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Swiss Transportation Safety Investigation Board STSB

Final Report No. 2303 by the Swiss Transportation Safety Investigation Board STSB

concerning the accident involving the ATR 72-202 commercial aircraft, registration D-ANFE,

on 4 December 2014

on runway 14
of Zurich Airport (LSZH)

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Ursachen

Der Unfall ist darauf zurückzuführen, dass während der Landung das Bugfahrwerk nicht zentriert war und somit die beiden Bugräder nicht frei drehen konnten. In der Folge war die Kontrolle über die Steuerung des Bugfahrwerkes, das erheblich beschädigt wurde, nicht mehr gegeben.

Das Zusammenwirken der folgenden Faktoren wurde als wahrscheinlichste Ursache für den Unfall ermittelt:

- ein am Bugfahrwerk um 180° verdreht angeschlossener Eingabehebel (*valve input lever*) des Differentialsteuerventils;
- mangelhafte Instandhaltung des Bugfahrwerkes.

Die Möglichkeit, den Eingabehebel (*valve input lever*) aufgrund seiner baulichen Auslegung (*design*) um 180° verkehrt anschliessen zu können, wurde als beitragender Faktor ermittelt.

Die im Rahmen einiger Stunden später durchgeführten Pistenkontrolle (*runway inspection*) vorgefundenen Kleinteile des Flugzeuges auf der Piste haben die Entstehung und den Verlauf des Unfalls zwar nicht beeinflusst, stellen aber dennoch ein Sicherheitsrisiko (*factor to risk*) dar.

General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances and causes of the accident which is the subject of the investigation.

In accordance with Art 3.1 of the 10th edition, applicable from 18 November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the German language.

All information, unless otherwise indicated, relates to the time of the accident.

All times in this report, unless otherwise indicated, are stated in coordinated universal time (UTC). At the time of the accident, Central European Time (CET) applied as local time in Switzerland. The relation between LT, CET and coordinated universal time (UTC) is:
LT = CET = UTC + 1 hour.

Contents

Final report

Synopsis

Owner	BKM Luftfahrt-GbR, 63654 Büdingen, Germany
Operator	Avanti Air GmbH & Co.KG, 57299 Burbach, Germany
Manufacturer	Avions de Transport Régional (ATR), Toulouse, France
Aircraft type	ATR 72-202
Country of registration	Germany
Flight number	F7 286
Registration	D-ANFE
Location	Zurich Airport (LSZH)
Date and time	4 December 2014, 07:02 UTC

Investigation

The accident occurred at 07:02 UTC. The notification was received at 07.20 UTC. The investigation was opened immediately by the Swiss Transportation Safety Investigation Board (STSB). The STSB informed the following states of the accident: Canada, Germany and France. Germany and France designated an authorised representative who assisted with the investigation.

This final report is published by the STSB.

Summary

At 05:33 UTC on 4 December 2014 the ATR 72-202 aircraft, registration D-ANFE, took off from Dresden airport (EDDC) on a scheduled flight to Zurich (LSZH), with two pilots, two flight attendants and 26 passengers on board.

After an uneventful descent and approach, D-ANFE touched down normally at 07:02 UTC on runway 14 at Zurich airport in a light northerly wind. After the nose landing gear wheels had come into contact with the runway approximately 1050 m after the runway threshold, both tyres separated from the wheel rims, whereby the left tyre got blocked between the wheel rims and the right tyre completely detached and was found 2080 m after the runway threshold. The nose landing gear continued to slide only on the wheel rims approximately 1520 m after the runway threshold.

By means of an asymmetrical power setting of the two engines and asymmetrical braking of the main landing gear wheels, the flight crew managed to vacate the runway at the next intersection. The flight crew then requested the fire brigade, as they suspected there was a problem with the landing gear.

All the occupants were uninjured. The passengers left the aircraft using the onboard steps and were taken by bus to the arrival terminal.

The runway was closed immediately after this event and re-opened for operation with a reduced rate of arrivals after a runway inspection at 08:07 UTC.

Causes

The accident is attributable to the fact that during landing the nose landing gear was not centred and so the two nose gear wheels could not turn freely. Subsequently it was no longer possible to exercise control via the nose landing gear steering system, as the nose landing gear was substantially damaged.

The interaction of the following factors was determined as the most probable cause of the accident:

- a valve input lever of the differential control selector valve which had been fitted to the nose landing gear in an inverted state (rotated through 180°);
- inadequate maintenance of the nose landing gear.

The fact that the valve input lever can be attached incorrectly, in an inverted state (rotated through 180°) as a result of its structural design was determined to be a contributing factor.

Though the small parts of the aircraft found on the runway during a runway inspection performed hours later did not contribute to the origin and history of the accident, they nevertheless constitute a factor to risk

Safety recommendations and safety advices

One safety recommendation, however no safety advice is issued with the final report.

1 Factual information

1.1 Flight preparations and history of the flight

1.1.1 General

The recordings of the radiotelephony, cockpit voice recorder, flight data recorder, radar data and a video camera, together with the statements of the crew members, were used for the following description of the pre-flight history and the history of the flight.

Throughout the flight the commander was pilot flying (PF) and the copilot was pilot monitoring (PM).

The flight was operating under instrument flight rules (IFR). It was a commercial flight from Dresden (EDDC) to Zurich (LSZH) on behalf the airline Etihad Regional under flight number F7 286.

1.1.2 Pre-flight history

The nose landing gear (NLG) on an aircraft of the same type, registration D-ANFC, was sent for overhaul to the AAR Corporation in January 2014. The differential control selector valve (DCSV) (cf. Section 1.6.2.6) was examined and repaired.

After the overhauled NLG was refitted on D-ANFC on 10 March 2014, the flight crew complained on 25 March 2014 that the nose wheel steering was stiff. The subsequent rolling tests confirmed this observation and a further examination showed that the pressure indication with the nose wheel steering switched on fell faster than in the off position (cf. Section 1.6.2.6). Also, hissing in the hydraulic system was perceivable, as if there was a leak somewhere. However, an external inspection of the DCSV in connection with this provided no evidence.

It was subsequently decided to replace the DCSV (P/N: C24568000-4 S/N: U284) fitted to D-ANFC with the one from D-ANFE. The problem of the stiff nose wheel steering was then eliminated and the aircraft again behaved normally when rolling.

The DCSV (P/N: C24568000-4 S/N: U284) removed from D-ANFC was sent for inspection under warranty to AAR Corporation. In the corresponding teardown report it was noted that the functional tests were successful according to the manufacturer's standards and the complaints could not be reproduced.

The identically constructed DCSV provided as a replacement (S/N: U356) was fitted on 6 May 2014 to D-ANFE. No report on the subsequent functional tests is available (cf. Section 1.6.2.6.4). Since that time and up to the day of the accident, there had not been any complaints from flight crews in the technical logbook in relation to any stiffness in the nose wheel steering.

On the basis of a complaint by the same flight crew which was involved in the accident on the following day, on 3 December 2014 the following entry was made in the D-ANFE technical logbook:

"*Crew reported after touchdown A/C moves to the right without any brake or engine reverse, also during taxi* […]*."*

As noted in the technical logbook, after detailed fault-finding without being able to reproduce the original complaint in a rolling test, brake unit 3 on the right main landing gear was replaced because of a hot back plate.

1.1.3 History of the flight

At 05:33 UTC on 4 December 2014, aircraft ATR 72-202, registration D-ANFE, took off from Dresden airport (EDDC) on a scheduled flight to Zurich (LSZH). On

board the aircraft under the flight plan call sign DWT286 and the radio call signal "*Darwin two eight six"* were two pilots, two flight attendants and 26 passengers.

As the result of a fault, during the cruising flight the air conditioning system unit 1 had to be reset once; thereafter it functioned normally for the remainder of the flight.

After an uneventful descent and approach, D-ANFE touched down normally at 07:02 UTC on runway 14 at Zurich airport in a light northerly wind. According to the flight crew's statements, the touchdown of the main landing gear and the nose landing gear occurred normally.

After the nose landing gear wheels had come into contact with the runway approximately 1050 m after the runway threshold, the tyre of the right nose landing gear wheel separated from the nose landing gear during landing roll. The nose landing gear continued to slide on the wheel rims approximately 470 m after nosewheel touchdown (cf. Section 1.12.1). The commander later stated that shortly before reaching intersection H1 he had noticed that the steering was not functioning correctly.

At 07:04:12 UTC the copilot then reported the following to the air traffic controller (ATCO) in the aerodrome control tower (TWR): *"Darwin two eight six uh we have a problem, we're on the runway trying to vacate."* He also requested the ATCO to summon the fire brigade because he suspected hot brakes.

Steering was then performed by the flight crew by means of asymmetrical power setting of the two engines and by asymmetrical braking of the main landing gear wheels. The ATCO then instructed the crew to vacate the runway, if possible via intersection H1[1] . This was also the flight crew's intention, since the vibrations increased during landing roll.

The two flight attendants later stated that after touchdown the aircraft had deviated somewhat to the right and the landing roll-out felt as if the runway was very bumpy.

The aircraft was brought to a standstill shortly afterwards at the Category (CAT) 1 stop bar on taxiway (TWY) H1.

The fire-brigade arrived shortly afterwards at the aircraft and examined the brakes for overheating.

Once the aircraft had come to a standstill, the copilot asked the ATCO for a runway inspection of runway 14 to be performed, since he suspected there had been problems with the tyres and consequently damage to the runway. The runway inspection was undertaken immediately; a tyre from the nose landing gear of D-ANFE was found on the centre line of runway 14 approximately 2080 m from the runway threshold (cf. Section 1.10.3). In addition, abrasion marks were found; however, these were not assessed as restrictive for the continued operation of runway 14.

The commander informed the cabin crew that there was a technical problem and that the fire brigade was on site for safety reasons. He also informed the passengers that they would be able to disembark the aircraft normally after the arrival of the passenger bus.

