Air Accidents Investigation Branch

Department of Transport

Report on the incident to Airbus A320-212, G-KMAM London Gatwick Airport on 26 August 1993

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents) Regulations 1989

London: HMSO

LIST OF RECENT AIRCRAFT ACCIDENT REPORTS ISSUED BY AIR ACCIDENTS INVESTIGATION BRANCH

2/93	AS 332L Super Puma, G-TIGH, near the Cormorant 'A' platform, East Shetland Basin, on 14 March 1992	May 1993
3/93	Lockheed 1011 Tristar, 9Y-TGJ, near 'KIRN' VOR, Germany, on 9 March 1992	June 1993
4/93	British Aerospace 146-300, G-UKHP, at Aberdeen Airport, Dyce, Scotland, on 31 March 1992	August 1993
5/93	British Aircraft Corporation/SNIAS Concorde 102, G-BOAB, over the North Atlantic, on 21 March 1992	November 1993
1/94	Aerospatiale AS355F1 Twin Squirrel, G-OHMS, Near Llanbedr Airfield, Gwynedd, on 8 December 1992	January 1994
2/94	RAF Tornado GR1, ZG754 and Bell JetRanger III, G-BHYW, at Farleton Knott near Kendal, Cumbria, on 23 June 1993	June 1994
3/94	Boeing 737-2Y5A, 9H-ABA, at London Gatwick Airport on 20 October 1993	June 1994
4/94	Boeing 747-243, N33021 at London Gatwick Airport on 7 February 1993	August 1994
5/94	Cessna 550 Citation II, G-JETB at Southampton (Eastleigh) Airport on 26 May 1993	July 1994
6/94	Piper PA-31-325 C/R Navajo, G-BMGH 4 nm south east of King's Lynn, Norfolk on 7 June 1993	November 1994

These Reports are available from HMSO Bookshops and Accredited Agents

Department of Transport
Air Accidents Investigation Branch
Defence Research Agency
Farnborough
Hampshire GU14 6TD

16 December 1994

The Right Honourable Brian Mawhinney
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr D F King, an Inspector of Air Accidents, on the circumstances of the incident to Airbus A320-212, G-KMAM at London Gatwick Airport on 26 August 1993.

I have the honour to be
Sir
Your obedient servant

K P R Smart
Chief Inspector of Air Accidents

Contents | Page

Contents (continued) **Page**

Contents (continued) **Page**

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	-	Air Accidents Investigation Branch
ADD	-	Acceptable Deferred Defect
AMS	-	Approved Maintenance Schedule
amsl	-	above mean sea level
AMTOSS	-	Aircraft Maintenance Task Orientated Support System
AOC	-	Air Operators Certificate
APS	-	Aircraft Prepared for Service
ATA	-	Air Transport Association
ATC	-	Air Traffic Control
BCARs	-	British Civil Airworthiness Requirements
BITE	-	Built-In Test Equipment
CAA	-	Civil Aviation Authority
CRS	-	Certificate of Release to Service
CRT	-	Cathode-ray tube
°C, M, T	-	°Celsius, magnetic, true
DFDR	-	Digital Flight Data Recorder
DME	-	distance measuring equipment
ECAM	-	Electronic Centralized Aircraft Monitoring
EEPROM	-	Electrically Erasable Programmable Read Only Memory
FCOM	-	Flight Crew Operating Manual
FDR	-	Flight Data Recorder
GSU	-	Gatwick Support Unit
HF	-	High frequency
hrs	-	hours
ICAO	-	International Civil Aviation Organization
ILS	-	Instrument landing system
JAR	-	Joint Aviation Requirement(s)
km	-	kilometre(s)
kt	-	knot(s)
LAE	-	Licensed Aircraft Engineers
lb	-	pound(s)
LWTR	-	Licence Without Type Rating
MEL	-	Minimum Equipment List
NAA	-	National Aviation Authority
nm	-	nautical mile(s)
PCA	-	Power Control Actuator
PMDB	-	Production Management Data Base
QNH	-	pressure setting to indicate elevation above mean sea level
QRH	-	Quick Reference Handbook
RCTA	-	Radio Technical Commission for Aeronautics
SEC	-	Spoiler Elevator Computer
SGML	-	Standard Generalised Markup Language
UK	-	United Kingdom
UTC	-	Co-ordinated Universal Time
VACBI	-	Visual And Computer Based Instruction
VHF	-	Very high frequency

Air Accidents Investigation Branch

Aircraft Accident Report No: 2/95 (EW/C93/8/3)

Registered owner:	Guinness Peat Aviation Ltd
Operator:	Excalibur Airways Ltd
Aircraft Type and Model:	Airbus A320-212
Registration:	G-KMAM
Place of incident:	London Gatwick Airport Latitude 51° 09' N Longitude 000° 11.4' W
Date and Time:	26 August 1993 at 1531 hrs
	All times in this report are UTC except as stated

Synopsis

The incident was notified to the Air Accidents Investigation Branch (AAIB) at 2030 hrs on 26 August 1993, by which time the aircraft had been rectified and returned to service. The investigation, which began the next day was conducted by Mr D F King (Investigator in Charge), Mr J J Barnett (Operations), Mr A P Simmons (Engineering) and Mr R J Vance (Flight Recorders). Mr R Green of the Centre for Human Sciences, DRA Farnborough and Dr S Baker of the UK Civil Aviation Authority (CAA) were consulted on the human performance issues relevant to the actions of the aircrew and the engineers.

The incident occurred when, during its first flight after a flap change, the aircraft exhibited an undemanded roll to the right on takeoff, a condition which persisted until the aircraft landed back at London Gatwick Airport 37 minutes later. Control of the aircraft required significant left sidestick at all times and the flight control system was degraded by the loss of spoiler control.

The investigation identified the following causal factors:

(i) During the flap change compliance with the requirements of the Maintenance Manual was not achieved in a number of directly relevant areas:

During the flap removal the spoilers were placed in maintenance mode and moved using an incomplete procedure, specifically the collars and flags were not fitted.

The re-instatement and functional check of the spoilers after flap fitment were not carried out.

(ii) A rigorously procedural approach to working practices and total compliance with the Maintenance Manual was not enforced by local line management.

(iii) The purpose of the collars and the way in which the spoilers functioned was not fully understood by the engineers. This misunderstanding was due in part to familiarity with other aircraft and contributed to a lack of adequate briefing on the status of the spoilers during the shift handovers.

(iv) During the independent functional check of the flying controls the failure of spoilers 2 to 5 on the right wing to respond to right roll demands was not noticed by the pilots.

(v) The operator had not specified to its pilots an appropriate procedure for checking the flight controls.

Fourteen safety recommendations were made during the course of the investigation.

1 Factual Information

1.1 History of the flight

During the night before and the day of the incident flight the right-hand outer flap, which had been damaged, was changed. It was originally agreed between the operator and the maintenance organisation that the aircraft would be ready for a return to service at 0700 hrs. However, this proved to be an unrealistic estimate for the aircraft's return to service and this time had to be amended at least twice as the job progressed, putting the engineering team under some pressure to complete the task. At approximately 1500 hrs the aircraft was handed over by the maintenance organisation to the operator's flight crew at the departure stand. The commander commenced an external inspection of the aircraft whilst the co-pilot went to the flight deck to prepare the cockpit and to negotiate a suitable departure slot time. The remaining preparations for flight were completed and the aircraft was pushed back from the stand at 1520 hrs to make good its departure slot time of 1530 hrs. After starting both engines, but prior to taxiing, each pilot carried out a series of actions and selections before reading a printed checklist to confirm that these had been completed. These checks included a check of the primary flight controls by each pilot.

The flight control check was performed independently by each pilot exercising his sidestick in both the roll and pitch axes in order to check correct movement of the flight controls. As he performed his sidestick check, each pilot observed movement of the flight controls using the lower Electronic Centralized Aircraft Monitoring (ECAM) display. The check of rudder movement was carried out by the commander with the co-pilot 'following through' with his rudder pedals and observing the ECAM display. In accordance with the airline's Standard Operating Procedures the commander began his check of the flight controls soon after engine start whilst the co-pilot carried out a series of nine memorised switch selections and checks before starting his check of the flight controls. Each pilot initiated his flight control check by moving his sidestick to full left deflection and then moving it in a clockwise direction around or close to the physical limits of stick travel. At this stage of preparation for flight, the act of moving the sidestick from neutral normally displays the flight controls system 'page' on the lower ECAM but on this flight the automatic presentation did not occur for either pilot; they each had to interrupt their checks to select manually the required page. Neither pilot could remember whether he had manually selected any of the other 'pages' before he commenced his flight control check.

The commander could not recall whether he checked the controls immediately or shortly after selecting the appropriate ECAM page but he did recall looking at the page when doing the check. Whilst the commander was performing his check, the co-pilot selected FLAPS 1 (slats 18°, flaps 10°) and, as the flaps and slats moved, the commander paid special attention to the flap/slat indications which were shown on the upper ECAM display. The commander completed his flight controls check and shortly afterwards asked the co-pilot to read the 'After-Start' checklist; when he reached the 'Flight Controls' item, the co-pilot performed his flight control check before responding to this item. The commander remembered looking at the ECAM 'Flight Controls' page whilst the co-pilot carried out those checks, as did the co-pilot himself, but the co-pilot recalled that he did not observe the display whilst the commander performed his check, except during rudder pedal movement. Neither pilot announced to the other when or in which direction he was moving his sidestick. After their independent checks, both pilots believed that the flight controls were responding correctly to sidestick and rudder pedal movement.

Whilst taxiing to the holding point for Runway 08R, the pre-take-off checklist displayed on the ECAM was actioned to ensure that the aircraft was correctly configured for a FLAP 1 takeoff. The co-pilot checked the take-off CONFIG warning by pressing a button on the ECAM control panel and both pilots confirmed that there were no abnormal or unusual warnings. When the aircraft was aligned with the runway, the commander handed control to the co-pilot for takeoff. The take-off roll began at 1530 hrs and the ground phase was normal. At an indicated airspeed of about 153 kt the co-pilot initiated rotation and, as the aircraft became airborne, it started an undemanded roll to the right. At first the co-pilot attributed the undemanded roll to crosswind and applied left sidestick but the aircraft continued to roll to the right and he had to apply full left sidestick to contain the undemanded roll; meanwhile the commander uttered words to the effect that the co-pilot should take action to correct the situation. At about 300 feet above ground level, thinking that his sidestick might be faulty, the co-pilot handed control to the commander. The commander also had to apply almost full left sidestick to maintain wings level; he did not resort to the secondary effects of rudder to augment roll control. During the climb to the flap retraction altitude of 1,700 feet there were no ECAM warnings but as the aircraft passed 1,700 feet the ECAM sounded a repetitive chime to indicate a significant failure (most warnings are inhibited during takeoff until 1,500 feet radio height in the climb). The messages shown on the upper display were F/CTL ALTN LAW and F/CTL SPLR FAULT indicating that the flight control system had reverted to alternate law and that some spoilers were inoperative. The pilots completed flap retraction whereupon roll control improved slightly, although the commander's sidestick was still significantly displaced to the left.

