AIRCRAFT ACCIDENT REPORT 4/2008

Air Accidents Investigation Branch

Department for Transport

Report on the incident to Airbus A320-214, registration G-BXKD at Runway 09, Bristol Airport on 15 November 2006

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996

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Department for Transport
Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
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Hampshire GU11 2HH

January 2008

The Right Honourable Ruth Kelly
Secretary of State for Transport

Dear Secretary of State

I have the honour to submit the report by Mr R J Tydeman, an Inspector of Air Accidents, on the circumstances of the incident to Airbus A320-214, registration G-BXKD at Bristol Airport on 15 November 2006.

Yours sincerely

David King
Chief Inspector of Air Accidents

Contents

Appendices

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	Air Accidents Investigation Branch
agl	above ground level
AIDS	Aircraft Integrated Data System
AirN@V	Computerised manual of Airbus aircraft
AIP	Air Information Package
AMM	Aircraft Maintenance Manual
amsl	above mean sea level
ATA	Air Transport Association
ATC	Air Traffic Control
ATIS	Automatic Terminal Information System
ATS	Automatic Throttle System
BITE	Built In Test Equipment
CAA	Civil Aviation Authority
CFDIU	Central Fault Display Interface Unit
CFDS	Central Fault Display System
CG	centre of gravity
CVR	Cockpit Voice Recorder
EASA	European Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitor
EIU	Engine Interface Unit
FCOM	Flight Crew Operating Manual
F/D	Flight Directors
FDR	Flight Data Recorder
FO	First Officer
ft	feet
ft/min	feet per minute
ft/sec	Feet per second
g	normal acceleration
GMT	Greenwich Mean Time
gw	gross weight
gwl	gross weight landing
HDG	Heading
hrs	hours (clock time as in 12:00 hrs)
hPa	hectopascal (equivalent unit to mb)
ILS	Instrument landing system
JAR	Joint Aviation Regulation
kg	kilogram(s)
km	kilometre(s)
kt	knot(s)
LDA	Landing Distance Available
LGCIU	Landing Gear Control and Interface Unit
m	metres
MAC	Mean Aerodynamic Chord
METAR	a timed meteorological report
MLG	Main Landing Gear
mm	millimetre(s)
N_1	engine fan or LP compressor speed
ND	Navigation Displays
nm	nautical mile(s)
PAPI	Precision Approach Path Indicator
PDF	Portable Document Format
PF	Pilot Flying
PFR	Post Flight Report
PNF	Pilot Non Flying
QNH	pressure setting to indicate elevation above mean sea level
RALR	Radio Altimeter Descent Rate
RTF	radiotelephony
SB	Special Bulletin
SIL	Service Information Letter
TAF	Tactical air force
TCAS	Traffic Collision Avoidance System
TDZ	Touch Down Zone
UK	United Kingdom
UTC	Co-ordinated Universal Time (the contemporary equivalent of GMT)
V_{APP}	approach speed
VRTA	vertical acceleration
V/S	vertical speed
°C,F,M	Celsius, Fahrenheit, magnetic

Air Accidents Investigation Branch

Aircraft Accident Report No: 4/2008 (EW/C2006/11/02)

Registered Owner and Operator	Thomas Cook Airlines UK Ltd
Aircraft Type	Airbus A320-214
Serial No	735
Nationality	British
Registration	G-BXKD
Place of Incident	Runway 09, Bristol Airport
Date and Time	15 November 2006 at 1932 hrs
	All times in this report are UTC (equivalent to local time)

Synopsis

The Air Accidents Investigation Branch (AAIB) was notified by the Bristol Tower ATC watch supervisor on 16 November 2006 of an incident involving a diversion of an A320 aircraft, G-BXKD, to Manchester Airport. The diversion resulted from a landing gear malfunction after takeoff from Bristol Airport. Subsequent enquiries revealed that the landing gear had been damaged during the previous landing at Bristol on 15 November. The following Inspectors participated in the investigation:

Mr R J Tydeman	Investigator-in-Charge
Mr R W Shimmons	Operations
Mr P A Sleight	Engineering
Mr A Burrows	Flight Data Recorders

The A320 aircraft had landed at Bristol Airport in a strong crosswind, with associated turbulence. During the shutdown procedure the crew were presented with an automatically generated aircraft warning indicating that certain parameters had been exceeded during the landing. The crew recorded the exceedence in the Technical Log. A type-qualified engineer met the aircraft on arrival and complied with his understanding of the technical checks required after the generation of such a warning. Substantial damage had occurred to the landing gear, but this damage was not detected before the aircraft was cleared for a further flight. On that flight the crew experienced landing gear problems after takeoff, together with other warnings, and diverted to Manchester Airport. Following further engineering activity, the aircraft was again released for flight without the damage being detected; this resulted in a repeat of the gear problems and other warnings after takeoff. The damage to the landing gear was eventually discovered after the subsequent landing at Manchester.

The investigation identified the following contributory factors:

1. The A320 aircraft landed at Bristol Airport in a strong crosswind with associated turbulence; the landing was classified as ‘hard’ because specified parameters were exceeded at touchdown.

2. The autopilots were disconnected about 100 ft above the runway threshold. In the prevailing turbulent conditions, this allowed insufficient time to separate the piloting tasks of taking control of the aircraft and flaring the aircraft to land.

3 The engineers maintaining the aircraft at Bristol had not received adequate training in the use of the computer software supporting the operator’s aircraft manuals.

4. The Airbus aircraft manuals did not differentiate, in their effectivity coding, how the implementation of Service Bulletins affected specific aircraft.

5. No connection was made between the previous LOAD <15> report and the subsequent 20GA sensor failure, indicating the internal damage to the landing gear.

6. Guidance provided in the aircraft manuals required to interpret the LOAD<15> report was unclear and differences existed between sections, particularly with regards to corrective action.

Four Safety Recommendations have been made.

1 Factual Information

1.1 History of the flight

Incident flight

The flight crew were scheduled to operate a passenger flight from Bristol Airport to Larnaca Airport, in Cyprus, and the return flight to Bristol Airport. Since the surface wind for the landing back at Bristol was forecast to be a crosswind of between 30 to 35 kt, the commander decided that he would be the Pilot Flying (PF) for the inbound flight.

In accordance with company procedures, the First Officer (FO), who was the Pilot Non Flying (PNF) for the inbound flight, completed an external inspection of the aircraft before the return flight: she did not report any defects. The flight to Bristol was initially uneventful. Prior to descent the ATIS indicated that Runway 09 was in use, with a surface wind from 170º at 22 kt, gusting to 35 kt; the lowest cloud base was about 2,000 ft. The commander was very familiar with Bristol Airport and knew that there was a down slope after the touch down zone (TDZ). He therefore decided to land with full flap and to keep the autopilot and autothrust engaged for as long as possible; he included this information in his brief to the FO. For the subsequent ILS approach, the commander used heading and vertical speed (HDG, V/S) modes and 'managed speed' with both Flight Directors (F/D) selected; both autopilots were engaged. When the aircraft was 5 nm from touchdown the Bristol Tower controller transmitted, "*Cleared to land Runway 09 with surface wind 180º / 23 kt gusting 33 kt*".

The crew had fully configured the aircraft for landing early on the approach. The commander considered that the aircraft was stabilised on the glide slope and the localiser and was maintaining the required airspeed. Because of the forecast wind conditions, both pilots were closely monitoring the wind indication on their respective Navigation Displays (ND). There was no significant turbulence until the aircraft descended below 250 ft agl. During the approach, the crew noted that the wind was indicating approximately 50 kt from a southerly direction. At about 208 ft radio altitude, the commander disconnected the autopilot and both pilots then felt the aircraft roll suddenly to the left. (Due to the ground profile on the final approach, this corresponded to about 102 ft above the runway threshold). They both independently considered a go-around but the commander corrected the aircraft attitude promptly and effectively and continued the approach. At about 70 ft agl there was another uncommanded roll to the left but this was again corrected promptly by the commander. He retarded the thrust levers on the 'Retard' command, applied rudder to align the aircraft with the runway centre line and flared for the landing. As he did so, the aircraft suddenly sank and the landing, within the TDZ, was very firm. The aircraft bounced slightly and the commander was aware of the FO calling "Go-around". However, he had already selected reverse thrust on both engines, and with the spoilers deployed, he responded "No". The aircraft retardation on the runway was good and the commander vacated the runway at Taxiway Bravo.

The FO had been monitoring the approach and had commented to the commander that the wind had been from the south between 40 and 50 kt; the direction appeared to stay within about 10º. She also recalled that they had sufficient fuel to make a second approach and then divert to London (Gatwick) or Birmingham. During the approach, she noted that the aircraft was maintaining the glideslope and localiser and that the PAPIs appeared to be accurate. She heard the commander advising her that he was disconnecting the autopilot. Her perception was that the touchdown was heavy, with the right gear touching down first, and with the aircraft to the left of, but aligned with, the runway centreline. She believed that the aircraft was going to become airborne again and this had prompted her to call for a go-around. She was also aware of a 'Dual Input' call and believed that she may have momentarily obstructed her sidestick controller.

The commander taxied the aircraft to the allocated stand and after shut down, a LOAD <15>[1] report was automatically generated and printed. In addition to entering the report activation into the Technical Log, the crew passed the hard copy of the LOAD <15> report to the engineer who came to the flight deck. The commander also reported that they had landed quite hard and could the engineer have a look around the aircraft; his main concern was that there may have been evidence of a tail-scrape on the underside of the aircraft. Subsequently, as the crew left the aircraft the commander saw the engineer give him a "thumbs up", which the commander interpreted to mean that there were no obvious signs of damage to the aircraft.

The flight crew subsequently submitted an Air Safety Report stating that the aircraft had experienced a LOAD <15>landing.

1 A LOAD <15> report is automatically generated following a parameter exceedance and is presented to the crew on paper via a printer on the centre consol; See para 1.6.4.

Engineering action

The engineer, working for a third party contractor at Bristol met the aircraft and spoke with the flight crew. He was handed the LOAD <15> report, with the crew stating that it meant that "we came in a bit hard". The engineer put the report to one side and completed the normal external checks. These checks did not include any areas specifically related to a heavy landing. Following the checks, he gave his usual wave and "thumbs up" to the flight crew as a gesture of "goodbye"; it was not intended to be an indication that everything was fine with the aircraft.

Having completed the routine inspections he then dealt with the LOAD <15> report. The engineer had not seen a LOAD <15> report before, and as he was unaware of its relevance he referred to the Aircraft Maintenance Manual (AMM) using the Airbus computerised aircraft documentation system 'AirN@V'. He initially referred to AMM task 31-37-00 page block 200 '*AIDS INPUT INTERFACE ((FDMIU)) – MAINTENANCE PRACTICES*' and in particular the associated flow chart. The engineer then navigated to AMM 05-51-11 PB 601 '*INSPECTIONS AFTER HARD/OVERWEIGHT LANDING – INSPECTION / CHECK' TASK 05-51-11-200-004*'. He then checked the effectivity which quoted '***ON A/C 001-013, 301-302*'; G-BXKD was effectivity code 006. The engineer then spent the next seven hours inspecting the aircraft. The check did not reveal any visible signs of damage and the engineer released the aircraft back into service.

Subsequent flight

On 16 November, another flight crew reported to fly the aircraft from Bristol to Lanzarote. The commander noted from the Technical Log that the aircraft had produced a LOAD <15> report on its previous landing and that a hard landing check had been completed before the aircraft was returned to service. No defects were noted during the external inspection of the aircraft prior to the flight.

After takeoff, the landing gear would not retract and multiple warnings were presented on the Electronic Centralised Aircraft Monitor (ECAM), including an indication of a partial failure of the anti-ice system and an inoperative No 1 engine reverser. When it was safe to do so the commander selected the landing gear down and up again, in accordance with the ECAM procedures. The landing gear retracted correctly but the other warnings remained together with others that cycled on and off. The crew declared a 'PAN' and established a holding pattern at 5,000 ft amsl. With the possibility of problems with the landing gear, asymmetric reverse thrust and anti-icing, the crew decided to divert to Manchester, an airfield with a long runway, where the weather conditions were good and, because it was their main operating base, where appropriate maintenance support was available.

Prior to leaving the holding pattern, the landing gear was lowered to ensure its correct operation, to reduce the ECAM messages and to increase the fuel consumption and thereby reduce the landing weight. The crew subsequently completed the Overweight Landing Check before making a gentle touchdown on Runway 24 Left at Manchester.

Engineering action

Prior to the aircraft's arrival at Manchester, Maintrol contacted an engineering team and made them aware that the aircraft was inbound with problems with the landing gear and thrust reversers. On its arrival the engineers looked at the automatically generated Post Flight Report (PFR), which identified a problem with the right Main Landing Gear (MLG) extend sensor 20GA.

Examination of the sensor using the Landing Gear Control and Interface Unit (LGCIU) confirmed a hard fault with the sensor, which was changed. At this point one of the engineers became aware of the technical log entry for the LOAD <15> report. However, as this had been cleared with an adequate inspection, and as there were no visible signs of damage to the landing gear, the engineer did not take any further action.

The AMM includes information regarding the actions required following a sensor replacement and states:

> *'(2) If necessary do an inspection of the applicable MLG sensor and target clearance…'*

The engineers decided it was not necessary to carry out this inspection; the basis for this decision was that the sensor was fixed and the adjustment of the target had not been altered during the sensor replacement. If this inspection had been carried out, it would have required the aircraft to be jacked. Following the sensor replacement the aircraft was released to service for a non-revenue ferry flight to Bristol. The aircraft documentation, including the LOAD <15> report were taken to Maintrol and handed to a specialist technical services engineer in the operator's engineering department.

Third flight

After approximately 2 hours, the aircraft was returned to service and the same flight crew, together with the cabin crew, were requested to position the aircraft to Bristol. After takeoff, the landing gear failed to retract and the crew were presented with almost the same warnings as on the previous flight. They reselected the landing gear down declared a 'PAN' and returned to land at Manchester.

Engineering action

After landing, the engineers took the aircraft to a hangar for jacking. During the jacking, it became evident that the right MLG had suffered severe internal damage. The inner sliding tube was over extending and the attached axle and the main wheels were only prevented from detaching by the torsion links.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor/none	7	179	0

1.3 Damage to aircraft

The right main landing gear internal upper diaphragm tube had ruptured allowing the inner sliding tube to over extend. There was no other damage to the aircraft.

1.4 Other damage

Nil.

1.5 Personnel information

The following information relates to the crew involved in the landing at Bristol on 15 November 2006.

1.5.1 Commander

Male:	Aged 41 years	
Licence:	Airline Transport Pilot's Licence	
Aircraft Ratings:	Airbus A320 and Boeing 757	
Last Licence Proficiency Check:	26 June 2006	
Last Line Check:	19 December 2005	
Last Medical:	25 September 2006	
Flying experience:	Total all types:	11,200 hours
	On type:	5,600 hours
	Last 90 days:	184 hours
	Last 28 days:	59 hours
	Last 24 hours:	9 hours
Previous rest period:	13 hours	

1.5.2 First Officer

Female:	Aged 30 years	
Licence:	Airline Transport Pilot's Licence	
Aircraft Ratings:	Airbus A320 and A330	
Last Licence proficiency Check:	6 October 2006	
Last Line Check:	28 April 2006	
Last Medical:	11 July 2006	
Flying experience:	Total all types:	3,076 hours
	On type:	1,719 hours
	Last 90 days:	136 hours
	Last 28 days:	44 hours
	Last 24 hours:	9 hours
Previous rest period:	13 hours	

The following information relates to the crew involved in the flights from Bristol and Manchester on 16 November 2006

1.5.3 Commander

Male:	Aged 43 years
Licence:	Airline Transport Pilot's Licence
Aircraft Ratings:	Airbus A320
Last Licence Proficiency Check:	29 September 2006
Last Line Check:	31 March 2006
Last Medical:	4 October 2006

Flying experience:	Total all types:	7,853 hours
	On type:	4,165 hours
	Last 90 days:	110 hours
	Last 28 days:	68 hours
	Last 24 hours:	nil
Previous rest period:	13 hours	

1.5.4 First Officer

Male:	Aged 29 years	
Licence:	Airline Transport Pilot's Licence	
Aircraft Ratings:	Airbus A320, Bae 146 and BAe ATP	
Last Licence proficiency Check:	29 September 2006	
Last Line Check:	15 July 2006 2006	
Last Medical:	12 July 2006	
Flying experience:	Total all types:	3,508 hours
	On type:	789 hours
	Last 90 days:	148 hours
	Last 28 days:	39 hours
	Last 24 hours:	nil
Previous rest period:	13 hours	

1.5.5 Engineer 1

Male:	Aged 41 years
Licence:	Part 66 B1 issued 27 September 2002
Aircraft Ratings:	A320/321 (CFM 56)
	A320/321 (V2500)

Engineer 1 was a line maintenance engineer based at Bristol. He had been working with the third party maintenance organisation for 2 years. Prior to this he spent 2 years with another maintenance organisation, and the previous 6 years with an aircraft manufacturer dealing with structural passenger to cargo conversions.

