**AAIB Bulletin No: 2/94** **Ref: EW/C93/5/3** **Category: 1.1**

**INCIDENT**

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| **Aircraft Type and Registration:** | Airbus Industrie, A320-211, D-AIPP |
| **No & Type of Engines:** | 2 CFM56-5-A1 turbofan engines |
| **Year of Manufacture:** | 1990 |
| **Date & Time (UTC):** | 30 May 1993 at 1318 hrs |
| **Location:** | London Heathrow Airport |
| **Type of Flight:** | Public Transport |
| **Persons on Board:** | Crew - 6 Passengers - 91 |
| **Injuries:** | Crew - None Passengers - None |
| **Nature of Damage:** | 3 burst tyres, 2 wheel hubs and brake packs destroyed |
| **Commander's Licence:** | Airline Transport Pilot's Licence (German) |
| **Commander's Age:** | 40 years |
| **Commander's Flying Experience:** | 6,500 hours (of which 750 were on type)<br>Last 90 days - 174 hours<br>Last 28 days - 74 hours |
| **Information Source:** | AAIB Field Investigation |

**History of Flight**

Lufthansa flight LH4114 left Hannover, Germany at 1203 hrs for a scheduled passenger flight to London Heathrow Airport. An ILS approach was flown to Runway 27L. The crew received ATIS information 'Romeo', timed at 1245 hrs. This contained the following information:

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|---|---|
| Runway | 27L |
| Surface wind | 220°/11 to 34 kt |
| Visibility | 15 km in showers |
| Cloud | 6 oktas base 2,800 feet |
| Temperature/Dew point | 16°/9°C |
| QNH | 1003 mb |

Severe wind shear was forecast for the last 100 feet on final approach.

The approach was flown with flap selected to the number 3 position and the target threshold speed was 140 kt; this was increased by 10 to 15 kt to take account of the wind speed. The autobrake was selected to LOW. The crew reported that they experienced only moderate turbulence and no wind shear.

The touchdown appeared, to the crew, to have been normal with no evident yaw. During the initial part of the landing roll, the commander gained the impression that the aircraft was running on a flat tyre, however, he selected reverse thrust and applied moderate braking and had no problem keeping the aircraft straight. The first officer's attention was drawn by a single chime audio warning to the Wheel System page which was displayed on the Electronic Centralised Aircraft Monitoring (ECAM) system display unit. The page carried low tyre pressure warnings for mainwheels numbers 1,3 and 4; he informed the commander. As the aircraft slowed the first officer noted that a fault caption was displayed which showed that NORMAL braking was inoperative and that anti-skid protection and nosewheel steering had been lost.

As the aircraft slowed it became more difficult to steer and began to turn to the right. The commander increased braking and brought the aircraft to a halt, on the runway, about half way along block 84; this was only a short distance from the aircraft's normal turn off point in block 83. As there appeared to be no immediate danger, the commander decided not to order an emergency evacuation. The engines were shut down and communication with the emergency services was established. The time was 1318 hrs.

The Fire Chief decided that it would be safer to leave the occupants on board until the aircraft's stability was assured. Airbags and jacks were used to support the aircraft and the crew and passengers were evacuated at 1458 hrs; there were no injuries. The aircraft was brought to a condition where it could be towed from the runway at 1720 hrs and the runway was reopened at 1739 hrs.

The weather report to ATC at 1315 hrs was:

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|---|---|
| Surface wind | 230°/20 kt with gust to 30 kt |
| Visibility | 10 km in showers |
| Cloud | 6 oktas base 2,300 feet |
| Temperature/Dew point | 15°/10°C |
| QNH/QFE | 1003 mb/1000 mb |

The wind shear warning was still in force.

## Initial Examination

The aircraft had come to a halt slewed sharply to the right 1,330 metres from the runway threshold. The left outer mainwheel tyre had an X-shaped rupture from a single area of heavy abrasion but the rest of its periphery was undamaged. The left inner tyre had remained inflated with a single area of heavy abrasion. The two right wheels had been ground down to the hubs and brake packs, producing a single flat area of damage on each tyre and wheel. The segments of the tyres which still remained intact appeared quite undamaged.