The co-pilot contacted Gatwick approach by RT and notified the controller of their inability to follow the Southampton departure. After amplification of the control problem by the commander the controller asked the crew to take up the holding pattern at Mayfield (about 10 nm south east of the airport) at 3,000 feet. This would have required turns to the left and shortly afterwards the controller offered an alternative to the published holding pattern of radar monitored right-hand turns which the crew accepted. The pilots then reviewed and actioned the ECAM warnings; each action, when completed, was cleared from the ECAM display by pressing the appropriate button. Both pilots recalled that at no time was any 'affected system' page displayed on the lower ECAM display.

The approach instructions presented on the ECAM were to execute a FLAP 3 landing (22° of slat and 20° of flap) at 10 kt faster than the normal reference air speed and to allow for a 20% increase in the normal landing distance. The commander followed the ECAM instructions and asked Air Traffic Control (ATC) for radar vectors for right-hand turns to intercept Gatwick's Runway 08 Instrument Landing System (ILS) centreline at about 8 nm finals. Whilst positioning for the approach the commander summoned the senior cabin crew member to the flight deck as normal (ie at about the same time after takeoff as was commonplace); he instructed her to keep the passengers strapped in and informed her that they would be returning to Gatwick with a technical problem. Shortly afterwards the commander informed the passengers on the cabin address system that the flight would be returning to Gatwick with a technical problem.

The aircraft was given radar vectors with right turns to intercept the Runway 08R ILS localiser centreline at 8 nm from touchdown and cleared to descend to 2,000 feet altitude. As the aircraft was prepared for landing, the selection of FLAPS 1 (now slats 18° flaps 0°) made little difference to roll control and sidestick position for level flight. At 1553 hrs (23 minutes after takeoff) the commander reported that the aircraft was established on the localiser. However, some 35 seconds later as FLAPS 2 was selected and the slats and flaps began to extend to 22° and 15° respectively, the commander had to apply and hold full left sidestick to retain wings-level. He perceived that the degradation in roll control with the flaps lowered to position 2 was too severe for a safe landing and so he decided to abandon the approach. Engine power was increased, the flaps and slats were retracted fully and airspeed was increased. These actions improved roll control and the commander informed ATC that he would have to re-configure the aircraft for a higher speed approach. ATC then responded with radar vectors towards the Mayfield area which the commander was able to follow.

The commander then asked the co-pilot to look for advice and speeds for a FLAP 1 landing. The co-pilot looked in the Quick Reference Handbook (QRH) and the Flight Crew Operating Manual Volume 3 (FCOM 3) but he was unable to find the page he wanted. Prior to a recent revision of the FCOM 3 contents, the commander had extracted and copied pages relevant to non-normal aircraft handling and had placed them in a personal folder which he kept in his flight bag. He had also re-numbered the pages to reflect the revised layout of the FCOM 3. He passed the folder to the co-pilot who used it to find the page numbers that he needed and then the co-pilot extracted the required information from the FCOM 3. The co-pilot calculated a final approach speed and the required landing distance using a table in the FCOM 3.

At 1557 hrs when the commander was ready for the second approach, he accepted an offer of radar vectors for a continuous right turn onto finals to intercept the ILS localiser at about four to five nautical miles from the runway. ATC informed the crew that both Runways 08R and 08L were available. On the downwind leg FLAP 1 was selected and the aircraft was flown at 'S' speed (normal manoeuvre speed for this configuration) until close to final track. On final approach the commander reduced airspeed to the calculated speed of 166 kt but this was coincident with the minimum selectable speed for the configuration so he increased it by two knots to make some allowance for the crosswind. The approach was flown in direct law (an automatic consequence of lowering the landing gear whilst in alternate law) and the commander had no great difficulty in retaining adequate roll control. He saw the airfield from several miles out and ATC allowed him to self position without the complication of changing frequency to Gatwick Tower. At 800 feet altitude on final approach the commander overcame minor speed and thrust oscillations by reverting to manual thrust control. The aircraft landed at 1607 hrs (37 minutes after takeoff); touchdown was smooth, on the centreline and within the touchdown zone. Maximum reverse thrust and medium autobrake were used to stop the aircraft and achieve a turnoff at exit BRAVO which is about 370 metres from the end of the runway. A shorter landing distance could have been achieved through manually overriding the 'Medium' autobrake selection but the commander considered that this was unnecessary. At exit BRAVO the fire crews inspected the aircraft's hot wheel brakes and noticed that some panels on the starboard wing were sticking up. Later the aircraft was towed to Stand 132 where the passengers disembarked.

During the flight neither pilot attempted to observe the positions of the flight controls, either as indicated on the lower ECAM display or directly by viewing the outer wings through the cockpit windows.

When it became known that an incident had occurred the Airbus representative and two engineers from the maintenance organisation were asked to meet the incoming aircraft. It was observed that several right-hand spoilers were up while the aircraft was taxiing. On investigation it was found that the spoiler actuators for No 2, 3, 4 and 5 right-hand spoilers were in the maintenance mode. The spoiler actuators were placed in the operation mode. A duplicate inspection of the actuators and a function check was carried out. The aircraft was then released to service.

The aircraft was examined by the AAIB during the night of 30/31 August when it was returned to the maintenance facility for re-fitment of the removed flap which had been repaired. In addition to examining the aircraft, the flap change task was observed by the AAIB.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor/None	7	185	-

1.3 Damage to aircraft

None.

1.4 Other damage

None.

1.5 Personnel information

1.5.1	Commander:	Male, aged 50 years
	Licence:	Airline Transport Pilot's Licence
	Instrument Rating:	Renewed on 25 February 1993
	Base Check:	17 August 1993
	Line Check:	25 February 1993
	Medical Certificate:	Class I issued 2 March 1993 endorsed as valid only whilst wearing corrective spectacles
	Flying experience:	Total all types: 10,977 hours
		Total on type: 324 hours
		Last 90 days: 176 hours
		Last 28 days: 53 hours
	Duty time:	3 hours
1.5.2	First officer:	Male, aged 31 years
	Licence:	Airline Transport Pilot's Licence

Instrument Rating:	Renewed on 27 May 1993
Base Check:	4 May 1993
Line Check:	1 June 1993
Medical Certificate:	Unrestricted Class I issued 16 March 1993
Flying experience:	Total all types: 3,287 hours
	Total on type: 279 hours
	Last 90 days: 234 hours
	Last 28 days: 88 hours
Duty time:	2 hours 45 minutes

1.5.3 Engineering Personnel

Throughout this section, authorisation on a particular type may only cover certain limited activities.

Nightshift from 1900 hrs 25 August to 0700 hrs 26 August 1994

Nightshift engineer:	Male, aged 54 years
Licence:	LAE with Certificate of Release to Service (CRS) authorisations on: B747/JT9D; B747/RB211-524; B747/CF6-50E2; A320/CFM56; DC10/CF6-50; DC10/CF6-6; BAC 1-11; B737-200/JT8D-15; B767/RB211/524H(ETOPS); B767-200; B767-300ER/CF6-80C2B6F(ETOPS); B767/P&W 4000.
Experience:	LAE since 1981
First Assistant:	Male, aged 28 years
Licence:	LAE without A320 CRS authorisation
Experience:	12 years including apprenticeship
Second Assistant:	Male, aged 33 years
Licence:	LAE with A320 CRS authorisation
Experience:	16 years including apprenticeship

Nightshift Foreman:	Male, aged 37 years
Licence:	LAE with A320 Avionics CRS authorisation
Experience:	LAE since 1983

Dayshift from 0700 to 1900 hrs Local time on 26 August 1993

Dayshift engineer:	Male, aged 53 years
Licence:	LAE with CRS authorisations on: DC10/CF6-50; A320/CFM56; BAC 1-11; B737-200/JT8D-15; B737-300/CFM56-3; B737-400/CFM56-3C.
Experience:	LAE since 1966
First Assistant:	Male, aged 26 years
Licence:	None
Experience:	7 years including apprenticeship
Second Assistant:	Male, aged 20 years
Licence:	None
Experience:	4 years including apprenticeship
Dayshift Foreman:	Male, aged 38 years
Licence:	LAE without A320 CRS authorisation
Experience:	LAE since 1978
Duplicate Inspecting engineer:	Male, aged 46 years
Licence:	LAE with CRS authorisations on: B747/CF6-50E2; B747-100/200/JT9D & RB211-524; B757-236/RB211-535; B757 (ETOPS); A300-600/CF6-80C2; A310-200/CF6-80; A310-300/CF6-80C2; A320/CFM56; BAC 1-11/SPEY; DC10/CF6-6 & CF6-50.
Experience:	LAE since 1980

1.6 Aircraft information

1.6.1 General Information

Type:	Airbus Industrie A320-212
Constructor's number:	301
Fleet serial number:	057
Year of manufacture:	1992
Certificate of Registration:	UK CAA Certificate of Registration G-KMAM/R1 issued 22 April 1992
Certificate of Airworthiness:	UK CAA Transport Category (Passenger) Certificate of Airworthiness issued 30 April 1993, valid for 3 years
Total airframe hours:	4,643:56 hours
Engines:	2 CFM 56-5-A3 turbofan engines No 1 position serial 73160 No 2 position serial 731614

1.6.2 Aircraft Weight and Centre of Gravity

Zero Fuel Weight:	57,503 kg
Maximum Take-Off Weight Authorised:	75,500 kg
Aircraft Take-Off Weight:	66,803 kg
Aircraft Centre of Gravity (on takeoff):	33.5% MAC

1.6.3 Electronic Centralized Aircraft Monitor (ECAM) System

The ECAM system drives two CRT display units located one above the other in the centre of the instrument panel. The upper display has four areas which present the crew with primary engine, fuel quantity, and flaps and slats position indications. It also displays text messages regarding checklists, warnings, cautions and reminders. The lower display shows any one of 12 aircraft system synoptic displays (pages) or a 'STATUS' page giving the operational status of the aircraft after failure including recovery procedures. Each page also displays some flight data such as time and air temperature.

The display units have an associated control panel which allows selection of the various displays on the display units. Each of the 12 synoptic pages can be selected using an associated selector button and the information displayed is colour coded. Red and amber are used to display failures, green is used to display normal operation and white is used for titles, remarks and fixed symbols. Blue is used to illustrate actions to be carried out and limitations, whereas magenta is used for particular messages such as inhibition messages. Photographs of some relevant displays are shown at Appendix 1.