All the occupants were uninjured. They were able to disembark the aircraft using the onboard steps and were taken by bus to the arrival terminal.

The runway was closed immediately after the event. As a result, four aircraft which were on approach behind D-ANFE had to go around. After a subsequent inspection

[1] H1 is to the first possibility of vacating runway 14 (see Annex 1).

at 08:07 UTC, the airport operator cleared runway 14 for operation at a reduced arrival rate. The first landing after reopening took place at 08:20 UTC.

1.1.4 Location and time of the accident

Location of the accident	Runway 14 at Zurich Airport, Switzerland
Date and time	4 December 2014, 07:02 UTC
Lighting conditions	Daylight
Coordinates	N 47° 28' 29" / E 008° 32' 47" (WGS 84)
Elevation	423 m AMSL corresponding to 1387 ft AMSL[2]
Final position of the wreckage	South of the stop bar on taxiway H1

1.2 Injuries to persons

1.2.1 Injured persons

Injuries	Crew members	Passengers	Total number of occupants	Other
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	4	26	30	Not applicable
Total	4	26	30	0

1.3 Aircraft damage

The nose landing gear of the aircraft was substantially damaged (cf. Section 1.12.2).

1.4 Other damage

The runway was inspected after the accident, but not mechanically cleaned (cf. Section 1.17.1). Apart from a few tyre marks and abrasion marks, there was no other substantial damage. A 2 metre long section of the surface was repaired at a later date.

On the afternoon of the day of the accident, a second extensive inspection of runway 14 and taxiway H1 was performed (cf. Section 1.10.4). During this inspection, small parts were found (cf. Figure 9).

1.5 Personnel information

1.5.1 Commander

Person	Dutch citizen, born 1963
Licence	Airline transport pilot licence aeroplane (ATPL(A)) according to the standards of the European Aviation Safety Agency (EASA) issued by the Civil Aviation Authority (CAA) of the Netherlands

[2] AMSL: above mean sea level

Flying experience	Total	7278 hours
	On the type involved in the accident	1596 hours
	During the last 90 days	81:15 hours
	Of which on the type involved in the accident	81:15 hours

All the available information indicates that the commander was rested and healthy when he came on duty. There are no indications that fatigue played a part at the time of the accident.

1.5.2 Copilot

Person	German citizen, born 1977	
Licence	Commercial pilot licence aeroplane (CPL(A)) according to joint aviation requirements (JAR) issued by the Deutsche Luftfahrt-Bundesamt (LBA)	
Flying experience	Total	1820 hours
	On the type involved in the accident	1195 hours
	During the last 90 days	85:01 hours
	Of which on the type involved in the accident	85:01 hours

All the available information indicates that the copilot was rested and healthy when he came on duty. There are no indications that fatigue played a part at the time of the serious accident.

1.5.3 Cabin crew

The two members of the cabin crew, born in 1975 and 1977 respectively, were German citizens.

1.6 Aircraft information

1.6.1 General information

Registration	D-ANFE
Aircraft type	ATR 72-202
Characteristics	Twin-engined regional aircraft with turboprop power plant, constructed as cantilevered high-wing in full metal construction with retractable landing gear in nose landing gear configuration
Manufacturer	Avions de Transport Régional (ATR), Toulouse, France
Year of manufacture	1991
Serial number	272
Owner	BKM Luftfahrt-GbR, 63654 Büdingen, Germany
Operator	Avanti Air GmbH & Co.KG, 57299 Burbach, Germany
Engine	Pratt & Whitney (PW) 124 B

Propeller	Four-blade variable-pitch propeller	
Relevant equipment	Passenger version with upper cargo door; no tyre pressure indication system (TPIS) installed.	
Hours of operation, airframe	43 937 hours TSN[3]	45 330 CSN
Of which NLG	34 366 CSN	7581 CSO
Hours of operation / number of landings of the DCSV (S/N U356, P/N C24568000-4) since installation on 6 May 2014	565:48 hours	532 FC
Mass and centre of gravity	Both the mass and centre of gravity were within the permitted limits according to the aircraft flight manual (AFM).	
Last planned maintenance	Airframe A-check on 10 November 2014 at 43883 TSN and 45283 CSN	
	NLG A-check on 10 November 2014 at 34 319 CSN	
	Line and weekly check in the night of 4 December 2014 (approx. 02:00 UTC)	
Technical restrictions	None	
Authorised fuel grade	Kerosene JET A1	
Fuel on board	According to the flight plan, the fuel on board on approach to Zurich Airport included approximately 400 kg of extra fuel, allowing 40 minutes of holding procedures.	
Registration certificate	Issued by the Deutsche Luftfahrt-Bundesamt (LBA) on 23 May 2013 valid till removal from the aircraft register	
Airworthiness certificate	Issued by the LBA on 23 May 2013	
Airworthiness review certificate	Date of issue: 29 August 2014	
	Date of expiry of validity: 18 September 2015	
Area of certification	Commercial	
Category	IFR by day/night, IFR Category II	
Modifications	None relevant to the accident	

1.6.2 Selected aircraft systems and equipment

1.6.2.1 General

The only systems described below are those which were of significance in regards to the accident; in the present case these consisted of the most important assemblies of the nose landing gear.

[3] TSN: time since new, TSO: time since overhaul, CSN: cycles since new, CSO: cycles since overhaul, FC: flight cycles

1.6.2.2 NLG assembly description

The nose landing gear of the ATR 72-202 is of the forward retractable type. It consists of a leg assembly and a drag brace, which is not shown in Figure 1. The leg assembly incorporates the shock absorber and the nose wheel steering actuating system. This is composed of the differential control selector (DCSV) which controls the hydraulic control pressure and delivers this pressure to the nose wheel steering actuator. When a steering force is applied, the nose wheel steering actuator transfers the control pressure to the rotating tube which is connected to nose gear wheels.

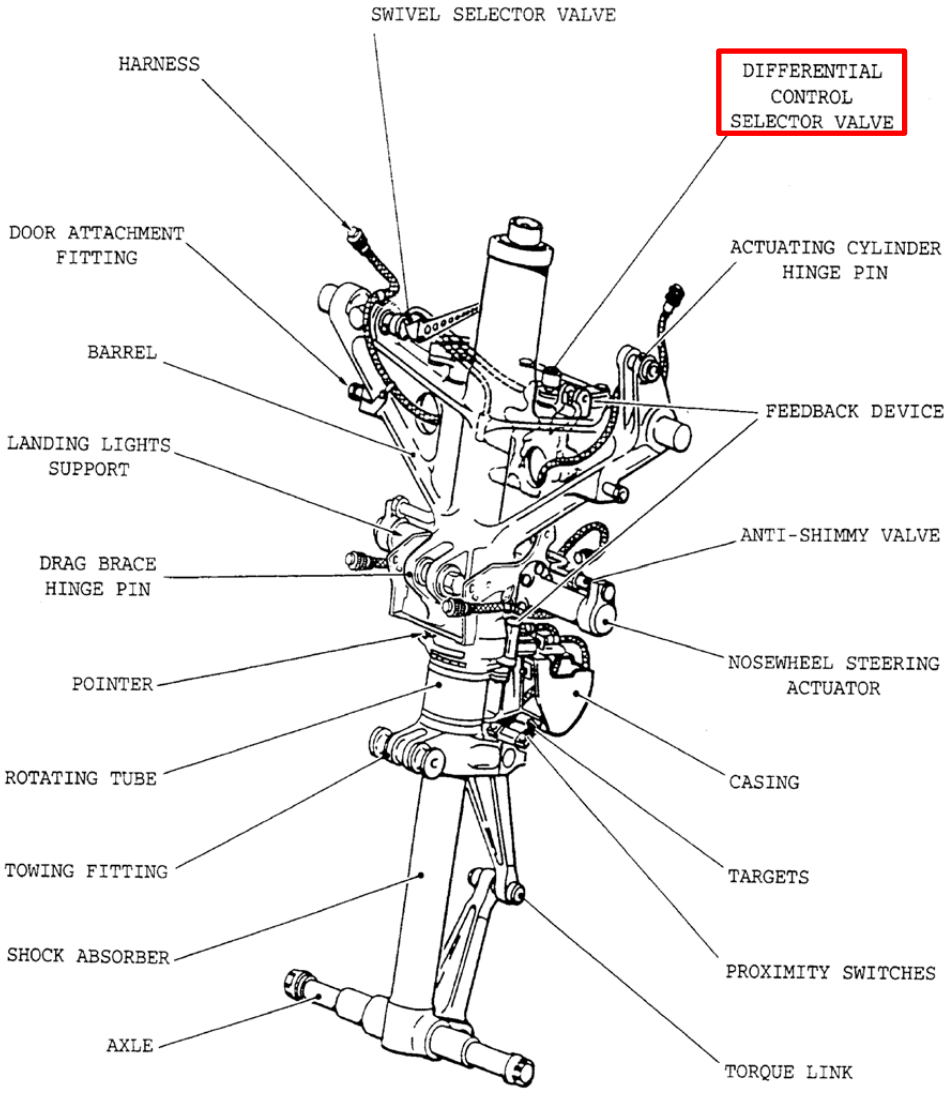

Figure 1: Illustration of the nose landing gear components with the description differential control selector valve (DCSV) framed in red

The drag brace maintains the landing gear in either the retracted or extended position. There are no sensors which register the locking of the nose wheels. The turning angle is fed back exclusively mechanically to the steering tiller in the cockpit. The DCSV and the nosewheel steering actuator are mounted on the back side of the nose landing gear unit and are therefore difficult to see and reach.

1.6.2.3 Nose landing gear shock absorber

The nose landing gear is equipped with a double-acting hydropneumatic shock absorber. The latter absorbs the energy acting on the nose landing gear during landing as well as the deflections which occur when taxiing on uneven surfaces.

