 2000

**1.5.2 Copilot**

Person	Italian citizen, born 1961	
Flight duty times	Rest time: 11 hours Start of duty: 10:55 UTC Flight duty time at the time of the incident: 3:45 hours	
Licence	<i>Brevetto e licenza di pilota commerciale di velivolo</i> - corresponding to a commercial pilot's licence, issued by the Ministero dei Trasporti e Navigazione, Direzione Generale dell'Aviazione Civile, Servizio Navigazione Aereo, Italy, valid until 13.09.2005	
Ratings	Type rating Embraer EMB 145 LR as copilot Type rating ATR 42/72 as copilot Type rating P180 as pilot in command Radiotelephony International RTI	
Instrument ratings	Embraer EMB 135/145, last extended on 13.09.2000	
Last simulator check	with Alitalia Express on 03.03.2001	
Last line check	with Alitalia Express on the occasion of the type rating check EMB 145 on 07.09.2000	
Medical certificate	Last periodic examination on 13.09.2000	
Flying experience	3200	hours total
on the type involved in the incident	436:30	hours
during the last 90 days	177	hours
of which on the type involved in the incident	177	hours
during the last three days	6:27	hours
of which on the type involved in the incident	6:27	hours
on the day of the incident	0:33	hours
of which on the type involved in the incident	0:33	hours
Conversion to the aircraft type involved in the incident	September 2000	

## 1.6 Aircraft Information

### 1.6.1 Aircraft I-EXME

Aircraft type	Embraer EMB 145 LR (long range)
Characteristics	Twin-jet regional commercial aircraft, constructed as a cantilever low-wing aircraft of full metal construction with retractable landing gear in nosewheel layout. The passenger cabin is designed for 48 passengers and a maximum three person flight crew and two person cabin crew are specified.
Wing span	29.87 m
Length	20.04 m
Height	6.75 m
Maximum take-off mass	22 000 kg
Maximum landing mass	19 300 kg
Fuel capacity	6396 l
Manufacturer	Embraer – Impresa Brasileira de Aeronautica S/A, S. José dos Campos, Brazil
Registration	I-EXME
Serial number	145-282
Year of construction	2000
Owner	Alitalia Linee Aeree Italiane SpA, Viale Alessandro Marchetti, 111 – 00148 Rome (I)
Operator	Alitalia Express SpA, Viale Alessandro Marchetti, 111 – 00148 Rome (I)
Airworthiness certificate	dated 4 July 2000, issued by the Ente Nazionale per l'Aviazione Civile (ENAC) valid until 3 July 2003
Registration certificate	dated 6 July 2000, issued by the Ministero dei Trasporti e Navigazione, Direzione Generale dell'Aviazione Civile, 3° Servizio Trasporti Aerei, Italy, valid until removal from the aircraft register
Certification	VFR with visual ground contact VFR in areas with VHF radio coverage IFR in areas with VHF radio coverage Flights in known icing conditions Night flights B-RNAV <sup>10</sup>

<sup>10</sup> B-RNAV – basic area navigation: a method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

Flight time reserve	According to the flight plan, take-off fuel was 2200 kg. Among other things, this included a trip fuel of 844 kg. The remaining 1356 kg would have allowed the aircraft to fly to the alternate aerodrome at Stuttgart plus 10 minutes holding, without having to use the final reserve of 420 kg.
Speed limitations (selection)	Extension of flaps to 9°: 250 KIAS Extension of flaps to 22°: 200 KIAS Extension of flaps to 45°: 145 KIAS Extension of landing gear: 250 KIAS Use of wipers: 170 KIAS
Technical limitations	The two reversers were deactivated because of a manufacturer's service bulletin and could not be used at the time of the accident.
Mass and centre of gravity	The aircraft's mass on take-off from Milan (I) was 19 614 kg. Given the load at the time and the landing mass of 18 700 kg, mass and centre of gravity were within the permitted limits.

### 1.6.2 Aircraft performance on landing

At the applicable landing mass of 18 700 kg, a temperature of 19 °C and an aerodrome elevation of 1400 ft AMSL, according to the Alitalia Express operation manual part B (OM-B) the following runway lengths are necessary as a function of the runway condition, the prevailing wind and the selected flap setting:

Runway condition	Wind	Flaps	Minimum required landing distance
wet	No tailwind	45°	1747 m
wet	10 kt tailwind	45°	1997 m
5 mm standing water	No tailwind	45°	2120 m
5 mm standing water	10 kt tailwind	45°	2782 m
wet	No tailwind	22°	2519 m
wet	10 kt tailwind	22°	2849 m

For all these values, the OM-B assumes that the landing threshold is crossed at a height of 50 ft AGL and at the reference speed  $V_{ref}$  which is dependent on the current landing mass. For the landing mass of 18 700 kg applicable in the current case, and flaps set at 22°, the OM-B specifies a  $V_{ref}$  of 146 KIAS. If a landing is attempted with flaps set at 45°,  $V_{ref}$  is 133 KIAS. To these values one adds – if there is no headwind or gusts of wind – a minimum wind factor of 5 kt, thereby arriving at the approach speed  $V_{app}$ . In this way, for no wind or a tail wind, for a landing with flaps set at 22° one obtains a  $V_{app}$  of 151 KIAS and for a landing with flaps at 45° a  $V_{app}$  of 138 KIAS.

If, on flying over the landing threshold with a speed 10 kt in excess of  $V_{ref}$ , the minimum required landing distance is increased by 12%.

## 1.7 Meteorological Information

### 1.7.1 General weather situation

On 3 August 2001 a trough of low pressure extended from Holland towards Iceland. The associated cold front was situated over Switzerland. Humid air was blowing towards the Alps in a south-westerly upper air current.

