Air Accident Investigation Central Directorate

Final Accident Report

Accident involving Sudan Airways Airbus 310

Registration ST-ATN

At Khartoum Airport

On 10th of June 2008 at 1726 UTC

بسم الله الرحمن الرحيم

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Civil

الإدارة المركزية للتحقيق في حوادث الطائرات

Investigation

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Date: -03.11.2010

Ref:-CAA/ACC/ST-ATN, A310

Aircraft Accident
Final Report

1. Aircraft Operator:	**Sudan Airways**
2. Aircraft Owner	**Sudan Airways**
3. Aircraft Model:	**A310**
4. Nationality & **Registration:**	**Sudanese – ST-ATN**
5.Place & date of Accident	**Khartoum Airport** **Date 10/06/2008 at 1726 UTC**

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Attachments :-

Annex I : radio communications transcription
Annex II : BEA technical document st-n080610_rec01 dated July 10, 2008
Annex III : Messier-Bugatti report, April 2009
Annex IV : CEAT report n° MT-09/9154 100/F1/A, October 2009

Glossary

AAICD	**Air Accident Investigation Central Directorate**
BEA	**Bureau d'Enquetes et d'Analyses pour La securite de L'Aviation Civile**
ICAO	**International Civil Aviation Organization**
DGCA	**Director General of Civil Aviation Authority**
UTC	**Universal Coordinated Time**

PREAMBLE

This investigation report is on the accident involving Sudan Airways Airbus 310 registration ST-ATN at Khartoum International Airport on the 10th of June 2008. This report has been prepared in accordance with Annex 13 to the Convention on International Civil Aviation and the Sudan Air ACT 1999. In accordance with Annex 13, the sole objective of the investigation is the prevention of accidents and incidents, it is not the purpose of this activity to apportion blame or liability.

Synopsis:-

Sudan Airways flight 109, an international passenger flight departed Damascus (Syria) to Khartoum (Sudan) with 214 persons on board including 11 crew. The flight diverted to Port Sudan (Sudan) due to bad weather at Khartoum. The flight continued to Khartoum later that night. The weather was poor with thunderstorm and rain over Khartoum. The captain commenced a normal approach to runway 36 and landed at 1726 UTC. The aircraft longitudinally overran the runway, came to a stop at 215 meters beyond its end and burst into flames on its right side.

An investigation board consisted of the following was formed by the minister:-

1- Eng.: Sir Elkhatim Kambal CAA head of the committee.
2- Capt: Abd El Fatah Sati CAA Saftey & Operation Directorate.
3- Eng. Abd El Samai Adam Ali CAA Air Accident Investigation Department .
4- Kamil Ahmed Mohamed CAA Air Accident Investigation Department.
5- Abd El karim Abd El Latif CAA EX Licencing Department.
6- Mohamed Elhasan Taha CAA EX Airport Management.
7- Abd El Muniem Tyfor CAA Aviation Security Department.
8- Eng. Abd El Ggadir Sir El Khatim Sudan Airways Engineering Department.
9- Capt. Osman El Saied. Sudan Airways Capt on the type (TRE)

BEA of France (Bureau d'Enquetes et d'Analyses pour la sécurite de l'Aviation Civile) has appointed Mr. Francois Hochart as accredited representative assisted by Mr. Vincent Ecalle who arrived Khartoum shortly after the accident together with the Airbus team which consisted of :

1. Mr. Albert Urdiroz. Flight safety Director.
2. Mr. Xavier Barriola. Flight safety Director.
3. Jean-Philippe Pelissier. Propulsion systems.
4. Jean-Paul Rozzi. Structures.
5. Christophe Duphil. Systems.

The authority conducting the investigation is CAA AAICD with participation of BEA and Airbus. Authority releasing the final report is the minister.

1 Factual Information:

1.1 History of the flight

The Airbus 310 serial number 548 owned by Sudan Airways Was entered in Sudan Civil Register on 15/09/2007 , designated registration marks ST-ATN in accordance to registration certificate
No. 0493 dated 15/09/2007 and issued with Certificate of airworthiness No AWP/COA/0203/2007 dated19/09/2007. .
On the morning of 10th June at 8:30 hrs (local time 05:30 UTC) after arriving from Cairo with a deactivated no 1 engine reverse as being a carry forward defect and being labeled according to MEL, the captain accepted the aircraft to carry out its scheduled flight to Amman via Damascus. The trip en-route to Amman was uneventful.

Same day in the afternoon, the Airbus A310, ST-ATN, was en-route flying from Damascus (Syria) to Khartoum (Sudan) with 203 passengers and 11 crew members on board. The Airbus approached Khartoum in the afternoon and due to bad weather conditions, the captain decided to divert to Port Sudan. The aircraft landed Port Sudan Airport normally and was refuelled with 20 tons of Jet A1. As mentioned by the Captain that he was in contact with Khartoum enquiring about the weather. After staying on ground at Port Sudan for about 1:15 hour, and being informed that the weather was getting better, the Captain decided to return back to Khartoum. A310, ST-ATN, took off to Khartoum where the captain initiated a night approach for the runway 36 as pilot flying. He got the clearance to land after the controller provided him with wind information (320° / 7 Kt) and runway condition (wet). The left engine thrust reverser was unserviceable and inhibited as per Minimum Equipment List (MEL) procedures.

The aircraft landed smoothly about 17:26 UTC. R/W 36 landing and within 900 meters range from the threshold of R/W 36 as stated by the flying pilot. The captain reported that he experienced some difficulties in maintaining the aircraft on the centre line just after setting both thrust levers in the reverse position. Then he did not succeed in slowing down the aircraft nor could stop it before the end of the runway. The aircraft longitudinally overran the runway and came to a stop 215 meters after the runway end. Then it caught fire on its right side.

The right hand slides could not be deployed, the crew and the passengers evacuated the aircraft from the left front slide, twenty nine passengers and one cabin crew were fatally injured.

1.2 Injuries to Persons:

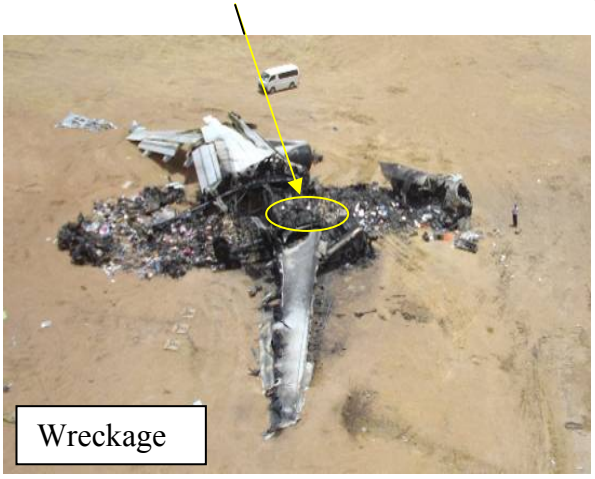
Injuries	Crew	Passengers	Others
Fatal	1	29	None
Serious	None	Not available	None
Minor / None	None	Not available	None

1.3 Damages to aircraft

1.3.1 Structure

The main part of the fuselage was severely burnt. Wreckage examination showed that:

- The bottom and top skins of the wing box structure fractured at the main right gear attachment area. This assembly rotated forward and down, with the top of the assembly (top of landing gear) in contact with the ground.
- The main fire area was between the right engine and the right wing root.



Wreckage

Main right gear

1.3.2 Engines

Engine 1 thrust reverser was inspected to be stowed and de-activated.
Engine 2 thrust reverser was inspected to be fully deployed.

Engine 1 did not show evidences of foreign objects ingestion.
Engine 2 fan blades condition was consistent with foreign object ingestion.

Visible parts of both engines core did not present any trace of engine fire.

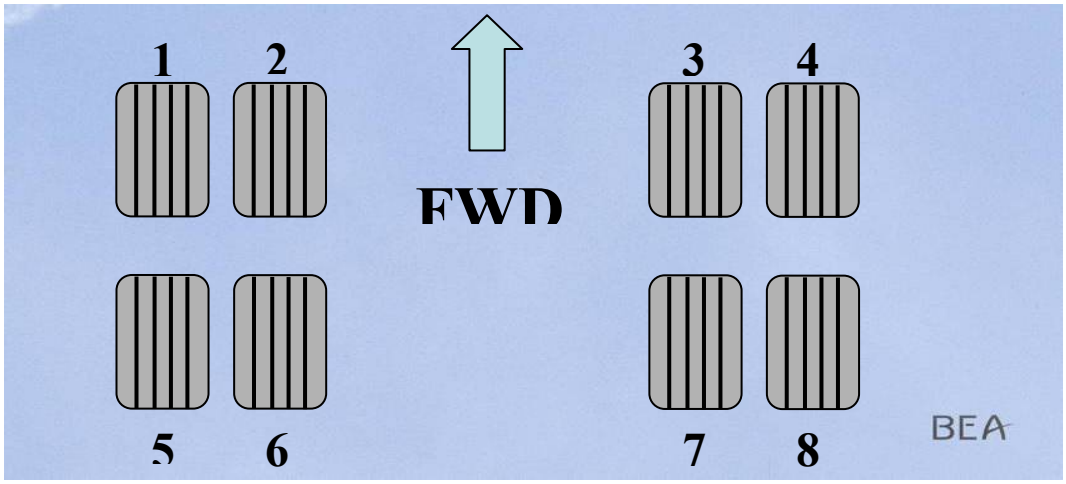
Engine 1 (LH)

Engine 2 (RH)

1.3.3 Tires and Wheels

All tires including the Nose Landing gear ones were found installed on the wheels.
All tires of the two Main Landing Gears showed evidence of braking.

Note: No braking system is installed on A310 nose landing gear.