The ground marks on Runway 27L, which were identifiable with the landing of D-AIPP, began with skid marks (continuous and unvarying) from the left mainwheels at 546 metres from the threshold. At 550 metres there were similar marks for the right wheels. At 742 metres the left wheel marks disappeared. The left outer wheel mark disappeared before the inner and there were indications that the outer tyre ruptured at this point. As the left inner wheel did not deflate it would appear that at that point the left wheels became free to rotate though the outer had already ruptured. There was one further, brief, skid from the left wheels at 1,070 metres. The skid marks from the right wheels were continuous to the point at which the aircraft came to rest with metal deposit on the runway becoming evident in the latter part of the trail and it appears that the right wheels had not rotated at all from the start of the skid.

The mainwheels were changed and the aircraft removed from the runway. During the post-accident checks with new brake packs and wheels fitted the brake and anti-skid systems performed normally. The Braking and Steering Control Unit (BSCU) and the Brake Dual Distribution Valve (BDDV) were removed for specialist examination. Neither unit showed any abnormality on test but the behaviour of the BSCU during the landing was scrutinised more closely using information from the aircraft's ECAM system and the BSCU's own Built-in Test Equipment (BITE) together with information from the Flight Data Recorder (FDR) and the Cockpit Voice Recorder (CVR).

## ECAM Post Flight Report

The ECAM Post Flight Report contained a record of two ECAM warning messages which had been displayed at the time (13.15 to within 1 minute) corresponding to the aircraft's landing time; 'BRAKES A/SKID NWS FAULT' (sic) and 'WHEEL TYRE LO PR'. Low pressure tyre warnings are inhibited above an airspeed of 80 kt. The 'BRAKES A/SKID NWS FAULT' warning signified that both BSCU systems had failed and, with the failure of nosewheel steering, the noseleg would be free to castor. A list of failure messages within the same recorded minute contained one showing a BSCU failure signalled from channel B. Other failure messages concerning tyre pressures and 'BRAKE TEMP SENSOR OR MONIT UNIT' were the result of the tyre bursts and the gross wheel damage which destroyed a temperature sensor on the right outer mainwheel.

## Flight Recorders

Following the incident the CVR and FDR were removed from the aircraft and replayed successfully at the AAIB.

The CVR produced a recording starting approximately 18 minutes before landing and finishing about 13 minutes afterwards. Five seconds after touchdown, a cockpit warning chime sounded, followed 1 to 2 seconds later by a sharp increase in the level of vibration in the cockpit. At 12 to 13 seconds the commander said words to the effect of "Sounds like flat tyres". Immediately after this a second cockpit warning chime sounded and coincident with the chime the first officer reported that there were three flat tyres. The sound of vibration began to reduce at about 17 seconds and by 24 seconds it was inaudible. Half a minute after touchdown the commander informed the tower that he had three flat tyres and then 20 seconds later that he was unable to leave the runway.

The FDR recorded over two hundred parameters, however, the recorder did not record the positions of the brake pedals and the parking brake or the hydraulic braking pressures. A selection of the relevant parameters that were recorded is shown in Figure 1 from shortly before landing to the end of the landing run.

Following a normal descent the aircraft touched down at a recorded airspeed of 158 kt and a groundspeed of 140 kt at time 13 seconds in Figure 1. The left main landing gear contacted the runway first, then the right gear only and finally all three gears, as indicated by the peak normal 'g' values of 1.30 g, 1.34 g, and 1.17 g respectively. By 16 seconds the spoilers had deployed and the aircraft was decelerating at an average of 0.13 g. This corresponds to aerodynamic braking; LO autobrake produces 0.17g deceleration and MED 0.3g. The deceleration increased to 0.30 g at 17 seconds, peaking to 0.44 g at 20 and 21 seconds, times at which the reverse thrust, indicated by N1 Eng1, was 40% to 42%. During the period 21 to 22 seconds the aircraft attitude changed from wings level to 1.5° right wing down. Towards the end of the landing run, roll had increased to 3° right wing down, and deceleration had decreased to 0.20 g to 0.25 g. The nominal landing heading of 270° was maintained until 31 seconds, after which it increased to a final value of 290°. The rudder, biased to the right during the early stages of the landing roll moved to a maximum of 24° left, as the aircraft turned to the right. The first cockpit chime sounded at a recorded groundspeed of 128 kt (airspeed 150 kt ) at 18 seconds, and the second warning chime at 27 seconds when the aircraft had a recorded airspeed of 77 kt.