### 1.7.2 Weather conditions at Zurich airport

#### 1.7.2.1 Weather at the time of the serious incident according to information from Meteo-Swiss

Cloud	1 – 2/8, base at 800 ft AAL 5 – 7/8, base at 1800 ft AAL
Precipitation	moderate rain
Meteorological visibility	3000 m
Wind measurement point runway 14/16	from 190° at 4 kt, gusting to 8 kt
Wind measurement point runway 34	from 150° at 4 kt, gusting to 8 kt
Air temperature	19 °C
Dew point	18 °C
Atmospheric humidity	98%
Atmospheric pressure	QNH 1018 hPa
Risks	None

#### 1.7.2.2 Aerodrome weather reports

In the period from 14:20 UTC until after the incident, the following METAR (aerodrome weather reports) applied:

031420Z 16004KT 4000 RA FEW010 SCT025 BKN050 19/18 Q1017 TEMPO 3000

031450Z 16004KT 2100 +RA FEW008 BKN018 19/18 Q1018 TEMPO 1500

In plain language, this corresponds to: On 3 August 2001 shortly before the issue time of the 14:20 UTC aerodrome weather report, the following weather conditions were observed on Zurich aerodrome:

Wind	from direction 160°, speed 4 kt
Meteorological visibility	4000 m
Precipitation	moderate rain
Cloud	1-2/8 at 1000 ft AAL 3-4/8 at 2500 ft AAL 5-7/8 at 5000 ft AAL
Temperature	19 °C
Dew point	18 °C
Atmospheric pressure	1017 hPa, pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere



Landing forecast	In the two hours following the weather observation it is to be expected that meteorological visibility will at times be reduced to a value of 3000 m. It is expected that the total time of this change will be less than one hour.
Similar conditions apply to the second METAR: On 3 August 2001 shortly before the issue time of the 14:50 UTC aerodrome weather report, the following weather conditions were observed on Zurich aerodrome:	
Wind	from direction 160°, speed 4 kt
Meteorological visibility:	2100 m
Precipitation	heavy rain
Cloud	1-2/8 at 800 ft AAL 5-7/8 at 1800 ft AAL
Temperature	19 °C
Dew point	18 °C
Atmospheric pressure	1018 hPa, pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere
Landing forecast	In the two hours following the weather observation it is to be expected that meteorological visibility will at times be reduced to a value of 1500 m. It is expected that the total time of this change will be less than one hour.

### 1.7.3 Weather radar recordings

In addition to the data from the Meteoswiss radar recording, which is compiled from the measurements of the three weather radar stations at La Dôle, Albis and Monte Lema, it was possible in the present case to use the recordings of the Doppler weather radar of the Institute of Atmospheric and Climate Science of the Swiss Federal Institute of Technology Zurich on the Höggerberg (cf. Appendix 4). On the plot for 14:40 UTC a band of precipitation is discernable which extended from Wettingen over the Lägern as far as Eglisau. Isolated small cells of rain lay over Kloten and Zurich and to the west of Winterthur. In some places over the Lägern, heavy precipitation was occurring.

No lightning was registered on the entire northern side of the Alps between 14:00 and 15:00 UTC and the Kloten automatic station did not record any electrical discharges from 14:00 to 15:00 UTC.

### 1.7.4 Weather according to eye witnesses

The pilots involved stated that it was raining heavily during the landing.

An airport employee who had been in the immediate vicinity of the head of runway 14 described the weather as follows: *“Die Sicht war durch starken Regen sehr beeinträchtigt. Die Piste 14 und der Rollweg H3 waren sehr nass, stehende Pfützen. – Visibility was very badly affected by heavy rain. Runway 14 and taxiway H3 were very wet, with standing puddles.”*

## 1.7.5 Astronomical information

### 1.7.5.1 Position of the sun

Azimuth	248°
Elevation	41°

## 1.8 Aids to navigation

### 1.8.1 Runway 14 instrument landing system at Zurich Airport

Runway 14 at Zurich Airport is equipped with a LOC 411 localizer as well as a glide path transmitter GS 412, supplied in 1999 by Thales ATM. Runway 14 is therefore authorised for category CAT IIIB precision approaches.

The displacement error for the runway 14 ILS CAT III glide path is  $\pm 0.12^\circ$ . If the nominal glide path is displaced outside a range of  $+0.3 / -0.22^\circ$  (alarm course), an alarm is triggered.

When converted to distance, the listed angular deviations give the following height deviations:

ILS-DME distance [NM]	displacement error	alarm course
4	$\pm 53$ ft	+131 ft / -97 ft
6	$\pm 79$ ft	+197 ft / -144 ft

According to the operator's information, the ILS 14 Zurich installations were in normal operation at the time of the incident and were available to the operational services without restriction.

## 1.9 Communication

Radio communication between the crew and the air traffic controllers at the different ATC units took place within the normal framework. Transcriptions of the radio conversations which are directly related to the flight involved in the incident are provided in Appendix 1.

## 1.10 Information on the airport

### 1.10.1 General

Zurich Airport is located in north-east Switzerland. In 2001, the skyguide air navigation services company handled a total traffic volume of about 297 000 instrument flight rules (IFR) arrivals and departures.

At the time of the incident an extensive building programme was in progress, centred on the dock midfield located within the triangle formed by the three runways.

The dimensions of Zurich airport runways are as follows:

<b>Runway</b>	<b>Dimensions</b>	<b>Elevation of runway threshold</b>
16/34	3700 x 60 m	1390/1386 ft AMSL
14/32	3300 x 60 m	1402/1402 ft AMSL
10/28	2500 x 60 m	1391/1416 ft AMSL

The threshold of runway 14 is displaced by 150 m. For this reason, at the time of the incident 3150 m of runway length was available for a landing on runway 14.

The reference elevation of the airport is 1416 ft AMSL and the reference temperature is specified as 24.0°C.

### **1.10.2 Runway equipment**

Zurich airport is characterised by a system of three runways, two of which (16 and 28) intersect at the airport reference point. The approach corridors of two other runways (14 and 16) intersect approximately 850 metres north-west of the threshold of runway 14. Runways 16 and 14 are equipped with a CAT III instrument landing system (ILS) and are therefore suitable for precision approaches. Runway 28 allows non precision approaches on the basis of VOR/DME Kloten (KLO). At the time of the incident, the approach sectors of runways 14 and 16 were equipped with a minimum safe altitude warning (MSAW) system. This system triggers a visual and acoustic alarm in air traffic control if aircraft infringe defined minimum altitudes. No MSAW was installed in the approach sector for runway 28.