On the day of the incident, he commenced work at 1600 hrs and finished at 0330 hrs. Prior to arriving for work he felt suitably rested, and had at least 6 hours sleep. This was his fourth 12-hour night shift, having already worked similar hours on 12, 13 and 14 November. During the night following the incident, he was not under any undue pressure. After dealing with a Boeing 757 belonging to the operator of the maintenance organisation, G-BXKD was the only other aircraft with which that he had to deal.

1.5.6 Engineer 2

Male:	Aged 47 years
Licence:	Part 66 A, B1, B2, C issued 30/12/2003
Aircraft Ratings:	Boeing 757, Airbus A320, Airbus A330

Engineer 2 was a Base engineer in Maintrol for the operator of G-BXKD and based at Manchester. He was an avionics engineer, with some engine approvals but no airframe approvals. The day of the aircraft's arrival at Manchester was the engineers first day of a 4-day schedule of 12-hour shifts; this had been preceded by a 4-day rest period.

1.5.7 Engineer 3

Male:	Aged 36 years
Licence:	Part 66 A, B1, B2, C issued 2/8/2005
Aircraft Ratings:	Boeing 757, Airbus A320, Airbus A330

Engineer 3 was a licensed aircraft engineer with the operator of G-BXKD and was based at Manchester. He was an avionics engineer. The day of the aircraft's arrival at Manchester was his first day of a 4-day schedule of 12-hour shifts; this had been preceded by a 4-day rest period.

1.5.8 Engineer 4

Male:	Aged 42 years
Licence:	Part 66 A, B1, C issued 8/8/2005
Aircraft Ratings:	Boeing 757, Airbus A320, Airbus A330

Engineer 4 was a licensed aircraft engineer with the operator of G-BXKD and was based at Manchester. He held airframe and engine approvals but no avionics approvals. The day of the aircraft's arrival at Manchester was his first day of a 4-day schedule of 12-hour shifts; this had been preceded by a 4-day rest period.

1.6 Aircraft information

1.6.1 General information

Manufacturer:	Airbus
Type	Airbus A320-214
Aircraft serial number	735
Year of manufacture	1997
Number and type of engines	2 CFM56-5B4/P turbofan engines
Total airframe hours	32,147 Hours and 11,122 cycles
Certificate of registration	Issued 13 January 1999 and valid
Certificate of airworthiness	Issued 26 October 2006 and valid
Last maintenance	A check on 3 October 2006 at 31,774 hours
Maximum take off weight	77,000 kg
Maximum landing weight	64,500 kg
Maximum cross wind	Takeoff 29 kt (demonstrated) Landing 33 kt (demonstrated) Gust 38 kt (demonstrated) CAT II or CAT III Autoland 20 kt
Maximum tail wind	10 kt

1.6.2 Landing gear

The main landing gear of the A320 consists of a leg incorporating a shock absorber, torque links, side stay and retraction actuators.

The leg has a main fitting and a sliding tube and axle. The sliding tube fits and moves vertically inside the main fitting and together the two items provide the shock absorbing. The shock absorber function within the gear is a two stage unit with four chambers. A first stage chamber contains gas and hydraulic fluid, a recoil chamber of hydraulic fluid, a compression chamber and a second stage gas chamber, as depicted in Figure 1.

The damping tube, which contains the first stage orifice, is attached to the second stage cylinder. Movement of the damping tube through the orifice block decreases the fluid flow in the first stage increasing the damping effect. A floating piston in the second stage cylinder separates the hydraulic fluid of the compression chamber and the gas of the second stage chamber. During compression, the floating piston does not move until the pressures of the first and second stage chambers are equal.

The upper diaphragm tube is attached to the main fitting by a lateral pin at its upper end. This pin also contains the charging valve for the first stage chamber. The upper diaphragm tube is fixed, but the sliding tube moves vertically between the tube and the main fitting. The sliding tube has travel stops that engage with the bottom of the upper diaphragm tube, preventing the sliding tube from extending beyond the bottom of the tube during an extension, as depicted in Figure 2.

The torque links are attached to the main fitting and the sliding tube to align the axle and prevent rotation.

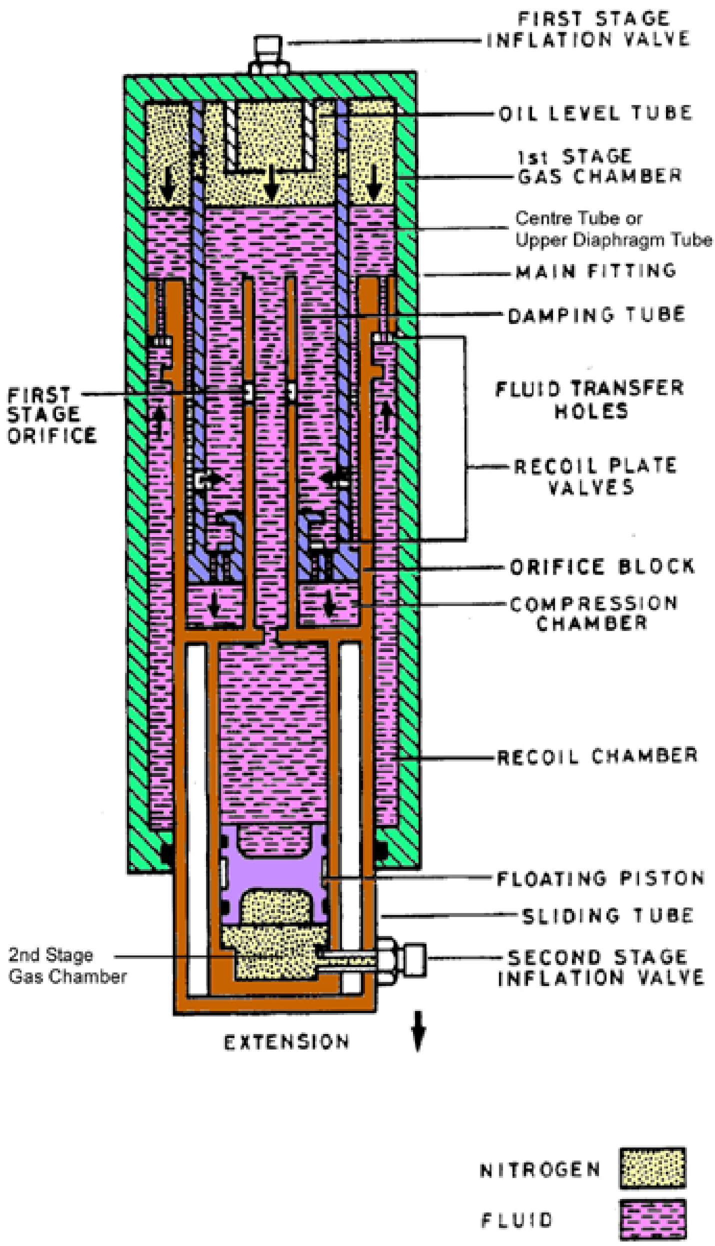


Figure 1

Simplified diagram of the landing gear internal operation

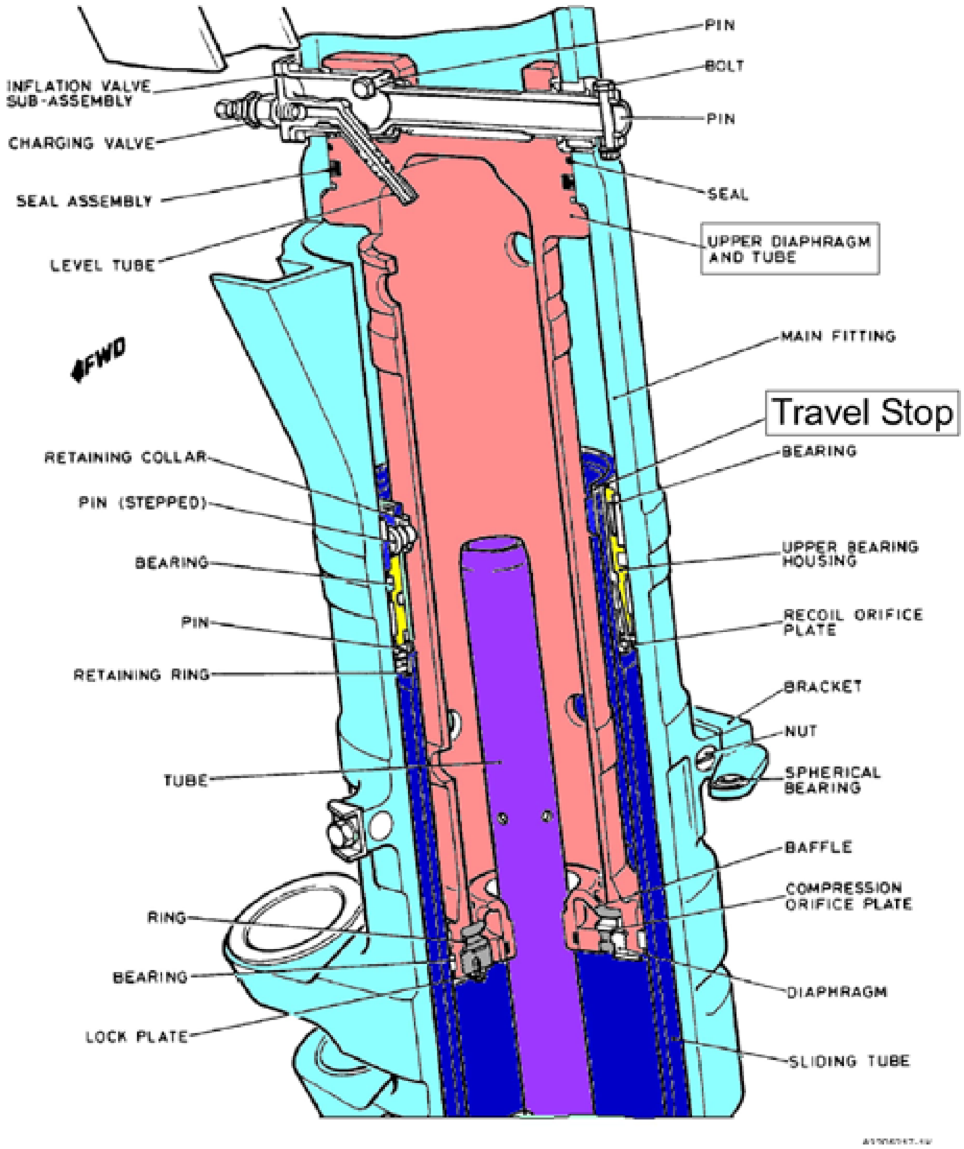


Figure 2

Upper section of the main landing gear

1.6.3 Landing gear warning system

The landing gear warning system consists of various proximity sensors, which feed positional data to the two LGCIUs. The LGCIU uses the sensor data, in addition to the gear lever position, to produce positional and warning information to the flight crew via the ECAM and the landing gear annunciator panel.

For each part of the gear that is monitored, there are two sets of proximity sensors, one feeding LGCIU1 and the other LGCIU2. The sensors detect the position of the landing gear doors, oleo compression and extension and the gear down and locked condition. The LGCIU uses the sensor data, especially the oleo compression and extension sensors, to determine whether the aircraft is in the air or on the ground. The LGCIUs then feed the air/ground information to the other systems on the aircraft. Only one LGCIU is in control of the landing gear during the flight, with control switching between the two units when the landing gear lever is selected DOWN or a fault is detected. Landing gear positional data, however, is not dependant on which LGCIU is in control.

The right main landing gear has two sensors which indicate whether the oleo is compressed or extended. Sensor 20 GA supplies LGCIU1 and 22GA supplies LGCIU2. Figure 3 shows the sensors and their location on the right main landing gear. With the oleo compressed by the aircraft weight, the sensors are out of proximity and when the oleo is extended; in the air, they are in proximity.

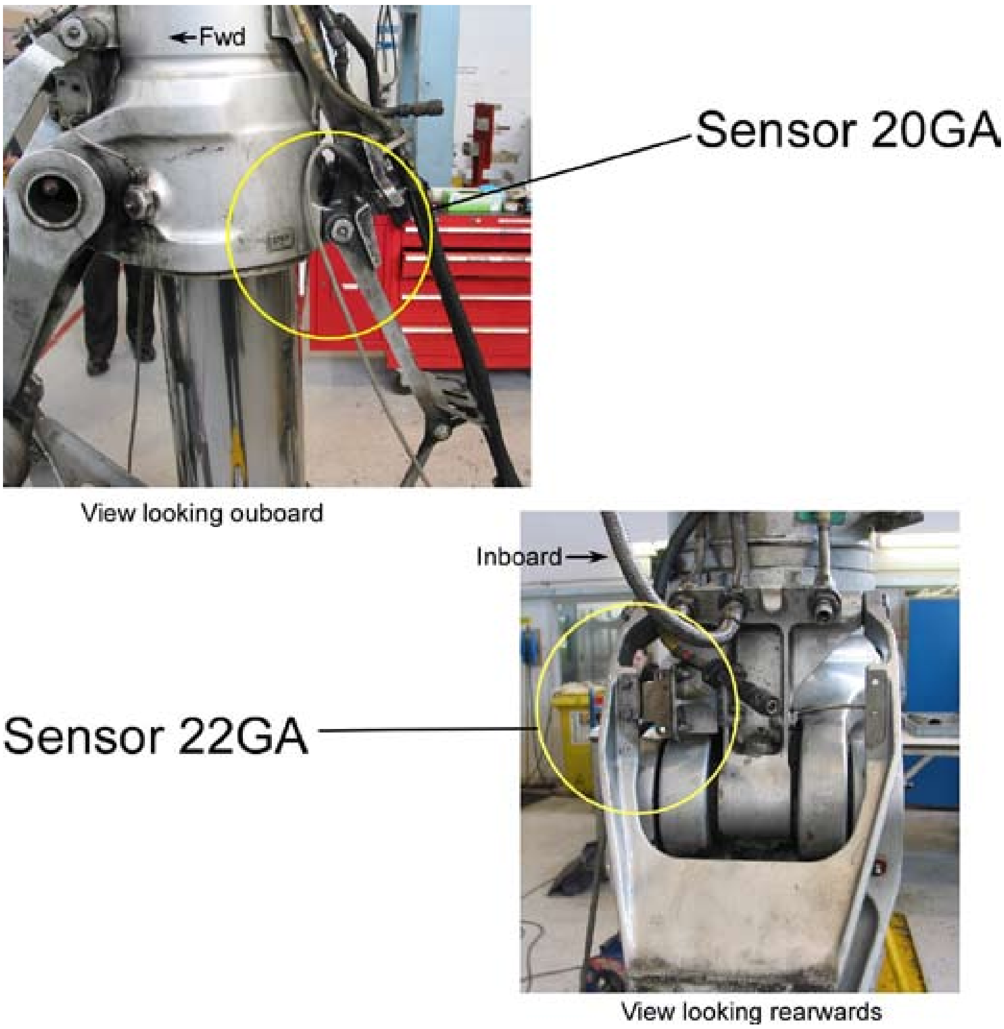


Figure 3

Sensor 20 GA and 22 GA location on right main gear

If a problem occurs with sensor 20GA, either due to a target problem or a sensor failure, this can result in several faults being reported on the aircraft. This sensor only supplies LGCIU1; if this unit is in control when the gear lever is moved to retract the gear, it will not allow the gear to retract. LGCIU1 also uses the sensor information to supply positional data to various systems. For example, with a sensor 20GA moving out of proximity in the air the following failures can occur:

1) Eng 1 EIU
2) FO pitot probe heat
3) Flying controls
4) Eng 1 thrust reverser
5) Fuel auto feed
6) TCAS

A failure of a sensor will also be latched on the BITE for the affected LGCIU and a message will appear on the PFR. A failure of sensor 20GA, due to a problem with the proximity of the sensor to the target, produces the following failure message on the PFR:

'32-31-73 R L/G EXT PROX SNSR 20GA TGT POS'

To assist in troubleshooting such a defect, there is a function on AirN@V (see section 1.18.3) where the fault codes on the PFR can be entered to find the correct section of the troubleshooting manual. In addition, the manufacturer issued a Service Information Letter (SIL) 32-067 which provided additional information about the faults expected following a sensor failure or an LGCIU failure.