1.6.4 Spoiler System

The A320 is equipped with five spoilers on each wing, numbered 1 (inboard) to 5 (outboard) on each side of the aircraft (Appendix 2). All of the spoilers act as lift dumpers and speed brakes (Nos 1 to 5). Spoilers Nos 4 and 5 provide load alleviation and spoilers 2 to 5 on each wing provide the roll control augmentation.

Each spoiler panel is driven by a hydraulically powered, electrically signalled actuator. The electrical command signals are passed to the spoiler actuators from the three Spoiler Elevator Computers (SECs). Three independent hydraulic systems power the spoilers. Spoilers 1 and 5 are powered by the green system, spoilers 2 and 4 are powered by the yellow system and spoilers 3 are powered by the blue system.

The spoiler actuators can function in any of four modes. In Active Mode the actuator will extend or retract in response to the electrical command signal from the relevant SEC. In Biased Mode the spoiler will retract; this situation arises if a valid signal from the SEC is lost and hydraulic power is available. If hydraulic pressure has been lost the actuator goes into Locked Mode, in which an internal closing valve functions so as to allow aerodynamic or other forces to retract the spoiler, but prevents extension. In addition the actuator can be placed in Maintenance Mode. The Maintenance Device, a small spanner operated cam mechanism, is turned to operate an internal spool valve (Appendix 3). The maintenance device and spool remain in the Maintenance position until manually returned to the Operational position. The spool isolates the hydraulic pressure and allows the fluid at the actuator piston ram to re-circulate freely (Appendix 4). Therefore the spoiler can be moved by hand and hydraulic pressure, if applied, cannot operate the spoiler. This type of actuator was introduced on the A320 because of concerns about the possibility of injuries from unexpected spoiler movements during maintenance. Actuators with the same general *modus operandi* are fitted to the A330 and A340.

Each spoiler actuator is equipped with a position feedback transducer which returns a position signal to its SEC. This position signal is also processed and displayed on the Flight Controls ECAM page as a discrete indication (Appendix 1). When a spoiler actuator is functioning normally its ECAM indication is green. Abnormal conditions which last longer than three seconds cause the relevant ECAM indications to turn amber. After five seconds of disagreement between the selected and achieved positions a chime sounds and the corresponding spoiler on the opposite side is signalled to close and is isolated. This is to provide symmetry in the majority of spoiler failure conditions and to facilitate Master Minimum Equipment List despatch with failed and isolated spoilers. When operating normally a spoiler is shown as a short horizontal green line if retracted or as a green 'fir tree' if extended. The ECAM display shows a spoiler as retracted if its deflection is less than 2.5 degrees. If a spoiler is in maintenance mode or otherwise non-functional and it is retracted no fault will be detected or displayed until a control demand is made. If more than three degrees of sidestick deflection is maintained for three seconds or more, the indications will change from green to amber and a chime will sound after five seconds. The three second delay exists to eliminate spurious false warnings caused by hydraulic and/or computational delays. Although a small additional margin exists within the three seconds, Airbus Industrie have advised that it is not possible to reduce the overall delay appreciably.

1.6.5 Maintenance Conducted Immediately Prior to the Incident Flight

Within this section all times are Local because of its relevance to the engineers' shift pattern and their circadian rhythms.

The right-hand outboard flap was removed during the nightshift of 25/26 and a replacement fitted during the dayshift of the 26 August 1993, in the maintenance organisation's Gatwick Support Unit (GSU) hangar.

Due to a birdstrike incident, the right-hand outboard flap on G-KMAM was the subject of repeat inspections under an Acceptable Deferred Defect (ADD) which referred to a Design Deviation Authorisation which expired at 2400 hrs on the 25 August. This ADD had been raised because a replacement flap section was not immediately available; the original flap was to be removed for repair and re-fitted later. This level of rectification task was acceptable within the terms of reference of the GSU staff, however, it was a relatively unusual event in itself and as such was a task not previously undertaken by the nightshift engineer allocated the job, an LAE with CRS authorisation on the A320, or any of his assistants. He had brought forward some tasks on G-KMAM to the night of 24/25 August, mostly component changes scheduled for the following night, to reduce the overall amount of work to be done when the flap was to be changed.

The flap change was not an item in the Approved Maintenance Schedule (AMS) and as such no pre-prepared stage sheets for the task were available. The planning of this work was limited to the provision of a job card containing a single reference to a chapter of the Maintenance Manual, 27-54-62 (Removal of the Outboard Flap, Installation of the Outboard Flap), and an attempt to provision the special tooling.

The nightshift engineer was required to ascertain from the Maintenance Manual the full requirements of the job in hand. He was not particularly familiar with the A320 Maintenance Manual and found its 'Aircraft Maintenance Task Orientated Support System' (AMTOSS) layout confusing. (The AMTOSS format is explained in para 1.17.4) He had received from the foreman a hard copy of the Maintenance Manual section 27-54-62 amounting to some 40 pages, which had been printed off at some earlier stage to identify the special tooling required. He also printed at least a further 20 pages relating to section 27-51-00 (Adjustment of the Flap Rigged Position). The source of these printed pages was a widely used type of microfilm reel reader/printer which did not ease the task of cross-referring between sections of the manual. Notwithstanding these difficulties, he extracted copies of sufficient relevant pages to ensure that the significant tasks were detailed or referred to at least. Although the spoiler isolation task was not printed off it was referred to in section 27-54-62 under 'Referenced Information'.

He was further required by company procedures to raise 'Aircraft Maintenance Continuation Sheets' detailing each stage of the work. As each stage was completed, the appropriate entry was required to be certified and stamped by a CRS authorisation holder, in this case the nightshift engineer himself. He was also required to raise an 'Aircraft Maintenance Control and Certification Sheet' to be certified complete when the job was finished. He stated that the preparation of the stage sheets was made quite difficult due to the layout of the Maintenance Manual, with references to subtasks in other parts of the Manual and aircraft effectivity references, which he did not always correctly interpret. (It should be noted that subtasks are actually detailed in the body of the main text, however other related Tasks are called up near the beginning of the procedure under 'Referenced Information' and these Tasks are to be found elsewhere in the Maintenance Manual). He prepared stage sheets for both the removal and re-fitting of the flap but on the incorrect forms. The company procedures placed the responsibility for calling up the re-instatement and duplicate inspection of critical systems, where required, fully upon the individual certifying the breakdown of those systems.

The special tools were ordered from Heathrow by Gatwick Fleet Control via the Materials Supply Group when the flap change was known to be required. The tooling supplied for the task was deficient or incorrect in several respects. It did not include the set of collars required to lock the spoilers up in accordance with the spoiler isolation procedure described in the Maintenance Manual (Appendix 5) nor did it include threaded adaptors to assemble the hoist attachments to the flap. These adaptors were required for the Excalibur aircraft but not for the maintenance organisation's own A320 aircraft, due to differences in the build standard. It included alignment tooling for the flap carriage bolts but this did not fit the bolts on G-KMAM and it also contained a number of items for which the nightshift engineer could find no obvious purpose.

Although the responsibility of the nightshift engineer as a CRS signatory was total, he had recourse to assistance through either his foreman or shift manager. The nightshift engineer stated that during the night at various times he approached his foreman concerning the deficiencies in the supplied tooling and for the assistance of a working party or person with direct experience of the task to be undertaken. He also stated that he requested 16 hours to complete the task. The foreman assisted with the tooling but did not recall being asked for either a working party or for an experienced person. At this time the aircraft was scheduled to be available for service by 0700 hrs the next morning, however, this was revised to 1000 hrs after some negotiation.

Whilst waiting for the aircraft the nightshift engineer used the time to carry out some tasks on a number of other aircraft. He met G-KMAM at the ramp and carried out a Ramp 1 check before it came into the hangar at about midnight. After positioning the aircraft in the hangar he fully retracted the flaps, isolated the hydraulics and tagged the relevant circuit breakers and the flap lever. The two assistants then removed the flap carriage covers and falsework panels for access and disconnected the angle gearbox as required by the Maintenance Manual. The right-hand flaps were then hand wound down in preparation for lifting off the outboard flap. At this stage the Maintenance Manual procedures had been followed with the exception of task ATA 27-60-00-866-001, the extension and locking of the four outboard spoilers. The nightshift engineer had not carried out this task because he did not have the required tooling, the spoiler collars. He also anticipated that the task might be unnecessary. At around 0300 hrs, while preparing the sling for attachment to the flap it was found that threaded adaptors were required. These were eventually located and delivered to Gatwick, but this incurred a two hour delay during which time attention was diverted to another aircraft. Between 0500 and 0530 hrs the sling was attached to the flap and the weight taken. During the course of removing the flap carriage bolts it was noticed that one cable on the sling was close to a spoiler and that damage might occur. One flap carriage bolt was out at this time and the job was becoming difficult so the nightshift engineer and his assistants placed each spoiler actuator in the maintenance mode in turn and moved the spoilers up to clear the sling. The remaining flap carriage bolt was then removed and the flap lifted off the aircraft and placed on trestles.

At about this time, around 0600 hrs and just before the flap was lifted off, the nightshift engineer verbally briefed the oncoming dayshift engineer, also an LAE with CRS authorisation on the A320, who was to continue with the flap change, of the status of the job. When interviewed after the incident, neither engineer could recall mention of the spoilers. During this verbal handover it was pointed out to the nightshift engineer that the stage sheets had been made out on the incorrect forms. He then transferred the removal stage sheets to the correct 'Aircraft Maintenance Continuation Sheets' but did not do the same for the re-fitment stage sheets. The action of operating the spoiler maintenance devices was recorded in the rewritten stage sheets as, 'Fully extend and lock applicable spoilers', which is the wording used in the Maintenance Manual. The new stage sheets, and the originals on the incorrect format, were left as a guide for the dayshift, however the incorrect sheets were subsequently disposed of and never recovered, in spite of a search following the incident. Therefore, although it is certain that reference to the spoiler isolation existed on the rewritten stage sheets, it is not known if corresponding references to re-instate and function the spoilers were made on the original re-fitment sheets. These actions are detailed in the Maintenance Manual.

At around 0650 hrs the engineer who would ultimately carry out the duplicate inspection arrived, another LAE with CRS authorisation on the A320, and stated that he would now undertake the re-fitment as work assignments had been changed. Subsequently this re-assignment was cancelled so the roles became those initially anticipated, however, the verbal handover was repeated. Both engineers recalled that this verbal handover did contain specific reference to the spoilers to the effect that there was a potential hazard if hydraulic power was applied in that the spoilers would then close. The brief was not understood to mean that the spoilers were isolated. It is worth noting that on the Boeing 757 and 767, types commonly handled by the GSU, this would have been a correct assessment of the situation, however it is not possible for an A320 spoiler actuator to move under hydraulic power when in the maintenance mode. Very shortly after this the work assignments reverted to the original plan.