Wheel 1
LH

Wheel 2
LH MLG

Wheel 3
RH

Wheel 4
RH

Wheel 5
LH MLG

Wheel 6
LH MLG

Wheel 7
RH MLG

Wheel 8
RH MLG

1.3.4 Landing gears

Nose Landing Gear

Nose Landing Gear

Nose Landing Gear did not collapse and was found few degrees turned to the right. Nose landing Gear down-locking indicator was found in down-locked position.

Left main landing gear

The front of the bogie was stuck on the ground. The bogie axle was aligned with the runway direction but not with the aircraft direction.

Left Main Landing Gear

The torque link was broken. This indicated that aircraft pivoted around the left main landing gear when it stopped.
Shock absorber extension was measured (380 mm), indicating that it was not deflated.


Right Main Landing

Right main landing gear

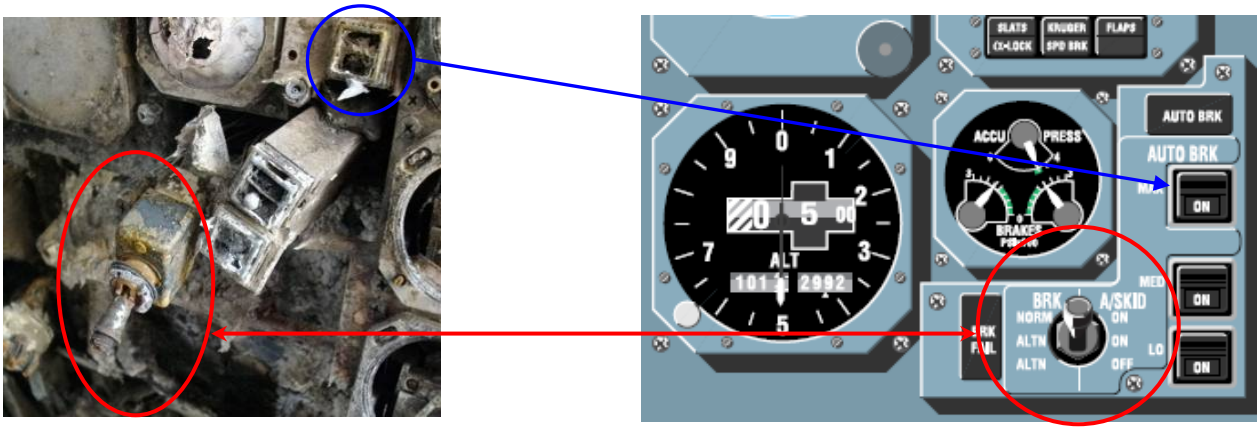
Main right undercarriage was attached to the wing box structure pieces.

The right brace strut and the brace strut actuating cylinder were found partially melt.

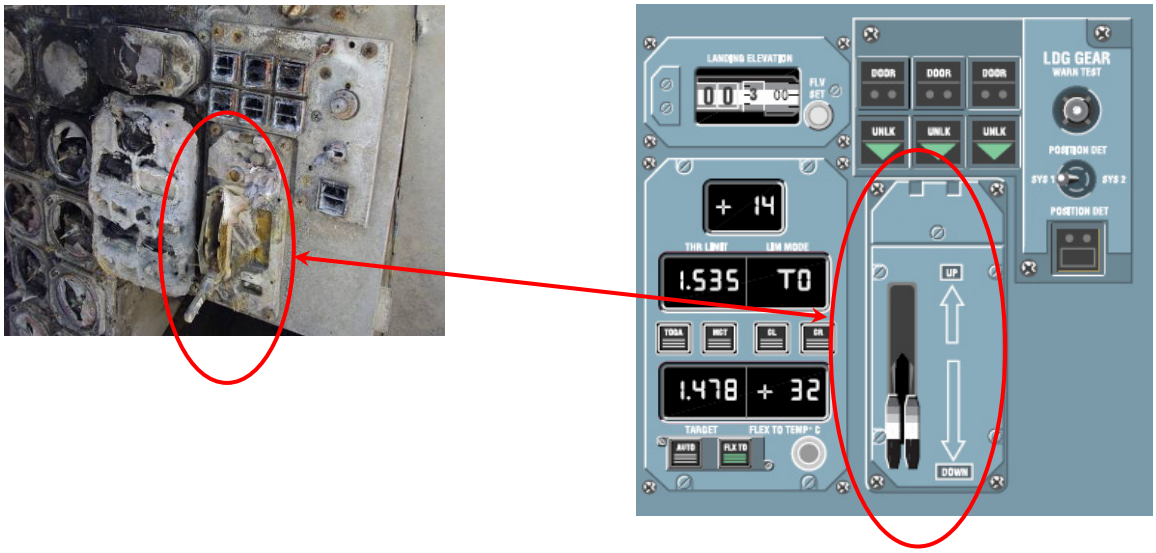
The cross brace was still attached to the Rib 5 but found separated from the structure area on the other side (brace strut side). The retraction actuator was found attached on both sides.

1.3.5 Cockpit

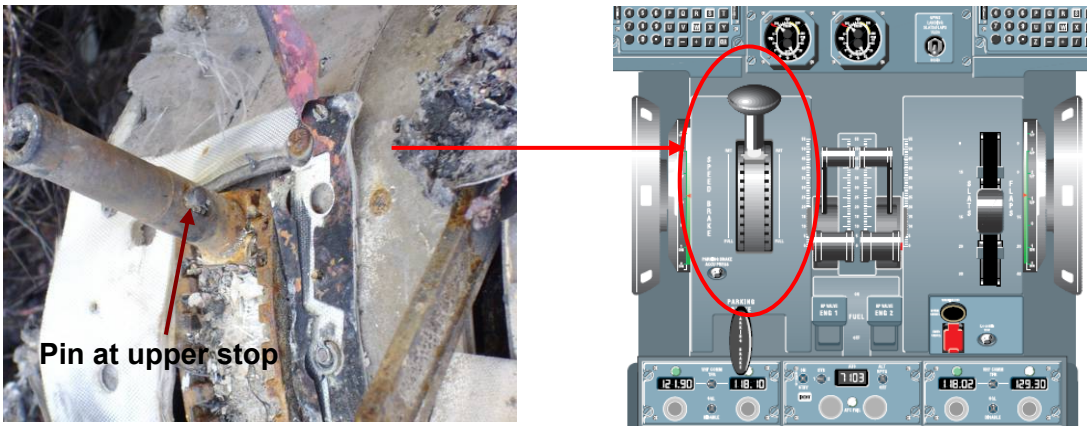
The "BRK A/SKID" lever (FIN 96GG) was found hanging from the 401VU panel, in the position indicated on the below picture. This position was consistent with the switch being set to "ALTN OFF" (Alternate braking / Anti skid off)
The 3 push buttons of AUTO BRK selection were severely damaged by fire.



The Landing gear control handle was found in DOWN position:



The speed brake/ground spoilers control lever, located at central pedestal, was damaged by fire, but the position of the pin at upper stop of its groove indicated that lever was in ARMED position.



1.4 Other damages

Some of approach lights masts of R/W 18 were damaged.

1.5 Personnel information

Name & Nationality	*Pilot in Command*	*First Officer*
	Sudanese	Sudanese
Age	60	50
License type No. and validity	ATPL 007 valid till 31.08.08	ATPL 0121 valid till 30.06.08
Rating	Group (1) B737-200 B707 , A310 , A300-600 Group (2) DHC6, F27	Group (1) PA, 28-140/180 Group (2)A310 , A300 F27, FK MK 50 B737, A320
Total flying HRS	14180Hrs	9879 Hrs
Total hrs on type	3088 Hrs	3347 Hrs
Total last 3 months	93.3 Hrs	170.47 Hrs
Total last 28 days	51 Hrs	40 Hrs
Total last 7 days	20.52 Hrs	24.8 Hrs
Total for the previous day	Nil	Nil
Last proficiency check	14.03.2008	05.12.2007
Last route check	20.10.2007	29.07.2007
Last medical check	Valid till 31.10.2008	Valid till 30.06.2008
I/R validation	Till 12.03.2009	Till 20.06.2008
Rest provide	> 24 Hrs	> 24 Hrs

1.6 Aircraft Information

1.6.1 Airframe

Type	A310 -324
Manufacturer	Airbus industries
Date of Manufacture	1990
Serial .No.	548
Registration	ST-ATN
Total hrs, since new (TSN)	53233 hrs 37 mints
Time since last C check	2011:37 hrs
Total Cycles	21524
Cycles since last C check	2039

The aircraft entered the C check on 26/03/2007 when it was owned by Air India being registered as VT-EVF. The check was carried by The JorAMCo ((Jordan Aircraft maintenance limited). During this check 41 discrepancies where found including fuel leakage on right and left wings on different parts and being rectified in addition to some corrosion spots.