The shock absorber consists of an inner tube which is linked to the barrel and a concentric sliding rod on which the axle for the two nose wheels is fixed. The inner tube and the sliding rod are each equipped with a cam which interlink and thus ensure the nose wheels are centred when the shock absorber is fully extended, i.e. the nose landing gear is not in a compressed state (cf. Figure 2).

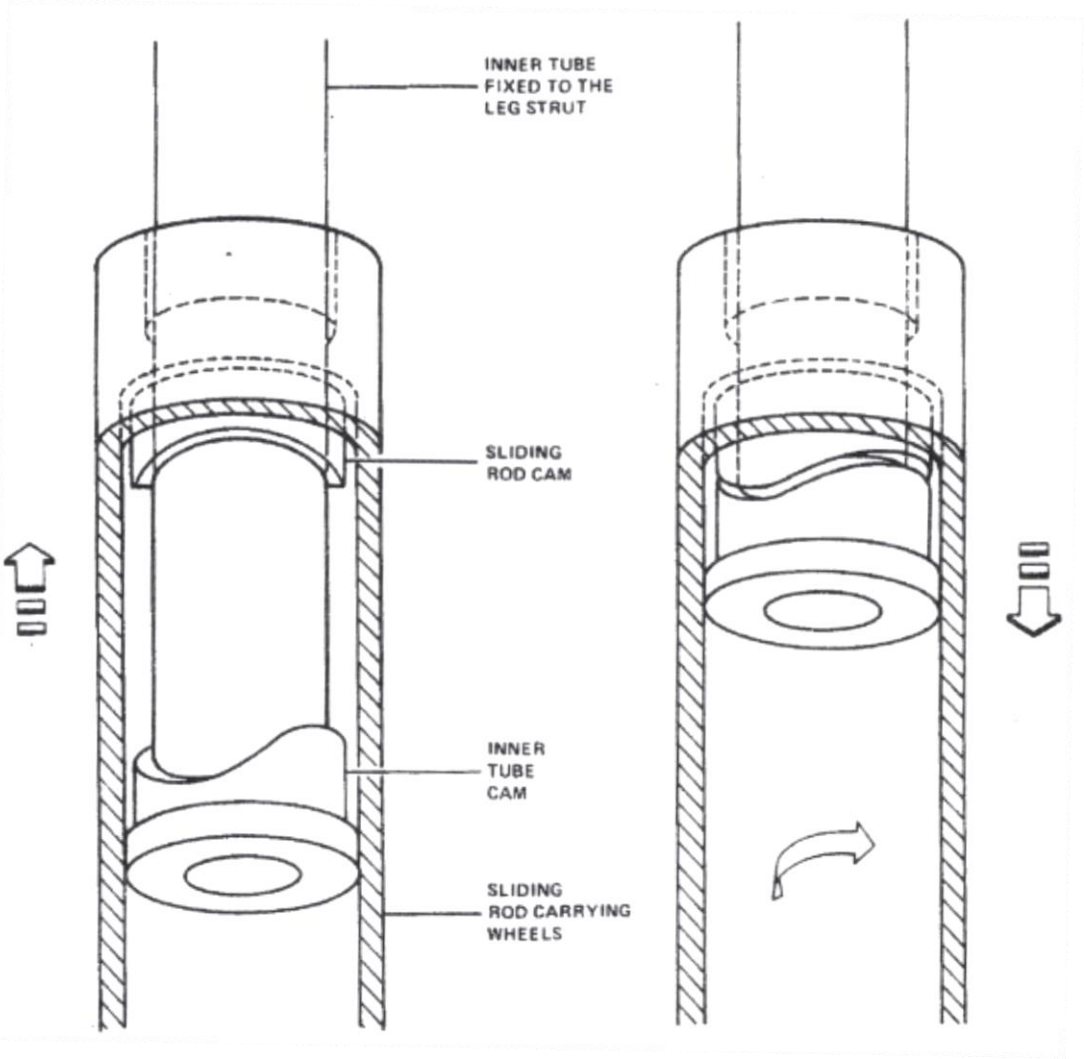

Figure 2: Illustration of the nose landing gear shock absorber in the compressed state on the left and in the extended state on the right, in which the nose landing gear is centred via the cams.

1.6.2.4 Steering mechanism

The nose wheel steering (NWS) system is hydraulically powered and is operated from a mechanical tiller in the cockpit on the captain's side below the left side window. The tiller operates a complex system consisting of control cables, cranks and control levers to deliver mechanical inputs to the differential control selector valve (DCSV) (cf. Section 1.6.2.6).

The tiller can rotate 112° on each side corresponding to maximum nose wheel steering angles of 60° to the left and right. A spring mechanism assembly centres

the tiller control when it is released and returns the nose wheels to the neutral position.

The differential control selector valve (DCSV) translates the mechanical inputs from the tiller control in the cockpit into hydraulic control signals to the nose wheel steering actuator. This generates hydraulic forces to turn the nose wheels up to 60° left or right from centre. A feedback device interrupts the hydraulic pressure in the DCSV once the desired turning angle has been attained.

1.6.2.5 Retraction and extension of the nose landing gear

The nose landing gear (NLG) can retract only when the aircraft is no longer in ground mode.
With the nose wheels not centered, the shock absorber is not fully extended due to the two cams (cf. Figure 2). As a consequence, the proximity switches cannot detect the NLG in air mode and the NLG cannot be retracted.

1.6.2.6 Differential Control Selector Valve (DCSV)

1.6.2.6.1 Description

The differential control selector valve (DCSV) is mounted above the nose wheel steering actuator on the rear side of the nose gear. Two hydraulic lines connect the nose wheel steering actuator to the DCSV and this in turn is connected via two hydraulic lines to the blue hydraulic system (pressure and return lines). On its upper side the DCSV is mechanically connected via the valve input lever and the feedback device and other components to the tiller control in the cockpit. In turn the valve input lever is connected to a rocking plate which drives the DCSV through a control piston. In addition it has a control valve which connects both hydraulic lines to the nosewheel steering actuator control valve in order to allow free rotation of the NLG assembly during towing operations. In addition this assembly acts as an anti-shimmy. With the DCSV in its disassembled state, the valve input lever can rotate freely; add to this, it is not symmetrically constructed – one end is longer than the other (cf. Figure 3).

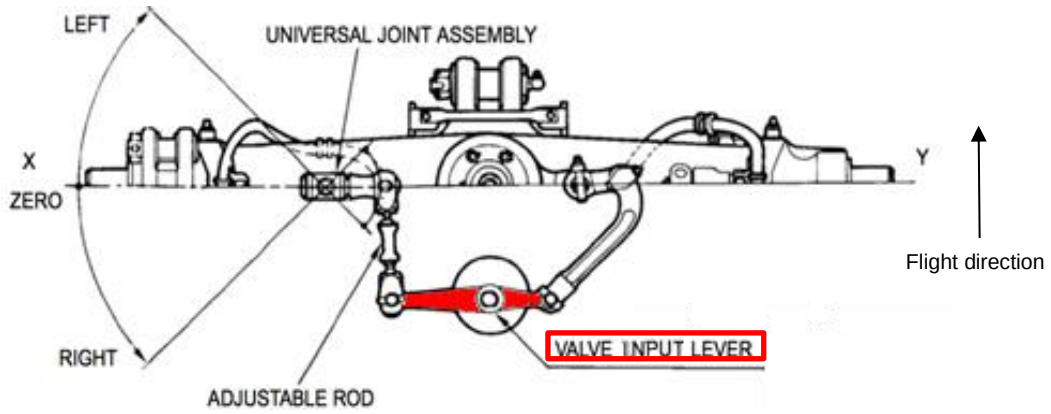

Figure 3: Illustration of the differential control selector valve (DCSV) with the valve input lever framed in red and the input angle (X) in a range of - 36 degrees to + 36 degrees.

Hydraulic pressure to the DCSV can be interrupted by either an electric solenoid valve or a swivel valve. The electric solenoid valve can be operated by the guarded nose wheel steering switch (N/W STEERING SW) in the cockpit or via the multi-function computer (MFC). Before aircraft towing operations, the nosewheel steering must be switched off to prevent damage. Depending on whether the aircraft is in the air or on the ground, the MFC releases hydraulic pressure to the

DCSV. The swivel valve mechanically interrupts the hydraulic pressure when the nose gear is not extended and locked.

1.6.2.6.2 Operation

When the valve input lever is actuated the axis of the rocking plate is moved by up to 5°, which in turn causes the control piston to move up or down. The DCSV then applies hydraulic pressure accordingly to the nose wheel steering actuator until the feedback device returns the valve input lever to the neutral position and ceases rotation of the NLG assembly.