When the fault shown above for 20GA is entered into the troubleshooting function of AirN@V the manual directs the engineer to troubleshooting manual task '*32-31-00-810-842 L/G Shock Absorber Extended Proximity Sensor TGT POS Fault (20GA thru 25GA)*'. The first step for this task is to carry out '*AMM TASK 32-31-00-720-002 Functional Test of the Normal Extension and Retraction of the Landing Gear*'. This check requires the aircraft to be jacked.

1.6.4 LOAD <15> report

The A320 aircraft has an Aircraft Integrated Data System (AIDS). This system receives information from many systems on the aircraft through its Data Management Unit (DMU). The DMU then processes this data and produces reports based on various parameters, such as an exceedence. One such group of reports are structural. The structural report is identified as a LOAD <15> report (Appendix A) and is produced when the following conditions are met on landing (nb there are additional parameters for turbulence in flight):

1) The radio altimeter descent rate (RALR) is less than (higher rate of descent) than 9 ft/sec. (Code 4100)

2) The vertical acceleration (VRTA) is more than 2.6G during +/- 0.5 secs before and after landing. (Code 4400)

3) The aircraft gross weight (GW) is more than the maximum landing gross weight (GWL) and the radio altimeter rate (RALR) is less than -6 ft/sec. (Code 4800)

4) The aircraft gross weight (GW) is more than the maximum landing gross weight (GWL) and vertical acceleration is more than 1.7G. (Code 4900)

5) For a bounced landing the vertical acceleration (VRTA) exceeds 2.6G for +/- 0.5 seconds of a detected bounced landing. (Code 4500)

The original DMU fitted to the A320 did not have the capability to produce the LOAD <15> report. A modification to the DMU was introduced by Service Bulletin (SB) A320-31-1124. This SB was embodied on G-BXKD on 8 November 2001

The LOAD <15> report was introduced following a hard landing on an A320 aircraft, of 3.54G, on 3 March 1994. Following that hard landing the aircraft flew another three flights before problems with the landing gear, during retraction, were discovered on 6 March 1994. Examination revealed the left gear had suffered a fracture of the upper diaphragm tube and the right gear had an ovalised upper diaphragm tube. The reason for introducing a LOAD <15> report was to highlight the severity of the heavy landing and to call up more comprehensive checks.

1.6.5 Post Flight Report

The Post Flight Report (PFR) is a maintenance report that is automatically produced at the end of each flight. It shows, in a print out, the ECAM warnings and fault messages recorded during the flight. The Central Fault Display System (CFDS) produces the report. The fault information is received from aircraft system BITE and sent to the Central Fault Display Interface Unit (CFDIU) during the flight. The report is headed with information of the aircraft, date, time, flight number, and departure and arrival station. The report is then split into two sections. The first section contains a list of ECAM warnings, along with the time (GMT), the phase of flight, the ATA chapter of the affected system and an explanation of the warnings. These warnings are those which caused an effect on the flight deck. The second section contains the failure messages; these also show the time (GMT), phase of flight, affected ATA chapter, together with a textual explanation of the failure, the source of the failure and any identifiers. The PFR for the flights following the hard landing are shown in Appendices B and C.

1.6.6 Weight and balance

The aircraft's weight for the landing at Bristol Airport was calculated to be 63,210 kg; the maximum landing weight was 64,500 kg. Its centre of gravity (CG) was 34% Mean Aerodynamic Chord (MAC), which represents a slightly aft CG position.

1.7 Meteorological information

1.7.1 Bristol weather 15 November 2006

An aftercast from The Met Office at Exeter for the time of the incident showed that there was a low pressure system centred near Bristol producing a strong south-south-westerly flow over the Bristol area. There were outbreaks of light rain and drizzle with a surface visibility between 6 and 10 km. There was scattered to broken stratus cloud, with a base between 800 to 1,500 ft, and broken to overcast strato-cumulus cloud, with a base at 2,000 ft. The 1,000 ft wind was from 190º at 40 to 45 kt and the surface wind was from170º at 20 to 25 kt, gusting 35 to 45 kt. The low level forecast charts issued for the period were forecasting moderate, occasionally severe, low level turbulence over the Bristol area.

The TAF for Bristol Airport issued at 1919 hrs and covering the period 1900 to 0400 hrs showed the following information:

> The surface wind was forecast to be from 170º at 16 kt, gusting to 27 kt; visibility greater than 10 km; broken cloud at 2,000 ft. Temporarily from 1900 to 0100 hrs: surface wind from 170º at 22 kt, gusting to 37 kt; visibility 6,000 m; broken cloud at 1,000 ft; with a 30% probability, between 1900 and 0400 hrs, of a temporary deterioration to 4,500 m visibility with broken cloud at 600 ft.

The METAR for Bristol Airport issued at 1920 hrs showed the following information:

> Surface wind from 170º at 21 kt, gusting to 32 kt; visibility 6,000 m in rain; a few clouds at 1,200 ft and broken cloud at 2,000 ft; temperature +12º with a dew point of +11º ; QNH 992 hPa.

The METAR for Bristol Airport issued at 1950 hrs showed the following information:

> Surface wind from 170º at 23 kt; visibility greater than 10 km in rain; a few clouds at 1,500 ft and broken cloud at 2,200 ft; temperature +13º with a dew point of +11º; QNH 992 hPa.

The Bristol ATIS information is broadcast continuously, with the surface wind obtained from the Runway 09 anemometer. Prior to the approach, the crew confirmed that they had received information 'Papa', which contained the following information:

> Runway 09 in use; surface wind from 160 at 22 kt, gusting to 32 kt; visibility 7 km in moderate rain; scattered cloud at 1,000 ft; broken cloud at 1,800 ft; temperature +12º, dew point +10º; QNH 992 hPa; touchdown elevation 613 ft; runway WET, WET, DAMP.

The recorded surface wind for Runway 09, at 1930 hrs, indicated that over the previous 10 minutes the mean direction was from 181º, with extremes between 166º and 194º, and the mean speed was 22 kt, with extremes between 15 kt and 33 kt.

The recorded surface wind for Runway 27, at 1930 hrs, indicated that over the previous 10 minutes the mean direction was from 180º, with extremes between 163º and 208º and the mean speed was 23 kt, with extremes between 13 kt and 40 kt.

The Tower controller passes the wind to crews together with the landing clearance. This wind is obtained from the anemometer related to the runway in use and is the mean wind from the previous two minutes. Flight crews sometimes ask for the instantaneous wind and if so, the controller would include the phrase "Instant Wind" with the information.

1.7.2 Weather at Manchester 16 November 2006

Following problems with the landing gear selection after takeoff from Bristol the aircraft returned to the hold at 5,000 ft to allow time for the crew to consider their options. Their preference was to land in good visual conditions, at an airport with a long dry runway. They obtained the current weather for Gatwick, Stansted and Manchester. Manchester was reporting the following conditions: a surface wind from 200º at 7 kt, visibility greater than 10 km, a few clouds at 3,200 ft, a temperature of +9º and a dewpoint of +7º, the QNH was 992 hPa and there was no significant weather.

1.8 Aids to navigation

Not relevant.

1.9 Communications

RTF recordings were available of the ATIS information at Bristol and the ATC frequencies at both Bristol and Manchester Airports.

1.10 Aerodrome information

Runway 09 at Bristol has a Landing Distance Available (LDA) of 1,938 m and is 46 m wide. Runway 09 is equipped with High Intensity runway edge and centre-line lights, a High Intensity Approach Lighting system and 3º PAPIs, which are located on the left side of the runway approximately 1,300 m from the threshold. The Runway 09 anemometer is positioned just to the north of the PAPIs. The threshold elevation of Runway 09 is 613 ft amsl and the displaced threshold elevation of Runway 27 is 601 ft amsl.

The UK AIP contains a warning that '*Pilots may experience windshear / turbulence, especially if the wind is strong south-easterly (using Runway 09) or strong westerly (using Runway 27).*'

1.11 Flight Recorders

1.11.1 Description of recorders

Cockpit Voice Recorder

The aircraft was fitted with a solid-state Cockpit Voice Recorder (CVR), which recorded the last two hours of flight crew speech and cockpit area microphone sounds. Unfortunately, since the AAIB was not notified of the incident until G-BXKD had completed two further flights, the CVR recordings from the landing at Bristol had been overwritten.

Flight Data Recorder

The aircraft was fitted with a solid-state Flight Data Recorder (FDR), which recorded over 26 hours of data. A large number of flight data parameters and discretes were available, including relevant air data, engine parameters, the positions of control surfaces and cockpit controls and wind shear detection. The operator provided a copy of the downloaded data to the AAIB.

1.11.2 Relevant FDR information

A time history of the relevant flight parameters during the approach and landing at Bristol is shown at Figure 4. The data presented starts with G-BXKD established on the ILS approach to Runway 09 at an altitude of 180 ft, both autopilots and the automatic throttle system (ATS) were engaged and the ATS was commanding 51% N_1. The airspeed, which had progressively decreased during the approach, was generally between V_{APP} -4 kt and V_{APP} + 6 kt (V_{APP} was 139 kt) and the aircraft's rate of descent was about 780 ft/min. The flaps and slats were extended (22.5º and 25º respectively) and the landing gear was down and locked.

The wind was from a southerly direction, between 30 and 40 kt, with gusts above these values[2]; this wind velocity prevailed throughout the remainder of the descent and landing. The FDR discrete parameter relating to wind-shear detection (sampled once per second) indicated that no wind-shear was detected throughout the approach.

2 Although the wind speed (and direction) was sampled once every four seconds, parameters such as angle of attack (sampled once per second) and normal acceleration (sampled eight times per second) showed increased activity (about a mean) from 5,500 feet, indicating significant turbulence and gusts.

Autopilot disengagement to touchdown

Both autopilots were disengaged as the aircraft descended through an altitude of approximately 208 ft (which corresponded to about 102 ft above the runway threshold) and was turning to the left through a heading of 104ºM; at this time the recorded wind was from 180º at 38 and 40 kt. The commander then took control, maintaining the turn to the left before applying full right sidestick and rolling out on a heading of 100ºM; there were variations in pitch control (Figure 4, Point A) as the aircraft continued to descend on the glideslope[3]. Variations in the relationship between groundspeed and airspeed indicate the presence of an increasing headwind of about 6 kt. At about the same time a small amount of differential thrust, nose-left, occurred coincident with the full right stick input. The level of thrust on the right engine was sufficient to trigger the ATS to initially deactivate, then disengage, at about 75 ft, as the aircraft rolled through wings level with a roll rate of about 5.6º/second (Figure 4, Point B).

As G-BXKD continued to roll, now right wing down, the roll rate increased to 7.7º/second before the commander applied full left sidestick. As a consequence of successive pitch control inputs the rate of descent increased from 750 ft/min up to 1,000 ft/min. The PF initiated the flare 42 ft above the runway threshold with an increasing nose-up pitch input. G-BXKD then rolled to 5º right wing down at 27 ft agl, reducing to just over 2º right wing down one second later, during which the pitch attitude increased from 3º to 5º and the airspeed reduced from 142 kt to 131 kt. The groundspeed, however, remained fairly constant at 143 kt, indicating a change in the wind from a slight headwind to a tailwind in excess of 10 kt over a period of approximately two seconds (Figure 4, Point D). The crosswind just prior to touchdown was about 30 kt.

The commander then selected full back stick and the aircraft's pitch continued to increase, reaching about 5.5º at touchdown 0.3 seconds later. The airspeed also increased slightly to 132 kt together with a very small (1-2% N_1) increase in engine thrust, while the aircraft remained approximately 2º right wing down now with 7.5º left rudder applied whilst maintaining a heading of 100ºM.

Touchdown and landing ground roll

A maximum pitch attitude of 6.7º was recorded just after touchdown, together with a peak normal acceleration of 2.9g as both right and left main gear oleos compressed within a second of each other (right main first).

3 From capture of the ILS glideslope and localiser beams at about 3,000 feet pressure altitude to touchdown, G-BXKD remained within -0.45 dots (below beam) and +0.23 dots (above beam) of the glideslope and -0.07 dots (left of beam) and +0.10 dots (right of beam) of the localiser.

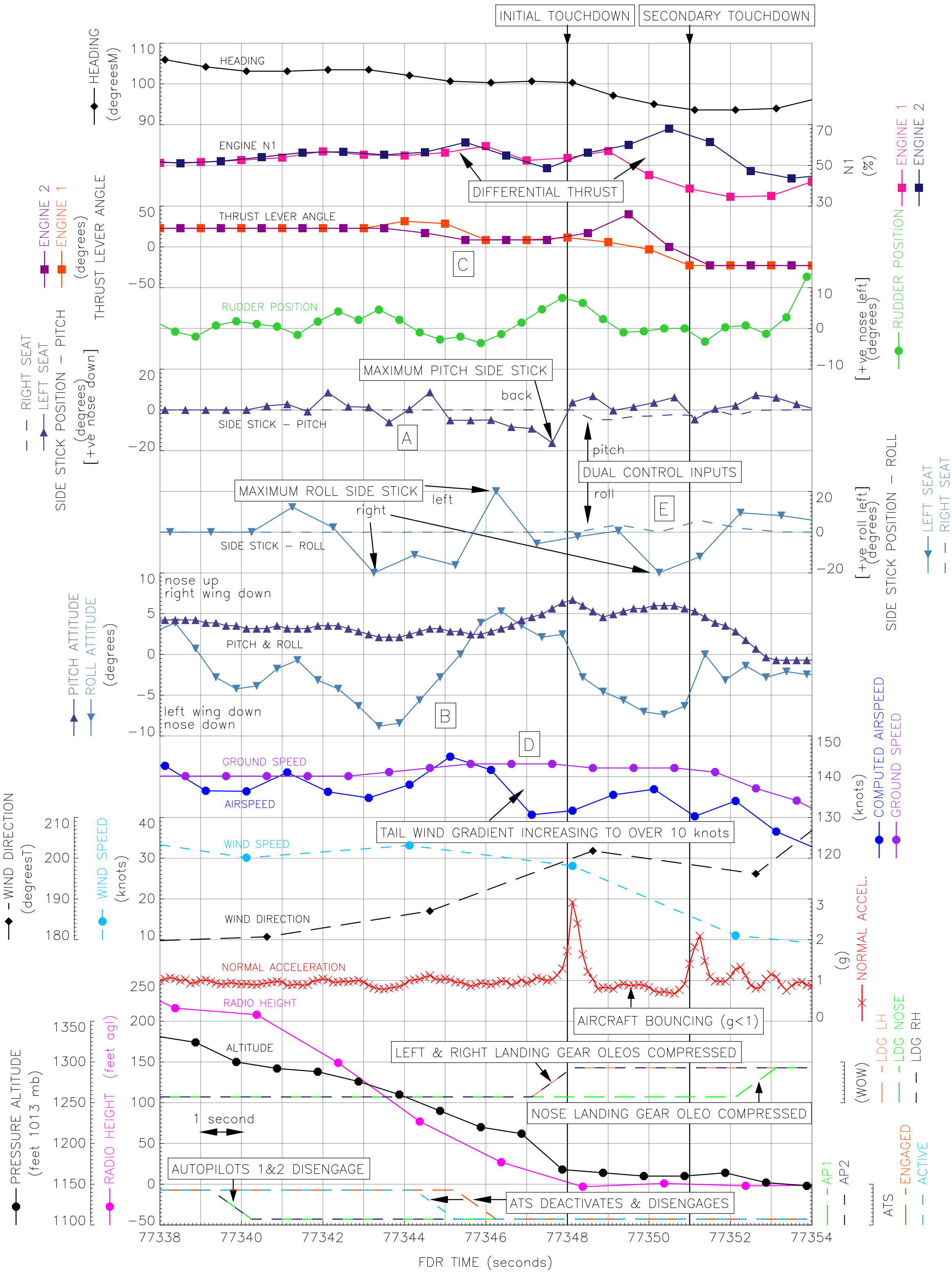


Figure 4

Salient FDR Parameters
(Incident to G-BXKD on 15 November 2006)

The commander then released the right-roll stick input as well as applying some nose-down stick input. Stick inputs were also made by the FO a fraction of a second later, but to the left and back (Figure 4, Point E). The aircraft then bounced, rolling through wings level to 7.4º left wing down before the commander input full right stick; this was countered by the FO applying a left roll input. The bounce, indicated by the normal acceleration measuring less than 1g, lasted over two seconds, during which the main gear oleos either remained compressed or one or both mains gears extended briefly (between the once per second sample rate recorded for oleo compression).