1.6.2 Engines

Type	Engine No. 1	Engine No. 2
	PW 4152-3	PW 4152-3
Manufacture	pratt & Whitney	Pratt & Whitney
Date of Manufacture		
Serial .No.	P724891	P724936
Total hrs, since new (TSN)	31939Hrs 47 mints	29349Hrs 47 mints
Time since overhaul (TSO)	10055 Hrs 47 mints	17191 Hrs
Cycles	4221	7242

1.6.3. Weight and balance

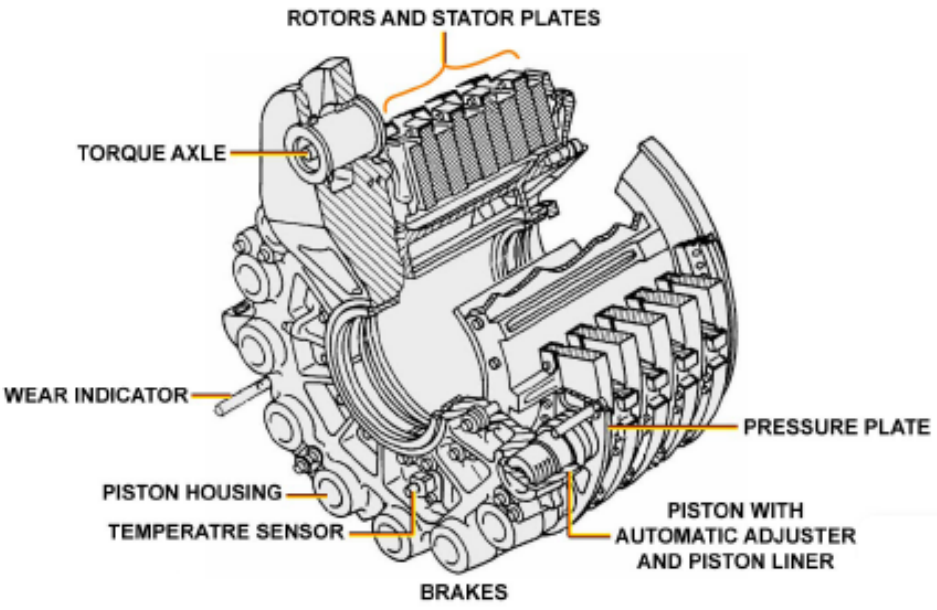
Estimated weight at landing: 120.9 tons
Centre of gravity: 26%
Aircraft weight and balance were within the limitations

1.6.4. Aircraft thrust reversers

Aircraft was dispatched with engine 1 thrust reverser (LH) inoperative. It has been operated for one day as per MEL airline procedure.

1.6.5. Aircraft braking system description

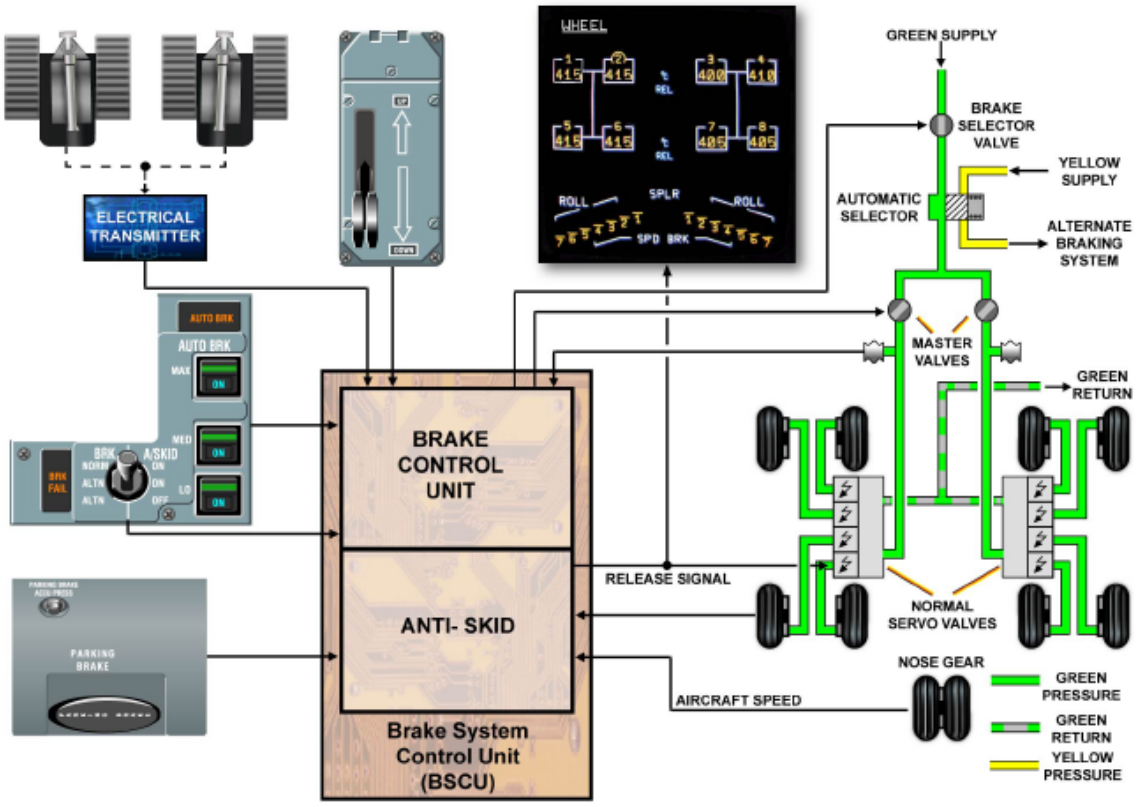
The 8 main gear wheels are equipped with multi-disc brakes each operated by two independently supplied sets of pistons (Normal & Alternative systems). The Normal braking system is supplied from the green hydraulic system, and the Alternative braking one from yellow hydraulic system.
Each brake is equipped with an automatic adjuster wear indicator and temperature sensor.



In manual Normal braking, electrical braking orders are sent by the brake pedal transmitter unit to the Brake system control unit (BSCU). The BSCU energizes the normal brake selector valve allowing green pressure to supply the brakes through the automatic selector, the master valves and the normal servo-valves.
Normal brake pressure is not indicated. A BRK FAIL light alerts the crew in case of failures.
The three positions switch (NORM/ON, ALTN/ON, ALTN/OFF), on the instrument panel, serves to switch from green system to the yellow system, and to disconnect the anti skid.

The anti skid is based on the comparison of the rotational speed of the nose and main gear wheels, preventing the wheels from locking and protecting the tires.

Normal braking with anti skid is available with the BRK/A/SKID switch in NORM/ON position.
Alternate braking with anti skid is obtained with BRK/A/SKID switch in ALTN/ON position, or NORM/ON position if green hydraulic pressure is not available or drop during braking.
Alternate braking without anti skid is obtained if BRK/A/SKID switch is set in ALTN/OFF position.



1.6.6. Auto Brake

This system serves to reduce the delay in braking in the event of an acceleration-stop (Max Mode) or limit the deceleration upon landing to a preselected value. The auto brake system is designed to assure a straight roll out and optimized landing distance on contaminated runways.

The pushbutton switches control the arming of the system with several deceleration rates. The selectable deceleration rates are:

- MAX: maximum braking pressure
- MED: approximately 3.00 m/s^2
- LOW: approximately 1.70 m/s^2

MAX mode is normally selected for takeoff. MED and LOW modes are normally selected for landing. When LOW is selected, progressive pressure is sent to the brakes 8 seconds after the ground spoiler deployment order.

1.6.7 Maintenance

The review of the logbooks indicated that during the previous flights:

- No braking systems issue was highlighted.
- No report concerning the GPWS was highlighted.
- Engine 1 thrust reverser was found stuck in open position after landing on April 22, 2008 and deactivated up to May 10, 2008. RH master actuator was replaced and the issue was closed till June 09, 2008 when the issue reoccurred.

According to Sudan Airways line maintenance representatives, no tire inflation pressure information was recorded in the documentation since the aircraft was reportedly equipped with Tire Pressure Indicating System (TPIS) and thus, the check was to be done by the crew before each flight.
No TPIS sensors were found fitted to the wheels, showing that this aircraft was not equipped with TPIS.

1.6.8. EGPWS

The aircraft was fitted with an EGPWS P/N 965-0976-003-206-206.
“Terrain Terrain” followed by “Pull-up Pull-up” aural warnings were triggered 19 seconds after touch-down till the aircraft stop. These aural messages were Mode 2 warnings, based on radio altitude and closure rate associated.
These warnings were spurious ones since no warnings should be triggered below 30ft.
The EGPWS was not recovered. Also SUD A310 MSN548 was not in the effectivity of Airbus Service Bulletin reference A310-34-2163 (Complete wiring and install EGPWC with enhanced functions inhibited), meaning that the installation was not defined by Airbus.
Consequently Airbus was not in a position to explain these spurious warnings.

1.7 Meteorological Information

- METAR HSSS 10/1600z 36012 kt 6000M TRBO OV. ST. SCT 056 BKN 140 26/23 Q 1013 NOSIG.
- METAR \HSSS 10/1630 32007kt 6000M TRBO OV. ST SCT 056 BK 140 Q1013.
- METAR \HSSS 10/1700 27002kt 9/9 Ts Ra OV. ST few050 SCT 056 BK 140 26/26 Q1013.
- METAR \HSSS 10/1730 18012kt 1Cb050 4Sc 056 7Ac064 Q1010.8
- METAR \HSSS 10/1800 18017kt 1Cb050 3Sc 050 7Ac065 33/21 Q1009.8
- METAR \HSSS 10/1830 15010kt 9/9 few050 Cb to E SCT 056 few050 SCT 056 Q1010.
-

During approach the aircraft was provided by METAR reported at 16000Z. On final approach the aerodrome tower controller provided the aircraft with wind information reported at time 1630z.

1.8 Aids to Navigation:

None-precision (VOR/DME) approach was in progress for R/W 36 as the VOR/DME was operating normal, precision approach (ILS) R/W 36/18 was not calibrated ref. NOTAM (A0089/08).

1.9 Communications

Radio communications between the aircraft and Khartoum approach and tower were normal and were not a factor in this accident. (See attached transcription in Annex I)

1.10 Aerodrome Information

Khartoum airport (HSSS) has one asphalt landing-and-takeoff runway (18/36). It measures 2980 x 45 meters.
Aerodrome reference point is N153525.28 E0323311.35 and elevation is 1260ft.
R/W 36 threshold coordinates are N153433.94 E0323311.83 and elevation is 1260 ft.
R/W 18 threshold coordinates are N153558.94 E0323311.03, elevation is 1265 ft.
The airport is (equipped?) with:

- a 3 degree precision approach path indicator (PAPI)
- CAT 1 approach and runway lighting system for R/W 18

- CAT 2 for R/W 36.