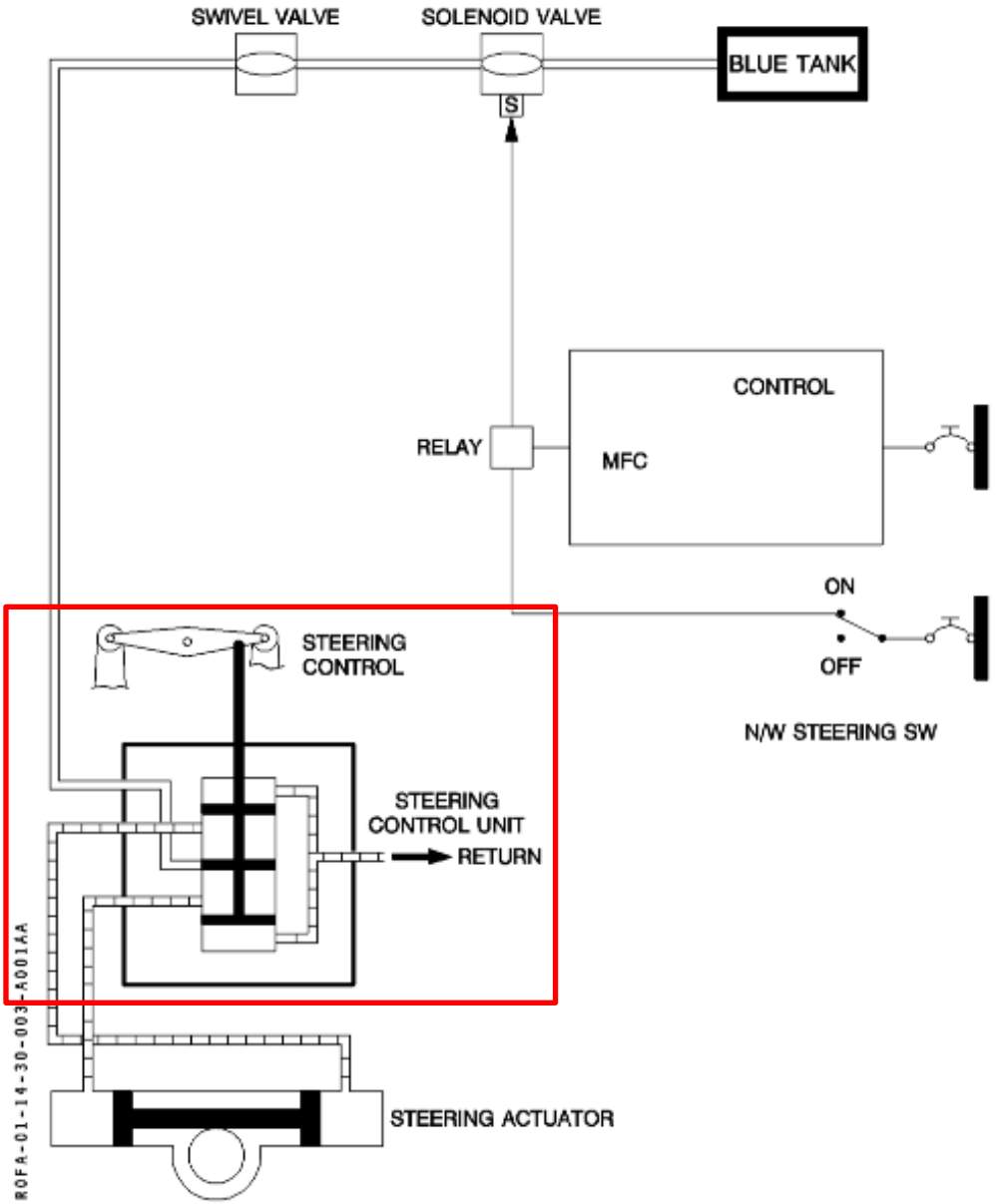

Figure 4: Hydraulic circuit for the nose wheel steering with the DCSV in simplified representation (framed in red)

1.6.2.6.3 Removal and Installation of the DCSV

In the maintenance instructions (aircraft maintenance manual), the following comments are provided in Section 32-51-00:

"Item 003 (Removal) To prevent any inversion during the re-installation of the differential control selector valve, notice the position of the valve input lever."

"Item 004 (Installation) Place the differential control [*selector*] *valve input lever in position noted during the removal, with the long leg of the valve input lever pointing at the left side of the aircraft."*

The aforementioned comments in the manual were the consequence of an incident whereby an aircraft was operated with a DCSV which had an incorrectly positioned valve input lever. The valve input lever, which had been rotated about its longitudinal axis by 180° before being attached, caused the nose wheel steering to be stiff to operate and the nose wheels could not be correctly steered (cf. Section 1.18.1).

After installation of the DCSV the functional test is referred to as follows "*Item 006 (functional test steering system): see job instruction card 325100-FUT-10000".*

1.6.2.6.4 Functional check of the steering system

After the usual warning and safety instructions and the preparation of the electric and hydraulic systems, the following functional test is prescribed in the AMM[4] 32-51-00 FUT 10000-001 in Section 005 (original in English):

1. Move the tiller slowly and fully in one direction, and check that:
    - the movement of the nosewheel landing gear is synchronized with that of the tiller.
    - immediately after the tiller stops, the nosewheel landing gear also stops
    - no high spots can be felt.
2. Check that the maximum displacement of the nosewheel landing gear in relation to the neutral position is between 57° and 63°.
3. Repeat the operation moving the tiller in the opposite direction.
4. Move the tiller control as rapidly as possible from stop to stop, and check that the time taken by the nosewheel landing gear to move is between 5 and 7 seconds.
5. Release the tiller from max LH and RH positions and verify that the nosewheel landing gear autonomously returns to the neutral position and deviation (non-return-to-zero) is less than 5°.
6. Verify that the difference in the LH and RH non-return-to-zero angles is max 1°.

Note: If the limits of steps 2, 5 and 6 above are exceeded, job instruction card 325100-ADJ-10000 should be followed.

1.7 Meteorological information

1.7.1 General weather situation

Switzerland was between a bridge of high pressure over northern central Europe and a low pressure system over the Tyrrhenian Sea. Extensive layered clouds covered central Europe and the northern foothills of the Alps. In the Zurich area the cloud ceiling was at approximately 4300 ft AMSL, at the base of a distinct temperature inversion.

Below the inversion light winds were blowing from the east to south-east sector. In the highest 100 to 200 m of the layered clouds, there was a presence of hoarfrost.

[4] AMM: aircraft maintenance manual, FUT: functional test

In lower layers of cloud, icing was not expected. Above the stratus, fields of altocumulus with virgae headed north north-east.

Weather/cloud	5/8 – 7/8, 600 ft AAE[5]
Visibility	7 km
Wind	Variable, 2 kt
Temperature/dew point	3 °C / 2 °C
Atmospheric pressure (QNH)	1013 hPa (pressure reduced to sea level, calculated using the values of the ICAO[6] standard atmosphere)
Hazards	None

1.7.2 Astronomical information

Position of the sun	Azimuth: 124°	Elevation: 1°
Lighting conditions	Daylight	

1.8 Aids to navigation

The relevant navigation aids were in normal operation and were fully available.

1.9 Communications

Radiocommunications between the flight crew and the air traffic control units took place in English and without any technical difficulties.

1.10 Aerodrome information

1.10.1 General

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

1.10.2 Runway equipment

Zurich Airport is characterised by a system of three runways. Runways 16 and 14 are equipped with a Category III instrument landing system (ILS) and runway 34 is equipped with a Category I ILS. Runway 28 is equipped with an uncategorised ILS which features increased weather minima compared to Category I. These runways are therefore suitable for precision approaches.

The runways at Zurich Airport have the following dimensions:

Runway designation	Dimensions	Elevation of the runway thresholds
16/34	3700 x 60 m	1390/1388 ft AMSL
14/32	3300 x 60 m	1402/1402 ft AMSL
10/28	2500 x 60 m	1391/1416 ft AMSL

At the time of the accident all three runways were available for landings with their entire runway length.

1.10.3 First runway inspections

The runway inspection was undertaken immediately after the landing of D-ANFE

[5] AAE: above aerodrome elevation

[6] ICAO: International Civil Aviation Organization

from intersection H3 (runway 32 threshold cf. Annex 1) at 07:06 UTC. The runway inspection was performed visually, slightly offset to the right of the centre line, along the runway. A tyre from the nose gear of D-ANFE was found on the runway centre line approximately 2080 m from the threshold of runway 14 (cf. Figure 5).

Figure 5: During the inspection of runway 14 after the landing of D-ANFE the tyre of the right nose wheel was found approximately 2080 m from the runway threshold. Beside it, white and black traces are visible.

According to the statement of the Airport Manager, who performed this inspection, he was unable to find any other parts of the nose landing gear at the location where the tyre was found. After he had recovered the tyre, he continued the inspection until the end of runway 14, turned and - again slightly offset to the right of the centreline - drove back along the centre line of runway 14 towards the starting position. As he did so, he noticed black rubber traces, which later turned to white and black traces (cf. Figure 5). According to his statements, he did not assess the traces as restrictive for flight operations.

At intersection H1 the Airport Manager vacated runway 14 again and drove to the aircraft, where he co-ordinated with the fire brigade, the airport and the police. At this point he did not yet want to reopen the runway, as he intended to carry out another runway inspection. Just before 08:00 UTC he set off, with a member of the fire brigade who acted as a driver, along the centre line, from intersection H1 as far as intersection G, where they turned round and drove back along the centre line to intersection H1. A speed of 60 km/h was maintained; this was 5 km/h below the maximum speed for a runway inspection. These drives were additionally recorded using the Airport Manager's camera in video mode. Nothing remarkable was found during this inspection. After this inspection, runway 14 was cleared for operations by the Airport Manager at 08:07 UTC.

1.10.4 Second runway inspection

At approximately 13:30 UTC, a second inspection of runway 14 was performed in the presence of the Flughafen Zurich AG construction maintenance department and two representatives of the STSB. More parts of the tyres, metal slivers and a balance weight from the nose landing gear of D-ANFE were found (cf. Figure 9). During this inspection, it was ascertained that a 2 m long section of the surface

would have to be repaired and that this would probably be performed in the spring or summer of 2015.

1.10.5 Rescue and fire-fighting services

Zurich Airport is equipped with Category 10 fire-fighting resources. The airport's professional fire brigade is on permanent stand-by during flight operations.

1.11 Flight recorders

1.11.1 Flight data recorder

1.11.1.1 General information

Type	UFDR
Manufacturer	Sundstrand Data Control Inc.
Year of manufacture	1983
Serial number	2145
Number of parameters	131
Recording medium	Solid state memory
Duration of recording	Approx. 30 hours

It was possible to analyse the digital flight data recorder (DFDR) and all available data was at the disposal of the investigation. The positions of the foot pedals and tiller control are not recorded (cf. Section 1.6.2.4).