### **1.10.3 Rescue and fire-fighting services**

Zurich Airport was equipped with Category 9 fire-fighting resources. The airport's professional fire-fighting services were on permanent stand-by during flight operations.

### **1.11 Flight recorders**

The aircraft was equipped with two digital flight recorders. The cockpit voice recorder (CVR) recorded four channels for a period of 30 minutes onto solid state memory. The digital flight data recorder (DFDR) also had solid state memory and recorded 124 parameters from the last 24 hours of operation of the aircraft.

It was possible to read and analyse both systems. A section of the parts of the CVR essential for the course of the flight is integrated into Appendix 1. The DFDR parameters necessary for an understanding of the incident are illustrated graphically in Appendix 2.

### **1.12 Wreckage and impact information**

The aircraft was examined in detail after being recovered. Among other things the following findings were made:

- No external damage was visible.
- The landing gear tyres showed no traces of aquaplaning.
- The traces in the engine inlets before the first compressor stage showed that the engines had sucked in soil and dirty water before they had stopped. The compressor blades themselves seemed visually undamaged.

### 1.13 Medical and pathological information

There is no indication that the mental or physical capabilities of the crew were in any way adversely affected. Immediately after the serious incident, a breath test for alcohol was carried out on the commander and copilot, which provided negative results.

### 1.14 Fire

Fire did not break out.

### 1.15 Survival aspects

As the aircraft's structure remained intact when it overran the runway and the residual energy of the aircraft was dissipated over a distance of approximately 150 m, the occupants were subjected to deceleration which did not differ substantially from a braking procedure on the runway.

When the aircraft had stopped, the commander informed the cabin crew and the copilot handled radio communications with Zurich Tower. The on ground emergency checklist was not executed, as the crew did not order an evacuation. It was possible to leave the aircraft normally.

### 1.16 Test and research

#### 1.16.1 Altimeter display during the final approach

According to the CVR recordings, at 14:37:24 UTC and 14:37:54 UTC the commander pointed out that the altimeters of I-EXME were displaying altitudes 200 feet too low compared with those published on the approach charts. For this reason both the aircraft's flight path with regard to the transmitted glide path and the altimeter display were examined more closely.

The DFDR data show that the autopilot, working in glide slope and localizer captured mode was guiding the aircraft with very slight deviations from the transmitted glide path.

The aircraft manufacturer, Embraer, writes in the aircraft flight manual (AFM) that depending on the configuration (landing gear and flap setting) and on the speed, a correction must be made to the displayed altitude. The corresponding graph for the present case (gear up, flaps 9°), *"altitude position error correction pilot's and copilot's pitots"*, provides the following correction values for the altimeters in the final approach:

- speed 222 KIAS : + 20 ft (ILS-DME distance 6 NM)
- speed 219 KIAS : + 18 ft (ILS-DME distance 4 NM)<sup>11</sup>

Moreover, during the approach the atmospheric pressure increased slightly. The METAR report at 14:50 UTC, based on an atmospheric pressure measurement in the ten minutes before the time of issue, indicated an atmospheric pressure of 1018 hPa. This value corresponds to a pressure range from 1018.0 to 1018.9 hPa, as the published QNH is always rounded down to the next integer value in hPa.

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<sup>11</sup> Shortly before I-EXME reached an ILS-DME distance of 4 NM, the landing gear was extended. Since no corresponding graph is available for gear down, flaps 9°, by approximation that for gear up, flaps 9° was used.

According to the CVR and DFDR recordings, the crew had set a QNH of 1017 hPa on their altimeters. If one assumes that during the approach an average reference atmospheric pressure of 1018.5 hPa applied, as a result of these two effects the altitude displayed in the aircraft would have been 60 ft too low at an ILS-DME distance of 4 NM or 6 NM.

The air temperature in the lower air strata was on average 7 °C higher than the standard atmosphere values. This meant that the altimeter was displaying values which were approximately 2.5 % too low. At a true altitude of 2000 ft AAL, this leads to a display which is about 50 ft too low.

The recorded DFDR data were compared with selected values of the independent radar altimeter and with the display on the ground. This showed that the I-EXME altimeter system was supplying values which deviated from reality by max. 25 ft. The trend of the incorrect display was also towards a values which was too low.

### **1.16.2 Braking procedure**

Analysis of the DFDR showed that during the braking procedure the brake pedal pressure which was generated by the flight crew was not maintained at the maximum but varied greatly (cf. Appendix 2). Consequently the antiskid system did not have the constant maximum brake pressure to establish the optimal braking effect.

During the braking procedure on the runway, the DFDR did not record any lurching movement around the vertical axis which would give an indication of aquaplaning.

Furthermore, the DFDR data show that during braking the crew moved the control column markedly forwards (cf. Appendix 2).

## **1.17 Organizational and management information**

### **1.17.1 The Alitalia Express airline**

#### **1.17.1.1 General**

The Alitalia Express airline is an airline which at the time of the incident operated a fleet of regional aircraft of the types ATR 42-300, ATR 72-212, ATR 72-212A and EMB 145 LR. The company was a subsidiary of the Alitalia S.P.A. airline and among other things made flights on its behalf.

#### **1.17.1.2 Operational procedures**

##### **1.17.1.2.1 General**

The operational procedures were prescribed by the parent company Alitalia and laid down among other things in the pilots' handbook. The following operational procedures are relevant to the current incident.