Fire fighting and rescue facilities are CAT 9.

1.11 Flight Recorder

The CVR and FDR were recovered and analyzed by the French BEA at Le Bourget, France, in presence of Sudanese CAA and Airbus representatives *(See attached BEA technical document st-n080610_rec01 dated July 10, 2008 in Annex II)*.

The subject equipment was identified as follows:

- UFDR : Allied Signal PN 980-4100-DXUN, S/N 4449
- CVR: Honeywell, Identification plate was not attached

The FDR offered a recording capacity of 25 hours (magnetic tape).
The CVR offered a recording capacity of 30 min or 2 hours, depending on the track (solid-state memory).

DFDR

CVR

1.11.1 DFDR read-out

<u>On this DFDR</u>:

- The control column, control wheel and rudder pedal orders were not recorded.
- Only the right elevator, both ailerons and the rudder deflection were recorded.
- Neither the brake pedals deflection nor the pressure were recorded.
- The auto brakes, anti skid status were not recorded.

The plots associated to the read-out are attached in Annex II.

Note: the Throttle Resolver Angles (TRA) are an image of the thrust lever angle (TLA). They were recorded at a rate of 1 point every 4 seconds, while the Engine Pressure Ratio (EPR) was recorded at a rate of 1 point every second. Consequently, regarding the plots extracted from the DFDR, there could be a time difference between the TRA change and the EPR response associated.

Findings

1.11.1.1. During the descent and the approach

- Spoiler 5 FAULT/OFF parameter turned to FAULT (these spoilers were recorded as working when the aircraft landed in Port Sudan)
- SLAT/FLAP was in full configuration
- Auto Pilot was deactivated at 800ft
- Auto Thrust (ATHR) was engaged
- TRA was at 50° (CLIMB)
- Ground Spoilers were armed

1.11.1.2. On short final

- Aircraft heading was 355°
- At time 17.25.05, TRA was set to 37° (Idle)
- Computed Airspeed (CAS) was 140 kts.
- Ground speed was 155 kts ⇔ tailwind = 15 kt

1.11.1.3. Landing 5 touch down (at t_0 = 17:25.07 UTC)

At t_0:

- Both left and right landing gears were compressed (LHSQUAT & RHSQUAT set to 1).
- Vertical acceleration (VRTG) was recorded at 1.1g.
- Ground speed was 155 kt.

At t_0 + 5 seconds:

- Spoilers 5 detected faulty at 17.25.12.
- TRA of both engines were set to maximum reverse position.
- Nose landing gear was compressed (NOSQUAT set to 1).
- Longitudinal acceleration (LONG) was about 0.1g.
- Ground speed was 145 kt.

Between t_0 + 13 seconds and t_0 + 16 seconds:

- TRA1 and TRA2 were set to Idle position with thrust reverser deselected.
- Longitudinal acceleration (LONG) was between 0.1g and 0.14g.
- Ground speed was 124 kt decreasing.

- Maximum rudder deflection was 5°.

Note: a single chime was recorded 14 seconds after the nose landing gear squat was recorded compressed. This single chime is assumed to be the "BRK A/SKID" switch selected to "ALTN OFF", as reported by the crew.

At t_0 + 19 seconds:
- GPWS warning "TERRAIN TERRAIN" was generated during 2 seconds.
- Ground speed was 111 kt.
- Longitudinal acceleration was 0.14g.

At t_0 + 20 seconds:
- Longitudinal acceleration (LONG) decreased from 0.14g to 0.08g.

At t_0 + 21 seconds:
- GPWS warning "PULL UP" was triggered.
- Ground speed was 106 kt.
- Longitudinal acceleration was 0.08g.

At t_0 + 22 seconds:
- Longitudinal acceleration (LONG) decreased from 0.08g to 0.02g, then increased again to 0.08g.

At t_0 + 29 seconds:
- TRA2 was set to 10°. TRA1 was still at 36.7° (Idle).
- Longitudinal acceleration was 0.08g.

At t_0 + 32 seconds:
- TRA of both engines were set to 6.7° (Mechanical stop of maximum reverse position).
- Longitudinal acceleration (LONG) was around to 0.1g (min 0.06g / max 0.14g).
- Ground peed was 93 kt.

After t_0 + 32 seconds (overrun):
- Ground speed was 76 kt (t_0 + 32 seconds).
- Vertical acceleration (VRTG) increased up to 2.36g.
- Longitudinal acceleration (LONG) increased up to 0.41g.

1.11.2 CVR read-out

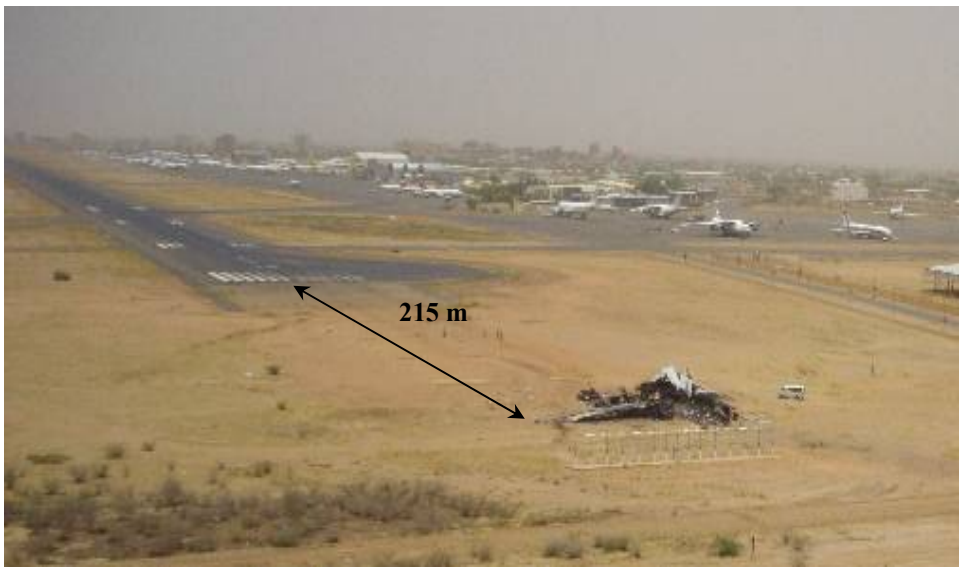
The reading indicated that (refer to transcript in Annex I):
- the captain got the clearance to perform an approach on runway 36,,

- the aircraft was fully configured for landing, checks completed (as confirmed by the co-pilot),
- the captain got the clearance for landing,
- the controller gave the following wind information: 320° / 07 kt,
- the controller informed the captain about the runway condition (rain, wet)
- the co-pilot suggested the use of auto-brake and the captain decided not to use it,
- the co-pilot announced: “centre line”
- the co-pilot announced: “centre line left”
- a single chime was recorded about 20 seconds after touch down,
- GPWS warnings were triggered several times prior to overrun (TERRAIN”, “PULL UP”)

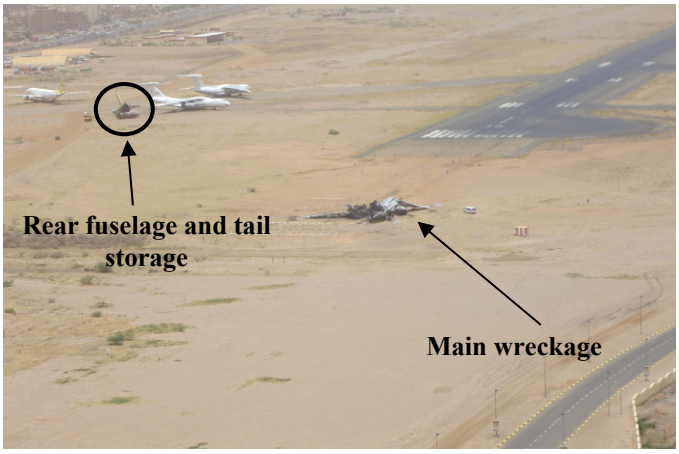
1.12 Wreckage and impact information

The day after the accident:

- Middle and forward aircraft sections, that included wings, engines, and cockpit, were located at about 215 meters from the end of runway 36, on hard ground.



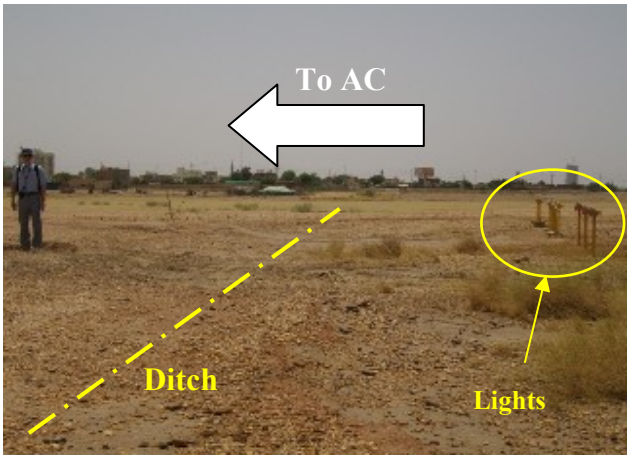
- Rear section of the aircraft structure was transported to an aircraft parking area aside of the runway. This rear section included the rear fuselage, fin and rudder, horizontal stabilizer and elevators, Auxiliary Power Unit (APU).