The FO's back stick input (about ¼ full back) was maintained throughout the bounce while the commander continued to apply varying forward stick inputs, at times of slightly greater absolute magnitude than the FO's. The aircraft's pitch attitude initially reduced to 4.6º nose-up before rising to 6º then reducing to 5º at the end of the bounce. Directional control during the bounce was initially maintained with rudder; asymmetric thrust was applied when the thrust on the right engine was increased briefly to just below 70% N_1 as the left engine thrust was reducing to 40% N_1.

G-BXKD was about 6º left wing down just before the second touchdown during which a peak normal acceleration of 2.1g was recorded. The nose wheel oleo compressed a further one to two seconds later. The remainder of the ground roll was uneventful.

1.12 Aircraft and site examination

1.12.1 General

Following the landing at Bristol a LOAD <15> report was generated; this is shown in Appendix A. The report generation code was 4100, indicating that the report was generated due to the radio altimeter descent rate being a maximum of -13.2 feet/sec (in the period 0.5 seconds before and after landing); this was less than the -9 feet/second limit. The report also indicated a large vertical acceleration of 2.91g; the limit being 2.6g. At sample S1, the values recorded by the DMU one second before landing show:

Sample	Radio Altimeter	Radio Altimeter Rate	Pitch Attitude	Pitch rate	Roll Attitude	Roll Rate	Yaw Rate
S1	180 feet	1.8 ft/s	4.4° nose up	1.8°/s nose up	3.2° Right wing low	5.8°/s (left roll)	0°/s
S2 Landing	0 feet	-15.2 ft/s	6.7° nose up	1.8°/s nose up	2.7° right wing low	0°/s	-1.8°/s nose left

Sample	Vertical Acceleration	Longitudinal Acceleration	Lateral Acceleration
S3	-2.91 g	0.18 g	0.14 g
S4	0.65 g	0.03 g	-0.05 g

1.12.2 Bristol

The engineer at Bristol carried out an inspection of the aircraft using maintenance manual check '*05-51-11-200-004 Inspection after hard/overweight landing*'. The check took seven hours to complete and did not reveal any problems with the aircraft. The engineer did not know about, nor carry out, the more comprehensive check '*05-51-11-200-004A*', which would have required the aircraft to be jacked-up.

1.12.3 Manchester first arrival

When G-BXKD arrived at Manchester after the takeoff from Bristol, a team of three engineers met the aircraft and inspected the PFR (see Appendix B). One of the engineers, from his interpretation of the PFR, believed there was a fault with the right main landing gear sensor 20GA. The engineer carried out a test on the LGCIU, which confirmed a hard fault on sensor 20GA and it was decided to replace this sensor. One of the engineers obtained a spare sensor, whilst another obtained the troubleshooting and maintenance manual instructions for the fault and sensor replacement respectively. Prior to the sensor replacement, the connector on 20GA appeared to be contaminated with a carbon substance, so it was removed, cleaned and refitted. However, since a replacement sensor was now available it was replaced as a precaution. A subsequent BITE of the LGCIU was satisfactory and the aircraft was released for service. The engineer who released the aircraft was aware of the previous hard landing at Bristol, due to the technical log entry. However, as this had been signed off with a satisfactory inspection and that there was no visible damage to the aircraft no further action was taken.

At the time it was decided not to jack the aircraft, partly because the next flight was a non-revenue flight and partly because the sensor target had not been disturbed. The target is the item that determines the sensor to target adjustment, since the sensor is fixed.

1.12.4 Manchester second arrival

When the aircraft returned to Manchester, the same engineering team met the aircraft. They had now been made aware that the landing at Bristol had been a severe hard landing and that the aircraft should have been jacked up. Therefore, the team decided to take the aircraft to the maintenance hangar for jacking. As the aircraft was jacked it was discovered that the right main landing sliding tube was over extending and that his had caused sensor 20GA to move out of proximity.

1.12.5 Manufacturer's examination

The aircraft was taken out of service and subjected to a detailed structural examination by the aircraft manufacturer. This inspection took several days and revealed no additional damage to the aircraft. The aircraft was returned to the operator on 2 February 2007.

1.12.6 Landing gear examination

A check of the relationship between the oleo pressure and its extension was found to be within the maintenance manual limits.

The right main landing gear was removed from the aircraft and taken to the manufacturer for a detailed strip examination. Due to the damage, the sliding tube was allowed to over-extend to 675 mm between the centres of the torque link fittings; the manual states that this extension dimension should be 632.95 +/ 3.85 mm.

Whilst in the over-extended state, sensor 22GA remained in proximity, whilst 20GA moved out of proximity. An examination of the torque and slave links did not reveal any signs of distress. Prior to the strip an attempt was made to compress the oleo, but this was not possible.

The gear was then stripped down. After removal of the torque links, the main fitting was lifted from the sliding tube. This revealed a total rupture of the upper diaphragm tube (see Figure 5). The rupture had occurred in compression with the fracture around the orifice holes. The damping tube had also bent. There was no damage to the chambers or the gland seals, which is why the oil/air pressure was retained in the gear.

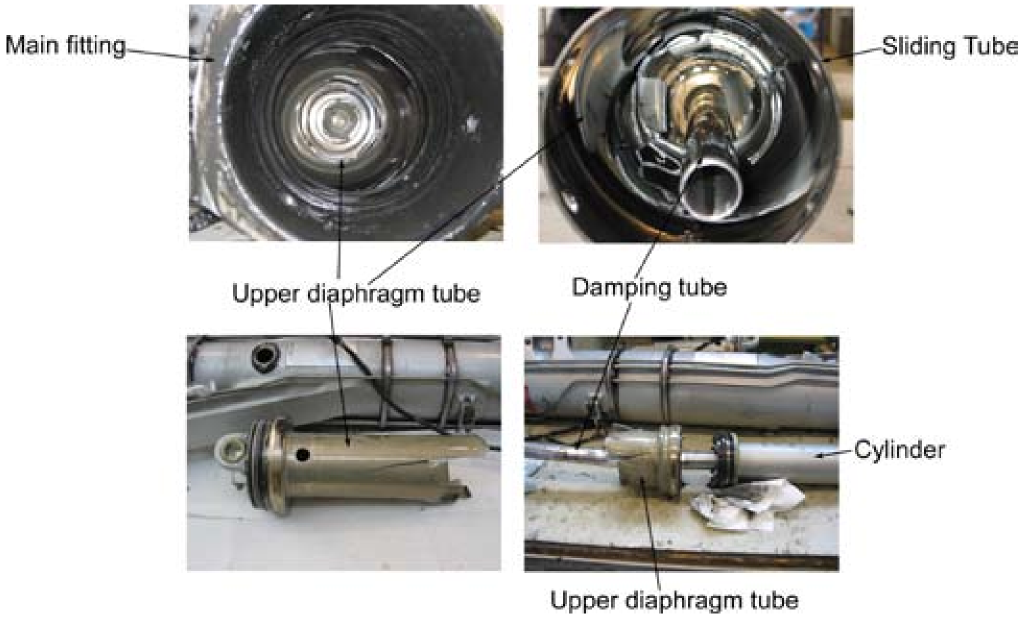


Figure 5

Damage to the main landing gear upper diaphragm tube

1.13 Medical and pathological information

Not relevant.

1.14 Fire

None.

1.15 Survival aspects

Not relevant.

1.16 Tests and research

Nil.

1.17 Organisational and management information

1.17.1 General

The aircraft was operating out of Bristol for the winter period only. The operator did not have a maintenance presence at the airport and therefore contracted this to a local third-party maintenance organisation.

1.17.2 Third-party maintenance organisation

The third-party maintenance organisation is part of an airline that operates out of Bristol, and they held a JAR 145 approval. They undertook line maintenance on G-BXKD operator's aircraft during the winter season, running from 1 November 2006 until 30 April 2007.

The facility at Bristol carried out maintenance up to 'A' check level, it did not have access to any hangarage. There were 10 engineers on a 4-on, 4-off, 12-hour shift pattern. They carried out line maintenance on their own operator's aircraft as well as for three other operators, including that of G-BXKD. The manuals for all of these operators, except that of G-BXKD, were provided in PDF format.

The contract was for routine maintenance ramp maintenance and defect rectification. The expectation of the operator was that any non-routine maintenance and defects were reported to their Maintrol at Manchester, so that the serviceability of the aircraft could be established. This was especially relevant if the aircraft was required to have any lengthy maintenance, which might affect the next day's operation.

As part of the requirements for maintenance of the operator's aircraft, the engineers at Bristol were required to have undertaken training by the operator. This included information on their procedures and documentation, but no training was provided on how to use the AirN@V system. There were 10 engineers at Bristol at the time of the incident, 3 of the 10 had not completed this training including the engineer who had carried out the inspection work on G-BXKD following the heavy landing.

The operator was responsible for providing airworthiness data to the third party maintenance organisation, this included maintenance manuals and engineering bulletins. When an engineering bulletin was received at Bristol a copy was given to each engineer and then kept on file within the office; Service Bulletin 31-01 was included in the file. The maintenance manual in use at Bristol for the operator of G-BXKD was AirN@V, which was at revision Feb 06. At the time of the incident, however, the latest manual version was Aug 06, with the Nov 06 revision just issued. During the summer season, revisions were not necessarily sent to Bristol since they were not supporting the aircraft at that time, however at the start of the winter season, the contracted period, the manuals were updated. The maintenance manual updates had not been sent at the time of the incident to G-BXKD. The Nov 06 manual revision was sent to Bristol on 16 Nov 2006. The revisions to the manual, however, did not have any bearing on the investigation.

There had been no formal training at Bristol on the use of AirN@V at the time of the incident.

As part of the subcontracting process, the operator's quality department carried out audits of the third party maintenance organisation on a yearly basis. The last audit, prior to the incident, was carried out on 7 December 2005, with no findings.

The last CAA audit at Bristol was on 10 Aug 2005, with no findings.

1.17.3 Operator

The operator's maintenance organisation was based in Manchester and they held a JAR 145 approval. At Manchester there were facilities to carry out maintenance to 'A' check level, but also to carry out defect rectification, modifications and repairs. The operator also had access to hangar facilities at the maintenance base.

The accountable manager was the Engineering and Maintenance Director, who had a number of managers reporting to him. All the engineering maintenance activity was co-ordinated through Maintrol. Any communication from outstations with regard to the aircraft serviceability and assistance in defect rectification was via Maintrol. The engineers in Maintrol then co-ordinate the required assistance, and contact other personnel as required, such as the technical service engineers. Maintrol also co-ordinate the manpower and facilities for unscheduled maintenance, such as problems arising from in-flight defects and diversions.

Manual updates for outstations and third party organisations were managed by the technical library. A form is sent with the relevant documents, with a requirement for the recipient to sign it and return within 30 days.

The operator did not hold an EASA CS-21 design approval. Therefore, if there was a need to operate the aircraft outside of the prescribed maintenance manual procedures, they would have required the approval of the manufacturer.

1.18 Additional information

1.18.1 Company procedures

The maximum demonstrated crosswind for landing, as detailed in Airbus FCOM 3, was 33 kt gusting to 38 kt. It is accepted practice by the operator that although the indicated crosswind may be out of limits during the approach, providing the latest tower reports are within landing limits the approach may be continued.

In July 2006, the operator issued an amendment to the Flight Crew Operating Manual (FCOM) volume 3. The amendment provided details on the LOAD <15> report and specified the required action if one was generated. It states:

> *'The 3 line header 'TECH LOG ACTION REQUIRED' is unique to this report and indicates to the crew that some form of maintenance action is required. Under no circumstances will the crew be required to interpret the LOAD <15> report, although a brief decode has been included for reference purposes only*
>
> *In the event that a LOAD <15> report is generated Maintrol must be sent a fax of the report. Once decoded the Maintrol manager will advise if dispatch is permitted. In the event that dispatch is permitted a tech log entry must be made and ADD raised if away from base'*

1.18.2 LOAD <15> report interpretation

When a LOAD <15> report is generated it is in the format as shown in Appendix A; the report requires interpretation by the ground engineer with reference to the maintenance manual. The section that deals with the LOAD <15> report is '*MM 31-37-51 AIDS – STRUCTURE REPORTS – DESCRIPTION AND OPERATION*'. This part of the manual provides a description of each of the parameters produced by the report. Having interpreted the report, reference is then made to '*MM 31-37-00 page 201 AIDS INPUT INTERFACE ((FDIMU)) - MAINTENANCE PRACTICES*'. This provides instructions on how to read the LOAD <15> report and to determine what action is required. Figure 203 of this procedure contains a flow chart, giving required actions depending on the information on the LOAD <15> report (see Figure 6). For the case involving G-BXKD the flow chart ends in '*HARD LANDING => INSPECTION AS PER AMM 05-51-11*'.

To assist their engineers in interpretation of the LOAD <15> report, the operator issued their own engineering bulletin, 31-01. The bulletin states:

> *'Where a load report <15> has been generated AND THE PARAMETERS STATED IN THIS BULLETIN ARE CONFIMED OVER LIMITS the aircraft may not depart until the requirements of AMM 05-51-11 and this engineering bulletin have been complied with.'*

The bulletin also provides a detailed breakdown of the information contained on the LOAD <15> report.

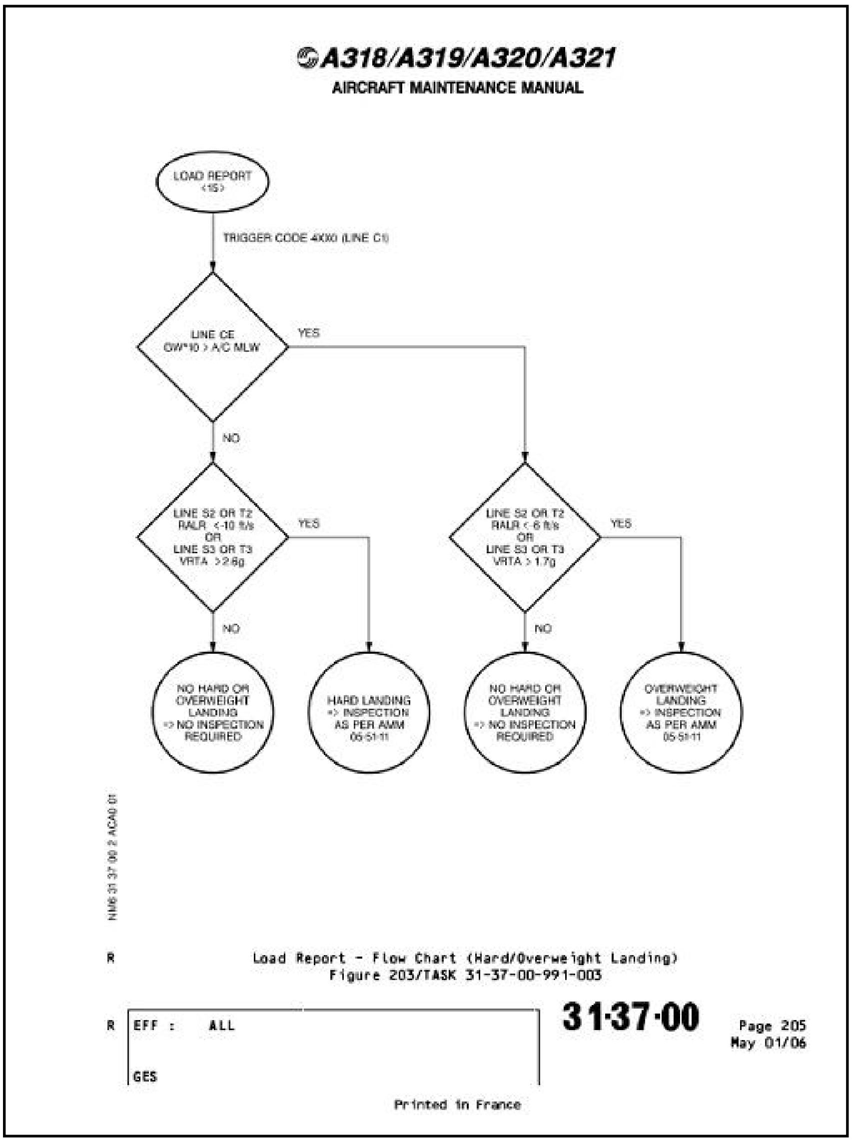


Figure 6

LOAD <15> report flow chart

1.18.3 Aircraft maintenance manuals

The aircraft maintenance manuals produced by Airbus are available in three formats: hard copy, PDF or on AirN@V. Most maintenance organisations do not use hard copy and use either PDF or AirN@V.