#### 1.17.1.2.2 Conditions for a stabilised final approach

The Alitalia Express pilots' handbook, part 8, operating techniques, demanded on page 8.55 under paragraph 2.7.10 *The Stabilized Final Approach*, among other things:

*"For all instrument final approaches the standard operating technique is the stabilized approach; this technique requires a constant rate of descent from the FAP or FAF crossing altitude (with due regard for any prescribed step-down fix) and*

- *All briefings and check-lists performed;*
- *The aeroplane on the desired flight path (visual or instrument, with or without the backup of a correct slope signal) with an approximate constant rate of descent of 600 to 800 ft/min (normally not in excess of 1000 ft/min);*
- *The aeroplane configured for landing and in trim;*
- *The engines spooled up;*
- *Airspeed within plus 10 kt/minus 5 kt of target approach speed;*
- *Only small changes in heading and pitch to maintain the desired flight path.*

*The target approach speed for the estimated landing weight ( $V_{ref}$ ) and additives for the reported surface wind are specified in the AOM.*

***All the above conditions should be achieved not below the minimum stabilization height of 1000 ft AAL in all instrument and visual final approaches. If not stabilized, at 500 ft AAL (400 ft after a circling) discontinue approach.*** (Bold type in original).

#### 1.17.1.2.3 Minimum altitude at the outer marker

The *Alitalia Express pilots' handbook, part 8, operating techniques* described under paragraph 2.7.7.3 *The Outer Marker*, among other things, that in the approach to the outer marker<sup>12</sup> (OM) the corresponding altitude was to be observed and complied with up to the OM or navigation fix.

- *"Descent below the OM crossing altitude should not be made prior to overflying the OM or an equivalent DME fix."*

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<sup>12</sup> Outer marker: lobe-shaped marker beacon which is used in the instrument landing system (ILS) to identify the first predetermined point during an instrument approach. The OM is typically located four to seven NM from the runway threshold on the extended centreline of the runway.

## 1.17.1.2.4 Braking procedure

With regard to the effect of the wheel brakes, the *Alitalia Express pilots' handbook, part 8, operating techniques*, on page 8.77 under paragraph 2.9.2 *Landing Techniques*, described the effect of the control column:

- ***“A slight forward pressure on the control column throughout the landing roll will assist in a better directional control. Do not, however, apply excessive forward pressure since the elevator will unload, to some extent, the main wheels and thus reduce braking.”***  
(Bold type in original).

In the *Alitalia Express operations manual part B* under *normal procedures*, section 02.40.01 *after landing*, the use of the wheel brakes is described as follows:

- *“To maximize braking performance on dry or wet runways apply maximum continuous pressure on the brake pedals. The ANTISKID system will modulate the brakes for an optimum braking performance. DO NOT PUMP THE PEDALS.”*

## 2 Analysis

### 2.1 Technical aspects

#### 2.1.1 General information on the aircraft

No technical restrictions applied, apart from the two reversers which were deactivated because of the aircraft manufacturer's service bulletin. The warnings recorded by the flight recorders did not relate to technical malfunctions or systems failures.

### 2.2 Operational aspects

#### 2.2.1 Initial situation for the approach

For the approach and landing, no substantial operational limitations applied at the beginning of the approach. In particular, a sufficiently long runway with precision approach aids was available and the fuel reserves would have permitted holding, a go-around or flying on to an alternate aerodrome without any problems. The landing mass of I-EXME at that time was within the permitted limits. The circumstance that the reversers, which play no part in the calculation of the minimum required landing distance, could not be used was taken into account by the crew and explicitly mentioned by the copilot at 14:26 UTC as part of the approach briefing.

According to the METAR report at 14:20 UTC, received by the crew at 14:22 UTC, a wet runway was to be expected. The commander recalled this report at 14:35 UTC, when he was carrying out the approach check: *"Heavy raining...se ben ricordo..."*. This fact indicates that the commander was at that time expecting heavy rain during landing.

Under these conditions, the crew intended to land with flaps set at 45°.

#### 2.2.2 Performance of the approach

The descent planning and position follow-up were appropriate until the aircraft reached the ILS on the extended center line of the runway.

At 14:32:32 UTC flight AZA 568 received from the ATC unit an authorisation to determine their speed themselves: *"AZA 568, speed for the time being at your discretion."* This information was confirmed by the flight crew. Subsequently, for the entire approach, I-EXME received no further restrictions concerning the choice of speed.

In the final approach the crew continued to maintain approximately the initial approach speed. The DFDR data show that during this phase relatively high power values were set. A deliberate speed reduction to an approach speed adapted to the conditions did not take place. Among other things this meant that the flaps could not be set to 45°, as had been originally intended by the crew.

No systematic adaptation of approach speed and configuration with the aim of stabilising the glidepath at 1000 ft AAL or 2400 ft AMSL and preparing for landing is detectable.

During the final approach a tailwind component with values of up to 40 kt was present. During the last 8 NM of the final approach, this tailwind led to an average ground speed of 227 kt. Between the ILS-DME distance of 2 NM and flying over the landing threshold, the tailwind component reduced and the aircraft touched down with virtually no wind.



### 2.2.3 Altitude control during the final approach

At 14:37:24 UTC and at 14:37:54 the commander commented on the current altitude. In both cases when he did so, according to the CVR, he mentioned that the altimeters were indicating an altitude 200 ft below that on the approach charts. As his statements prove, he expected an altitude of 3400 ft AMSL at an ILS-DME distance of 6 NM and 2730 ft AMSL at 4 NM. As the DFDR recordings prove, during this phase the aircraft was following precisely the guide beam transmitted by the glide path transmitter. The difference ascertained by the crew very probably resulted from a combination of the following circumstances:

- Since the temperature in the layers of air close to the ground was 7 °C higher than the values in the standard atmosphere, at 3400 ft AMSL (true altitude) the altimeters indicated a value approximately 50 ft too low.
- In both cases the actual QNH value was 1 to 1.9 hPa higher than the reference atmospheric pressure set on the altimeters.
- At an ILS-DME distance of 6 and 4 NM, the altitude position error led to an altimeter indication which was about 20 ft too low.
- When comparing the altitude with the values from the approach chart for an ILS distance of 6 NM, the commander erroneously related the altimeter indication to the altitude of the localizer approach of 3400 ft AMSL, not the altitude of the glide path, 3370 ft AMSL.
- The altitude comparison concerning the reference altitude at 6 NM took place shortly before 14:37:24 UTC, when I-EXME was located at an ILS-DME distance of 5.8 NM. According to the DFDR recordings, at this time an altitude of 3170 ft with reference to the set QNH of 1017 hPa was indicated in the cockpit.
- The altitude comparison concerning the reference altitude at 4 NM took place shortly before 14:37:54 UTC, when I-EXME was located at an ILS-DME distance of 3.7 NM. According to the DFDR recordings, at this time an altitude of 2520 ft with reference to the set QNH of 1017 hPa was indicated in the cockpit.