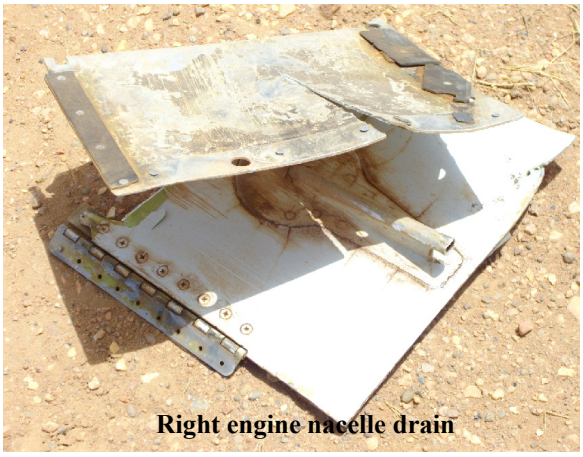


- Runway 36 ended into a stabilized pavement before changing to hard ground.
  In the continuation of runway 36 there were 6 series of lights, used for landing on runway 18, and a row of antennae.
  Rubber marks were observed on the end of the runway and the stabilized pavement.

- There was a ditch (between the 3rd and 4th series of lights) which dimension was about 0.9 meters width and 0.5 meter deep. There were no traces of aircraft impact with the ground in the overrun area. However,

the drain of the right engine nacelle showing scrapping marks was found after the ditch at about 110 meters from the runway threshold, possibly suggesting a contact of the nacelle with the ground.
There were no other aircraft parts found outside the wreckage perimeter.




Right engine nacelle drain

1.13 Medical and Pathological Information

All crew and passengers were medically examined, slight injuries were detected. The deceased bodies were taken to the morgue for identification.

1.14 Fire

There was no evidence of fire neither on the runway nor between the runway and wreckage location. The fire started when the aircraft stopped.

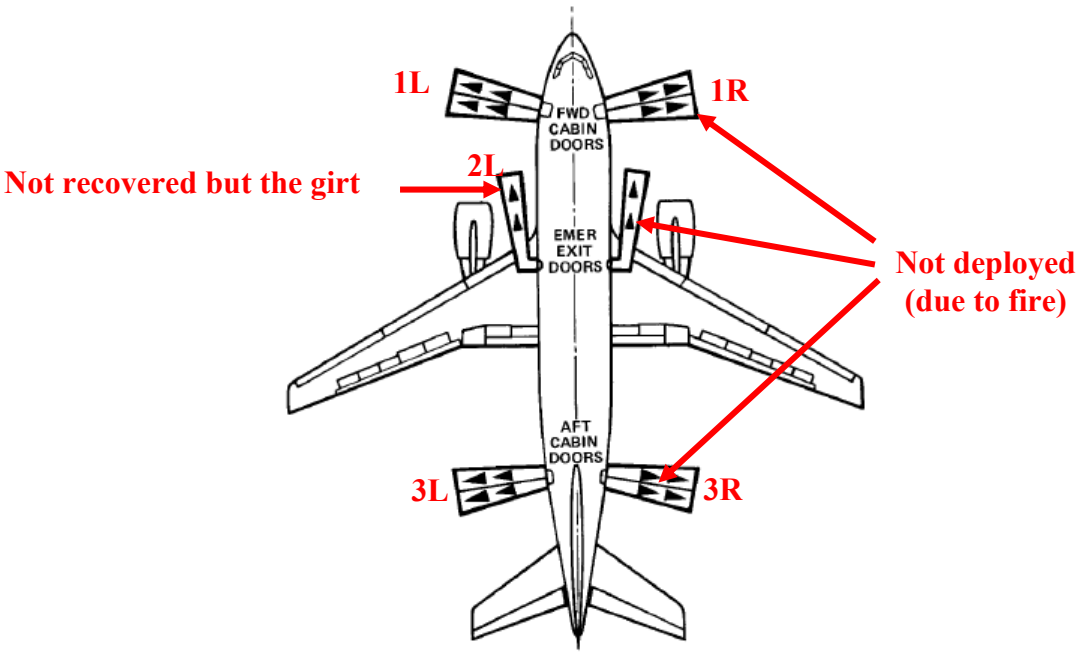
The **main fire area was between the right engine and the right wing root**.
Visible parts of both engines core did not present any trace of engine fire.

1.15 Survival Aspect

Aircraft wreckage was observed in the following configuration:

- The three left doors (1L, 2L, 3L) were opened, slides 1L and 3L were deployed and deflated, girt of slide 2L was attached to the door.
- According to the Captain interview, doors 1R, 2R and 3R were not used due to fire on right side.
  - Door 1R: it was not possible to extract it from the wreckage or to determine the condition of its mechanism. Its slide was found not deployed.

- Door 2R: neither the door nor the slide was recovered.
- Door 3R: it was found opened, with its slide in place not deployed.



The captain reported that:

- The aircraft evacuation was difficult since a heavy smoke quickly spread through the cabin.
- The left rear slide (door 3L) could not be used since the height above the ground was too big.
- He saw the middle slide (door 2L) deployed and confirmed that a lot of passengers used the left forward slide (door 1L) to evacuate the wreckage.
- Interviews with the Cabin crew members showed the followings:-
  - Communication between cabin crew members was not adequate.
  - Personnel Protective Equipments were not used.
  - Passengers were not briefed on safety measures before and during the trip.
  - Hand luggage delayed evacuation process.

1.16 Tests and research

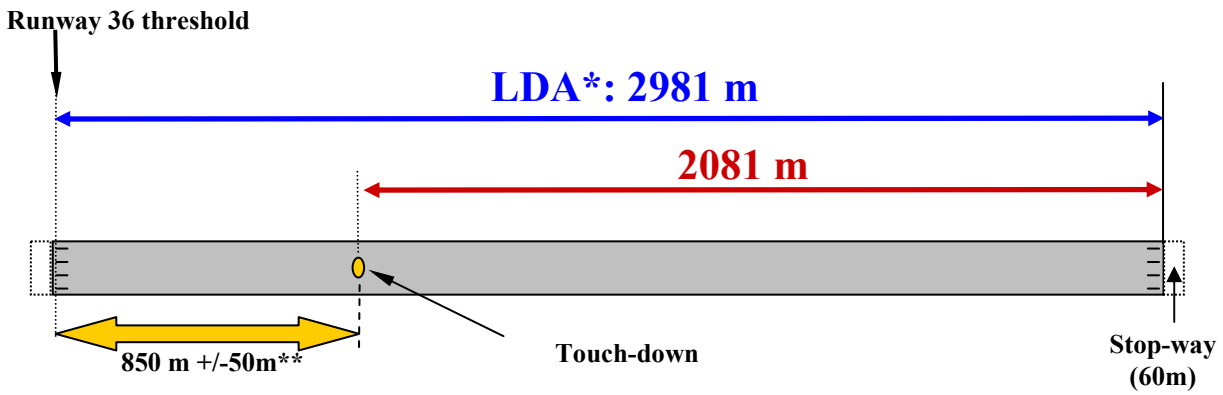
1.16.1 Simulations

Simulations were carried out by the BEA or overviewed by the BEA when made by Airbus.

16.1.1.1 Trajectory re-computation

The aircraft trajectory was re-computed using DFDR data and mapping performed on site. The touchdown point was estimated at 850 meters (+/- 50 m) after runway 36 threshold.
The following data were taken into account for all computations:

- A310-324 fitted with Pratt and Witney PW-4152 engines
- Brakes: Messier Bugatti MHB carbon (72 MJ max brake energy)
- Weight: 120.9 tons
- Slats/Flaps configuration: 30/40°
- CG location: 26.4%
- Pressure altitude: 1308 ft
- Temperature: ISA + 16 °C
- Runway length: 2981 meters, no slope



* LDA: Landing Distance Available

1.16.1.2. Landing distances simulations (with information provided by ATC)

The aim of this simulation was to determine the required landing distance after taking into account the information provided to the Captain by the controller.

⇨ ***Additional data used for simulation:***

- Air conditioning: ON.
- Anti ice: OFF.
- Wind 7kt / 320° (wind passed by ATC).
- No thrust reverser available.

⇨ ***Results***

- **Dry runway**:
  - Actual Landing Distance (ALD): **1 048 meters**
  - Required Landing Distance (RLD) = ALD/0.6 = **1 746 meters**
- **Wet runway:**
  - Actual Landing Distance (ALD): **1 475 meters**
  - Required Landing Distance (RLD) = RLD_{dry} x 1.15 = **2 008 meters**