The dayshift engineer returned to the aircraft at around 0730 hrs. He carried out a pre-installation check and prepared the flap for lifting. He also arranged for the Estimated Time to Service to be revised, initially to 1200 hrs and then to 1500 hrs. During the first attempt to fit the flap the sling broke and had to be repaired, incurring a short delay. Following this the flap was installed without further difficulty. The flaps were hand wound up and the flap drive shaft re-connected. The rigging was checked using the Maintenance Manual procedure on the sheets printed by the nightshift. Rigging boards were placed on the wing and it is most likely that this is when the spoilers were placed in the retracted position. The rigging was satisfactory without any adjustment being required. After locking the flap carriage bolts the dayshift engineer arranged for the duplicate inspection of the carriage bolts, flap drive and asymmetry transducer, which was carried out by the duplicate inspecting engineer previously mentioned. The remaining stage sheets required were completed. Flap function checks were carried out by the dayshift and duplicate inspecting engineers and duly certified. The duplicate inspecting engineer asked if anything further was required and was advised not. There was a burst of activity to release the aircraft for 1500 hrs as the work pack and Technical Log were completed. The aircraft was then delivered for service.

When it became known that an incident had occurred the Airbus representative, an Avionics engineer and the duplicate inspecting engineer were asked to meet the incoming aircraft. It was observed that several right-hand spoilers were up while the aircraft was taxiing. On investigation it was found that the spoiler actuators for No 2, 3, 4 and 5 right-hand spoilers were in the maintenance mode. The spoiler actuators were placed in the operation mode. A duplicate inspection of the actuators and a function check was carried out. The aircraft was then released to service.

1.7 Meteorological information

A ridge of high pressure persisted over northern England and Scotland with a cloudy northeasterly airflow over the Gatwick area. During the incident flight the mean surface wind was from 030° at 8 to 10 kt with variations in direction between 350° and 070°. The weather was fine with a visibility of 40 km; the cloudbase was scattered at 3,000 feet and broken at 4,500 feet. The surface air temperature was +17°C to +18°C, the dewpoint was +7°C and the aerodrome QNH (sea level pressure setting) was 1021 hectopascals.

1.8 Aids to navigation

Radar vectors were provided by the Gatwick approach controller. Precision approach guidance to Runway 08 was obtained from the ILS/DME installation.

1.9 Communications

VHF radio communications with Gatwick ATC were satisfactory. Tape recordings of the appropriate conversations were obtained. The commander also spoke to Gatwick Handling and British Airways engineering on VHF radio and he tried, unsuccessfully, to contact his company's headquarters on HF radio through the Portishead Radio Aeronautical Service and a landline connection. Recordings of these communications were not obtained.

1.10 Aerodrome and approved facilities

The aircraft departed from and landed on Runway 08 Right at Gatwick which is 3,159 metres long and 46 metres wide; the mean slope is downwards by 0.05%. The runway threshold elevation is 202 feet amsl and the surface is grooved asphalt with concrete at each end. The take-off distance available is 3,311 metres and the landing distance available is 2,766 metres. The airport is equipped to ICAO Category 9 for Rescue and Fire Fighting.

1.11 Flight recorders

The aircraft was despatched after re-instatement of the right wing spoilers and consequently the Cockpit Voice Recorder data relating to the incident was recorded over.

The Digital Flight Data Recorder (DFDR), a Loral F800, was removed from the aircraft for replay; the quality of the recovered data was found to be unacceptable. On the incident takeoff there was little accurate data recovered from the time the aircraft began its take-off roll until it was airborne. Throughout the recording there were intermittent losses of data synchronisation; the frequency of these losses increased when the aircraft made any manoeuvre. The recorder was taken to Airbus for replay where similar results were obtained.

Further investigation revealed that there was a history of problems with the F800 installation in the A320 reported by operators and accident investigation authorities. Airbus informed AAIB that they had made a number of approaches to Loral regarding the operation of the F800, however the situation had not improved. In 1989 Airbus took the decision to undertake all test and certification flights using a flight recorder of different manufacture and only fit the F800 when the aircraft was delivered to a customer. In addition, they bench tested each F800 before fitting it to an aircraft in an attempt to ensure acceptable DFDR operation.

In conjunction with the operator's contracted maintenance organisation and Hunting Aviation, Loral's representative in the UK, AAIB discovered that all four of the operator's A320s had DFDR problems. These were identified as random track changing, erroneous Built-In Test Equipment (BITE) indications and corruption of recorded data, particularly at aircraft takeoff.

The track changing and BITE problems were cured by the replacement of an Electrically Erasable Programmable Read Only Memory (EEPROM) unit in the F800. Loral issued a service bulletin detailing the work necessary to rectify the track changing fault and this was made mandatory after considerable pressure had been exerted by industry and government agencies.

The causes of the data corruption are more problematical. Data recorders are often mounted on an anti-vibration tray for installation in the aircraft, and the F800 installation in the A320 was no exception. The requirement is for the recorder/tray combination to perform correctly under the environmental conditions as laid down in RTCA (Radio Technical Commission for Aeronautics) document DO160, 'Environmental Conditions and Test Procedures for Airborne Equipment'. The mounting tray as combined with the F800 on the A320 had not been tested to the requirements of DO160. Trials conducted by the Engineering organisation and the recorder manufacturers, after this incident, showed that substantial improvements could be made to the quality of the recorded data during takeoff if a mounting tray approved to the appropriate issue of DO160 were to be fitted.

1.12 Aircraft Examination

The aircraft was examined at the maintenance facility at Gatwick during the night of 30/31 August 1994. Flight control checks similar to those performed by the pilots after starting engines but before taxiing were carried out by the AAIB team on the flight deck of the incident aircraft. The checks were conducted with all spoiler servo control actuators in the flight position and again with spoiler actuator Nos 2 to 5 on the right-hand wing placed in the maintenance position. The tests were conducted in the presence of representatives from the aircraft manufacturer, the maintenance contractor and an aviation psychologist. The objectives of the tests were to determine:

a. The response of the flight control surfaces to sidestick movement.

b. The response of the ECAM system and displays to sidestick inputs.

c. The response of the flight control computers and ECAM system to abnormal spoiler positions.

The flight control tests showed that:

a. The responses of the elevators, ailerons, rudder, flaps and slats to control movements were unaffected by the mode of the spoiler servo control actuators.

b. When the spoilers were operating normally, if the sidestick was pushed rapidly in the roll sense to full deflection, the lower ECAM display indicated aileron movement fractionally before spoiler movement and all the flight control position symbols were coloured green.

c. When the spoiler servo control actuators on the right-hand wing were selected to maintenance mode and the spoilers were parked in the 'UP' position, the ECAM system detected a fault three seconds after the flight control computers were brought on line with both sidesticks centralised. An alerting chime sounded two seconds after the fault was detected and fault messages were displayed on both upper and lower ECAM screens.

d. When the spoiler servo control actuators on the right-hand wing were selected to maintenance mode and the spoilers were parked in the 'DOWN' position:

(1) The flight controls responded normally and correctly to roll left commands with no abnormalities displayed or detected by the ECAM system.

(2) When either sidestick was moved to the right, the ECAM displayed aileron movement but the spoiler symbols for both wings remained unchanged in shape or colour for three seconds; all the spoiler symbols were green in colour and correctly showed that all the spoilers were deflected by less than 2.5°.

(3) If the sidestick was held to the right of neutral for three seconds or longer, a fault was detected. After the fault was detected, the ECAM displayed amber symbols for spoilers Nos 2 to 5 on both wings and an amber 'LAF DEGRADED' fault message on the lower display. Irrespective of the subsequent position of the sidestick, once the fault had been detected and displayed on the lower ECAM display, two seconds later a chime sounded and the upper ECAM screen displayed an amber 'F/CTL SPLR FAULT' message.

(4) If the sidestick was moved to the right of neutral and then returned to neutral or to the left of neutral within three seconds, the ECAM did not detect a fault.

e. The aileron and spoilers Nos 4 and 5 on the left and right wing were visible from the corresponding pilot's seat.

f. Appropriate synoptic 'pages' on the lower ECAM display did not always change automatically as the aircraft was prepared for flight. If the automatic page sequencing was interrupted by a manual page selection, that manual selection required cancelling for the automatic sequencing to resume. The appropriate 'page' was available using the relevant system select button but again, unless this button was pressed once more to reset the computer logic, the next automatic 'page' change did not take place. However, irrespective of the method used to display the correct 'page', the system logic appeared to reset itself once a fault was detected and the affected system 'page' was then displayed until the fault was cleared, whereupon the display automatically changed to the appropriate 'page'.

1.13 Medical and pathological information

There were no injuries.

1.14 Fire

There was no fire but the Gatwick rescue and fire fighting service were placed on standby and attended the aircraft as it landed.

1.15 Survival aspects

The passengers and crew disembarked normally and without injury.

1.16 Tests and Research

None.

1.17 Additional information

1.17.1 Aircraft Library

Aeroformation is the flight training organisation for Airbus Industrie. One of its functions is to produce training guidance material and recommended 'Standard Operating Procedures' for Airbus customers. 'TRAINING MEMO' 2058 Issue 2 dated 14 January 1993 marked for distribution to 'All A320 Instructors' and relevant to all operators detailed the recommended method for checking the flight controls before takeoff. The contents of this memo, which are reproduced at Appendix 6, were repeated in the FCOM 3 at Revision 20. Excalibur Airways had incorporated parts of Revision 20 within its FCOM 3 but those parts relating to NORMAL PROCEDURES were not incorporated because Excalibur Airways produced its own NORMAL PROCEDURES section.

The aircraft library contained reference documents which might be needed by the crew for operation of the aircraft in normal and abnormal situations. Two documents which the flight crew referred to for advice on coping with the degraded flight control system were the QRH and the FCOM 3.

The QRH was supplied, originated and updated by Airbus Industrie. It contained some specific procedures which were not displayed on the ECAM.

With the exception of one section, the FCOM 3 was prepared and updated by Airbus Industrie. The exceptional section entitled 'Normal Procedures' was originated, supplied and amended by Excalibur Airways Ltd. This section of the FCOM 3 contained expanded information relating to normal procedures. An extract of these procedures which documented the requirement and sequence of flight control checks by each pilot is at Appendix 7.

The Abnormal and Emergency Procedures section of the FCOM 3 contained the following sections:

a. Flight Controls
This section contained numerous procedures for coping with abnormal situations. The complete section was revised by Airbus Industrie and had an issue date of December 1992. The following pages from the 'Flight Controls' section are reproduced at Appendix 8.