On the basis of the above facts and with regard to the functional capability of ILS 14 it can therefore be concluded that from reaching the glide path up to switching off of the autopilot, flight AZA 568 moved within the specified tolerances for the displacement error.

The CVR recordings, however, indicate that the flight crew were distracted by this apparent discrepancy between the altimeter display and reference altitudes on the approach chart, or that they were busy analysing it for some time.

### 2.2.4 System warnings and aborting a go-around

When the aircraft flew over the Stadlerberg, the radar altitude was for a short time less than 1200 ft, triggering the *"LANDING GEAR"* warning. This warning sounded until the gear was lowered a few seconds later.

At 14:38:09 UTC, the ground proximity warning system (GPWS) issued a category 4B synthetic voice warning *"TOO LOW, TERRAIN"*, because the flaps were only set at 9° and were therefore not in a possible landing configuration.

The copilot reacted to the GPWS warning three seconds later by initiating a go-around. After the declaration *"Riattacco – Go-around"*, he switched off the autopilot, altered the pitch of 1° attitude nose down (AND) by pulling on the control column to 5.8° attitude nose up (ANU) and pushed the engine power levers forward. The commander interrupted this go-around with the words *"No, Andiamo sotto!– No, we're going down!"*

The copilot's decision to go around was appropriate; indeed, in this phase I-EXME was in various respects not in a stabilised condition for the final approach: at an altitude of about 800 ft AAL, though the aircraft was actually on the glide path, its speed was nevertheless some 70 kt above the desired approach speed and the flaps were still set at 9°, not in the specified position of 45°.

On the basis of these facts and working on the principle that a go-around, once it has been initiated, should not be aborted, the commander's intervention seems difficult to understand. Since no thunder cells were present in the vicinity of the aerodrome, a standard missed approach procedure would have been possible from the meteorological viewpoint.

As a result of aborting the go-around, during which the copilot had briefly increased power to 81% N1, the aircraft gained additional energy. At an ILS-DME distance of 1.8 NM, because of the short-term increase in attitude, it was about 370 ft above the glide path. The speed was about 190 KIAS and the ground speed was approximately 220 kt as a result of the tailwind component.

As the CVR documents, even after the aborted go-around the commander was still mentally preoccupied with the GPWS *"TOO LOW"* warning and was not able to explain it.

### 2.2.5 Landing and braking procedure

During the copilot's go-around attempt, the commander ordered the flaps to be set to 22° and made the comment: *"Male che va, andiamo giù con flaps a 22..."*. This fact shows that a landing with flaps set to 45° was actually envisaged. Since the highest permissible speed for the 45° flap setting is 145 KIAS, but the aircraft at this time was still flying at approximately 190 KIAS, this flap position could not be implemented.

I-EXME flew over the runway 14 landing threshold at a radio altitude of 186 ft, which, combined with the speed of 178 KIAS which was still high, would necessarily lead to a long landing distance. It is highly probable that in this phase the crew still did not recognise the imminent problems. This may be attributable to the following points:

- for turboprop aircraft on regional transport in particular, attempts are frequently made to achieve a long landing distance in order to avoid long taxiing times before vacating the runway.
- The two pilots had converted to the Embraer 145 only a few months before the serious incident. Before that, both were flying turboprop aircraft ATR42 and ATR72 belonging to the same airline.

Shortly before the aircraft flew over the landing threshold, the GPWS issued the warnings *"SINKRATE"*, *"PULL UP, PULL UP"* for 18 seconds, apart from a two second interruption, and then again *"SINKRATE, SINKRATE"*. The *"SINKRATE, SINKRATE"* warning constitutes a soft warning which is triggered when the aircraft's rate of descent is more than 1200 ft/min. The *"PULL UP, PULL UP"* warn-

ing is a hard warning which sounds when a rate of descent of 1700 ft/min is exceeded. In this phase I-EXME's rate of descent was up to 1740 ft/min. The activation of the GPWS hard warning constituted a clear indication to the flight crew that the approach was not stabilised in this phase either. This should have led to a go-around. Nothing indicates that this was taken into consideration.

The fact that during the landing procedure the copilot ordered the wipers to be switched on, even though according to the CVR he realised that the aircraft's speed at this time was still too high for this device to be used, shows that external visibility was very badly affected by the rain.

After touch-down, the aircraft still had between 1500 and 1700 m of runway available to complete the landing; because of the following factors this was not sufficient to bring the aircraft to a halt while it was still on the runway:

- Speed on touchdown was 167 KIAS and therefore 29 KIAS higher than the approach speed of 138 KIAS specified for the landing mass of 18 700 kg on flying over the landing threshold for a landing with the flaps set in the 45° position. The aircraft's kinetic energy on touchdown was therefore some 58% higher than on touchdown at the reference speed  $V_{Ref}$  of 133 KIAS.
- The braking manoeuvre was not carried out optimally. During roll-out the crew several times reduced pressure on the brake pedals which prevented the braking system from working optimally. Moreover, during this phase the crew pushed the control columns markedly forward. The associated downward deflection of the elevator displaced part of the weight of the fuselage onto the unbraked nosewheel gear, which again reduced the braking effect.
- The reversers were not available.

After the complete stop of the aircraft, the flight crew did without an evacuation and the passenger could disembark normally. This decision was appropriate with regard to the situation.