1.11.2 Cockpit voice recorder

1.11.2.1 General information

Type	Model FA2100
Manufacturer	L3 Communications
Year of manufacture	2005
Serial number	000352580
Number of parameters	4 audio channels
Recording medium	solid state memory
Duration of recording	2 hours

It was possible to analyse all four channels of the cockpit voice recorder (CVR) which were at the disposal of the investigation.

1.12 Wreckage and impact information

1.12.1 Impact and site of the accident

As is evident from the video recordings, the landing manoeuvre and touchdown of the wheels occurred normally. The nose wheels came into contact with the runway approximately 1050 m after the runway threshold 14. Subsequently both tyres separated from the wheel rims, whereby the left tyre got blocked between the wheel rims and the right tyre completely detached and was found 2080 m after the runway threshold. It was possible to measure the first abrasion marks from the rims on the surface some 1520 m from the threshold.

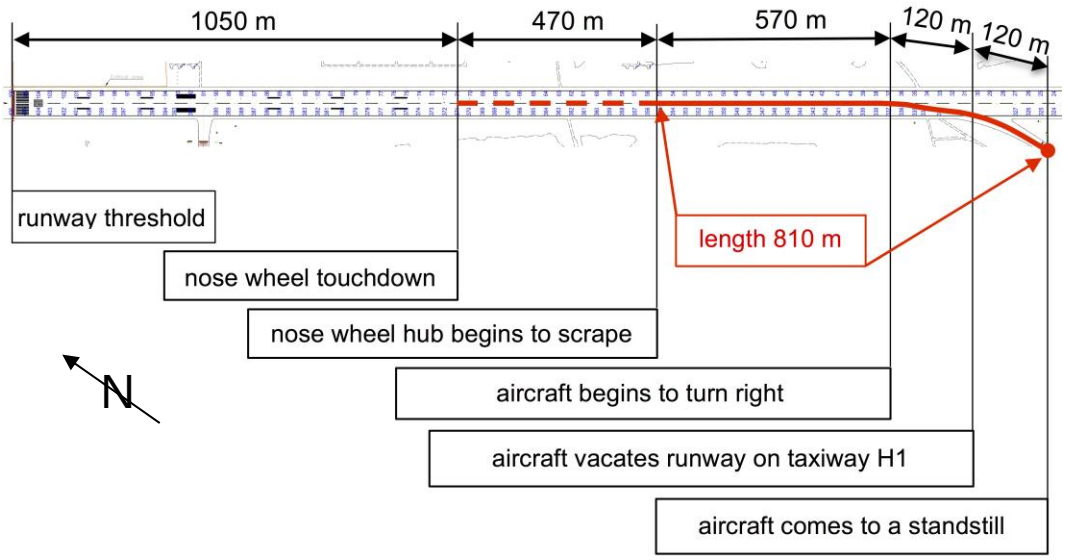

Figure 6: Schematic illustration of the landing sequence of D-ANFE on runway 14 and the exit via taxiway H1

Despite some lateral deviations from the runway centre line due to the alignment of the nose landing gear and the resulting damage, lateral control could be assured by setting asymmetrical power from the engines. It was finally possible to bring the aircraft to a controlled standstill behind the taxi holding position marker of taxiway H1. In the process, the surface of runway 14 was slightly damaged.

1.12.2 Wreckage

An initial inspection of the aircraft revealed, in addition to the damage to the nose landing gear, other damage to the right main landing gear door and a crack on a taxi light.

Figure 7: Damage to the nose gear of D-ANFE after landing; the left tyre got blocked between wheel rim, landing gear strut and axle.

The nose wheel tyres showed only one distinct abrasion mark on each of the running surfaces (cf. Figure 8).

Figure 8: Abrasion mark on each of both nose wheel tyres of D-ANFE

During the second runway inspection (cf. Section 1.10.4), parts of the tyres, metal pieces and a balance weight (cf. red ellipse in Figure 9) from the nose landing gear of D-ANFE were found.

Figure 9: Small parts of the nose gear found on runway 14

1.13 Medical and pathological information

None

1.14 Fire

Fire did not break out.

1.15 Survival aspects

Because the airframe remained intact, fire did not break out and there was no runway excursion, there was no immediate danger to passengers or crew. The passengers left the aircraft using the onboard steps and were taken by bus to the arrival terminal.

1.16 Tests and research

1.16.1 Initial investigations after the accident

Following the accident, the aircraft was inspected for damage. In addition, a series of tests were performed on various nose landing gear components.

The inspection of the nose landing gear and surrounding area required the removal of a number of components and structural elements. The inspection of the structural integrity of the nose landing gear extended from frame 2 to 13, including the webs between the frames. In the process, deformed beams, sheared fasteners and rivets and distorted ribs were searched for.

Testing of the steering of the nose landing gear system was performed in accordance with the manufacturer's test procedure with the aircraft jacked up, i.e. with the gear extended though not in contact with the ground (weight-off-wheels condition corresponding to the aircraft in flight). The following findings were made during these tests:

- The full deflection of the tiller in the cockpit to the left caused the nose landing gear to turn to the left at an angle of 93° from the neutral position.
- The full deflection of the tiller to the right caused the nose landing gear to turn to the right at an angle of 90°.
- According to the manufacturer's limits, the value attained should have been between 57° and 63° on both sides.
- After releasing the tiller from the full left position, the nose gear returned to the neutral position of 0°.
- After releasing the tiller from the full right position, the nose gear returned to a position of 11° to the right.
- According to the manufacturer's limits, the value attained should have been between 0° and 5°.
- The time taken for the nose landing gear to move from the full left position to the full right position, i.e. an angle of 93° left to 90° right was approximately 10.8 seconds. This value corresponds to approximately 17 °/s, conforming to the manufacturer specifications.
- In order to check the self-centring of the nose landing gear, the tiller was used to set the nose wheel to a value of 63° to the left and held in this position. The nose of the aircraft was then lowered towards the ground until a mass of approximately 1000 kg was acting on the nose wheel. The aircraft nose was then lifted until the nose landing gear shock absorber was fully extended. With hydraulic pressure connected, the nose wheel then returned to a value of 3° to the left of the neutral position.

After these tests, two lubricated metal plates (grease plates) were placed under the aircraft nose landing gear in order to test the nose gear steering system in weight-on-wheels conditions (corresponding to the aircraft on the ground), with the following results:

- The full deflection of the tiller to the left turned the nose landing gear to the left to a value of 93°.
- The full deflection of the tiller to the right turned the nose landing gear to the right to a value of 87°.
- After releasing the tiller from the full left position, the nose landing gear returned to a value of 5° to the left.
- After releasing the tiller from the full right position, the nose landing gear returned to a value of 10° to the right.

The forces needed to rotate the tiller control were then tested. The forces measured in this test were excessive. The tests were performed with a calibrated digital dynamometer attached to the tiller with a cable tie, and also with the aid of the electrically driven hydraulic motor. In principle there was sufficient space to perform the test. However, as the required forces were high, it was not always possible to maintain a 90° angle between the digital force gauge and the axis of rotation.

The tiller was then disconnected from the steering mechanism and its free movement checked. It was possible to turn the tiller without resistance which allows the conclusion that the stiff steering was due to the nose landing gear steering mechanism.

An inspection on site did not reveal any defect or fault in the nose landing gear. The wheel bearings were intact and showed no trace of overheating or other mechanical damage. The investigation of the nose landing gear bay and the surrounding area did not reveal any signs of damage. The nose gear was removed and returned to the manufacturer and the overhaul company for further investigation.

1.16.2 Investigation of the nose landing gear

The nose landing gear (NLG) shock absorber registered a pressure of 23.8 bar, which was within the nominal pressure of 25 +/- 5 bar.

The lower part of the sliding rod had damage which was attributable to inadequate lubrication.

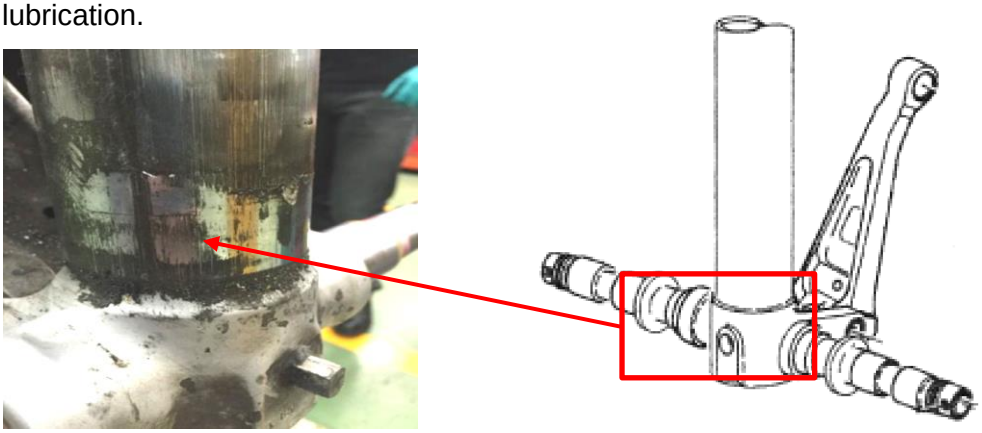

Figure 10: Damage to the lower part the nose landing gear sliding rod

The sliding rod of the NLG assembly exhibited markings which likewise indicated inadequate lubrication (cf. Figure 11).