Page No	Topic
3	Slats Fault/Locked
9	Alternate Law
12	Spoiler fault (loss of one or more spoilers)

b. Miscellaneous
The miscellaneous sub-section covered situations which did not fall conveniently into any of the other sub-sections (eg bomb on board; forced landing; ditching; emergency evacuation). Page 15 of the miscellaneous sub-section which covered approach speed and landing distance corrections for failures is reproduced at Appendix 9.

1.17.2 Maintenance Manuals

The Excalibur Maintenance Manual for G-KMAM was derived from the generic Maintenance Manual for the aircraft prepared by Airbus Industrie. It was arranged by Air Transport Association (ATA) chapter in the normal manner. The working copy held by the GSU at Gatwick was a microfilm reel, from which the relevant pages could be inspected and printed using one of several film readers. The manual refers to different aircraft by effectivity and this effectivity is determined by reference to the Maintenance Manual Supplement. G-KMAM carried the manufacturer's serial number 301, the Maintenance Manual Supplement shows the corresponding Fleet Serial Number to be 057 and it is this number which is referred to throughout the Maintenance Manual. The Supplement is a hard copy document and includes material such as temporary amendments to the Maintenance Manual.

The Airbus Industrie A320 Maintenance Manual is in AMTOSS format and the Maintenance Manual has been complemented with the Production Management Data Base (PMDB). The PMDB contains exhaustive material and planning data which operators previously had to collect from numerous individual documents. The Maintenance Manual procedures are linked to the PMDB by unique task and subtask numbers. The Maintenance Manual and PMDB are issued on computer media, paper and microfilm. The A320 Maintenance Manual, in AMTOSS format, conforms to the text interchange standard adopted by the ATA and known as Standard Generalised Markup Language (SGML). The A320 was the first aircraft to have a Maintenance Manual prepared in this format, which is becoming the standard format prepared by all airframe manufacturers. The McDonnell Douglas MD-11 has a similar format Maintenance Manual, and the Boeing 757 and 767 manuals are becoming available in the format.

In an AMTOSS Maintenance Manual there may be many subtask references on a single page, however these will not require any further cross referring by the engineer as the subtask is fully described. Related Tasks, as opposed to subtasks, are listed at the beginning of any procedure under 'Referenced Information' and do require cross referring if the detailed steps of the task are needed.

The A320 Maintenance Manual describes the removal of an outboard flap at ATA Chapter 27-54-62. It begins with several warnings associated with Health and Safety at Work, then describes the fixtures, tools, test and support equipment required to undertake the Task. It then lists 'Referenced Information', which consists of thirteen associated Tasks to be found elsewhere in the Maintenance Manual, although not all are effective for any one aircraft. It then describes the Job Set Up procedure and the removal task itself, with paragraphs annotated for specific aircraft effectivities. The first subtask described under 'Job Set Up', 27-54-62-865-053, is to operate two circuit breakers for the flight control system. The Maintenance Manual then describes five further subtasks on the same page.

A total of 17 subtasks are called up in the 9 pages of text which describe the overall Task.

The AMTOSS A320 Maintenance Manual and PMDB is formatted to facilitate the use of computer based information retrieval systems. Operators who use such systems can extract all the pages and related information for each Task by entering a single ATA chapter number or keyword but the user is still required to select such additional Tasks as needed from the 'Referenced Information'. In this case the layout of the document is not a problem, however not all operators can use such systems. The automated use of an AMTOSS manual is closely associated with the PMDB and this database is constructed around the manufacturers maintenance schedule. For operators where their AMS is not the same as the manufacturers maintenance schedule there are differences and incompatibilities. For those operators and units which do not use the automated AMTOSS facility the extraction of all the relevant information for a procedure is at best slow. In addition, the information is cluttered with subtask references which do not improve the readability. The process is time consuming and tedious when the document is being used manually on a film reader, however when used with a computerised retrieval system, it is quick and efficient.

The Airbus A320 manual format has been the subject of criticism from engineers. This criticism seems to be partly a criticism of the content, and partly of the AMTOSS format. Some airlines are considering the use of non-AMTOSS manuals and Airbus Industrie are preparing non-AMTOSS manuals for operators who request them.

When a manufacturer designs and constructs an aircraft type it is required to prepare, amongst other documents, a generic Maintenance Manual. The Manual is prepared from design office specifications and is subject to revision and updating throughout the life of the aircraft. Compliance with the Maintenance Manual is assumed in the regulatory process leading to Type Approval and also in the document 'Acceptance of Maintenance Support Arrangements for Holders of Air Operators Certificate' (AOC), required for the issue of an AOC. For these reasons and others, manufacturers operate procedures within their Product Support and Design functions which allow problems within the Maintenance Manual and related documentation to be reported and corrected. In many cases it is essential to obtain a quick response to a problem, therefore manufacturers use various means to establish and maintain 'quick access' channels. For example, Airbus Industrie notify a procedure in which a telephone call or facsimile message to them can be responded to initially in perhaps an hour, with written confirmation later.

When an operator receives its AOC from its Airworthiness Authority, that approval is based in part on the Authority's acceptance of the maintenance arrangements, including the AMS. That document will contain a condition stating that the operator is required to ensure that recommendations made by the aircraft or equipment manufacturers in Maintenance Manuals and Schedules, Service Bulletins and any other technical documentation is evaluated and where appropriate complied with. For non-AMS tasks the CRS signatory is required by the terms of his authorisation to ensure that the aircraft is maintained in accordance with the manufacturer's recommendations or other Design Authority approval (Approved Data). The operator may adopt the basic Maintenance Manual in its entirety or may modify parts of it under its own relevant approvals, but in either case compliance with the appropriate Maintenance Manual is required. From discussions with airlines, Airbus Industrie and the UK CAA this is clearly understood. Even so, it is widely recognised that compliance does not always occur.

Technically the position is similar. It is unanimously the view of all the organisations (as opposed to individuals) approached during this investigation, that the training, experience, knowledge, and qualifications required to obtain LAE status is insufficient to justify, on technical grounds, any deviation from the Maintenance Manual. There is no technical justification for deviations, however minor, from the Maintenance Manual except by an engineering organisation with appropriate design authority or in conjunction with the manufacturer as the Design Authority.

In summary, all maintenance is based on total compliance with the Maintenance Manual or other Approved Data and no deviation is permissible, on either legal or technical grounds, without Design Authority approval.

1.17.3 Licensed Aircraft Engineers (LAE)

The LAE is an individual who has, by virtue of his or her training and experience, been granted a Licence by the Airworthiness Authority. The licence indicates a level of knowledge required to correctly complete the maintenance function using the published procedures. The certification basis in a JAR 145 Organisation is founded on the principal that a Licence Without Type Rating (LWTR) is required as a basic qualification. Certification privileges are granted following 'type training' by the issue of company authorisation to the individual by the JAR 145 Approved Organisation. The CRS authorisations held allows the LAE to sign off work and to release the relevant aircraft types to service. Typically an LAE will have detailed knowledge beyond the required minimum standard acquired along with increasing experience, for example, of known problems with the aircraft type. However, there is no requirement or guarantee that the LAE will have any knowledge and/or experience to equip him or her to deviate from published procedures in a safe manner.

By contrast engineers within an appropriate Design Authority will generally have higher academic qualifications but will not necessarily hold Licences. More importantly, they will have access to the information required both technically and legally to make changes, authorise concessions or deviations, and to fully understand the implications of any such action. The framework in which they work will formally structure such activities, in accordance with the relevant company approvals.

The CRS signatory is fully responsible for ensuring that all maintenance is correctly and completely carried out, in accordance with published procedures. The signature on the CRS is intended to be the evidence that the aircraft has been correctly maintained. The LAE cannot avoid this responsibility and it is not mitigated or reduced by any circumstances or difficulties. In the case of the flap change on G-KMAM the LAE certified the work under his company authorisations.

In the UK the training of an LAE or CRS signatory is monitored by the CAA. An individual must possess basic academic qualifications and must pass a qualifying examination to obtain a Licence Without Type Rating. This may be in the disciplines of Engine and Airframes or Avionics. For some types of aircraft a further CAA examination specific to the type allows the LAE to be issued with a Licence With Type Rating. However, most large (over 30,000 lb) aircraft types, including the Airbus A320, can only be maintained by an approved organisation. In this case a CAA type rating is not available to the LAE, instead the approved maintenance organisation qualifies and authorises the LAE on the type. An LAE may hold several CAA type ratings and/or company authorisations.

For a UK Licence with or without type rating to remain valid the LAE must demonstrate to the satisfaction of the CAA that he has had at least six months acceptable experience within the previous two year period. LAEs with authorisations from an organisation itself approved by the National Aviation Authority (NAA) under Joint Aviation Requirement (JAR) 145 must, in addition to having six months relevant experience within a two year period, receive continuation training from the maintenance organisation. These minimum legal requirements may be supplemented by the approved organisation's own requirements and procedures, as was the case in this instance, for example the LAEs in this case were also subjected to periodic re-examination. The training and certification requirements for LAEs in the UK are detailed in British Civil Airworthiness Requirements, Section L and Airworthiness Notices 3 and 10.

The Training programme used by the maintenance organisation and accepted by the CAA used a Visual And Computer Based Instruction (VACBI) training system. It did not specifically include training on the use of the A320 AMTOSS format Maintenance Manual, and was not required so to do, but the training did include some specific coverage of the aircraft manuals. The VACBI system included an audio-visual section on the spoilers with discussion of each mode and some self-examination questions. The information presented on the Maintenance Mode was correct but brief and did not draw attention to the need to reset the spoilers to Operational Mode, nor did it clearly indicate that the system was any different from other aircraft. The information was supplemented by classroom discussion and verbal instruction at the lecturer's discretion.

1.17.4 The Maintenance Organisation

The flap change was not performed by Excalibur. The operator tasked a Maintenance Organisation, the engineering division of another operator open for third party work, to do the job. The organisation was approved by the UK CAA under JAR 145. This approval was specific to particular facilities, aircraft types and types of maintenance activity. JAR 145-40 requires the availability of specified equipment tools and material and implies correct use. JAR 145-45 'Airworthiness Data', requires the organisation to be in receipt of all necessary airworthiness data and implies total compliance with that data. The CAA, having reviewed the circumstances of the incident, considered the maintenance organisation to be compliant with both JAR 145-40, in that the tooling was available at Heathrow, and 145-45, since all of the relevant documentation was available in the GSU. However, the nightshift engineer did not receive the tooling required for the flap removal as identified in the maintenance manual and did not fully comply with the requirements of the maintenance manual.