The engineer at Bristol, who conducted the inspection of G-BXKD, had mainly used PDF manuals. The operator of G-BXKD had recently changed to using AirN@V and had provided Bristol with a copy of the software in February 2006. However, the engineer involved had only used AirN@V on one previous occasion, before his use of the system on the night of the incident.

PDF Manual

The PDF manuals are presented with a series of bookmarks, which refer to the ATA chapters. However, navigation of the PDF document is more akin to a book in which the pages are scrolled through until the required page is required. To print out a hard copy, the first and last page numbers have to be noted and then put into the print dialogue. The quickest way is to find the first page and then quickly scroll down until the next chapter is found, and then, noting this page number, print a complete section. The engineer at Bristol employed this method of obtaining a hard copy print.

AirN@V

AirN@V is the computerised manual introduced by Airbus for all its aircraft. It consists of a graphical interface with access to all the manuals for the particular type. The maintenance manual page consists of a table of contents in the left pane and the representative page selected shown in the right pane (see Figure 7).

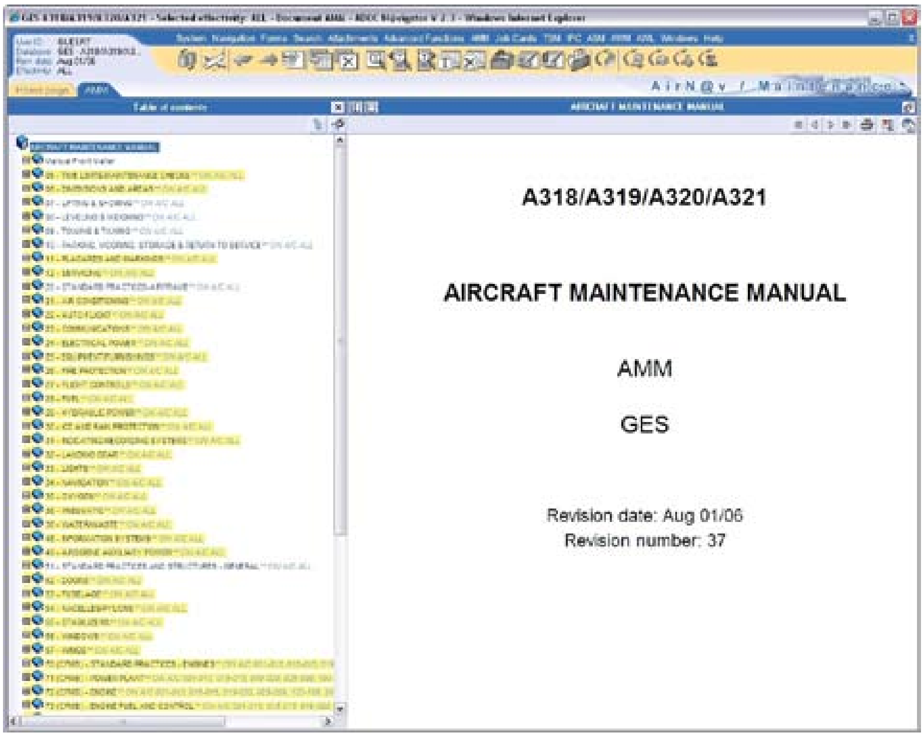


Figure 7

Opening screen of AMM on AirN@V

The menu at the top has various buttons allowing for the viewing of effectivity codes, searching, printing etc. The selection of a part of the manual can be carried out by selecting and expanding the ‘table of contents’ menu in the left frame. A ‘+’ by the side of the menu shows that there are levels below it; clicking on the ‘+’ expands the menu by one level. Selection of the text to the side of the ‘+’ opens the first page of that section in the right pane.

To find a specific section of the manual, for example ‘05-51-11’, the first action is to open the menus until 05-51-11 is visible in the table of contents. Firstly by clicking on the ‘+’ adjacent to ‘05 – Time limits/maintenance checks’, followed by the ‘+’ by ‘05-51 – Inspections’. This displays ‘05-51-11’ with ‘+’ to the side of it. Selecting the text to the side of ‘05-51-11’ opens the first page of that section, showing ‘05-51-11-200-004’, with the effectivity above it shown in red. This process is shown in Figures 8 and 9.

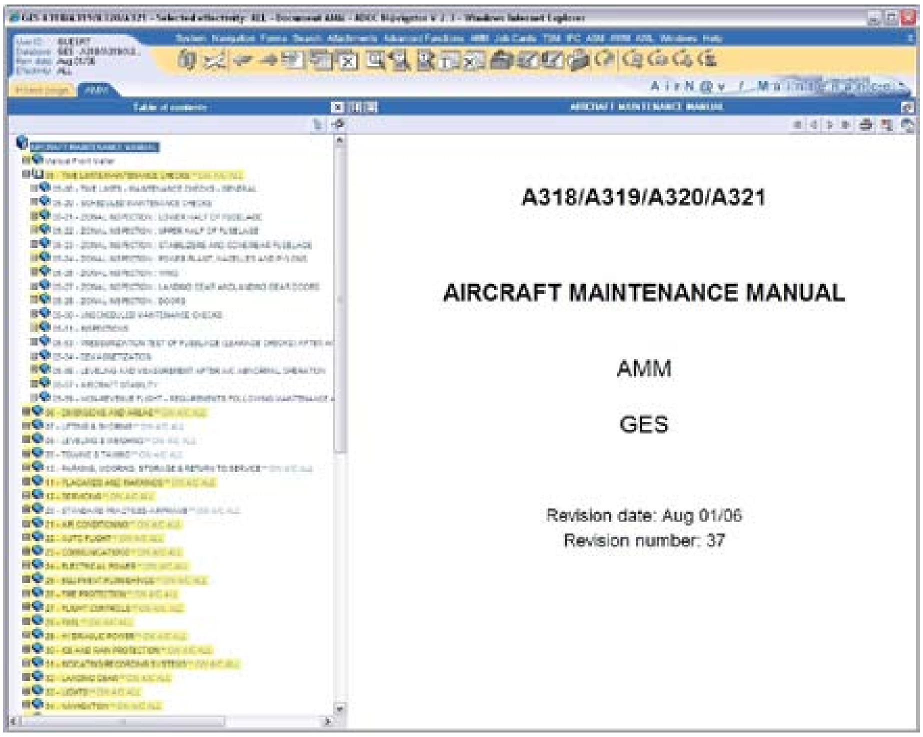


Figure 8

Menu selection on table of contents pane on AirN@V

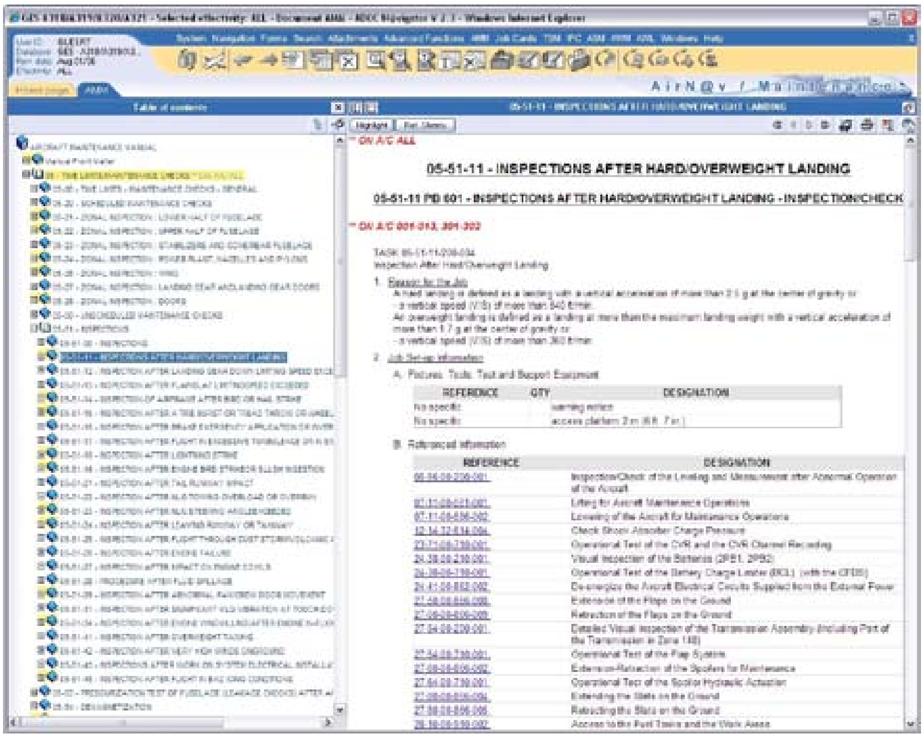


Figure 9

Further menu selection of 05-51-11 on AirN@V

The '+' to the side of the check shows that there are more sections to the task. Fully expanding the menu shows that there are two checks '05-51-11-200-004' and '05-51-11-200-004A', each with an effectivity shown by the side of the text, as shown in Figure 10.

Having located the required check by the use of the manual, a hard copy can be produced by selecting 'print job card' from the print button above the right pane. This prints out the selected check only, so for the example of '05-51-11-200-004', if the 'print job card' is selected when on the first page of '05-51-11' then only the task '05-51-11-200-004' will be printed and not '05-51-11-200-004A' as this is regarded as another job card. To print '05-51-11-200-004A', this check has to be selected from the expanded table of contents followed by 'print job card'.

If the engineer wishes to scroll through a check, it is not a simple case of using the mouse scroll button or the side bar. At the bottom of a small section of text the following appears:

'TEXT CONTINUES – SEE TEXT BELOW'.

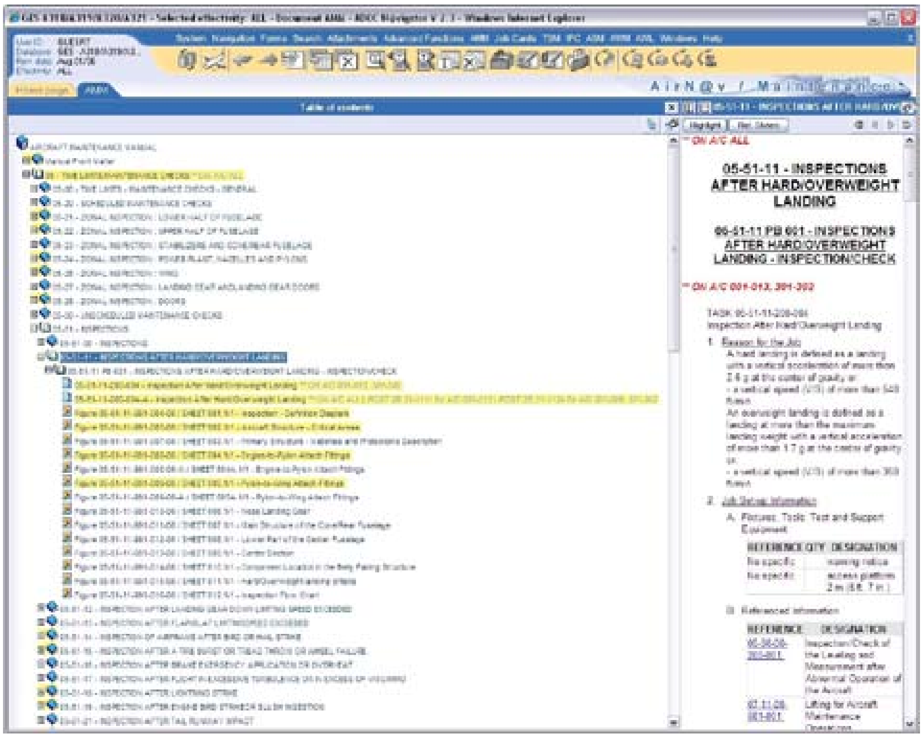


Figure 10

Fully expanded list of contents on AirN@V

This line must then be selected before the next section of text appears. Also, figures do not appear in the right pane as they would in the paper manual. To view the images they have to be selected either using the hot link on the right pane or by using the table of contents: see Figure 11.

Another way of finding a specific task is to use the AMM menu on the top line and selecting *'TASK/SUBTASK by ATA/word'*. Having entered the required task code a separate box appears with the results, showing all the applicable tasks including the effectivity codes with SB numbering if necessary. Selection of the line containing the code and 'open' button, opens the task in the right pane: see Figure 12.

The AirN@V system contains 'hot links' identified by text with a blue underline. When this contains a task number it also opens the same window. For example, in AMM 31-37-00 page 201 there is a reference to task 05-51-11-200-004 as a hot link: see Figure 13.