### 3 Conclusions

#### 3.1 Findings

##### 3.1.1 Technical aspects

- The EMB 145 LR, I-EXME, exhibited no technical defects which had an effect on the course of events of the serious incident.
- The two reversers were deactivated because of the aircraft manufacturer's service bulletin.
- The reversers are not taken into account when determining the aircraft's landing performance and are used as an additional reserve.
- The mass and centre of gravity of the aircraft were within the prescribed limits.
- According to the flight plan, flight AZA 568 was being operated with a fuel reserve which would have allowed the aircraft to fly from Zurich to the alternate aerodrome at Stuttgart and hold for 10 minutes. In addition, the final reserve of 30 minutes was still available.
- The ground navigation aids used for the approach were functioning normally.
- After the incident, the tyres of I-EXME did not exhibit any trace of aquaplaning.

##### 3.1.2 Crew

- According to the available documentation the crew were in possession of valid licences.
- There is no indication that the state of health or capabilities of the crew were in any way adversely affected.

##### 3.1.3 History of the flight

- Until the autopilot was switched off, the approach took place on an approach profile of approximately 3°.
- Until it was switched off, the autopilot was following the approach profile (ILS tracking) very accurately.
- At an ILS-DME distance of 5 NM, the warning "*LANDING GEAR, LANDING GEAR*" was issued, because the radio altitude on flying over the Stadlerberg was less than 1200 ft AGL and the gear had not yet been lowered.
- At an ILS-DME distance of 2.7 NM, the GPWS issued the warning "*TOO LOW, TERRAIN*", because the flaps were still set at 9°.
- At any ILS-DME distance of 2.5 NM and at an altitude of 800 ft AAL the copilot initiated a go-around, which was aborted a few seconds later by the commander.

- Up to an ILS-DME distance of 2.3 NM, the aircraft's speed was in excess of 200 KIAS.
- According to the airline's procedural regulations, a stabilised approach consisted of the following elements, among others: The aircraft is in landing configuration at a speed of  $V_{app} + 10/-5$  kt on a flight path which allows it to approach at a constant rate of descent of not more than 1000 ft/min.
- According to the airline's operations manual part B (OM-B), for a landing with flaps at  $22^\circ$  one obtains a  $V_{app}$  of 151 KIAS and for a landing with flaps at  $45^\circ$  a  $V_{app}$  of 138 KIAS.
- The airline's procedures envisaged that in the event of an unstabilised approach, a go-around must be initiated at the latest when an altitude of 500 ft AAL is reached.
- When I-EXME was at an altitude of 500 ft AAL, it was still 0.6 NM from landing threshold 14. Its speed was 182 KIAS; it was descending at approximately 1600 ft/min and in the cockpit the GPWS warning "*SINKRATE, SINKRATE*" was sounding.
- From the time at which the aircraft was at an ILS-DME distance of 0.5 NM until it had flown over landing threshold 14, it exhibited rates of descent of up to 1740 ft/min, which triggered the GPWS warnings "*SINKRATE, SINKRATE*" and "*PULL UP, PULL UP*".
- As the aircraft was flying over landing threshold 14, its gear was lowered, the flaps were at  $22^\circ$ , its speed was 178 KIAS and the radio altitude was 186 ft AGL.
- Eighteen seconds after flying over landing threshold 14 and between 1450 and 1650 m after the runway threshold, I-EXME touched down, with flaps set in the  $22^\circ$  position and at a speed of 167 KIAS.
- During the roll-out, the pressure on the brake pedals was released several times and the control columns were pushed forward.
- The aircraft overran the end of runway 14 at a speed of 64 KIAS and came to a standstill on the grass after approximately 150 m.
- The on ground emergency procedure was not executed and the passenger could leave the aircraft normally.

#### 3.1.4 General conditions

- During the approach and landing moderate precipitation was observed by the weather service.
- The flight crew received authorisation from the ATC unit to determine their speed at their discretion.
- From the DFDR recording it can be calculated that during the final approach there was an average tailwind component of 23 kt, which dropped to zero before the aircraft flew over the landing threshold of runway 14.
- Runway 14 at Zurich Airport has an available landing distance of 3150 m.

- According to the information in the airline's operations manual part B (OM-B), for a landing at an airport elevation of 1400 ft AMSL, at 19°C, with a landing mass of 18700 kg, 5 mm standing water and a tailwind component of 10 kt, the aircraft type EMB 145 LR has a minimum required landing distance of 2782 m with the flaps set at 45°.
- According to the information in the airline's operations manual part B (OM-B), for a landing at an airport elevation of 1400 ft AMSL, at 19°C, with a landing mass of 18700 kg, a wet runway and a tailwind component of 10 kt, the aircraft type EMB 145 LR has a minimum required landing distance of 2849 m with the flaps set at 22°.
- In case of standing water of 5 mm or more on the runway or when heavy rain is falling, the aircraft manufacturer specifies a flap setting of 45° for a landing.

### 3.2 Causes

The serious incident is attributable to the fact that after an unstabilised final approach the flight crew made a long landing with excessive speed on a wet runway and were unable to bring the aircraft to a halt on the remaining section of runway available.

The investigation determined the following causal factors for the serious incident:

- The flight crew carried out the speed reduction to late and choosed an aircraft configuration for the landing which was not adapted to the actual situation.
- The commander prevented the copilot from continuing the go-around which had already been initiated.
- The flight crew did not carry out a go-around despite the ground proximity warning systems (GPWS) hard warning indicating an unstabilized final approach.

The following factors may have aggravated the accident:

- The flight crew did not make optimal use of the wheel brakes.
- During the landing procedure, the flight crew pushed the control column forwards markedly, thereby reducing the effectiveness of the wheel brakes.