## Operation of the BSCU and braking system

The BSCU is a dual system computer which receives inputs from the pilots' braking and steering controls together with information on wheel speed, aircraft acceleration, brake temperature, aircraft

configuration, flight phase and autobrake selection. The BSCU produces output to control the steering, normal braking, autobraking and anti-skid functions as required. Each of the two systems within the computer (A and B) performs distinct acquisition, computing and monitoring functions and either can be the controlling system from start-up. The monitoring function acquires and computes its own data and compares this with that used in the acquisition and computing functions to check the correct operation of the unit. The anti-skid function is performed by comparing actual wheel speed with a computed reference speed. At spin-up the reference speed is set to the greater of two speeds; one calculated from the wheel speed signals and one from a standard value (50m/s) which is reduced with time from the first landing gear touchdown. When the spin-up speed reaches its maximum value, the reference speed is then reduced in accordance with the measured aircraft deceleration.

NORMAL braking, with anti-skid protection and using the GREEN hydraulic system, can be signalled either by the pilot brake pedals transmitter or through programmed autobraking. If autobraking is selected brake pressure is modulated to achieve either the programmed deceleration (LO and MED settings) or the maximum that the conditions will allow within the operation of the anti-skid system (MAX setting). ALTERNATE braking is available using the YELLOW hydraulic system with hydraulic signalling. The applied brake pressures and accumulator pressure are displayed on a triple indicator gauge. If anti-skid is unavailable in ALTERNATE braking because of electrical failure or YELLOW system reversion to accumulator pressure, brake pressures can be monitored through the triple gauge to avoid brake locking.

The BSCU BITE record contained error messages and troubleshooting data obtained by the monitoring channels for a defect in each system at the landing time to within 1 minute. The error message for system B indicated that a spurious control signal had been sent to the brake selector valve. Troubleshooting information contained within the BITE indicated that the main wheels had spun up to 135 kt, that the parking brake was not on, that no significant braking pressure was being applied and that NORMAL braking was available with system B in control. The error message for system A registered because there was a difference of at least 24 kt between the reference speed contained in the computation card of the control channel and that calculated within the monitor channel. Troubleshooting information contained within the BITE indicated that at the time of the error the aircraft was travelling at a groundspeed of 109 kt, that the left outer and both right mainwheels were not rotating whilst the left inner mainwheel was rotating at a speed of 73 kt and that only ALTERNATE braking was available without BSCU control and, therefore, with no anti-skid protection.

The information in the BITE shows that the failure in system B was the first failure and that system B was the controlling system at touchdown. The cause of the failure of system B, a spurious signal to the brake selector valve, was not understood by Airbus Industrie but was under active investigation as such failures had been recorded previously. On occasion these failures had resulted in the type of