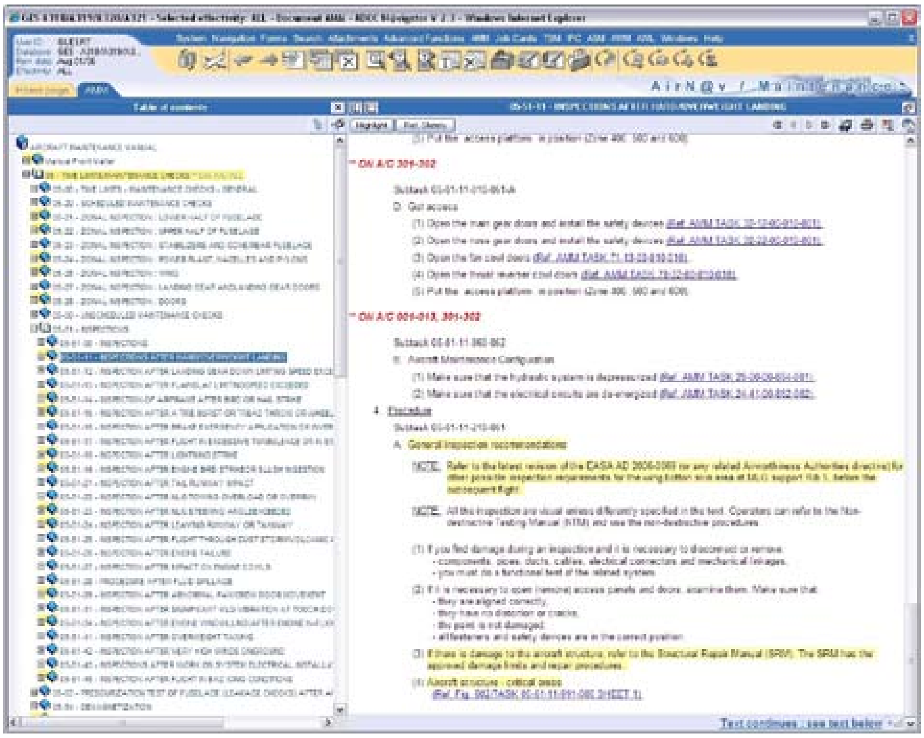


Figure 11

Screen shot of AirN@V showing ‘text continues…’

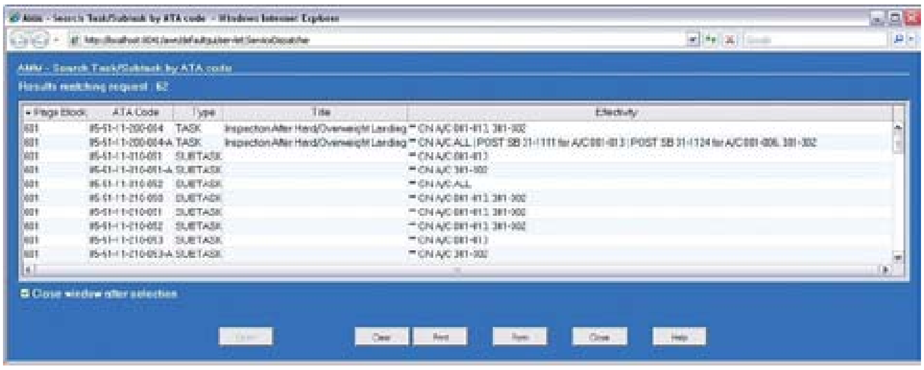


Figure 12

Search results for TASK/SUBTASK on AirN@V

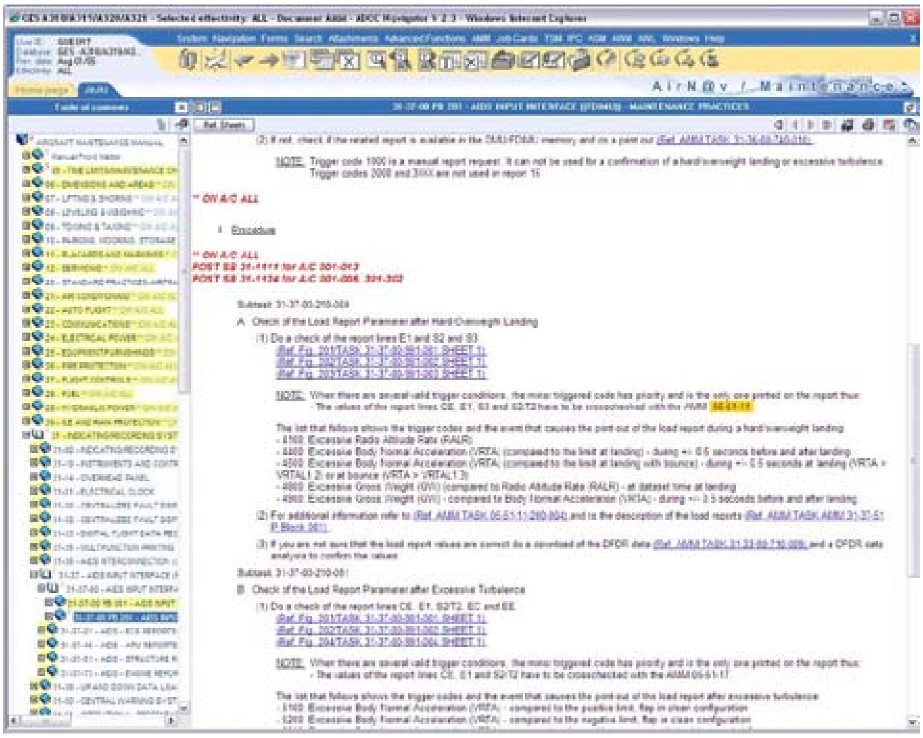


Figure 13

Hot links for AMM 31-37-00 on AirN@V

Selecting the hot link produces the following page (see Figure 14).

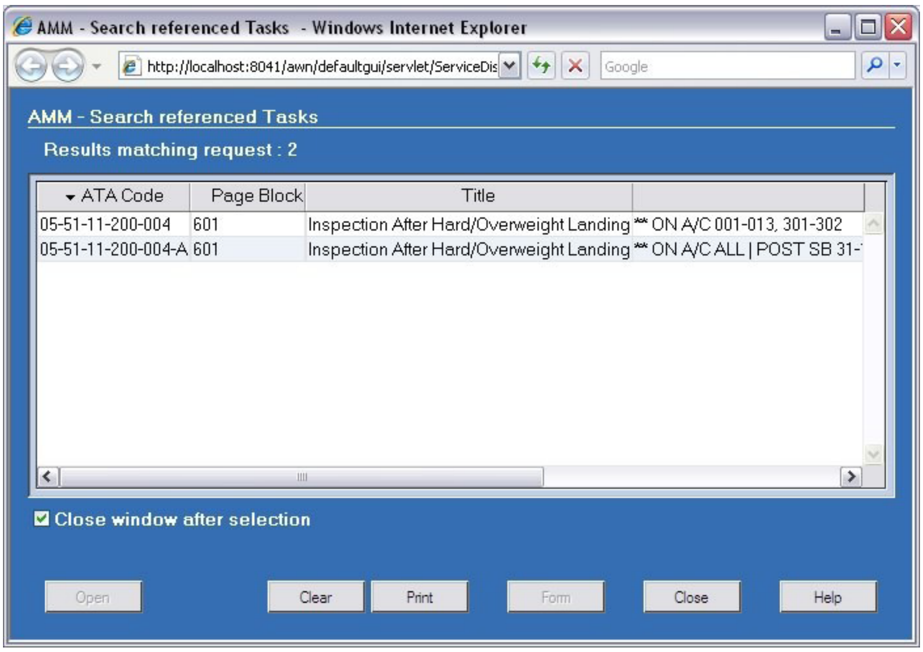


Figure 14

Search results on selection of hot link on AirN@V

This shows the two applicable tasks with the effectivity coding by the side, selecting 'open', gives the applicable check in the right pane.

The manual front matter contains an SB list. This lists all the applicable SBs and provides a status as to whether the SB is fully incorporated on the aircraft to which the manual is applicable. An incorporation code appears in the left most column; 'S' indicating that the aircraft applicable are not fully embodied so the effectivity is split and 'C' indicating the SB is completed. If the SB affects the manual it has a blue highlight, which when selected provides a list of affected parts of the manual (see Figures 15 and 16).

Although the system shows the SBs with split configuration it does not show which aircraft are embodied. In this case the engineer needs to refer to the operator to find out if the SB has been embodied in order to determine the applicable task.

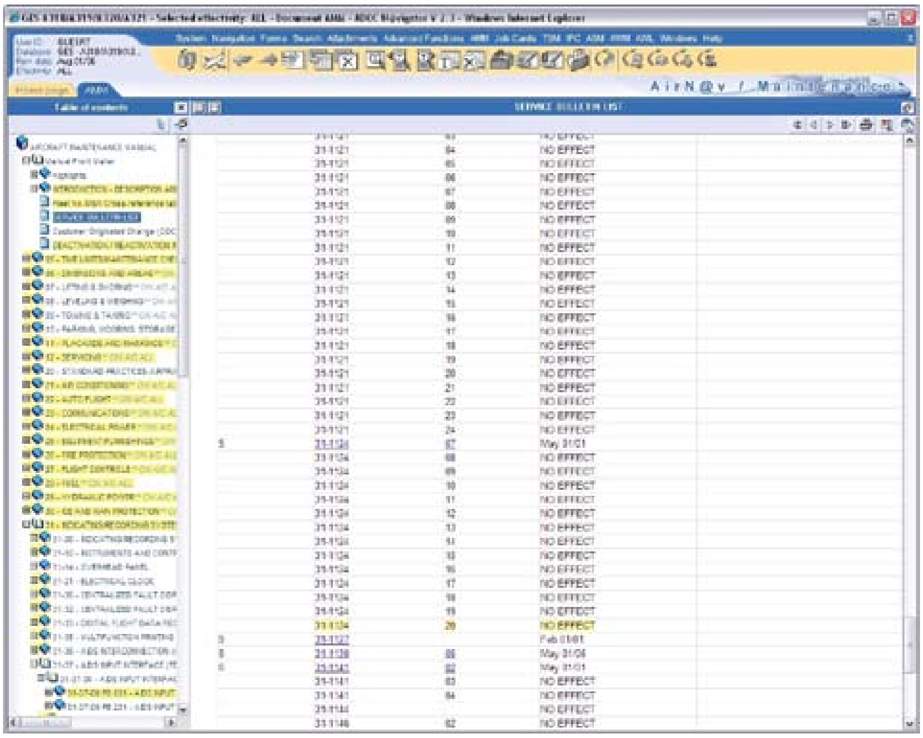


Figure 15

Service bulletin list on AirN@V

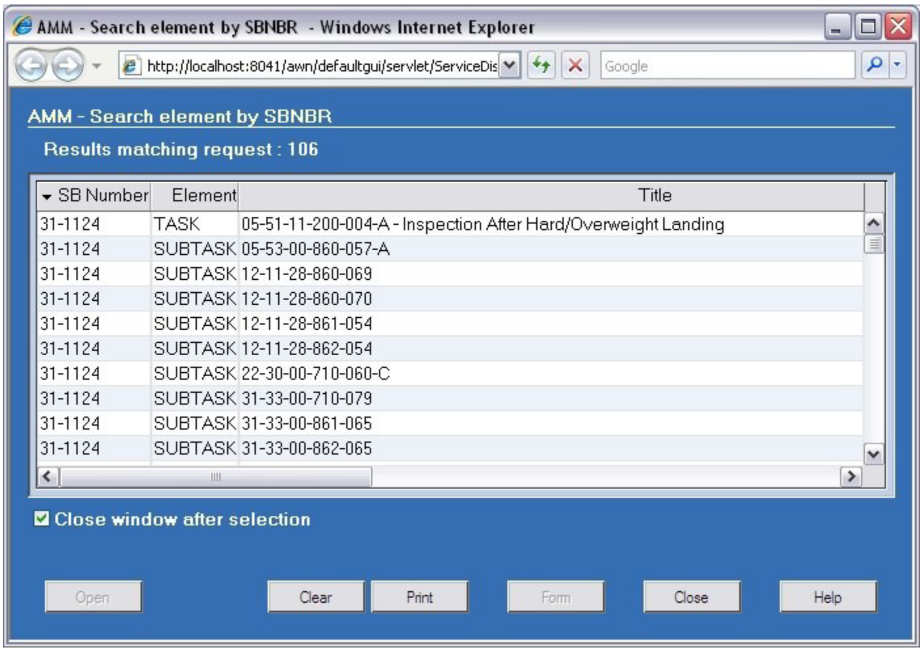


Figure 16

Search results after selection of hot link under SB number on AirN@V

Effectivity coding

Each manual is produced based on the aircraft's fit, design and modification status, therefore, checks can be different for various aircraft. To allow for this each aircraft has an effectivity code, these then appear against those checks that are applicable to that aircraft. G-BXKD had an effectivity code of 006, so any check with this code was applicable to the aircraft. However, if a SB has been issued the effectivity code appears with a caveat of 'Post SB XX-XXXX for a/c XXX'. The engineer would then have to consult the aircraft history to determine if the SB had been completed or not, and then apply the correct check as required by the manual. Although the effectivity for post SB is clearly shown, there is no respective change to old checks by showing an equivalent 'PRE-SB on a/c XXX'. Other manufacturers in their manuals provide clear indications of pre and post SB effectivities.

For example, the engineer at Bristol carried out check '05-51-11-200-004'. At the beginning of the check this has an effectivity of '***on a/c 001-013, 301-302*'. Which is clearly within the range for G-BXKD (effectivity 006). However, 49 pages later, check '05-51-11-200-004A' appears in the manual, with an effectivity of '***ON A/C ALL POST SB 31-1111 For A/C 001-013, POST SB 31-1124 For A/C 001-006, 301-302*'. Therefore, since G-BXKD was post SB 31-1124, check ‘05-51-11-200-004A’ was also applicable and superseded the previous check, even though the previous check had no indication that it was pre SB.

1.18.4 Heavy landing check

The ‘05-51-11-200-004’ Inspection, following a hard/overweight landing, was required following a crew report of a hard landing since, at the time, there was no other means of detecting this; the inspection is split into phases. Phase 1 is a general visual inspection for damage. Phase 2 is a more detailed inspection should damage be found during phase 1. Phase 3 is a very detailed inspection, requiring the removal of engines and pylons and is based on the results of the phase 2 inspections. With regards to the landing gear, the requirement to jack the aircraft is a phase 3 task, following a phase 1 visual inspection and phase 2 alignment check.

The ‘05-51-11-200-004A’ Inspection, following a hard/overweight landing, was introduced following the introduction of the LOAD <15> report. It states:

> *‘1. Reason for the Job*
>
> *After a flight crew report of a hard/overweight landing, you must do the inspections that follow before the subsequent flight’*

The AMM task then goes on to detail categories of severity for the heavy landing:

> *‘3. Job Set-up*
>
> *** ON A/C ALL*
>
> *Subtask 05-51-11-210-090 A. Hard/Overweight Landing Inspection Requirements*
>
> *(Ref. Fig. 611/TASK 05-51-11-991-015 SHEET 1)*
>
> *(Ref. Fig. 612/TASK 05-51-11-991-016 SHEET 1)*

(1) Definitions

There are several categories of hard/overweight landing:

(a) Hard landing

A hard landing is a landing with an aircraft weight less than the Maximum landing Weight (MLW) and:

- a vertical acceleration (VertG) equal to or more than 2.6 g and less than 2.86 g at aircraft Center of Gravity (CG) or,

- a vertical speed (Vs) equal to or more than 10 ft/s and less than 14 ft/s.

(b) Severe hard landing

A severe hard landing is a landing with an aircraft weight less than the Maximum landing Weight (MLW) and:

- a vertical acceleration (VertG) equal to or more than 2.86 g at aircraft Center of Gravity (CG) or,

- a vertical speed (Vs) equal to or more than 14 ft/s.

(c) Overweight landing

An overweight landing is a landing with an aircraft weight more than the Maximum landing Weight (MLW) and:

- a vertical acceleration (VertG) equal to or more than 1.7 g and less than 2.6 g at aircraft Center of Gravity (CG) or,

- a vertical speed (Vs) equal to or more than 6 ft/s and less than 13 ft/s.

(d) Severe overweight landing

A severe overweight landing is a landing with an aircraft weight more than the Maximum landing Weight (MLW) and:

- *a vertical acceleration (VertG) equal to or more than 2.6 g at aircraft Center of Gravity (CG) or,*

- *a vertical speed (Vs) equal to or more than 13 ft/s.*

(e) High pitch-rate landing

A high pitch-rate landing is a landing during which the pitch rate is more than 10 Deg/sec.

(2) Hard/overweight landing confirmation

(a) It is the responsibility of the flight crew to make a report if they think there was a hard/overweight landing.

(b) After a crew report of a hard/overweight landing, you must confirm the impact parameters to know the category of the landing.

To know this, refer to:

- *the DMU load report 15*

  (Ref. AMM TASK 31-37-00-200-001) or,

- *the FDRS read out.*

(c) When you know the category of the landing, you must do the inspections for that category.

NOTE: If you cannot comfirm the impact parameter values with the DMU or the FDRS, you must do the inspection with the steps for a severe hard/overweight landing.'

The checks are then defined based on the above category on the severity of the event.

'E. Inspection of the Main Landing Gears

NOTE: This inspection contains two inspection procedures:

- item 1. Inspection after a hard/overweight landing

- item 2. Inspection after a severe hard/overweight landing.

If you know the category of the landing, go directly to the necessary inspection. If you do not know the category, go directly to item 2. Inspection after severe hard/overweight landing.'

For a severe hard landing the inspection calls for the aircraft to be jacked up:

Item	***Insp Code***	***Inspection task***	***Phase 1***
2		*Inspection of the MLG after severe hard/ overweight landing*	
A		*Do the inspection of the MLG after hard or overweight landing (Ref. Item 1)*	*X*
		Lift the aircraft: *(ref 07-11-00-581-001)* *- make sure that extension of the shock absorber is smooth and full.* *- examine the sliding rod (the part you can see) for blue color, signs of bronze or chrome damage*	*X*

1.18.5 Training

To assist in the use of AirN@V there is a help section in the program. In addition on each of the AirN@V DVDs there is a folder containing several power point presentations on the use of the system and the various manuals. However, to access this folder requires the ability to 'explore' the DVD and to have the knowledge that the training folder exists. Placing the DVD into the drive automatically runs AirN@V but does not give the user direct access to the training files from the AirN@V interface. Therefore, a new user to the system will probably not be aware that training files exist since they are hidden on the disc. Exploring the disc requires the opening of 'my computer' then selecting the drive letter with the right mouse key and then selecting 'explore'. Double clicking on the drive letter causes the computer to automatically run the ADOC N@vigator installation software and does not open a navigation window.