Berne, 17 May 2006

Aircraft Accident Investigation Bureau

**This report has been prepared solely for the purpose of accident/incident prevention. The legal assessment of accident/incident causes and circumstances is no concern of the incident investigation (Art. 24 of the Air Navigation Law).**

**Glossary**

AAIB / BFU	Aircraft Accident Investigation Bureau / Büro für Flugunfalluntersuchungen
ADC	Aerodrome control (tower)
AGL	Above ground level
AMSL	Above mean sea level
AND	Attitude nose down
ANU	Attitude nose up
APW	Approach control west
ATIS	Automatic terminal information service
BFU / AAIB	Büro für Flugunfalluntersuchungen / Aircraft Accident Investigation Bureau
B-RNAV	Basic area navigation
CVR	Cockpit voice recorder
DFDR	Digital flight data recorder
DME	Distance measuring equipment, by means of which the slant range from the aircraft to the ground station is measured
FAF	Final approach fix
FAP	Final approach point
FL	Flight level
FMS	Flight management system
ft	Feet (1 ft = 0.3048 m)
ATCO	Air traffic controller
GPWS	Ground proximity warning system
G/S	Glide slope
HDG	Heading
hPa	Hecto pascal
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
ILS	Instrument landing system
KIAS	Knots indicated airspeed
kt	Knots (1 kt = 1 NM/h)
METAR	Aviation routine weather report
MSAW	Minimum safe altitude warning system
NM	Nautical Mile (1 NM = 1.852 km)
OM	Outer marker
PF	Pilot flying
PNF	Pilot not flying

QNH	Atmospheric pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere
RA	Radio altitude
ROD	Rate of descent
RWY	Runway
S/N	Serial number
UTC	Universal time coordinated
VERT SPD	Vertical speed
VOR	VHF omnidirectional radio range



## Appendix 1: Chronological sequence of essential events

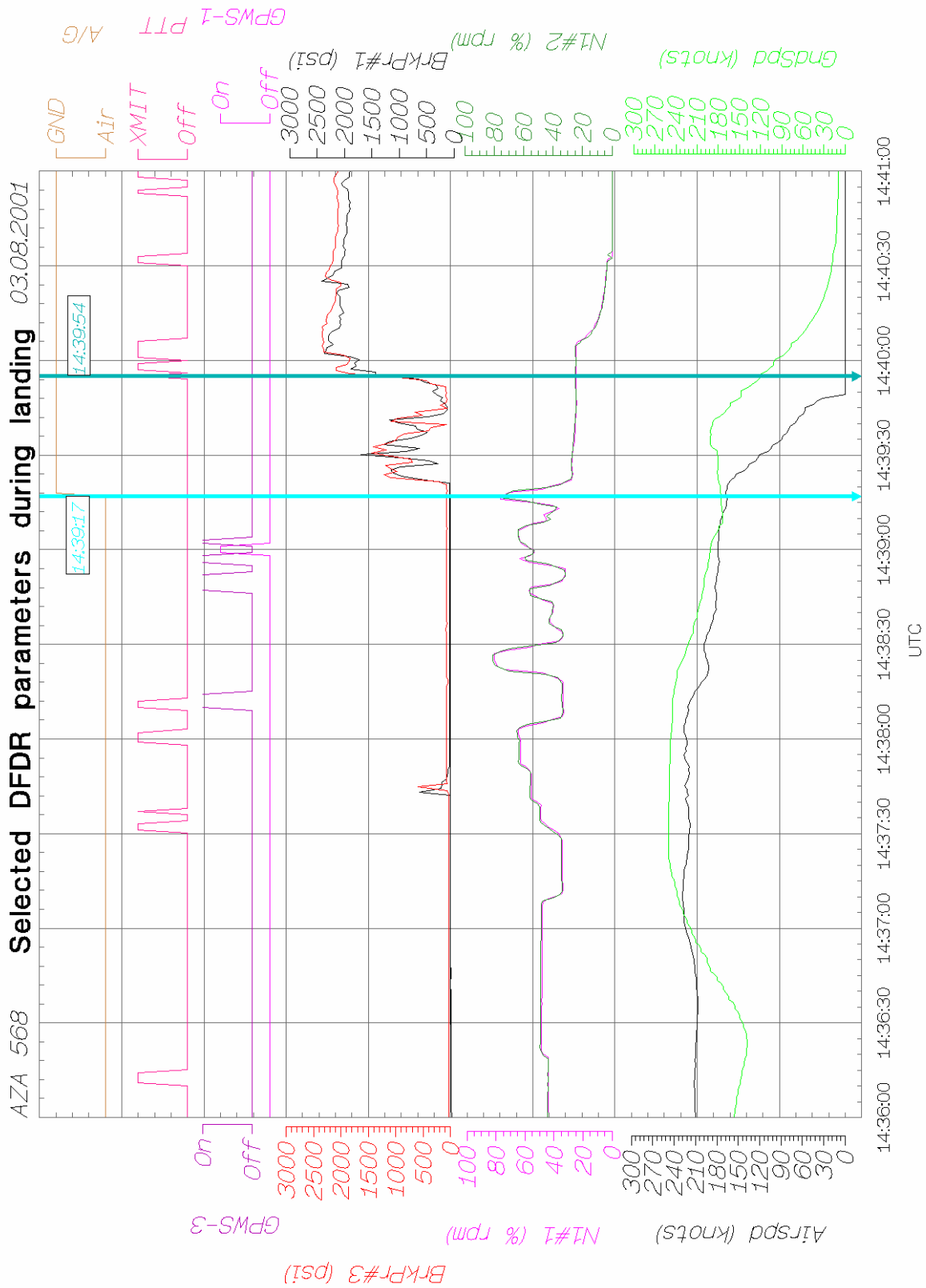
UTC	Event	Comment
14:21:30 – 14:22:40	The flight crew receives the ATIS message Tango: <i>“Zurich Information TANGO: Landing runway 14, ILS approach, departure runway 28, Met report Zurich 1420 ZULU: wind 160 degrees, 4 knots, visibility 4000 m, rain, few 1000, scattered 2500, broken 5000, temperature 19, dew point 18, QNH 1017, tempo visibility 3000 m, transition level 50. Speed limitation 240 kts, except on link route to RILAX. Taxiway KILO between runway two eight and taxiway BRAVO closed, taxiway HOTEL ONE closed.”</i>	
14:26	The copilot briefs the commander for the approach.	
14:31:54	APW informs the flight crew: <i>“AZA 568, twenty four miles touchdown.”</i>	A flight path of 24 NM to touchdown has to be expected. The aircraft is at FL 114.
14:32:32	APW left the choice of speed to the crew, by instructing: <i>“Alitalia five six eight, speed for the time being at your discretion.”</i> To this AZA 568 replied: <i>“We are two four zero and we’ll maintain, Alitalia 568.”</i>	
14:33:12	The aircraft is passing FL 80 in descent, the airspeed is 245 KIAS. The copilot ordered the flaps to be set to 9°.	Increase of the aircraft’s resistance.
14:35:24	AZA 568 leaves FL 60 in order to descend to 4000 ft QNH. The crew sets reference atmospheric pressure QNH to 1017 hPa on both altimeters. The commander then carries out the approach check and in the process mentions: <i>“heavy raining ... se ben ricordo... - heavy rain.... If I recall correctly”</i> .	
14:36:05	APW: <i>“Alitalia five six eight, right heading one one zero, cleared ILS one four, report established”</i> .	Clearance for ILS approach on runway 14
14:37:00	At an ILS-DME distance of 7.5 NM, the aircraft intercepts the glide path from above.	The airspeed is 225 KIAS
14:37:24	Commander: <i>“... 6 miglia, 3400...siamo bassi! ****<sup>1</sup>! 6 miglia 3.2 siamo 200 sotto – 6 miles, 3400... We are low! ****<sup>1</sup>! 6 miles 3.2 we’re 200 under”</i>	AZA 568 is approximately at an ILS-DME distance of 5.8 NM at 3170 ft in relation to the QNH of 1017 hPa.
14:37:30	AZA 568: <i>“Fully established one four, Alitalia five six eight”</i>	