JAR-145-65 requires an approved maintenance organisation '*....to establish an independent quality system to monitor compliance with and adequacy of....the procedures*'. The maintenance organisation had a comprehensive Quality System which had steadily evolved over a long period of time and included such a programme, based upon the requirements of the CAA and other authorities, and its own Approved Organisation instructions. JAR 145-65 further states that '*...Compliance monitoring must include a feedback system .....ultimately to the accountable manager to ensure, as necessary, corrective action.*' Within the organisation this requirement was met by the Quality Monitoring Programme which included the use of Quality Discrepancy Reports and Ground Occurrence Reports, which were both raised on a single form, an E1022. E1022s could be raised by any member of staff to bring a wide range of issues, including factors potentially influencing quality and engineering defects to the attention of the Central Monitoring Unit. The unit categorised and processed the reports, directing them to the relevant departments for investigation and action and provided a response to the originator. In addition there was an independent program of audits carried out by trained Quality Assurance staff and a programme of product sampling by local area management in which independent assessments of selected functions were made. Specialist committees and local Quality Forums reported to the Engineering Quality Management Review Board which was chaired by the Director of Engineering. He also chaired the Engineering Safety and Technical Strategy Board which reviewed safety related technical issues.

Subsequent to this incident a form E1022 was raised by the inspecting engineer, who was also aware that an investigation was in progress.

1.17.5 Unscheduled maintenance

The flap change on G-KMAM was not a scheduled maintenance item and as such, pre-prepared task planning information was not available. Maintenance, other than minor tasks was unusual on any A320 at this location, and on this build standard which differed from the maintenance organisations own fleet of A320s it was particularly so. However, it was what might be described as a 'normal' task for the GSU which was regularly required to undertake 'casualty maintenance'; work carried out at short notice and frequently of an unusual nature. Engineers within the GSU could expect to be required to undertake unfamiliar tasks with a minimum of planning support, as was the case in this instance.

In general, unscheduled maintenance is not programmed and interferes with utilisation of the aircraft in an unpredictable manner, therefore there is a subtle but real pressure to deliver in the shortest possible time. There is a tendency to estimate unrealistically short times for the aircraft to be out of service to avoid flight cancellations and the engineering team may then have to re-negotiate the return to service time just to accommodate the normal time to complete the work. As the task is unplanned it is quite likely that unforeseen problems will arise with facilities and equipment unavailable or at the wrong location causing further time 'overruns'.

1.17.6 Engineers Shift System and Shift Handovers

Both shifts involved in the flap change were working the normal pattern which consisted of a 12 hour dayshift, 12 hours off and a further 12 hour dayshift, then 24 hours off followed by a 12 hour nightshift, 12 hours off and a further 12 hour nightshift. Each pattern was followed by four days off after which the cycle repeated. Shift changes occurred at 7am and 7pm local time.

For the team on the shift which removed the flap, this was the second nightshift ie it was at the end of the shift cycle. The dayshift were at the beginning of their shift cycle.

Individuals who work an irregular shift pattern will from time to time be working when their circadian rhythms would normally induce rest and sleep. Body functions such as sleep, digestion, elimination of bodily wastes and core temperature may become desynchronised with the desired pattern of activity and with each other. The results can include sleepiness or hunger at inappropriate times, poor quality of sleep, lack of alertness with falling body temperature and propensity towards error and confusion. Most of the research into this type of problem has been directed towards the role of the flight crew, where it has been found that most errors occur at around 3am to 5am, when the body core temperature is at its lowest. For pilots flying at times of 'circadian low' it is accepted that printed checklists and a clearly spoken 'challenge and response' are the main protection against error. For engineers working in similar circumstances considerable protection is afforded by detailed adherence to published procedures or documentation and by the use of a valid checklist, such as a work pack.

To accommodate the handover of tasks from one shift to another the Maintenance Organisations Company procedures (AL-33-03) under, *'Responsibilities, Engineering Staff (All)* stated:

> *'Ensure an adequate handover of the task is provided when work is continued across shifts or otherwise transferred. All pertinent requirements shall be detailed and worksheets/cards annotated with sufficient detail to cover all stages of the task to be continued'.*

and under, Procedures, Handovers stated:

> *'In areas where tasks are often continued across shifts or otherwise transferred, a local procedure is required to ensure a comprehensive handover of the work from one person to another.*
>
> *Time should be granted to the persons involved to ensure that the handover period is uninterrupted. It must also be ensured that verbal and written handovers are not a substitute for documented worksheet requirements, which should also form part of the handover'.*

1.17.7 Spoiler systems on Boeing 757 aircraft

Several engineers, including the nightshift engineer whose team had set the spoilers in the maintenance mode, indicated that the A320 spoiler system was subtly different from other aircraft they were familiar with, and that this had resulted in confusion. Two aircraft mentioned were the Boeing 757 and 767 which are frequent visitors to the GSU. The spoiler system is very similar on each of these aircraft.

The visual similarities between the Boeing and A320 systems was marked. The B757 has six spoilers each side and the A320 has five, otherwise the mechanical and aerodynamic configuration is very similar. Each spoiler has a Power Control Actuator (PCA) which is hydraulically powered and electrically signalled, like the A320. Each PCA has a manual release cam which is similar in position and size to the A320's Maintenance Device and is operated with a small hand tool in order to manually raise the spoiler for maintenance (Appendix 10). The Maintenance Manual describes the use of PCA locks. For maintenance these are fitted around the extended ram of each spoiler PCA. The locks each carry a red warning flag. In construction, use and appearance they are very similar to the collars used in maintenance mode of the A320 spoilers. The most obvious difference between the two aircraft is that on the Boeing 757, the underside of each spoiler carries the following warning in orange letters on a white background:

WARNING
HAZARDOUS AREA

TO PREVENT AUTOMATIC RETRACTION IF HYDRAULIC POWER IS APPLIED OR IF ELECTRICAL POWER IS LOST DEACTIVATE SPOILER/SPEEDBRAKE PER MAINTENANCE MANUAL SECTION 27-61-00 BEFORE ENTERING AREA TO PERFORM ANY MAINTENANCE OPERATION

Even though there are marked similarities between the two systems there are important differences which are not obvious from a simple visual inspection. The Boeing PCA manual release cam mechanically overrides a thermal relief valve to release hydraulic fluid trapped after the system is depressurised. The Maintenance Manual states ...'*...a spoiler panel which was raised using the manual release cam when hydraulic power was removed will immediately retract if hydraulic power is reapplied.* ' (Ref 27-61-00 page 5 para C3). The MM contains numerous warnings about the possibility of the spoilers moving and describes the fitting of the PCA locks in the following terms: *'The installation of PCA locks is the recommended procedure for spoiler deactivation.............To prevent injury to persons or damage to equipment, do the 'Install PCA Locks........' group of steps.'* (Task 27-61-00-042-008). It is clear that the function of the PCA locks is to preclude spoiler movement which might otherwise occur. However it is not possible for an A320 spoiler actuator to move under hydraulic power when in the maintenance mode, and the collars do not perform the same function although the maintenance action is similar.

1.17.8 Previous incidents

The AAIB is aware of at least three other cases where A320 aircraft have been prepared for flight with a spoiler in the maintenance mode.

The first of these occurred in April 1990. An American operator's A320 turned back on the first flight after scheduled maintenance. The No 1 left-hand spoiler was confirmed to be floating up in flight. The spoiler was found to be in the maintenance mode.

The second incident occurred on 22 August 1991. A French operated A320 turned back due to severe vibration with flap deployed. This was later confirmed to be due to an inboard spoiler being in the maintenance mode.

In March 1993 a French operated A320 was found during the pre-flight checks to have an unserviceable spoiler at the No 3 right-hand position. The aircraft was despatched under the Minimum Equipment List (MEL). After takeoff the spoiler floated up and the crew elected to return. The spoiler was found to be in the maintenance mode.

1.17.9 Corrective actions taken by the Maintenance Organisation

Immediate local corrective actions were taken by the organisation and these were supplemented by company-wide actions a little later.
The most significant actions were:

> The engineers involved were provided with refresher training and assessed as being up to the standard required for holding engineering authorisations.
>
> The creation of a database was initiated to cover a series of identified, known defects on various aircraft. This was done to enable the production of task cards to cover the top hundred or so 'casualty' defects or component changes.
>
> Shift handover procedures were examined and it was determined that handover procedures between shifts were acceptable. Handover procedures between terminal areas and hangars could be improved. This is being examined further with a view to improving the process.

Staff from the GSU are no longer transferred to the terminal area on a regular basis as before, hence greater continuity is maintained in respect of work projects undertaken in the area.

Ground lock tooling in respect of A320 spoilers is now held at Gatwick as part of the stores inventory.

In addition, the training given to engineers has been amplified with instructors describing more fully the operation and implications of the spoiler system. Also, the training syllabus has been expanded to include specific instruction in the use of AMTOSS Maintenance Manuals.

1.18 New investigation techniques

None.

2 Analysis

2.1 Introduction

Through a series of errors and omissions during the flap change, the aircraft was returned to service with four of the five spoilers on the right-hand wing in the maintenance mode instead of the active mode. Functional checks of the flight controls by the maintenance crew before releasing the aircraft and by the flight crew after accepting it, should have detected the unfit for flight condition before the aircraft took off. Because the error went undetected, the flight crew were faced with a serious degradation of roll control at a critical moment of flight. The degradation was such that the commander felt unable to execute turns to the left and the retention of adequate roll control authority required a high speed landing with the trailing edge flaps retracted. Aided by the prompt and thoughtful assistance of the Gatwick air traffic control team, the crew of G-KMAM coped well in this highly unusual situation and the aircraft made a safe landing.

The emergency arose, not from any mechanical malfunction, but from a complex chain of human errors by the maintenance crew, and by both pilots who earlier, despite carrying out specific checks, did not notice that spoilers on the right wing were not responding to control inputs.

2.2 Actions, attitudes and perceptions of the engineers

The events documented and the statements of the engineers show that the Excalibur Maintenance Manual was not complied with at several stages. It is clear that the procedure to extend and lock the spoilers was not correctly carried out, however this seems to be the only demonstrable non-compliance by the nightshift. The dayshift did not carry out subtask 27-54-62-866-060, which re-instates and lowers the spoilers, nor did they carry out subtask 27-54-62-710-051 which is a function check of the spoiler system. In addition company requirements were not complied with in connection with the shift handover and the production of re-instatement stage sheets. These were not merely academic deviations from the 'letter' of the requirements as each contributed to significantly erode the safety system and create the resultant serious flight hazard.

The engineers whose teams carried out the flap change were widely experienced LAEs with authorisations on many different aircraft types. They had been maintaining aircraft for many years and so ability and experience were not in question. They were also aware of the potentially critical nature of their everyday tasks and did not act in a deliberately careless manner. They, and their assistants even though generally younger and less experienced, showed a commendable degree of professionalism during this investigation. Therefore the errors made were not simple acts of neglect or ignorance. Their approach implied that they believed there were benefits for the organisation if they could successfully circumvent problems to deliver the aircraft on time. They demonstrated that, on occasion, they would work around difficulties when they arose without reference to the Design Authority, including situations where compliance with the Maintenance Manual could not be achieved. Unfortunately this placed total responsibility for any consequences squarely on the individuals concerned.