1.16.1.3. Breaking performance simulation n°1 (with no braking input)

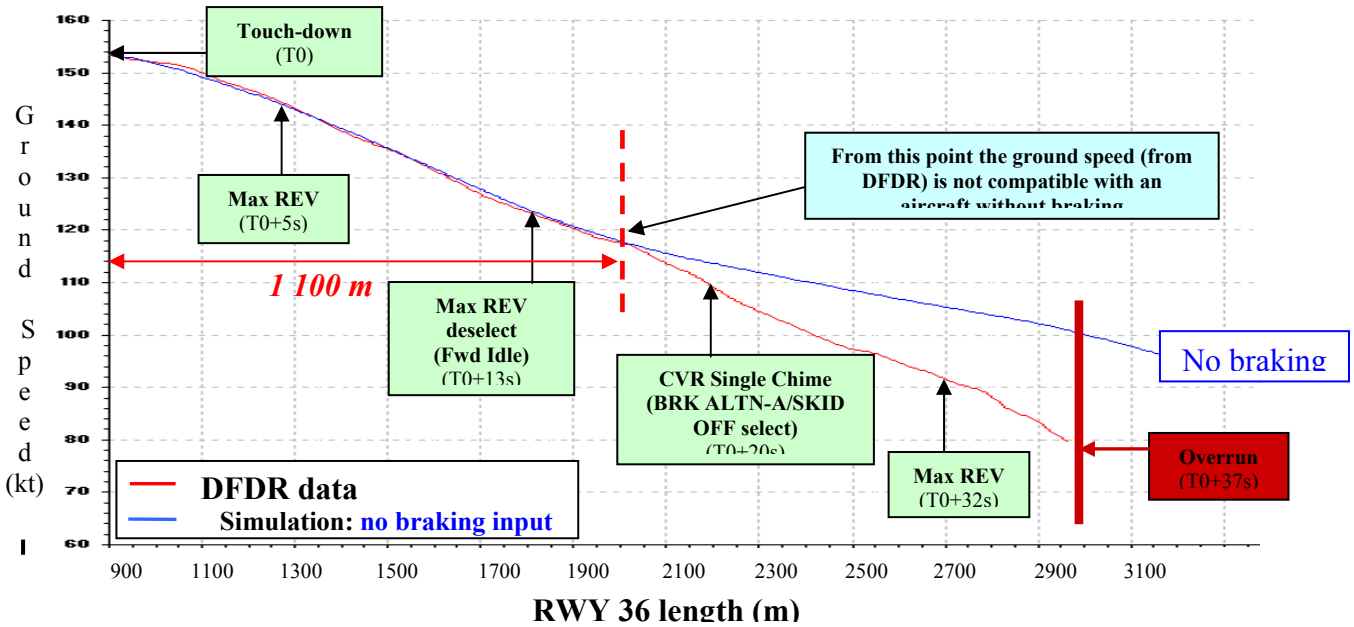
The aim of this simulation was to determine what would have been the evolution of the Ground Speed and deceleration, if no braking input had been applied during the whole landing rollout.

⇨ ***Additional data used for simulation:***

- Recomputed wind on ground: 10 kt tailwind
- Engine 1 (LH) thrust reverser not used
- Ground Speed at touch-down: 155 kt

⇨ ***Results***

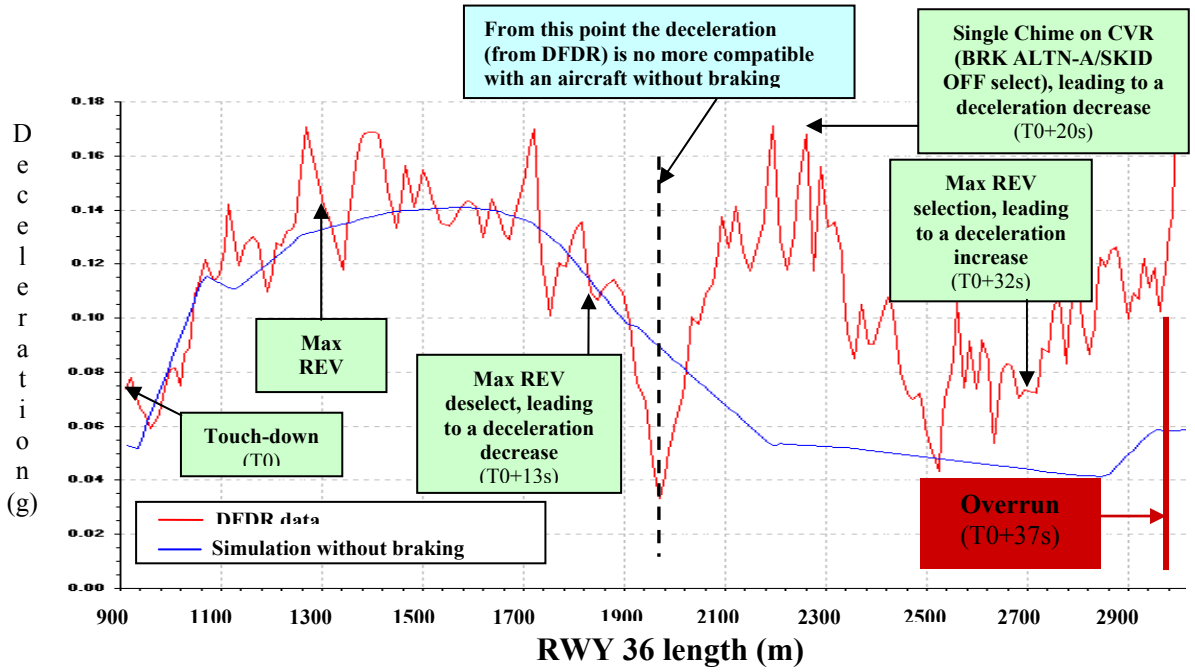
- **Regarding the ground speed**
  The red curve was determined with data coming from the DFDR.
  The blue curve was determined by simulation:
  - For a rollout without braking inputs (runway braking friction coefficient, μ, not applicable),
  - With thrust reverser 2 (RH) selected 5 seconds after touch-down and stowed 1800 meters after runway threshold (as for the event)



During the first 1 100 meters, the actual rollout matches with aircraft slowing down without braking.
After the first 1 100 meters, the actual rollout diverges from rollout without braking, which indicates that braking was effective

- **Regarding the deceleration**
  The DFDR records the longitudinal acceleration in the aircraft axis. For the need of simulation, the projection of this acceleration was computed on the aerodynamic axis.

Breaking performance simulation n°2 (with crew reported actions)

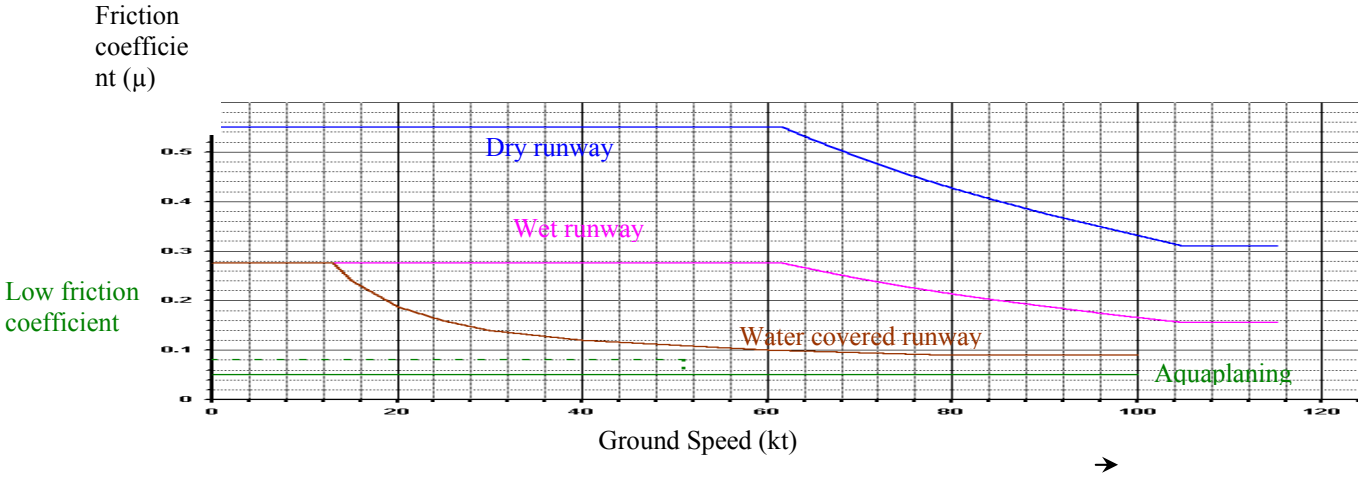


The aim of this simulation was to estimate the runway friction coefficient.

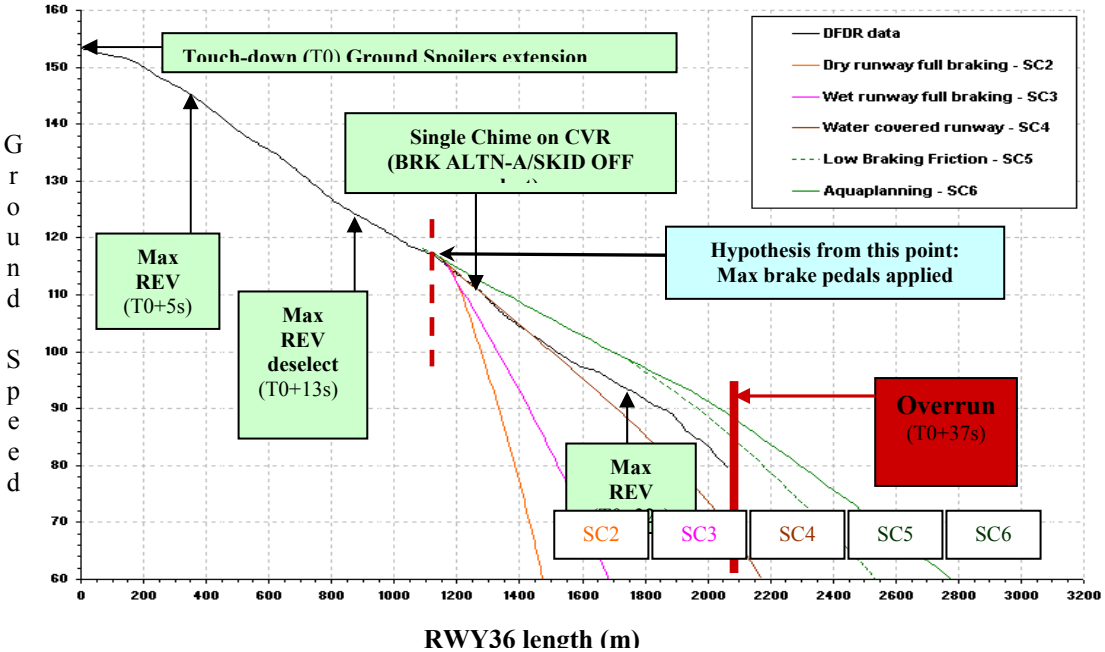
⇨ ***Additional data used for simulation:***

- Recomputed wind on ground: 10 kt tailwind.
- Engine 1 thrust reverser deployed after touch down, then stowed 1800 meters after runway threshold.
- Full braking input (max pedals) applied 2 000 meters after runway threshold for the following runway surface conditions:
  - Dry runway (curve "SC2")
  - Wet runway (curve "SC3")
  - Water covered runway (curve "SC4")
  - Low braking friction runway (curve "SC5")
  - Aquaplaning (curve "SC6")

  The runway braking friction coefficients (μ) used in these simulations are mentioned in the figure here after. They comply with the aircraft certification criteria.