2 Analysis

2.1 General

The landing at Bristol Airport was conducted in a strong crosswind with associated turbulence. During shutdown the crew was presented with an automatically generated aircraft warning that certain parameters had been exceeded during the landing. The crew reported the exceedence in the Technical Log. A type-qualified engineer met the aircraft on arrival and complied with his understanding of the technical checks required after such a warning. However, substantial damage had occurred to the landing gear and this damage was not detected before the aircraft was cleared for a further flight. On that flight the crew experienced landing gear problems after takeoff, together with other ECAM warnings, and diverted to Manchester Airport. Despite further engineering activity, the aircraft was once again released for flight without the damage being detected; this resulted in a repeat of the landing gear problems after takeoff together with the ECAM warnings. After the return to Manchester engineers discovered the damage. This analysis considers the two main aspects of this incident. Firstly, the landing at Bristol Airport which resulted in the damage to the gear and, secondly, why this damage was not detected on the two subsequent inspections.

2.2 Operational analysis

2.2.1 Landing at Bristol

The approach to Runway 09 at Bristol was flown in significant turbulence with a strong crosswind, with the wind varying between 40 and 50 kt with a mean direction from 185º. Because of the forecast wind conditions, both pilots were closely monitoring the wind indication on their respective NDs. The aircraft had been stabilised on the approach in the landing configuration. Both autopilots were engaged and the auto-thrust was engaged in speed mode; the airspeed, which had progressively decreased during the approach, was generally between V_{APP} -4 kt and V_{APP} + 6 kt (V_{APP} was 139 kt). When the Tower controller cleared the aircraft to land the surface wind was reported to be from 180º at 23 kt, gusting to 33 kt. The PF disconnected the autopilots when the aircraft was about 100 ft above the runway threshold, at which time the recorded wind was from 180º at 38 and 40 kt. The maximum demonstrated crosswind for landing is 33 kt, gusting to 38 kt.

The operator's procedures allow for an approach to be continued, even though the indicated crosswind may be out of limits during the approach, providing the latest tower reports are within landing limits. However, the operator has re-emphasised to its crews that this is the 'aircraft' limit, and crews may decide to be more conservative on the day. If there is any doubt then the crew should not continue the approach.

The commander disconnected the autopilots about 100 ft above the runway threshold, this was 5 seconds prior to initiating the flare and 8 seconds before touchdown. In the prevailing turbulent conditions this allowed insufficient time to separate the piloting tasks of taking control of the aircraft and flaring the aircraft to land. In addition, during the remaining flight to touchdown the pilot made a number of increasingly large control inputs, in both pitch and roll, in an attempt to maintain the required flight path. At the same time, changes to both the groundspeed and airspeed indicated the presence of an increasing headwind of about 6 kt. As a consequence of the successive pitch control inputs the rate of descent increased from 750 ft/min up to 1,000 ft/min and the aircraft descended below the glidepath. The PF initiated the flare 42 ft above the runway threshold with an increasing nose-up pitch input; the aircraft touched down at a pitch attitude of 5.5º and with full back stick applied. Just prior to touchdown the surface wind produced a tailwind of about 10 kt and a crosswind of about 30 kt. Therefore, the two main contributors to the heavy landing were the successive pitch control inputs which increased the rate of descent and the longitudinal wind gradient, with an increasing tailwind of about 15 kt just before touchdown.

The aircraft touched down on the right main landing gear, with 2.5º angle of bank to the right, and about 400 milliseconds later on the left main landing gear. At touchdown the indicated vertical acceleration was 2.91g and the vertical speed was 15.2 ft/sec. The aircraft bounced. The FO applied left roll input just as the PF released his right roll input. The aircraft continued to roll to the left. When it reached 7º angle of bank the PF ordered full right stick input, causing the aircraft to reverse its direction of roll. The FO then applied left roll input. Meanwhile the PF applied a nose down control input. As the pitch attitude decreased the FO applied and maintained a pitch up stick input. Although pilots are trained to 'shadow' the sidestick controller during critical flight phase (to effect a rapid take over of control if required using the take over push button) the FO did not recall any making any such sidestick control inputs.

2.2.2 Subsequent flights

After takeoff on the following flight, the flight crew were not able to retract the landing gear. This was due to sensor 20GA moving out of proximity and signaling to LGCIU1 that the right main landing gear was still compressed. It is likely, therefore, that LGCIU1 was in control during the take off from Manchester and as a result prevented the gear retraction. The gear lever was then selected down, in accordance with the ECAM procedures, thereby changing control of the landing gear to LGCIU2. The sensor on the right main landing gear supplying LGCIU2 was 22GA. This sensor had remained in proximity, indicating an extended gear, and therefore LGCIU2 allowed the gear to retract, despite it being over extended. Fortunately, the sliding tube was still able to be compressed as the wheels contacted the landing gear door and allowed the gear to retract. It is possible that had the gear not been able to compress during the retraction, there was the likelihood of damage to the gear and the gear door.

Having successfully retracted the gear the crew reviewed the remaining warnings whilst established in a holding pattern at 5,000 ft. Having considered the possible implications on their landing performance, the available runways and associated weather information they decided to divert to Manchester. This had the added advantage of being the main operating base for their company, where maintenance support would be readily available. Prior to leaving the holding pattern, they lowered the gear to ensure correct operation, to reduce the ECAM messages and to increase the fuel consumption and thereby reduce the landing weight. The crew subsequently conducted a gentle landing on Runway 24 Left at Manchester.

The aircraft was subsequently returned to service and the same crew were tasked to position the aircraft back to Bristol. After takeoff, the gear failed to retract and the crew were presented with almost the same warnings as on the previous flight. They reselected the gear down declared a 'PAN' and returned to land at Manchester.

2.3 Analysis of engineering activity

The significant damage to the right main landing gear upper diaphragm tube was caused by the initial heavy landing at Bristol. Although checks were carried out at Bristol, an opportunity to find this damage was missed. A second opportunity to discover the damage occurred at Manchester after its first arrival following the diversion. Again, this opportunity was missed. It was only after the second landing at Manchester that the damage was discovered.

2.3.1 Resistance of aircraft to damage

This, together with previous hard landings on A320 aircraft, demonstrates that the aircraft is able to withstand such landings without suffering major structural damage. The subsequent landings at Manchester also indicate how strong the landing gear is and that it is still capable of providing some shock absorbing despite the damage sustained. However, the weakest point appears to be the landing gear, and in particular the upper diaphragm, the failure of which is not readily apparent when the aircraft is on the ground. The failure only becomes apparent when the weight is taken off the oleo, such as during jacking.

Therefore, the only method of determining whether the landing gear has suffered any damage during the landing is to jack the aircraft. Following a serious incident in 1994 Airbus introduced a new DMU which could produce a LOAD <15> report, triggered when a hard landing has occurred. In association with the LOAD <15> report, Airbus also introduced levels of severity for the heavy landing, with a severe hard landing likely to produce landing gear damage. Therefore, a severe hard landing would require the aircraft to be jacked to take the weight off the main wheels. However, for this to be achieved two factors are essential. Firstly, the flight crew and engineers must understand what the LOAD <15> report is, and what it signifies, and secondly, that the report is correctly interpreted and the appropriate check is applied. If either of these are missed then the aircraft, as in the case with G-BXKD, could remain in service without any knowledge that the landing gear has been significantly damaged.

2.3.2 First opportunity to discover the damage

Because the appropriate limits had been exceeded during the landing the aircraft produced a LOAD <15> report, something that the engineer who met the aircraft had not seen before. The aircraft's operator had only recently started its winter season programme at Bristol, with support from the third party maintenance organisation. As part of this contract, the operator provided Bristol with the aircraft maintenance documentation, including the manuals; the manuals for G-BXKD were presented on AirN@V. The engineer at Bristol, who worked on G-BXKD, had only used AirN@V on one previous occasion and had had no formal training on the use of the system. The manuals he had used were generally in PDF format. Also, although the contract with the operator of G-BXKD had started, he had not received the required training from the operator on their practices, procedures and documentation.

Despite this lack of training he was able to navigate around AirN@V, and understood some of its functionality.

To interpret the LOAD <15> report and the required action he consulted the AMM on AirN@V. The initial information on the LOAD <15> report and the interpretation given in the flow chart in AMM 31-37-00, directed him toward AMM 05-51-11 pb 601. He used the table of contents menu in the left pane on AirN@V, and selected the line *'05-51-11 PB 601 – INSPECTIONS AFTER HARD/OVERWEIGHT LANDING – INSPECTION/CHECK'*. This presented him with task '05-51-11-200-004', since this was the first check in this particular section. The effectivity at the top of the page was within the range that related to G-BXKD (006).

With this information he believed that he had found the correct check, and he printed off the check using 'print job card' on the print menu. This provided him with a hard copy of the task '05-51-11-200-004'. He then completed the inspections. The inspection he carried out only required the jacking of the aircraft if damage was identified to the gear or the surrounding structure. Since he did not see any such damage he assumed that everything was in order and released the aircraft.

He was not aware, at that time, that there was another later, and more up to date, task within 05-51-11 pb 601, identified as task '05-51-11-200-004A'. In the absence of any training, he had assumed that when 'print job card' is selected it would provide all the variants of the check, both pre and post SB. This assumption derived from his familiarity with the process required to print off checks from the PDF system, in which the check has to be totally scrolled through to discover the end page for printing. Scrolling is something that is not easy to do on AirN@V and requires the selection of a hot link at the bottom of each section.

If the engineer at Bristol had been trained on AirN@V, he would have been aware that the menu in the left screen has to be fully expanded to show all the checks under a specific reference. Similarly, he would have also been aware of the search facility and the use of the hot links, which also shows all of the applicable checks.

Modern aircraft, such as the A320, have complex systems and the maintenance manuals for such systems, which are provided electronically, can be just as complex, particularly when various SBs and variations in equipment are incorporated within an operator's fleet. Therefore, adequate training in the use of these documents is essential to the continued safe operation of the aircraft. The operator provides bi-annual continuation training on policy, procedures and the use of its documentation, but this does not include the use of AirN@V. At the time of the incident to G-BXKD, 3 of the 10 engineers at Bristol had not completed this continuation training, including the engineer who carried out the inspection work on the aircraft following the initial heavy landing. The remaining 7 engineers that had received the operator's continuation training, had not received formal training on AirN@V.

As part of the subcontracting process for line maintenance, the operator's quality department carries out annual audits of the third party maintenance organisations. The operator's audit paperwork requires a check of the personnel's training, including the bi-annual continuation training, and following this incident an audit in December 2006 highlighted the 3 engineers who had not completed this training. This audit, however, did not highlight the fact that all of the engineers at Bristol had not received formal training on the recently introduced AirN@V system. If these audits do not identify failures in training, especially on new aircraft manual software which should be a reasonably straightforward area to audit, the efficacy of such audits must be in doubt.

When the engineer was first confronted with the LOAD <15> report he was unsure of its meaning. He therefore contacted a colleague within the maintenance organisation for advice. He did not, however, contact the operator's Maintrol at Manchester. The expectation of the operator was that at any outstation the engineers, whether their own or those from a third party, would contact them if there was any lengthy unscheduled maintenance or defects that may affect the operating schedule for the next day. In this particular case, the operator would have expected the engineer at Bristol to report the heavy landing, with its associated lengthy checks. Similarly, the engineer, who did not know the significance of the LOAD <15> report could have contacted the operator's Maintrol for advice. It is likely that had this occurred then the Maintrol engineer would have contacted the operator's specialist technical services engineer. He would then have been able to provide advice on interpretation of the report and the corrective action required. It is also likely that the Maintrol engineer, who was familiar with AirN@V, would have discovered the more appropriate check and found the requirement to lift the aircraft.

The task that was carried out was '05-51-11-200-004', which had an effectivity at the top of the page which stated:

> *'**ON A/C 001-013, 301-302'*

Since G-BXKD had an effectivity code of 006, this check was shown as being effective for that aircraft.

Task '05-51-11-200-004A', also related to inspections after a hard/overweight landing but had an effectivity that stated:

> *'**ON A/C ALL*
>
> *POST SB 31-1111 FOR A/C 001-013*
>
> *POST SB 31-1124 FOR A/C 001-006, 301-302'*

This check was also applicable to G-BXKD, since SB 31-1124 had been embodied in November 2001. This check was more detailed and categorised the severity of the heavy landing. Under this categorisation G-BXKD had experienced a 'severe hard landing' and the associated check required the aircraft to be lifted. If this check been followed, then the aircraft would have been jacked and the damage to the right main landing gear discovered.

Within Airbus manuals, if an SB amends the text, only those sections which are affected after the implementation of the SB have a statement to that effect. Those sections which are only applicable to PRE-SB aircraft, are not changed, so the effectivity coding remains as if the SB has had no effect. Had the effectivity against '05-51-11-200-004' stated PRE-SB 31-1124 then the engineer would have been aware that it was affected by an SB and it had been embodied. On discovering that it had been embodied, he would have then been directed to the relevant POST-SB check, in this case '05-51-11-200-004A'. It was therefore recommended that:

> Airbus amend their maintenance documentation effectivity coding to clearly state if the relevant section is only applicable to 'PRE-SB' aircraft, as well as those that are already marked as being 'POST-SB'. (Safety Recommendation 2007-105)

2.3.3 Second opportunity

The second opportunity to discover the damage was following the first landing at Manchester. Prior to the aircraft's arrival at Manchester, Maintrol had been made aware that the aircraft had diverted due to problems with the landing gear and thrust reversers. As a result, a team of engineers were briefed to meet the aircraft to carry out the required troubleshooting and rectification work. At this point Maintrol had not been made aware of the LOAD <15> report or the fact that it had suffered a heavy landing at Bristol. The ASR that was filed by the flight crew was not sent to Maintrol, but to the operator's safety department. Also, the engineer at Bristol had not been in contact with the operator's Maintrol either since he believed that the check, which had identified no damage, had been completed correctly. The first time that the engineering team become aware of the LOAD <15> event was when the aircraft's technical log was reviewed following its arrival. However, since the technical log had already been cleared, with a satisfactory inspection in accordance with the AMM, the engineering team believed that this was not the cause of the faults on the diversion flight. No further action with regard to the heavy landing, by the engineering team, was carried out following this first arrival.

The troubleshooting that was carried out correctly identified 20GA as the problem area. However, the root cause of the problem was not due to a sensor or target failure, but the over extension of the right main landing gear. On the ground everything appeared normal and the engineers did not connect the previous LOAD <15> report and a proximity problem with 20GA sensor to possible internal damage to the gear leading. Moreover, due to the apparent hard fault on the sensor, as shown on the LGCIU BITE, its replacement was the logical course of action. When the sensor was replaced the fault generated by the LGCIU BITE cleared; this led the engineers to the conclusion that the defect had been remedied. The aircraft was therefore released to service.

The troubleshooting had not been carried out using the troubleshooting manual, but by the use of the PFR and the LGCIU BITE. Had the faults on the PFR been input into the troubleshooting facility on AirN@V this would have directed the engineers toward a requirement to jack the aircraft, the damage to the right main landing gear would then have been discovered.