It was clear from his subsequent account and record of his actions that the nightshift engineer worked within the Maintenance Manual procedures insofar as he was able, given the tooling deficiencies and his willingness to complete the flap removal. It was not so clear that the dayshift gave as much attention to the written procedures, failing to realise the requirements to re-instate and function the spoilers, indicating a lack of knowledge of the Task as defined in the Maintenance Manual. The investigation did not reveal any evidence to suggest that the attitudes and working practices employed by these engineers during the flap change significantly differed from their usual attitudes and working practices.

It is difficult to imagine that such practices could be in even occasional use without the local line management being aware, and on this occasion the foreman was approached about the lack of the collars and should have been aware that the job continued without them. Such acceptance of the situation by local management would be seen as justification by the engineers. These effects were probably very subtle and far from being overt or deliberate, amounting to little more than a failure to insist upon a rigorously procedural approach to working practices and total compliance with the Maintenance Manual.

The industry, operators and manufacturers alike acknowledge that, although total compliance with approved procedures is a requirement, it is not always achieved. Engineers may in the past have assumed, perhaps without conscious thought, part of the design authority's responsibilities. However, the engineer, regardless of licences or authorisations, is neither permitted nor equipped to do so, even when he/she may have accrued many years of experience. While the potential for error has always existed, even with simple aircraft types, the skill and experience of those faced with day to day problems may well have been sufficient to achieve a safe conclusion. With the introduction of aircraft like the A320, A330, A340 and Boeing 777, it is no longer possible for maintenance staff to have enough information about the aircraft and its systems to understand adequately the consequences of any deviation. The avoidance of future unnecessary accidents with high technology aircraft depends on an attitude of total compliance within the industry being developed and fostered. Maintenance staff cannot know the consequences of non-standard operations on the systems.

Therefore the AAIB makes Safety Recommendation 94-41:

> The Civil Aviation Authority should formally remind engineers of their responsibility to ensure that all work is carried out using the correct tooling and procedures, and that they are not at liberty to deviate from the Maintenance Manual but must use all available channels to consult with a design authority where problems arise; if full compliance cannot be achieved the engineer is not empowered to certify the work.

It is significant that a shift change occurred during the flap change. The situation was further complicated by the initial allocation of an engineer to take over the job from the nightshift followed by a change of personnel and finally a reversion to the original allocation. This meant that the nightshift engineer conducted two handovers. These handovers did not achieve the intent of procedures published by the maintenance organisation in that they did not, 'Ensure an adequate handover of the task was provided'. The handovers took place, for the nightshift engineer, at a time when he could be expected to be tired and with circadian rhythms desynchronised.

The stage sheets, which should have provided documentation of the condition of the aircraft at handover and the requirements for re-instatement of all systems disturbed, were incorrect or incomplete. The stage sheets reflecting the flap removal were reproduced on the correct format and from examination after the event did include reference to, 'Fully extend and lock applicable spoilers', and so did indicate that the spoilers had been disturbed during the flap removal. The original stage sheets produced on the wrong forms for the removal and replacement were left for the dayshift but not recovered. It is not known if the original stage sheets referred to the spoiler reactivation or what status such sheets were thought to have. However, the stage sheets did contain adequate information for the dayshift to recognise the spoiler condition, assuming sufficient knowledge of the system.

Apart from the stage sheets, the handovers were verbal. The recollections of the individuals varied but it would appear that on neither occasion was the condition of the spoilers fully briefed or understood. It could be argued that, to 'ensure an adequate handover', written notes were necessary in addition to the stage sheets on all but the simplest of tasks, but none were explicitly required by company procedures.

The duplicate inspection and function check of the flaps appears to have been carried out satisfactorily. The duplicate inspecting engineer also took part in the flap function check, as required by BCAR chapter A6-2. It seems unlikely that either the dayshift or duplicate inspecting engineers made a check of the

Maintenance Manual flap and spoiler function requirements, as the subtask 27-54-62-710-051 requiring a spoiler function was the next item on the page after subtask 27-54-62-710-050 calling up the flap function check. The duplicate inspecting engineer relied on the dayshift engineer's understanding of the requirement for duplicate inspections rather than checking the Maintenance Manual. This appears to be accepted practice but, if duplicates are only conducted at the request of the engineer conducting the task and doing the primary inspection, some of the potential benefit of the duplicate inspection is lost. Therefore the AAIB makes Safety Recommendation 94-42:

> The Civil Aviation Authority should review the requirements for the conduct of duplicate inspections and consider the practicality of requiring the engineer conducting the duplicate inspection to review the task as detailed in the Maintenance Manual so as to come to an independent assessment of the scope of the duplicate inspection.

2.3 The Maintenance Organisation and its Quality programme

There were differences in the perceptions of the nightshift engineer and the shift foreman concerning the requests for assistance. Procedures existed by which the nightshift engineer could have made requests for tooling, labour, experienced help, a revision of the estimated time to service, engineering backup and even participation of the Airbus representative. In fact, these were only effective in actually obtaining some tooling, the sling adaptors, and a revised estimated time to service, which were essential for the task to be completed, despite other requests. The process did not work for the 'non-essential' matters. The nightshift engineer did not pursue these requirements vigorously and it appears that he may have held a perception that only 'important' matters, those which would inevitably stall the job, should be followed up in this way. If so, it could explain why he did not consult the Design Authority on how to proceed when the collars were not to hand. This decision, when compounded with the incorrect assumptions made about the purpose of the collars, was crucial.

If the engineer is to be able to ensure that the work is carried out using the correct tooling and procedures without deviation from the Maintenance Manual or other mandatory or company procedures, the industry must ensure that it has in place effective, rapid support, including usable systems for consultation with the Design Authority.

The Maintenance Organisation's Quality programme was comprehensive, actively supported at the highest level within the company and well promulgated on the shop floor. However, 'quality' was not engineered into the task of changing the flap on G-KMAM. Some features of the Quality System appeared not to be utilised by the engineers or failed to detect non-compliant practices.

1 Although the 'System' communicated its requirements to the engineers through procedures, posters and by other publicity, they were prepared to operate without ensuring total compliance with the Maintenance Manual. They did not appear to consider the lack of tools or confusing manual format to be 'reportable matters' and so did not appear ready to utilise fully the reporting routes to inform the 'Quality System' of issues which had the potential to affect quality.

2 Local line management, aware that the task was not correctly supported with the tooling required to achieve compliance with the Maintenance Manual did not appear to think that this was an issue to communicate to the Quality System.

3 The monitoring and sampling programs did, on occasions, detect the use of non-compliant practices but did not prevent them from being employed on this task.

It could be argued that the maintenance organisation's quality programme was not implicated in this event and that the incident resulted from local, undetectable deviations to the required practices. However, the aim is to achieve quality engineered into all tasks and this goal would be well served by the individuals raising and reporting such difficulties and deficiencies as those experienced during this job through the facilities of the quality programme. The procedures were available but they were not considered appropriate by the individuals engaged on the task.

2.4 Difficulties of unscheduled maintenance

The nightshift engineer was confronted with a task of which he had no previous experience and, because the flap change constituted unscheduled maintenance, planning was minimal. Support was initially limited to assistants who had never changed an A320 flap, an incomplete Maintenance Manual extract, a Maintenance Manual with a format he found confusing and tooling which was both incomplete and incorrect. In addition he was presented with an unrealistic estimated time to service.

Unscheduled maintenance is inherently unpredictable and therefore difficult to support. The staff need to be reasonably familiar with a number of different aircraft types, some of which they will not see often. The planning function is difficult because of the nature and immediacy of any problem, yet it is that same immediacy which places pressure on the engineers to deliver an aircraft even if planning support is reduced. The work pack may be minimal, as in the case of G-KMAM, and provide no guidance to the task. Notwithstanding this reduced support, the engineer holds the same responsibilities as if he were working on a scheduled maintenance input with full planning and provisioning support. In effect, at the point where he makes his decisions the airworthiness of the aircraft can become solely dependent on the actions or omissions of one individual. Even if duplicate inspections or function checks are called for by the Maintenance Manual, the engineer must realise this and arrange for it if it is to happen. A single path to failure is created, whereas in other areas of the design, maintenance and operation of the aircraft, some redundancy is required. The industry as a whole needs to recognise this problem and give particular support to those individuals placed in this position, and to minimise the occasions when significant maintenance is done in this way.

In ramp maintenance situations operators frequently use pre-planned stage sheets which briefly describe each action required giving the appropriate Maintenance Manual reference and providing boxes for an authorised signature. Also, at the bottom there is printed a Certificate of Release to Service. Such documents are required to be quite general, for example with ATA reference rather than specifically describing an operation, and should never be used in place of the Maintenance Manual. They do, however, provide an invaluable aide-memoire and allow easy confirmation that all critical tasks have been accomplished. This type of pre-planned stage sheet document would be appropriate for tasks such as the removal and replacement of control surfaces, flaps, landing gear assemblies and other major components and would be of considerable benefit in the non-scheduled maintenance environment. Therefore the AAIB makes Safety Recommendation 94-43:

> The Civil Aviation Authority should require a review of non-Approved Maintenance Schedule tasks which are likely to be encountered several times during the service life of a fleet so as to determine when pre-planned stage sheets should be required. The stage sheet for a task should call up all the relevant requirements of the Maintenance Manual and in particular should include stages for all re-instatements, inspections and function checks. Each such document should include boxes for an authorised signatory at each stage and should also include the Certificate of Release to Service.

As in this case, estimated times to service following casualty maintenance can be unrealistic and this places further pressure on the engineer to justify delays. The way in which different individuals will react to these pressures will vary but it is easy to see that such pressures could lead to errors of judgement. Clearly the individual responsible for the quality of the work must be given sufficient time to complete the task whilst adopting a procedural approach, adhering strictly to the requirements of the Maintenance Manual and all other mandatory and company practices. This requires the participation of line managers to screen the individual from undue pressure by the negotiation of realistic estimated times to service.

2.5 Maintenance Manuals format

Time pressures were exacerbated by the difficulties of dealing with a manual of unfamiliar format held on a film reader. The nightshift engineer did not understand the manual layout and found it particularly confusing when he tried to identify the significance of subtask references and the relevance of aircraft effectivity numbers. He printed additional pages for the job and it was necessary for him to judge how many extra pages were relevant and whether or not to print them. He stated that this was not an easy task and it is clear that he did not accomplish it completely, as he did not print certain tasks listed under 'Referenced Information', including the task 27-60-00-866-001 which covers extending and locking the spoilers. The difficulty of this task was probably no greater than commonly encountered by engineers and it is not possible to quantify how much if at all it contributed to the errors that then arose. However, failure to recognise the importance of the spoiler locking task and not printing it off was significant.