⇨ ***Results:***



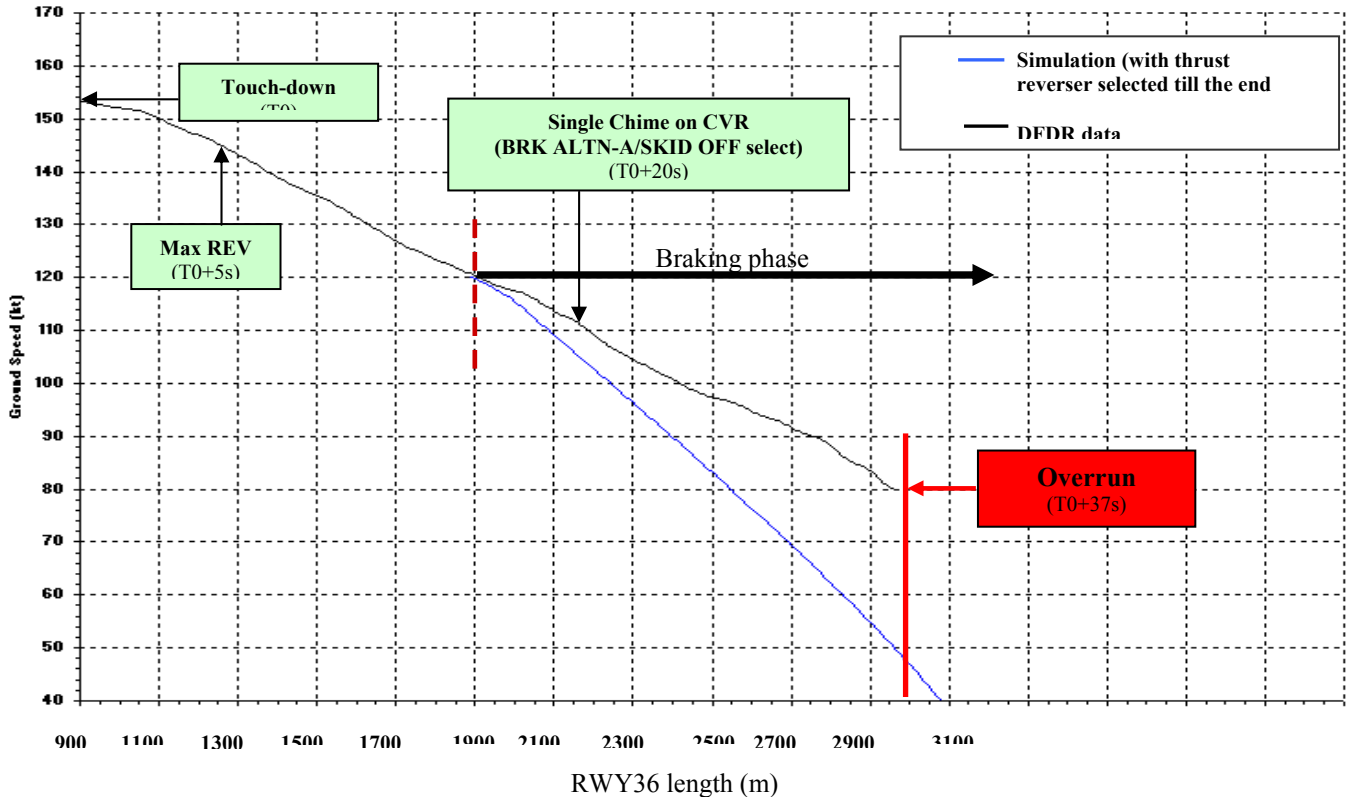
The **actual curve** (in black) is positioned between the **brown curve** ("water covered runway") and the **dotted green** one ("low braking friction").

1.19.1.5 <u>Breaking performance simulation n°3</u> (with one thrust reverser and full braking input)

The aim of this simulation was to determine what would have been the Ground Speed:

- With full braking input (max pedals) applied 2 000 meters after runway threshold.
- With thrust reverser kept selected till the end.

- With μ= 0.1, corresponding to a runway with low braking friction coefficient.



In that case, the aircraft would have overrun the runway at about 48kt instead of 76kt.

1.16.1.6 Simulation with non deployment of spoilers n°5

A simulation was made to check the effect of spoilers 5 inoperative. The simulation took into account "runway covered with water" conditions. This situation would lead to increase the speed at runway end by less than 5kt.

Nota: nothing was found regarding the spoilers in the maintenance documentation. When a specific spoiler (right or left) is declared failed, both spoilers (right and left) are inhibited. For the subject event, it was not possible to determine which side was faulty, and which component (actuator, EFCU, etc.) of the spoiler channel was the cause

1.16.2. Braking system

An investigation was carried out in April 2009 by Messier Bugatti, at Sudan Airways facilities in Khartoum. It was attended by representatives from:

- Sudanese CAA
- French BEA
- Sudan Airways
- Airbus

The investigation aimed at determining the status of both normal and alternate braking systems.

The results were the following (refer to Annex III Messier-Bugatti report, April 2009):

- Visual inspection:
  - All brakes were in good shape and within wear limits.
  - No leak was evidenced.
  - Several impacts related to the accident were observed.
  - Pistons were covered with earth.
  - Some pistons received melted aluminium.

- Hydraulic tests
  - All pistons were active under low pressure with no leak
  - At low pressure (200 Psi), the pistons were observed moving. Discs were no longer free to rotate and pistons applied pressure on thrust plate.
  - At high pressure (2000 Psi), no leak was witnessed.

1.16.3 Tires

The tires were shipped to France and examined in a French State Laboratory at the Centre d'Essais Aéronautique de Toulouse (CEAT, refer to Annex IV, report MT-09/9154 100/F1/A, 06 October 2009)

According to the conclusion of the CEAT:

- "8 tires show flat spot on the tread. 7 of 8 tires have burst, only the tire #1 (LH MLG – left front tire) did not burst.
- The flat spot damages are the consequences of a locking of the wheels. So, the 8 wheels of the main landing gears were locked.
- There was no evidence of hydroplaning seen on the tires. In fact, in case of hydroplaning, the damages of the tires are typical of a tread rubber reversion. That kind of marks was not seen on the tires.
- The rim of the wheels do not show flat wear marks. That indicates the rim did not scrap on the runway.
- The LH MLG marks seen close to the runway threshold and to the end of the stabilized pavement (cp Airbus factual report) indicate that the tires of the LH MLG were not burst."

1.16.4 Structure

Investigations were done to determine the cause of the right landing gear collapse with a part of the wing still attached. The results were the following:

- The maximum loads recorded by the DFDR during the rollout were the following (refer to annex II) :
  - Vertical g: +2.36
  - Longitudinal g: +0.78
  - Lateral g: -0.67
- According to certification requirements, structure is designed to resist to combined accelerations values up to 9 g.
- The structure analysis allowed confirming that the rupture was not caused by fatigue.
- On site investigation and Captain interview confirm that during the overrun, the aircraft destroyed some lights and antennae. Some parts were ingested by engine 2. Since the thrust reverser was deployed, these parts may have been thrown to the right wing.
- According to the Captain, the aircraft was on its three gears when he left the aircraft. Consequently the right landing gear did not collapse when the aircraft stopped, but later on.

1.17 Organization and management information

1.17.1 Sudan Airways

The operator Sudan Airways had a valid AOC NO-001 and a contract with Egypt air to carry out maintenance checks for the A310 type of aircraft. The documents regarding aircraft operation, maintenance and procedures were up dated.

1.17.2 ATC

ATC performance was inadequate in respect of the provision and updating weather information. At the time of the accident, there were no wind panel indicators in the tower for providing current wind velocity to arriving and departing traffic. Also the R/W lights were not controlled by the tower.

1.17.3 Meteorological Service

Meteorological service is available on a 24 HRS bases. The service can provide METAR, SPECI, short and long duration TAFS and SIGMET in addition to surface & upper air charts and briefing or consultation for flight crew.

1.17.4 Airport Fire Department

The number of airport fire fighting and rescue vehicles was sufficient but there was acute shortage in fire fighting personnel.
No means of communication between these vehicles and the station were available.
Due to rough and sandy surface around the crash site and lack of emergency exit routes, the response time was not in accordance with the standard.
Participation of civil defense fire vehicles in fighting the crash fire impaired the efficiency of airport fire and rescue vehicles.
The officers of the airport fire and rescue services were not permanently appointed. They were subject of being transferred to other departments after being well qualified and trained by CAA. So the leader of this operation appeared to have little experience in aircraft accident fire fighting.

1.18 Additional information

According to the recommendations which have been addressed to the DGCA the control of runway and associated lights are controlled by the airport control tower.