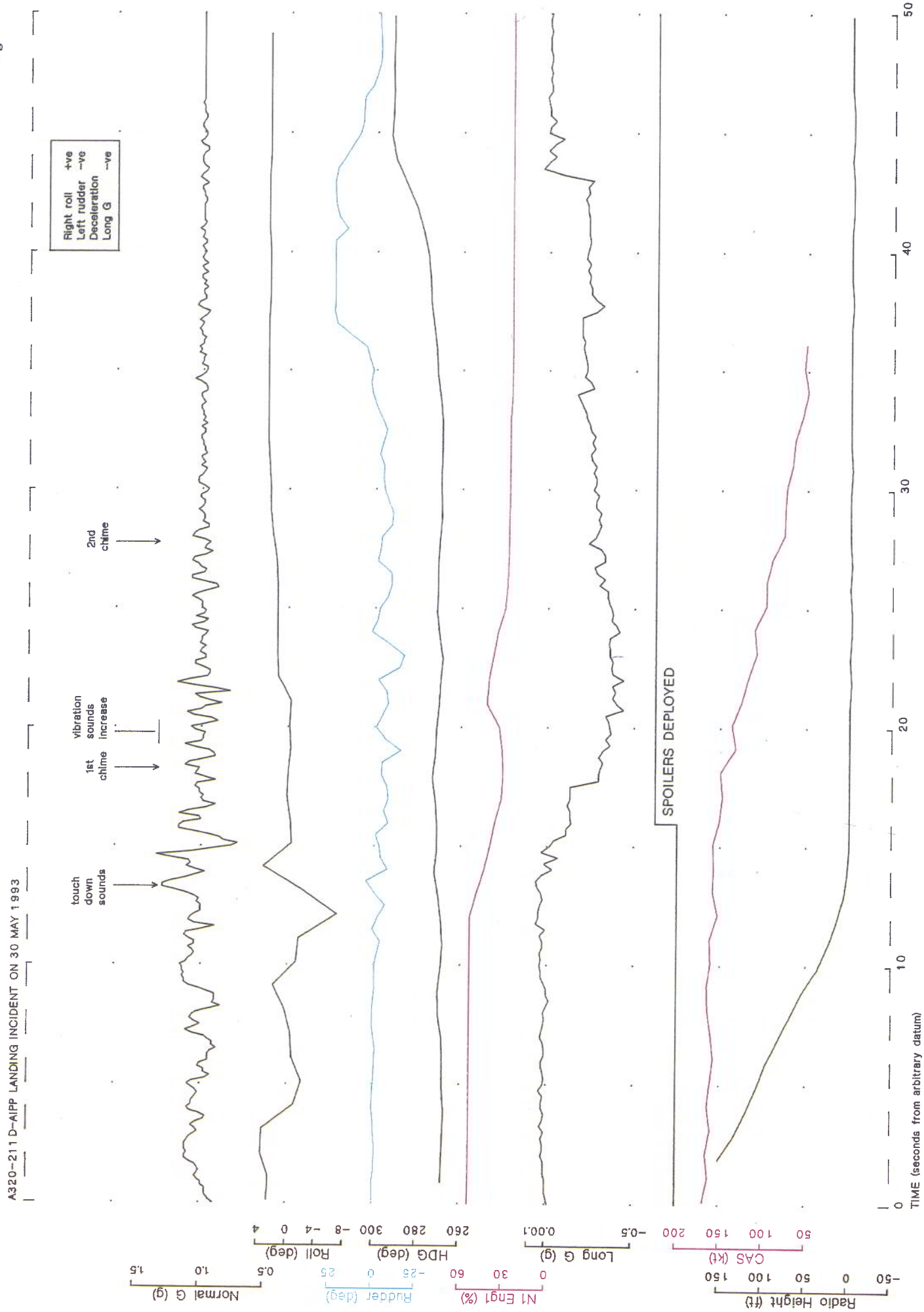
second system failure seen here. Airbus Industrie had found that the opening and closure of an external relay during the transfer from the failed system to the backup system resulted in voltage transients being passed into the acquisition card of the backup system. Such a transient could result in the failure of that system also. Inspection of the BITE reports contained within the BSCU indicated that at least 6 transfers from one system to the other had occurred in the previous 8 months.

The failure of system A immediately followed that in system B and was detected by the Flight Warning Computer which, after taking 1.75 seconds to confirm the failure, issued the ECAM warning 'BRAKES A/SKID NWS FAULT' on the upper ECAM display and sounded the first cockpit warning chime. The second chime, at 77 kt, was, most probably, the result of the tyre bursts for which the warning was inhibited above 80 kt.

**Safety Actions**

Although the cause of the first failure was still under investigation Airbus Industrie aim to eliminate the problem in the next BSCU standard planned for introduction in the third quarter of 1994. The BSCU on D-AIPP was to standard 5-4. The loss of the second system has been addressed by Airbus Service Bulletin A320-32-1115 which introduces relays with diode protection to eliminate the voltage transient. A modification to the BDDV is currently undergoing certification procedure to introduce a 'dual law' characteristic in the valve. While still allowing the same maximum braking pressure under ALTERNATE braking, the modified characteristic will reduce the initial rate of applied brake pressure versus pilot input to reduce the risk of wheels locking under the ALTERNATE system when no anti-skid protection is available.

**Figure 1**


A320-211 D-AIPP LANDING INCIDENT ON 30 MAY 1993
touch down sounds
1st chime
vibration sounds increase
2nd chime
Right roll +ve
Left rudder −ve
Deceleration −ve
Long G −ve
SPOILERS DEPLOYED
Normal G (g)
Roll (deg)
Rudder (deg)
HDG (deg)
N1 Engt (%)
Long G (g)
CAS (kt)
Radio Height (ft)
TIME (seconds from arbitrary datum)