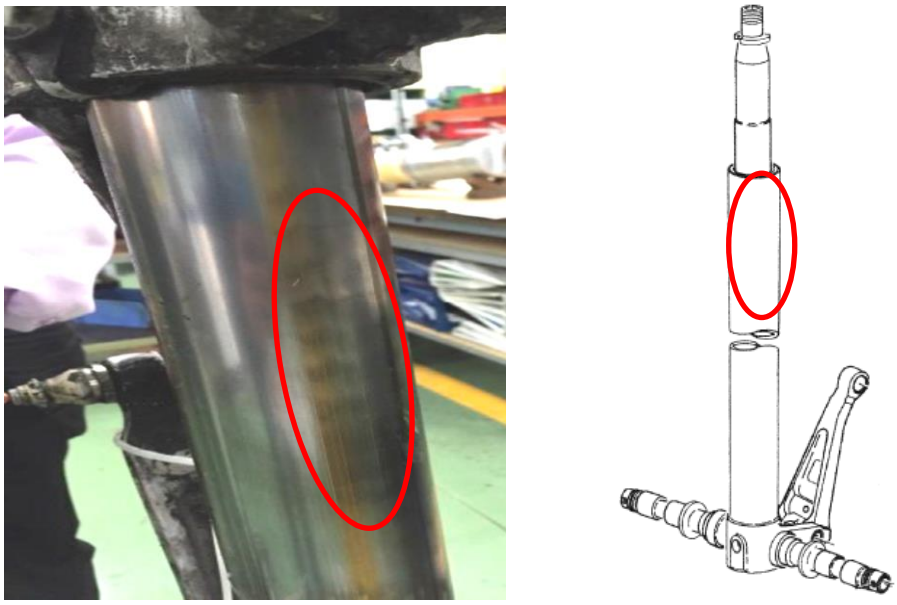

Figure 11: Markings on the sliding rod of the NLG assembly

The abrasion marks on the lower sides of the rod end bearings of the upper and lower torque link were a consequence of the nose gear sliding during the landing roll (cf. Figure 12).

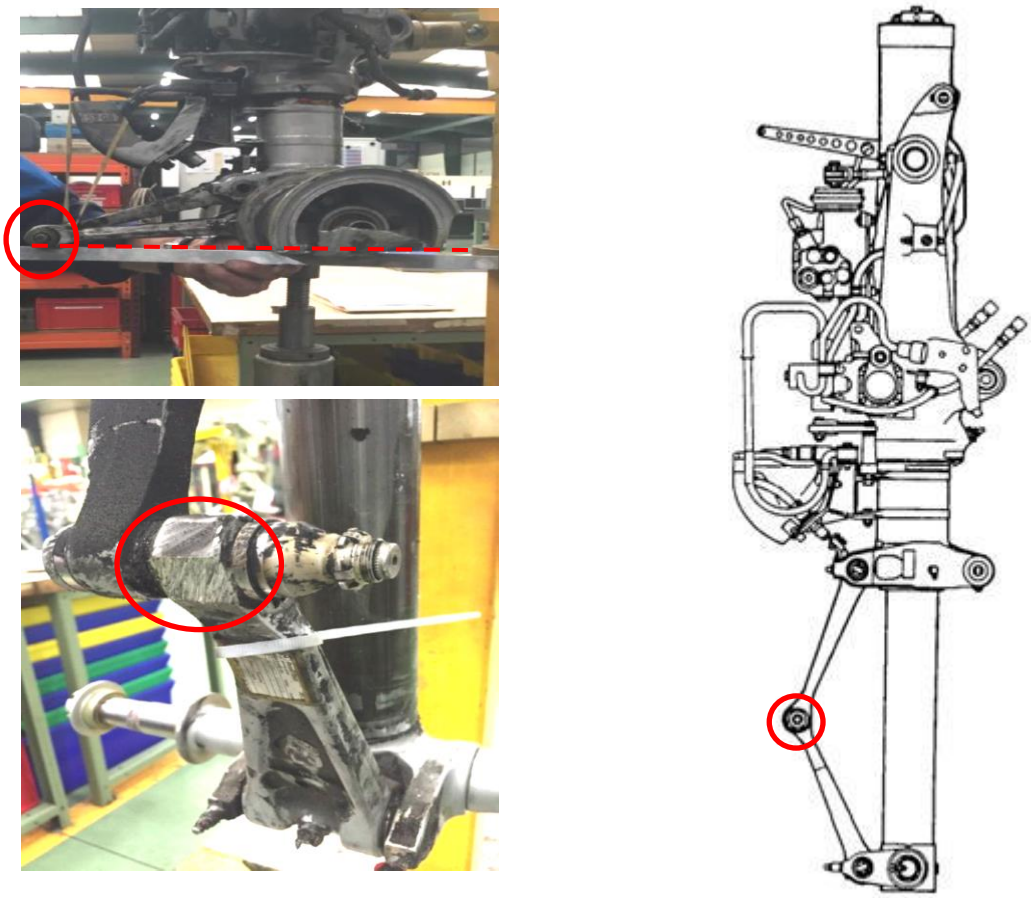

Figure 12: At the linkage between the upper and lower torque link both rod end bearings exhibited abrasion marks on the lower side.

The valve input lever of the steering system was found to be installed in an inverted state (rotated through 180° about the longitudinal axis - cf. Figure 13).

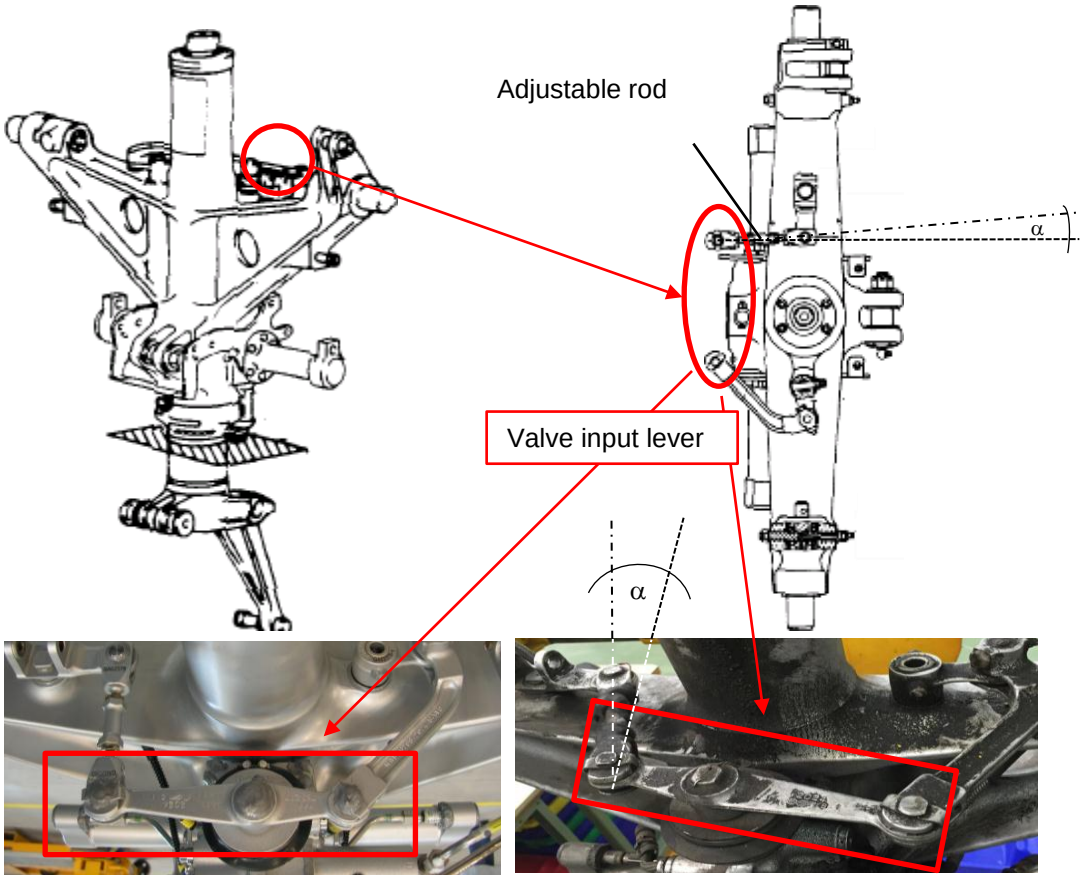

Figure 13: Correct (left image) valve input lever of the steering system (framed in red) and valve input lever with inverted installation (rotated through 180° in the longitudinal axis - right image)

This meant that the angle α (cf. Figure 13) of the adjustable rod was misaligned and was subject to mechanical strain.

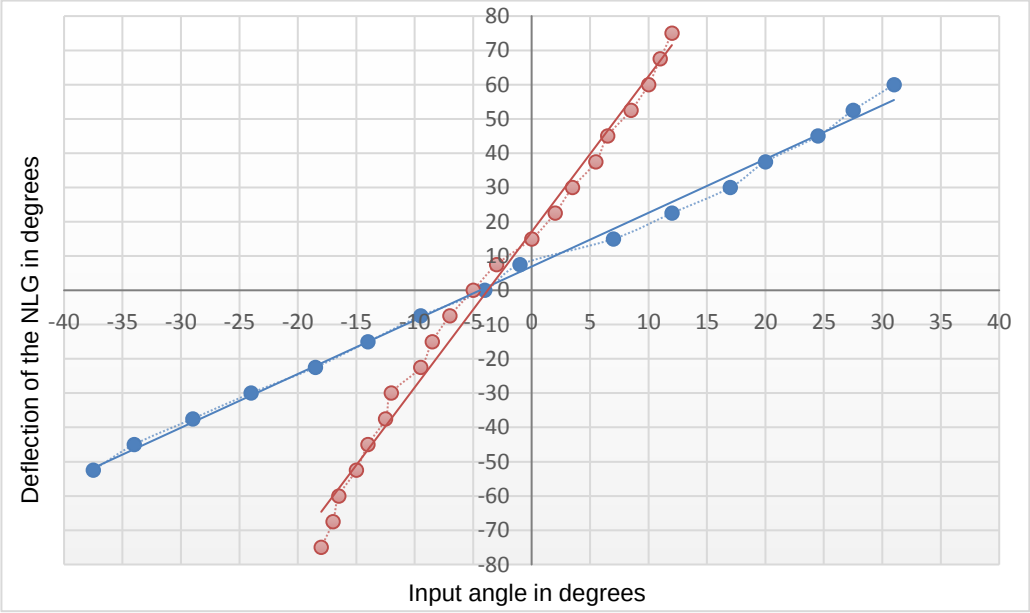

Figure 14: Illustration of the measured deflections of the nose landing gear (NLG) as a function of the input angle (X) over the full range from -36° to +36° (cf. Figure 3 in Section 1.6.2.6.1), with valve input lever in the normal position (blue points) and with valve input lever inverted (rotated through 180° - red points).