The decision to not adjust the sensor was logical since there had been no disturbance of the sensor target. Had there been a mention in the AMM or troubleshooting that a 20GA sensor fault, following a previous LOAD <15> report or hard landing, could be an indication of internal damage to the landing gear, then it is conceivable that the aircraft would have been jacked and the damage discovered. It was therefore recommended that:

> Airbus amend the A319/A320/A321 AMM to highlight the possibility of internal damage to the landing gear and to recommend the jacking of an aircraft following a fault of sensor 20GA or 21GA on a subsequent flight, after the generation of a LOAD <15> report. (Safety Recommendation 2007-106)

2.1.1 LOAD <15> report interpretation

The LOAD <15> report is not easy to interpret without the use of the AMM. The AMM provides some guidance on the meaning of each of the items and inspections that are required; however, AMM 31-37-00 pb 201 is at variance to the information contained in '05-51-11-200-004A', in particular the categorisation of the various landings. Also, AMM 31-37-00 pb 201 contains text that guides the engineer toward the task '05-51-11-200-004' and makes no mention of the later task '05-51-11-200-004A'. The flow chart provides a good visual reference for what is required, but it is inadequate in its guidance on the required checks based on the severity of the heavy landing; this information would provide clearer guidance if it was incorporated into AMM 31-37-00 pb 201. It was therefore recommended that:

> Airbus amend the A319/A320/A321 AMM ATA 31-37-00 to incorporate the classifications of landings quoted in AMM 05-51-11-200-004A into the text and the flow chart and to directly reference 05-51-11-200-004A as the more comprehensive check. (Safety Recommendation 2007-107)

The LOAD <15> report is clearly an important and detailed report. However, since the report is in a coded format, it requires the AMM task to decode the various numbers for a full understanding as to its relevance. The AMM already has categorisation of the severity of the event, it would be prudent to present this categorisation in plain English on the LOAD <15> report. This would indicate clearly the relevance and severity of the event to any engineer or flight crew member. It was therefore recommended that:

> Airbus amend the LOAD <15> report to describe clearly the classification of the event that generated the report, similar to those defined in AMM 05-51-11-200-004A. (Safety Recommendation 2007-108)

3 Conclusions

3.1 Findings

3.1.1 Flight operations

1. The flight crew that landed the aircraft at Bristol were licenced, qualified to operate the flight, and were in compliance with applicable flight and duty time limitations.

2. The aircraft's weight and centre of gravity were within limits for the landing at Bristol.

3. The landing at Bristol Airport was conducted in significant turbulence.

4. Both autopilots were disconnected at about 208 ft radio altitude, which corresponds to about 102 ft above the runway threshold.

5. When the autopilots were disconnected the crosswind was recorded to be 38 and 40 kt, whereas the maximum demonstrated crosswind for landing is 33 kt, gusting to 38 kt.

6. The crosswind just prior to touchdown was approximately 30 kt.

7. The pitch attitude at touchdown was approximately 5.5º. A maximum pitch attitude of 6.7º was recorded just after, together with a peak normal acceleration of 2.9g as both right and left main gear oleos compressed within a second of each other (right main first).

8. After the LOAD <15> report had been generated, indicating a hard landing, the aircraft commander entered the report activation into the Technical Log and passed a copy of the report to the engineer; the commander then filed an Air Safety Report.

9. After completing his inspection the engineer released the aircraft into service.

10. After the subsequent takeoff, the flight crew experienced problems in raising the landing gear, together with a number of ECAM warnings: they then diverted to Manchester Airport.

11. The landing gear problems, together with the ECAM warnings, were repeated after takeoff on the following flight; the flight crew returned to land at Manchester Airport.

3.1.2 Engineering aspects

1. The aircraft was certified, equipped and maintained in accordance with existing regulations and approved procedures. There was no evidence of any pre-existing defect with the aircrafts landing gear.

2. The right main landing gear suffered a rupture of the upper diaphragm tube following the heavy landing at Bristol.

3. Whilst the aircraft was on the ground the damage to the landing gear was not visible externally, and only became evident following the jacking of the aircraft.

4. There was no other damage to the aircraft.

5. A LOAD <15> report was generated following the heavy landing.

6. The engineer at Bristol had not seen a LOAD <15> before.

7. The aircraft manuals for G-BXKD were on a computer based system known as AirN@V.

8. The engineer at Bristol had only used AirN@V once before and had not received any formal training on the system.

9. The engineer had previously used the manuals in PDF format.

10. The engineer attempted to interpret the LOAD <15> report and used the flow chart in AMM 31-37-00, which directed him to the heavy landing check.

11. Using the AirN@V navigation menus the engineer selected '*05-51-11 PB 601 – INSPECTIONS AFTER HARD/OVERWEIGHT LANDING – INSPECTION/CHECK*'.

12. When using AirN@V the selection of the Page Block gave the first check in that section.

13. The engineer thought that he had the correct check, and printed it out using the 'print job card' selection on the print menu.

14. The inspection he carried out was as described in AMM 05-51-11-200-004; this did not require, nor lead to, jacking of the aircraft.

15. The engineer was not made aware of a later task AMM 05-11-200-004A.

16. AMM 05-51-11-200-004A was a more up to date check, which would have called for the jacking of the aircraft.

17. AMM 05-51-11-200-004A is available on AirN@V by either expanding the menu, scrolling through the pages or using search and hot links.

18. Scrolling through jobs is not easy to do in AirN@V, in comparison to PDF.

19. The engineer at Bristol did not consult the operator's Maintrol at Manchester.

20. The effectivity coding of AMM 05-51-200-004 indicated that it was effective for G-BXKD, there was no mention of any SBs.

21. AMM 05-51-200-004A was also effective for G-BXKD, but only POST SB 32-1124.

22. SB 32-1124 had been accomplished on G-BXKD, in November 2001.

23. Airbus manuals do not state if a section is for PRE SB aircraft in their effectivity coding.

24. The operator's Maintrol were not aware of the LOAD <15> report prior to G-BXKD's arrival at Manchester.

25. Following the aircraft's arrival at Manchester, troubleshooting led the engineers to a fault with sensor 20GA.

26. The apparent fault with 20GA was due to the overextension of the landing gear oleo after take off from Bristol.

27. During the troubleshooting no link was made between the sensor fault and the LOAD <15> report.

28. Although the engineers were aware of the LOAD <15> report for the landing at Bristol, the technical log had been cleared following the inspection so they did not pursue this further.

29. The AirN@V troubleshooting manual, for the faults described on the PFR and LGCIU BITE, would have required the aircraft to be jacked.

30. There was no mention in the AMM that a landing gear sensor fault, following a LOAD <15> report, could indicate internal damage to the landing gear.

31. Interpretation of the LOAD <15> report is not easy without the use of the AMM.

32. The flow chart in AMM 31-37-00, page block 201, does not provide the same categories, for the various events, as those in AMM 05-51-11-200-004A

33. The LOAD <15> report presents various figures that require decoding and is not in plain text.

3.2 Contributory factors

The investigation identified the following contributory factors:

1. The A320 aircraft landed at Bristol Airport in a strong crosswind with associated turbulence; the landing was classified as 'hard' because specified parameters were exceeded at touchdown.

2. The autopilots were disconnected about 100 ft above the runway threshold. In the prevailing turbulent conditions, this allowed insufficient time to separate the piloting tasks of taking control of the aircraft and flaring the aircraft to land.

3. The engineers maintaining the aircraft at Bristol had not received adequate training in the use of the computer software supporting the operator's aircraft manuals.

4. The Airbus aircraft manuals did not differentiate, in their effectivity coding, how the implementation of Service Bulletins affected specific aircraft.

5. No connection was made between the previous LOAD <15> report and the subsequent 20GA sensor failure, indicating the internal damage to the landing gear.

6. Guidance provided in the aircraft manuals required to interpret the LOAD<15> report was unclear and differences existed between sections, particularly with regards to corrective action.

4 Safety Recommendations

The following safety recommendations were made:

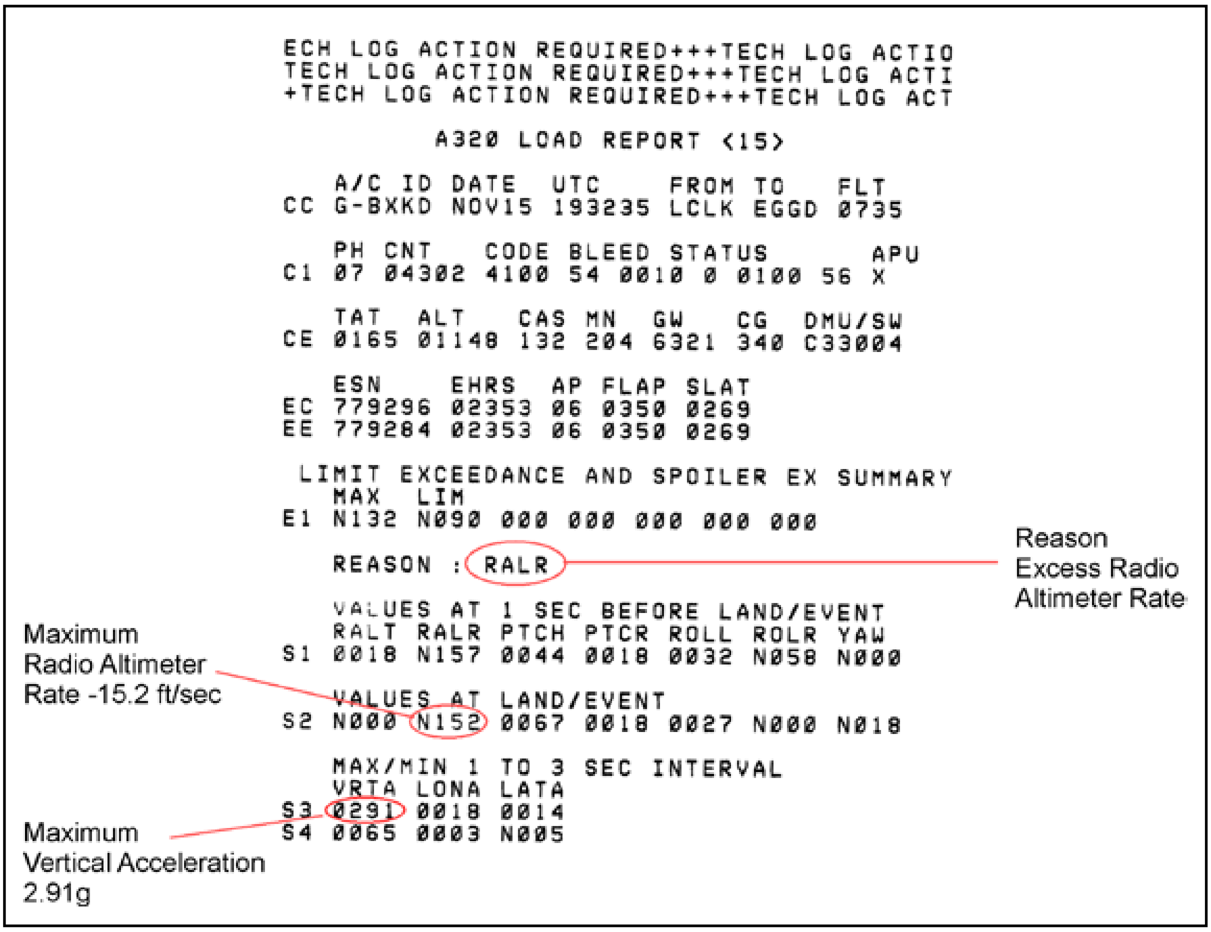
4.1 **Safety Recommendation 2007-105:** Airbus amend their maintenance documentation effectivity coding to clearly state if the relevant section is only applicable to 'PRE SB' aircraft, as well as those that are already marked as being 'POST SB'.

4.2 **Safety Recommendation 2007-106:** Airbus amend the A319/A320/A321 AMM to highlight the possibility of internal damage to the landing gear and to recommend the jacking of an aircraft following a fault of sensor 20GA or 21GA on a subsequent flight, after the generation of a LOAD <15> report.

4.3 **Safety Recommendation 2007-107:** Airbus amend the A319/A320/A321 AMM ATA 31-37-00 to incorporate the classifications of landings quoted in AMM 05-51-11-200-004A into the text and the flow chart and to directly reference 05-51-11-200-004A as the more comprehensive check.

4.4 **Safety Recommendation 2007-108:** Airbus amend the LOAD <15> report to describe clearly the classification of the event that generated the report, similar to those defined in AMM 05-51-11-200-004A.

R Tydeman
Principal Inspector of Air Accidents
Air Accidents Investigation Branch
Department for Transport
January 2008



```
ECH LOG ACTION REQUIRED+++TECH LOG ACTIO
TECH LOG ACTION REQUIRED+++TECH LOG ACTI
+TECH LOG ACTION REQUIRED+++TECH LOG ACT

          A320 LOAD REPORT <15>

    A/C ID DATE  UTC    FROM TO   FLT
CC  G-BXKD NOV15 193235 LCLK EGGD 0735

    PH CNT    CODE BLEED STATUS      APU
C1  07 04302 4100 54 0010 0 0100 56 X

    TAT   ALT    CAS MN  GW   CG  DMU/SW
CE  0165 01148 132 204 6321 340 C33004

    ESN     EHRS  AP FLAP SLAT
EC  779296 02353 06 0350 0269
EE  779284 02353 06 0350 0269

 LIMIT EXCEEDANCE AND SPOILER EX SUMMARY
    MAX  LIM
E1  N132 N090 000 000 000 000 000

    REASON : RALR

    VALUES AT 1 SEC BEFORE LAND/EVENT
    RALT RALR PTCH PTCR ROLL ROLR YAW
S1  0018 N157 0044 0018 0032 N058 N000

    VALUES AT LAND/EVENT
S2  N000 N152 0067 0018 0027 N000 N018

    MAX/MIN 1 TO 3 SEC INTERVAL
    VRTA LONA LATA
S3  0291 0018 0014
S4  0065 0003 N005
```


LOAD <15> Report

A/C ID	DATE	GMT	FLTN	CITY PAIR
.G-BXKD	16NOV	1051	TCX512K	EGGD EGCC

MAINTENANCE
POST FLIGHT REPORT

A/C ID	DATE	GMT	FLTN	CITY PAIR
.G-BXKD	16NOV	0923/1051	TCX512K	EGGD EGCC

ECAM WARNING MESSAGES

GMT	PH	ATA	
0923	02	22-00	AUTO FLT A/THR OFF
0927	03	21-61	AIR PACK 1+2 FAULT
0928	05	27-00	F/CTL
0928	05	77-00	ENG 1 EIU
0928	05	30-31	ANTI ICE F/O PITOT
0928	06	34-00	NAV TCAS FAULT
0928	06	32-00	L/G GEAR NOT UPLOCKED
0928	06	77-00	ENG 1 REVERSER FAULT
0928	06	32-00	L/G DOORS NOT CLOSED
0957	06	30-31	ANTI ICE F/O PITOT
1009	06	28-00	FUEL AUTO FEED FAULT (2)
1041	06	30-31	ANTI ICE F/O PITOT
1050	07	28-00	FUEL AUTO FEED FAULT

FAILURE MESSAGES

GMT	PH	ATA		SOURCE	IDENT.
0928	06	32-31-73	R L/G EXT PROX SNSR 20GA TGT POS	LGCIU 1	EFCS 1 EFCS 2 EIU1FADEC PHC 2/AFS
0928	05	34-43-34	TCAS (1SG)	TCAS	ATC 2 ATC 1 EIS 3 EIS 2 EIS 1
1050	08	32-31-71	CHECK LGCIU2 DISC INPUTS	EFCS 2	EFCS 1

Post Flight Report: Bristol to Manchester

A/C ID	DATE	GMT	FLTN	CITY PAIR
.G-BXKD	16NOV	1349	TCX512P	EGCC EGCC

MAINTENANCE
POST FLIGHT REPORT

A/C ID	DATE	GMT	FLTN	CITY PAIR
.G-BXKD	16NOV	1320/1349	TCX512P	EGCC EGCC

ECAM WARNING MESSAGES

GMT	PH	ATA	
1320	02	21-63	COND TRIM AIR SYS FAULT
1336	05	27-00	F/CTL
1337	05	77-00	ENG 1 EIU
1337	05	30-31	ANTI ICE F/O PITOT
1337	06	34-00	NAV TCAS FAULT
1337	06	77-00	ENG 1 REVERSER FAULT
1341	06	28-00	FUEL AUTO FEED FAULT

FAILURE MESSAGES

GMT	PH	ATA		SOURCE	IDENT.
1321	02	21-63-52	TRIM AIR PRESS VALVE OR PRESS SWITCH	TEMP CTL	
1337	06	32-31-73	R L/G EXT PROX SNSR 20GA TGT POS	LGCIU 1	EFCS 2 EFCS 1 EIU1FADEC PHC 2/AFS
1337	06	34-43-34	TCAS (1SG)	TCAS	ATC 2 ATC 1 EIS 3 EIS 2 EIS 1
1349	08	32-31-71	CHECK LGCIU2 DISC INPUTS	EFCS 1	EFCS 2

Post Flight Report: Manchester to Manchester