<sup>1</sup> Expressions which constitute a spontaneous personal assessment of the current situation as well as personal utterances without any direct relation to the incident are identified by \*\*\*\*

UTC	Event	Comment
14:37:37	Audio warning "LANDING GEAR" is triggered.  The crew lowers the landing gear.	I-EXME flies over the Stadlerberg at an ILS-DME distance of 5 NM.  ILS-DME distance: 4.1 NM, airspeed: 220 KIAS
14:37:53	Commander: "4 miglia 2730,...200 sotto ancora! – 4 miles 2730,...still 200 under!"	ILS-DME distance: 3.7 NM, Altitude: 2540 ft with reference to the QNH of 1017 hPa
14:37:58	AZA 568: "Zurich grüezi, Alitalia five six eight fully established one four". TWR: "Alitalia five six eight, Zurich Tower, good afternoon, cleared to land runway one four, wind one niner zero degrees, four knots".	
14:38:09 – 14:38:14	Warning from the ground proximity warning system (GPWS) sounds: "TOO LOW, TERRAIN".	ILS-DME distance: 2.7 NM Altitude 2220 ft AMSL or 820 ft AAL
14:38:12	Copilot: "Riattacco – Go-around", switches off the autopilot, alters the pitch of 1° angle nose down (AND) to 5.8° angle nose up (ANU) and pushed the engine power lever forward. The commander interrupts the go-around: "No, Andiamo sotto!– No, we're going down!" and orders the flaps to be set at 22°. The commander simultaneously points out that it would be possible to land with flaps set at 22°: "Male che va, andiamo giù con flaps a 22...".	Interrupted go-around
14:38:46 – 14:38:53	GPWS warning: „SINKRATE, SINKRATE“.	
14:38:55 – 14:39:04	GPWS warnings: „SINKRATE, SINKRATE“ - „PULL UP, PULL UP“ - "SINKRATE, SINKRATE"	At 14:38:59 AZA 568 crosses the landing threshold 14 at a radar altitude of 187 ft. The airspeed was 178 KIAS and the sinkrate was up to 1740 ft/min.
14:39:17	I-EXME touches down on the wet runway 14 with flaps set in the 22° position and at a speed of 167 KIAS.	
14:39:19	Commander: „Frena! Frena! Frena! Frena! – Brake! Brake! Brake! Brake!“	
14:39:22	Build up of braking pressure	Speed: 160 KIAS
14:39:23	Copilot: „Piano! Piano! Piano! Piano! Piano!...Non ce frega niente! – Slowly! Slowly! Slowly! Slowly! Slowly!...We don't worry!“	
14:39:26	Copilot: "*****...piano...stiamo uscendo! – *****...slowly...we are going out!"	
14:39:30	Commander: „Si, Ce l'ho con lo steering! Eh... - Yes, I got it on the steering! Eh...“	

UTC	Event	Comment
14:39:33	Copilot: <i>"No! No! Andiamo dritti! – No! No! Let's go straight!"</i>	
14:39:36	Commander: <i>„Andiamo nel prato! Andiamo nel prato! ***** *****! – We are going into the grass! We are going into the grass! ***** *****!"</i>	
14:39:40	Copilot: <i>"Vai dritto! Vai dritto! – Go straight! Go straight!"</i>	
14:39:44	Commander: <i>„ ***** ***** *****!"</i>	
14:39:54	The aircraft comes to a complete stop.	
14:40:51	AZA 568: <i>„Zurich AZA 568?"</i>	
14:40:54	TWR: <i>„Yes, AZA 568"</i>	
14:41:56	AZA 568: <i>„We are down the runway in the field and we request some assistance"</i>	
14:41:01	TWR: <i>"Yes, äh, we informed al...already the fire brigade, they are coming"</i>	
14:41:06	AZA 568: <i>"Well, thanks madam, and we will maintain this position and I think is ok, there is no fire, I need a bus to disembark the passengers."</i>	
14:41:14	TWR: <i>"Yes, thank you for information."</i>	

### Appendix 2: Selected DFDR Parameters



Swiss AAIB

Created: March 21, 2005

### Appendix 3: The site of the incident





### Appendix 4: Plot of Doppler weather radar of the FIT for 14:40 UTC