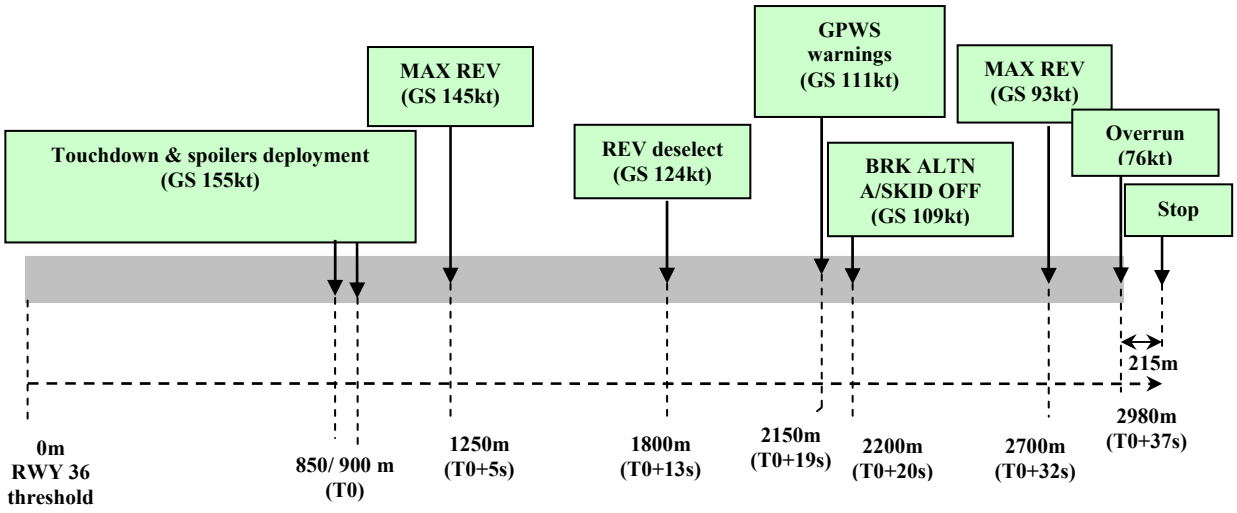
2. *Analysis*

General

On the day of the accident the aircraft was on schedule flight to Aman. It arrived Khartoum from Cairo with a deactivated No. one engine thrust reverser. According to Minimum Equipment List (as being approved by CAA Sudan) the aircraft may operate by this condition for fifteen days. The aircraft carried its designated mission with the deactivated thrust reverser on its route to Aman and back to Port Sudan. It was diverted to Port Sudan due to bad and rainy weather at Khartoum. After staying on ground for about 1:15 hours at Port Sudan the captain decided to proceed to Khartoum. He made a hold over Khartoum for about 20 minutes due to traffic as he stated. The weather was rainy and gusty. The weather relayed to him by Khartoum ATC was that of 16:00 and 1630 UTC. Then the aircraft was cleared to land R/W 36 and being informed by the ATC that the R/W was wet.

2.1. Sequence of events

According to the recorders analysis, the sequence of event was the following:



The captain was flying the aircraft. He complied with the control clearances and performed a stabilized approach. The CVR reading showed a good coordination between the Captain and the co-pilot.

The crew got headwind information from the controller (320 °, 07 kt). In these conditions, the simulation highlighted that the required landing distance would

have been sufficient to perform the landing on Khartoum runway 36 even if wet.

Just before the touchdown the FDR recorded 140 kt for Indicated Airspeed and 155 kt for Ground Speed. This means that the aircraft was actually subject to a 15 kt tailwind component. The crew seemed not to have realized it.
Due to tailwind, the aircraft touched down at about 850 to 900 meters from the threshold. A smooth landing was recorded which might also be a contributing explanation for such a long distance.

The simulations showed that the runway friction coefficient was poor which indicated that the pavement was very slippery. The controller informed the Captain that the runway was wet but the Captain decided not to switch the auto brake on, which is strongly recommended by the flight manual for special operation.

The crew felt the aircraft skidding to the right when the left thrust reverser was deployed, four seconds after touch down and due to the skidding the reverse was deselected nine seconds later at a speed of 124 knots. After deselecting the thrust reverser, the Captain pushed the left pedal and succeeded in putting the aircraft back to the centre line.

This come back was not the result of an aerodynamic effect since the rudder deflection was not big enough (5°) compared to the speed (around 130 kt). It could not have been induced by nose wheel steering since 5° rudder deflection corresponds to 1° steering rotation only. Thus, only a braking effect on the left main landing gear may have resulted in putting the aircraft back to the centre line.

The captain deployed again the left thrust reverser 32 seconds after touchdown at speed of about 87 knots, at a distance of about 80 meters from the end of R/W 36, but the speed was too low for this action to be efficient.
36 seconds after touchdown the aircraft overran R/W 36 at 76 knots, and vertical and horizontal accelerations up to 2.6 g and 0.76 g were recorded before the full stop. The combination of these maximum values is far from the acceleration value above which some structure damages may occur (9 g).

The fire is very likely due to a fuel leakage between the right engine nacelle and the right wing root. The aircraft was on its three gears after it stopped and no fatigue was evidenced on the broken parts of the structure. No traces of fire were found between the runway and the wreckage inspite of some witnesses statement that they saw the fire on the right side of the aircraft during its rolling on the runway. This indicates that:

- The fire started after the aircraft stopped or it my started within the deployment of engine No. 2 thrust reverser due to some fuel leakage.
- The fuel leakage was not the result of a structure breaking but was probably the consequence of a tank puncture made by the gusty wing fluctuation as was detected during the C check and being rectified or due landing lights or antennae or by some parts thrown to the wing through the trust reverser (Airbus recommends to stow the thrust reverser at low speed so as to avoid such issues).

2.2. Aircraft braking system

According to the FDR analysis, the left main gear braking system was working about 10 seconds after the touchdown when the Captain succeeded in putting the aircraft back on the centre line.
According to the brakes examination, no failure was evidenced on the equipment neither on the left main gear nor on the right one. No hydraulic failure was recorded on the FDR.
According to the rubber marks on the end of the runway as well as the results of the tires examination conducted by the CEAT, locking of wheels was evidenced on each tire. No hydroplaning traces were observed on the tires tread.
As a consequence, a braking system failure appears to be very unlikely.

2.3 Fire fighting operations

The investigation revealed that the fire could not be fought by the airport fire department with the required rapidity and efficiency. This was due to training as well as communications or infrastructure issues.

Conclusion

3.1 Findings

- The aircraft was dispatched to Amman with engine No. 1 thrust reverser deactivated
- The captain was the pilot flying, he performed a R/W 36 approach
- The crew got clearances for approach and landing.
- Aircraft was fully configured for landing, checks completed.
- The controller gave the following last wind information: 320° /07 kt.
- The aircraft was actually tailwind (15 kt).
- The controller advised the crew that the runway was wet.
- Auto brake was not selected.
- Touch down point was at about 900 meters beyond the runway 36 threshold.
- The captain landed smoothly and set both thrust levers in the maximum reverse and No. 2 reverser deployed normally and No. 1 reverse remained stowed.
- The ground spoilers deployed normally, except both spoilers No. 5
- The aircraft skidded to the right after the thrust reverser was applied.
- 10 seconds after touch down both reversers were stowed and thrust levers were set to idle
- The captain put the aircraft back to the centre line by differential braking.
- The wheels locked after the captain switched the anti-skid off and applied full braking on both pedals.
- The aircraft caught fire after stopping. It collapsed later on due to fire.
- Most of the crew members and the passengers succeeded in escaping through the front left L1.
- The fire fighting personnel could not provide a rapid and efficient service
- The investigation could not find evidence of aircraft technical issues which could have contributed to the accident.
- ILS R/W 36 was not calibrated.

3.2 Cause of the accident

The accident was due to a long flaring distance (900 meters from R/W threshold) on a wet slippery runway without selecting Auto brake and with one deactivated engine reverse in such rainy conditions. The remaining available landing distance turned out to be too short to allow the captain to stop the aircraft before the end of the runway.

Contributing factors:
The wind information was not appropriate as it was tail wind at time of landing.
The crew was not aware about the aircraft ground speed and the tail wind.

4 Safety Recommendation:-

SUDAN AIRWAYS:-

1) Have to strictly adhere to crew qualifications periodic training and evaluation for adverse weather conditions, abnormal and emergency procedures such as
   fire and evacuation multi crew (cockpit/cabin) training.
2) Aircraft maintenance schedules are to be revised and updated particularly in zones where structure is vulnerable to destruction and failure.
3) Aircraft maintenance cycles extensions, concessions and wavers are to be reduced /stopped.
4) Approvals of (MELs) Minimum Equipment Lists and (ADDs) carried forward defects, awarded to minimum, closely monitored and controlled.
5) FDRs /CVR are to meet the standard operation requirements as per Annex 6
6) To Chicago Convention.

CAA

1) Should increase the number of fire fighting personnel with the provision of the necessary personal protective equipment.
2) Should train fire fighting officers and should make the necessary arrangement for them not to be transferred **elsewhere**.
3) No vehicles other than airport fire fighting and rescue vehicles should participate in aircraft accident fire fighting.
4) Should develop and implement emergency plans for all airports.
5) Should establish emergency access roads to facilitate the movement of fire fighting and rescue vehicles.
6) Should establish reliable means of communication between the main fire fighting station and its vehicles and between the vehicles themselves.
7) Should establish a system of measuring friction level for wet runways.
8) Should ensure that tower controllers are properly trained and qualified.
9) Frequent ramp inspections/checks are to be conducted on airports, maintenance organizations, ATC equipment, airport runways, taxiways and aprons.
10) Urgent maintenance and calibration for ILS of both runways is highly recommended.
11) Control towers should be supplied with facilities for the provision of current surface wind velocity.

Eng.: Sir Elkhatim Kambal	Investigator-in-charge

Members of the Board

Capt: Abd El Fatah Sati	not participated
Eng. Abd El Samai Adam Ali	
Kamil Ahmed Mohamed	
Abd El karim Abd El Latif	
Mohamed Elhasan Taha	
Abd El Muniem Tyfor	
Eng. Abd El Ggadir Sir El Khatim	not participated
Capt. Osman El Saied.	