Subsequently a test series indicated that the transmission ratio between the inputs and actual deflections of the nose landing gear for a valve input lever which had been attached rotated through 180° was approximately three times higher than for a valve input lever which was correctly attached (cf. Figure 14).

With the valve input lever correctly installed, the adjustable rod did not exhibit any misalignment and the deflection of the nose landing gear wheels corresponded to the input at the tiller with an accuracy of 1 to 2°.

1.16.3 Functional test of the DCSV

The DCSV (S/N: U356) was tested at Hydrep in Dinard (F). All test values were within the prescribed values.

1.17 Organisational and management information

1.17.1 Aerodrome operator

Clearance to operate the runways at Zurich Airport is issued by the Airport Authority. Specifically, this is performed by the Airport Manager. An essential prerequisite for a clearance is a successfully performed runway inspection. The specifications for the performance of a runway inspection are listed in the corresponding process instruction.

Under point *"5.1 Inspection of movement areas (runways and taxiways)"* it is prescribed, among other things, that an additional runway inspection must be performed after incidents which might endanger aviation safety. The runway must be driven on and inspected on both sides of the centre line at a maximum speed of 65 km/h.

Deviation from this standard is permitted in the event of construction work. In such cases the inspection runs are more involved and must follow a different procedure.

1.17.2 Air transport operator

The operator Avanti Air was founded in 1994 at the Frankfurt am Main Airport. Two years later charter operations started with a Beechcraft 1900.

Since the move to Siegerland Airport in 2000 the company has maintained its offices and a hangar there. Two years later, the first commercial aircraft of the ATR type went into service.

With the IOSA[7] safety certificate, Avanti Air received confirmation in March 2010 of compliance with the operational safety standards of the IATA.

Avanti Air operates charter flights and also offers its aircraft in wet-lease to other operators, including Meridiana Fly, Air Berlin and Intersky. The flight which is the subject of this investigation was made on behalf of the airline Etihad Regional under flight number F7 286.

In May 2014 Avanti Air withdrew the ATR-72 registered as D-ANFC from service; at the end of 2014, after the withdrawal from service of D-ANFD, the fleet consisted only of the aircraft involved in the present accident.

1.17.3 Aircraft manufacturer

Avions de Transport Régional was founded in 1981 as a joint venture of the French Aérospatiale company (now Airbus Group) and the Italian company Aeritalia (now Alenia).

[7] IOSA: IATA operational safety audit, IATA: International Air Transport Association

The aircraft type ATR 42, the prototype of which made its first flight on 16 August 1984, was the first product. From December 1985 the commercial aircraft was ready to go into production and was certified. The further development, the ATR 72, was presented for the first time in 1985 and delivered from the following year.

By the end of September 2008 ATR had delivered 795 aircraft, 403 of the ATR 42 type and 392 of the ATR 72 type. In spring 2012 the 1000th ATR, an ATR 72-600, was delivered.

The aircraft manufacturer operates two of its own flight simulator centres, one in Toulouse and one in Singapore.

1.18 Additional information

1.18.1 Incident in New Zealand in 2009

On 24 May 2009 a flight crew reported problems with the nose landing gear steering when taxiing to the stand. They stated that the required force on the tiller was unusually high and the landing gear did not react correctly to the control inputs. The crew decided to stop the airplane and shut down the engines.

During fault-finding mission by the maintenance personnel it was found that valve input lever on the hydraulic differential control selector valve (DCSV) had been incorrectly installed in an inverted state, rotated through 180°. The lever was then installed correctly and the steering unit was subjected to a functional test. In the process a hydraulic leak was revealed at the valve, possibly due to internal damage caused by the incorrectly installed lever, finally leading to the replacement of the steering unit.

Inspection of the maintenance documents showed that the DCSV had been installed only two days before, because then too steering problems had been reported. The cause of that fault was attributed to significant play in the DCSV; the valve was subsequently replaced.

When the replacement unit was installed, the valve input lever was installed incorrectly by mistake. The subsequent functional tests showed that the nose wheel steering was stiff and that the self-centring was poor. A rolling test was performed, which indicated that after a steering input to the left was applied to the tiller, the self-centring only brought the gear back to 15° from the centre. Further adjustments were made to the steering control and the aircraft was cleared for service without the incorrectly installed valve input lever being detected.

Two facts should be noted in this context:

- The steering unit is difficult to access, between the landing gear and the rear wall of the landing gear shaft, and
- In its uninstalled state the valve control lever is freely rotatable through 360°.

The investigation concentrated primarily on the history of the technical trouble-shooting and fault rectification (human factors) and resulted in an amendment to the maintenance instructions. These require that when the valve input lever is removed, care must be taken as to how the lever is oriented, so that it can subsequently be re-installed in exactly the same position (cf. Section 1.6.2.6.3).

1.18.2 Incident in Brazil in 2015

On 25 August 2015, on an Azul Brasilian Airlines ATR 42-500 (MSN 0604), blocking of the nose landing gear steering was noted after a static engine test at the Belo Horizonte Pampulha aerodrome (SBBH) in Brazil.

During the subsequent inspection, it was found that the valve input lever on the hydraulic differential control selector valve (DCSV) had been installed the wrong way round. After it had been installed correctly, the nose landing gear steering functioned normally once again.

1.19 Useful or effective investigation techniques

Not applicable.

2 Analysis

2.1 Technical aspects

2.1.1 Origin of the accident

In the course of the investigation of the nose landing gear (NLG), the valve input lever on the hydraulic differential control selector valve (DCSV) was found to have been installed the wrong way round, rotated through 180° (cf. Section 1.16.2). This resulted on the one hand in excessive deflections of the nose landing gear depending on tiller control input (cf. Figure 14) and on the other hand to unusual stiffness of the nose wheel steering, as could be determined within the framework of the investigations after the accident (cf. Section 1.16.1).

Also, the damage and marks found on components of the NLG group (cf. Section 1.16.2) indicate pre-existing technical defects eventually having played a role which point to inadequate maintenance.

Within the framework of the investigation it was not possible to reconstruct the sequence of events of the accident in detail. The apparent damage to the tyres of both nose wheels however clearly indicates local overstressing (cf. Figure 8), leading to the conclusion that during the landing the nose landing gear was not centered and so the nose wheels were unable to rotate freely.

The tyre of the right nose wheel separated from the nose landing gear and the nose landing gear continued to slide only on the wheel rims approximately 470 m after nosewheel touchdown. The commander later stated that just before reaching intersection H1 he had noticed that the steering was no longer functioning correctly.

Both the accident under investigation and the two other cases, in New Zealand and Brazil, (cf. Section 1.18) make it clear that the stiff steering and the incorrect nose wheel steering control inputs had different effects in operation. This can possibly be explained by the setting of the adjustable rod and possible play in the DCSV respectively (cf. Figure 3). The findings made in the course of the present investigation do not exclude that the nose landing gear steering jammed during landing, similarly to the case of the Azul Brasilian Airlines ATR 42-500 (MSN 0604) in Brazil on 25 August 2015 (cf. Section 1.18.2). It is thus conceivable that the deflection of the nose wheels to the right remained unchanged until the aircraft came to a standstill (cf. Figure 7).

The identically constructed DCSV provided as a replacement (S/N: U356) was fitted to D-ANFE on 6 May 2014. In the period of approximately six months up to the day of the accident, there were no complaints or incidents related to the nose wheel steering. The STSB therefore comes to the conclusion that together with the valve input lever which had been installed rotated through 180°, the inadequate maintenance of the nose landing gear, in particular the lack of functional test after DCSV replacement (cf. Section 1.6.2.6.4), is considered as a further causal factor in the origin of the accident which is the subject of this investigation.

2.1.2 Installation and removal of the differential control selector valve

The valve input lever which was rotated through 180° and which was fitted to D-ANFE on 6 May 2014 is not an isolated case, as the two other incidents indicate (cf. Section 1.18). Based on the available information it cannot be excluded that the valve input lever had also been installed inverted (rotated through 180°) in the same year on the sister aircraft D-ANFC (cf. Section 1.1.2). As in the present case, test reports at that time showed that the differential control selector valve complied with the manufacturer's standards in the functional test.

Clearly, correct attachment of the valve input lever is associated with risks in view of the fact that this component is free to rotate if its ends are not attached (cf. Figure **3**). This was already recognised in the context of the incident investigated in New Zealand, which is why the following comments were entered in the aircraft maintenance manual under Section 32-51-00.

"Item 003 (Removal) To prevent any inversion during the re-installation of the differential control selector valve, notice the position of the valve input lever."

"Item 004 (Installation) Place the differential control [*selector*] *valve input lever in position noted during the removal, with the long leg of the valve input lever pointing at the left side of the aircraft."*

As the present accident and the latest incident on 25 August 2015 in Brazil (cf. Section 1.18.2) clearly show, the safety deficit involving incorrect attachment of the valve input lever still exists, hence the issuing of a safety recommendation by the STSB (cf. Section 4.2.1.2).

2.2 Human and operational aspects

2.2.1 Landing

After an uneventful descent and approach, D-ANFE touched down on runway 14 at Zurich Airport in a light northerly wind. According to the flight crew's statements, the touchdown of the main landing gear and the nose landing gear occurred normally. The commander later stated that just before reaching intersection H1 he had noticed that the nose landing gear steering was no longer functioning correctly. With the intention of vacating the runway via H1, in agreement with air traffic control, control of the aircraft was maintained by the flight crew by means of asymmetrical power setting of the two engines and asymmetrical braking of the main landing gear wheels. This course of action and the request to the air traffic controller to summon the fire brigade were appropriate in this situation.

On the operational side, on the basis of the two flight recorders and the statements of the crew members there are no indications which provide any possible explanation why the nose landing gear was not centered during landing roll.

2.2.2 Runway inspections

Once the aircraft had come to a standstill, the flight crew acted pro-actively by immediately requesting air traffic control that a runway inspection be performed, since problems with the tyres were suspected and therefore possible damage to the runway. Subsequently the right tyre of the nose landing gear was found approximately 2080 m from the runway threshold on the centre line of runway 14 (cf. Section 1.10.3).

Approximately one hour later the runway was cleared for operation at a reduced arrival rate after a further inspection. The first landing after reopening took place at 08:20 UTC.

During the runway inspection on the afternoon of the day on which the accident occurred (cf. Section 1.10.4) more small parts belonging to the nose landing gear of D-ANFE were found (cf. Figure 9). Even though the occurrence and history of the present accident were not affected by this, such small parts represent a safety risk for aircraft landing afterwards (factor to risk).

2.2.3 Fault reports and rectification

The DCSV provided as a replacement (S/N: U356) was fitted to D-ANFE on 6 May 2014. No detailed documentation is available regarding the subsequent functional

tests (cf. Section 1.6.2.6.4). It is doubtful whether these were performed correctly and completely after the installation, since the deflection angles on both sides, which exceeded the maximum values were clearly not noticed.

In the period of approximately six months until the day before the accident, there were no complaints from flight crews in the technical logs in relation to unusual stiffness or incorrect control inputs of the nose wheel steering. It is surprising that during this period no anomalies in connection with the taxiing or steering behaviour of D-ANFE were apparent, especially since up until the end of 2014 possibilities of comparing the individual aircraft existed (cf. Section 1.17.2).

Only on 3 December 2014, i.e. after over 500 landings, is there an entry by the same flight crew according to which the aircraft turned to the right about its vertical axis on landing, without there being any input via the wheel brakes or the engine reverse. The trouble-shooting concentrated mainly on the brakes, leading to replacement of the brake unit owing to a hot back plate. It is remarkable that the incorrect control inputs did not come to light on the occasion of the rolling tests which were performed (cf. Figure 14).

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for IFR flights.
- The last scheduled maintenance work (A-check) was performed on 10 November 2014 at 43 883 hours and 45 283 FC.
- The valve input lever on the hydraulic differential control selector valve (DCSV) was attached in an inverted state (rotated through 180°) on 6 May 2014.
- There is no evidence that the functional test required after installation of the DCSV was performed.
- Up until 3 December 2014, one day before the accident, there were no complaints in the technical logbook concerning the rolling or steering behaviour or other occurrences in connection with the nose wheel steering.
- The investigation provided indications of pre-existing technical defects on the nose wheel landing gear (NLG), indicating inadequate maintenance.

3.1.2 Crew

- The pilots were in possession of the required licences for the flight.
- There are no indications of the pilots suffering any health problems during the flight involved in the accident.
- Both the mass and centre of gravity of the aircraft at the time of the accident were within the permitted limits according to the aircraft flight manual (AFM).

3.1.3 History of the flight

- At 05:33 UTC on 4 December 2014 the commercial aircraft type ATR 72-202, registration D-ANFE, took off with 4 crew members and 26 passengers on board on a scheduled flight from Dresden Airport (EDDC) to Zurich (LSZH).
- After an uneventful descent and approach, the aircraft touched down normally at 07:02 UTC on runway 14 in a light northerly wind.
- After the nose landing gear wheels had come into contact with the runway approximately 1050 m after the runway threshold, the tyre of the right nose wheel separated from the nose landing gear during roll-out and remained lying on the runway.
- The nose landing gear continued to slide only on the wheel rims approximately 470 m after nose wheel touchdown.
- By means of asymmetrical power setting of the two engines and asymmetrical braking of the main landing gear wheels, the crew managed to taxi the aircraft from the runway via intersection H1.
- All the occupants were uninjured. They disembarked the aircraft using the onboard steps and were taken by bus to the airport building.

3.1.4 General conditions

- The weather had no influence on the origin of the accident.

- In the years 2009 and 2015 other aviation operators experienced two other incidents in which the cause was determined by the installation of the valve input lever of the nose landing gear in an inverted state (rotated through 180°).
- A total of three runway inspections were performed; immediately after the accident, approximately one hour later, and in the afternoon of the day of the accident.

3.2 Causes

The accident is attributable to the fact that during landing the nose landing gear was not centred and so the two nose gear wheels could not turn freely. Subsequently it was no longer possible to exercise control via the nose landing gear steering system, as the nose landing gear was substantially damaged.

The interaction of the following factors was determined as the most probable cause of the accident:

- a valve input lever of the differential control selector valve which had been fitted to the nose landing gear in an inverted state (rotated through 180°);
- inadequate maintenance of the nose landing gear.

The fact that the valve input lever can be attached incorrectly, in an inverted state (rotated through 180°) as a result of its structural design was determined to be a contributing factor.

Though the small parts of the aircraft found on the runway during a runway inspection performed hours later did not contribute to the origin and history of the accident, they nevertheless constitute a factor to risk.

4 Safety recommendations, safety advices and measures taken since the accident

Safety recommendations

According to the provisions of Annex 13 of the International Civil Aviation Organization (ICAO) and Article 17 of 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 and repealing Directive 94/56/EC, all safety recommendations listed in this report are intended for the supervisory authority of the competent state, which must decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, any establishment and any individual is invited to strive to improve aviation safety in the spirit of the safety recommendations pronounced.

Swiss legislation provides for the following regulation regarding implementation in the Ordinance on the Safety Investigation of Transport Incidents (OSITI):

"Art. 48 Safety recommendations

[1] The STSB shall submit the safety recommendations to the competent federal office and notify the competent department of the recommendations. In the case of urgent safety issues, it shall notify the competent department immediately. It may send comments to the competent department on the implementation reports issued by the federal office.

[2] The federal offices shall report to the STSB and the competent department periodically on the implementation of the recommendations or on the reasons why they have decided not to take measures.

[3] The competent department may apply to the competent federal office to implement recommendations."

The STSB shall publish the answers of the relevant Federal Office or foreign supervisory authorities at www.stsb.admin.ch in order to provide an overview of the current implementation status of the relevant safety recommendation.

Safety advices

The STSB may publish safety advices in response to any safety deficit identified during the investigation. Safety advices shall be formulated if a safety recommendation in accordance with Regulation (EU) No. 996/2010 does not appear to be appropriate, is not formally possible, or if the less prescriptive form of a safety advices is likely to have a greater effect.

The legal basis for STSB safety advices can be found in Article 56 of the OSITI:
"Art. 56 Information on accident prevention
The STSB may prepare and publish general information on accident prevention."

4.1 Summary

At 05:33 UTC on 4 December 2014 the ATR 72-202 aircraft, registration D-ANFE, took off from Dresden airport (EDDC) on a scheduled flight to Zurich (LSZH), with two pilots, two flight attendants and 26 passengers on board.

After an uneventful descent and approach, D-ANFE touched down normally at 07:02 UTC on runway 14 at Zurich airport in a light northerly wind. After the nose landing gear wheels had come into contact with the runway approximately 1050 m after the runway threshold, both tyres separated from the wheel rims, whereby the

left tyre got blocked between the wheel rims and the right tyre completely detached and was found 2080 m after the runway threshold. The nose landing gear continued to slide only on the wheel rims approximately 1520 m after the runway threshold.

By means of an asymmetrical power setting of the two engines and asymmetrical braking of the main landing gear wheels, the flight crew managed to vacate the runway at the next intersection. The flight crew then requested the fire brigade, as they suspected there was a problem with the landing gear.

All the occupants were uninjured. The passengers left the aircraft using the onboard steps and were taken by bus to the arrival terminal.

The runway was closed immediately after this event and re-opened for operation with a reduced rate of arrivals after a runway inspection at 08:07 UTC.

4.2 Safety recommendations

4.2.1 Valve input lever of the differential control selector valve

4.2.1.1 Safety deficit

In the framework of the investigation, the valve input lever of the hydraulic differential control selector valve (DCSV) was found to have been attached in an inverted state (rotated through 180°). The design of the freely rotatable input lever was determined to be a contributing factor in the origin of the accident.

In May 2009 a similar incident had already occurred to another operator in New Zealand, where the valve input lever which had been fitted in an inverted state (rotated through 180°) was the cause. Subsequently the following comments were added to the aircraft maintenance manual for the aircraft, under Section 32-51-00:

"Item 003 (Removal) To prevent any inversion during the re-installation of the differential control selector valve, notice the position of the valve input lever."

"Item 004 (Installation) Place the differential control [*selector*] *valve input lever in position noted during the removal, with the long leg of the valve input lever pointing at the left side of the aircraft."*

The most recent incident on 25 August 2015 involving another operator in Brazil, the cause of which was also traced to an inverted valve input lever (rotated through 180°), clearly indicates that the risk of incorrect assembly has still not been eliminated.

4.2.1.2 Safety recommendation no. 529

The European Aviation Safety Agency (EASA), together with the aircraft manufacturer, should ensure that it is no longer possible to attach the valve input lever of the hydraulic differential control selector valve (DCSV) incorrectly.

4.3 Safety advices

None

4.4 Measures taken since the accident

None

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014.

Bern, 9 May 2017 Swiss Transportation Investigation Safety Board

Annex 1: Aerodrome chart of Zurich Airport (adapted by the STSB)