2.6 Engineers' training

The training received by the engineers covered the aircraft in reasonable detail, however at the time of the incident it did not specifically cover reference to the Maintenance Manuals or Illustrated Parts Catalogue, although it did refer to the Fault Isolation Manual. The AMTOSS format was not formally taught. Since the incident specific training has been introduced to cover use of the manuals. Also, the VACBI interactive computer based training system allowed the individual to proceed at his own pace, independent of an instructor. While it might be expected that an instructor would cover every topic on the syllabus, a student using the VACBI system could completely miss out some items.

2.7 Aircraft variations A320/A310/B757/B767

The design of the A320 spoiler system carries several important implications. Airbus Industrie advise that the design philosophy of the maintenance mode and maintenance device is closely related to considerations of personnel safety during maintenance. Although the system bears strong visual and procedural similarities to the Boeing 757 and Airbus A310, for example, it introduces quite different issues for maintenance staff. It reduces the need for concern for the safety of personnel during work in progress but has important flight safety implications. Airbus Industrie have confirmed that with the spoilers in Maintenance Mode, the primary function of the collars becomes that of acting, with the flags, as visual indicators that some action is required to make the system fit for flight; they also prevent the spoilers from being pushed down accidentally by personnel on top of the wing. While it is possible that they would also prevent closure of the spoilers if hydraulic power were applied, it is noteworthy that on the A340 where the spoilers are larger and not easily moved manually there are no collars and only flags are supplied.

The collars and flags combine together with the Maintenance Manual Task 27-60-00-866-001 to create an important safety system which is part mechanical and part procedural. This was not recognised by the engineers; therefore the safety system was inadvertently negated and flight safety compromised. The ground safety issues with which the engineers were concerned were largely unaffected.

Experience of other aircraft types seems to have inhibited the process of familiarisation with the task in hand. Although time pressures were never overwhelming, it was necessary for each individual to judge when further cross checking of the procedures was justified in continuing each task. It seems likely that the decision, if it was a decision, not to review the spoiler operation and isolation information, was based upon familiarity with other aircraft. The assumption that this aircraft was like the Boeing 757/767 families, and like the earlier Airbus A310, was easy to make and crucially important. The problem becomes more subtle when, as in this case, a single type of aircraft undergoes detail design changes such as the flap hoist attachments on G-KMAM. The only defence against errors of this kind is the diligence and experience of the engineers. However, the industry as a whole should consider whether the existing means of notifying important features and changes to engineers is adequate, and further how and when such material gets read and digested. In addition, the large number of authorisations held by some of the engineers involved makes it questionable that all the relevant material could be reviewed. Therefore the AAIB makes Safety Recommendation 94-44:

> The Civil Aviation Authority, in consultation with operators, should review the procedures for advising engineers of technical information such as Service Bulletins, Airworthiness Directives and other manufacturers' publications.

2.8 Lessons from previous incidents

Para 1.17.3 details previous cases of A320 aircraft being despatched with spoilers in maintenance mode. The ease with which the spoilers can be disabled does give rise to concern and additional warnings in the Maintenance Manual would seem appropriate.

Therefore the AAIB makes Safety Recommendation 94-45:

> Airbus Industrie should amend the A320 maintenance manuals in the flap removal, flap re-fitting and spoiler de-activation chapters, to include specific, clear warnings of the need to re-instate and function the spoilers after de-activation. Similar amendments should be considered for Airbus A330 and A340 aircraft.
>
> This recommendation has been actioned by Airbus Industrie.

For items which carry warning flags, such as landing gear lock pins and pitot covers, the flag is attached to the item which needs to be removed before flight. Many engineers would interpret the collar and flag to mean simply that the collar must be removed before flight. The maintenance device has no independent visual indication of its condition and there is insufficient obvious connection with the spoiler collar. The A330 and A340 aircraft have flags which attach to the maintenance device, giving a much clearer indication of the status of the spoiler actuator.

Therefore the AAIB makes Safety Recommendation 94-46:

> Airbus Industrie should introduce an additional flag and attachment to clip over the hexagon of the maintenance device, to provide clear and independent visual indication of the need to reset the maintenance device, and to amend the maintenance manual procedures accordingly. These actions should be made mandatory by the Civil Aviation Authority for UK operators.

Airbus Industrie has initiated studies with the aim of developing a modification to the maintenance device to meet the intent of this recommendation. Studies are due to be completed by the end of 1994.

2.9 Systems Logic

2.9.1 ECAM display switching

The tests carried out by the investigation team on G-KMAM shortly after the incident showed that the lower ECAM system/status display would not automatically switch to the flight controls page when a sidestick was moved if a different page had been manually selected with a single push of the appropriate button on the ECAM control panel. To restore the automatic switching feature it was necessary to de-select the page with a second push of the page selector button. However, whenever the fault warning computer detected a fault, the system/status display automatically switched to the affected system page whether or not a different system page had been manually selected. During preparation for the incident flight, neither pilot could recall whether he had manually selected a system page before moving his sidestick. Therefore, it is possible that the need for both pilots to select the appropriate page when commencing their flight control checks stemmed from an earlier manual selection by one or both of them which had not been cancelled. Certainly the ECAM system worked correctly during the AAIB tests and none of the components had been disturbed since the incident.

2.9.2 Spoiler fault warning

The AAIB tests on G-KMAM showed that failure of a spoiler to deploy in response to a computer command was not signalled to the crew until after three seconds had elapsed. Once the fault had been detected the 'latched' fault messages and amber symbology could not be cleared by removing the sidestick demand for right roll. The fault indications on the upper ECAM display were clear and unlikely to be overlooked by pilots engrossed in a normal task because of the associated attention getting chime and lights. However, if a sidestick was moved to the right for less than three seconds before being returned to neutral, the fault was not detected and no warning was given. Had either pilot held his sidestick fully to the right for three seconds or more, the spoiler fault would have been detected by the fault warning computer and the flight phase of this incident would have been avoided.

The aircraft manufacturer stated that the delay of three seconds before fault warning was necessary to allow for transport delays in the flight control system and thereby prevent nuisance warnings. It is significant that neither pilot was aware that three seconds must elapse before the fault warning computer signals a spoiler fault. It may be argued that the pilots did not need to know, for if they followed the test procedure recommended by Airbus, the demand for roll was likely to exceed three seconds in both directions during the handling pilot's check. However, this incident demonstrates that not all A320 operators adhere to the manufacturer's recommended procedures. Moreover, the existence of the delay in fault warning was not published in the Flight Crew Manuals. Given that A320 crews have to place much faith in the reliability and scope of the fault warning computer, safety would be enhanced if they were made aware of its more important limitations. This philosophy could usefully be extended to all the 'fly-by-wire' range of Airbus aircraft.

Therefore the AAIB makes Safety Recommendation 94-47:

> Airbus Industrie should advise all operators of its 'fly-by-wire' aircraft of the requirement to hold full control deflection for the appropriate period during the flight control checks to allow fault warning computers to inform flight crews of any defects detected, and publish in the A320 FCOM the time taken for a fault warning to be triggered following the failure of a flight control surface to respond correctly to a computer demand.

2.9.3 Spoiler Retraction

When the fault in spoilers 2 to 5 on the right wing was detected, the Spoiler Elevator Computers commanded spoilers 2 to 5 on both wings to retract. Those on the left wing retracted but, because of the maintenance mode selected on the right wing these spoilers could not respond to the retract command. Thus, when deployment of the serviceable spoilers on the left wing was needed to balance the effect of the free floating spoilers on the right wing, they were unavailable. The only controls available to the crew with which to oppose the effect of four 'floating' spoilers were the ailerons and the secondary effect of rudder.

The retraction of the corresponding spoilers on the left wing was a feature of the flight control software to ensure symmetrical roll response. The failure modes foreseen by the A320 manufacturer which might produce faults on spoilers 2 to 5 inclusive were triple SEC fault and triple hydraulic fault; both were considered extremely improbable and neither would result in a residual roll asymmetry. The possibility that an aircraft might get airborne with multiple spoilers still in the maintenance mode, thereby causing an enduring undemanded roll, was not a design case. It was considered that a combination of proper maintenance procedures and thorough pre-flight checks would detect the maintenance error before the aircraft took off. However, although changes to the spoiler logic and fault detection systems might prevent a recurrence of unwanted spoiler retraction, this incident demonstrated that the aircraft remains controllable by aileron alone and that it can be landed safely. The expense of flight testing software changes and modifying aircraft in service would be inappropriate if a recurrence of the chain of events which led to the incident can be prevented by changes in the maintenance and flight control check procedures. Since there is ample scope for improving these activities, no changes to the flight control system are proposed.

2.9.4 Warning Suppression

Post-incident interrogation of the Centralized Fault Display System showed that it had recorded faults on right spoilers 2 to 5 at 1531 hrs but these faults were not signalled to the crew until the aircraft climbed through 1,500 feet radio height after takeoff. The suppression of the fault warning was an intentional feature of the fault warning computer logic wherein caution warnings relating to flight phases are inhibited to avoid disturbing alerts during high workload phases. Since, during the takeoff the spoiler fault was not detectable until after the aircraft rotated allowing differential air pressure to raise the spoilers, the warning remained inhibited during the takeoff and initial climb phases. There would have been nothing to gain from immediate warning of the spoiler fault since, by the time it was detected, the aircraft's speed was above decision speed, the pilots were committed to taking off, the aircraft was either airborne or almost airborne and it was designed to be controllable with any number of symmetrical spoiler faults. Once committed to becoming airborne, the pilots' concentration was better directed at controlling the aircraft near the ground rather than determining the source of the roll control problem. Furthermore, the swift handover of control between the pilots and their instinctive priority of retaining adequate roll control could have been compromised by unexpected warning noises and messages. Therefore, the suppression of the warning until 1,500 feet radio height contributed positively to the safe handling of the incident.

2.10 Flight crew procedures

2.10.1 Flight preparation

The aircraft was handed over to the crew in sufficient time for them to prepare for the flight without undue haste and the commander commenced his exterior inspection of the aircraft whilst the co-pilot boarded it to prepare the cockpit for flight. At this stage the flaps were up and all the spoilers were flush with the upper surface of the wing; in these positions the spoilers and flaps hide the spoiler actuators. Therefore, a visual check of the spoilers would have revealed nothing unusual.

2.10.2 Flight control checks

The first demand for spoiler deployment was made during the checks which followed the starting of both engines. In accordance with the operating company's own procedures the commander commenced his check soon after starting the engines whilst the co-pilot carried out other tasks. The limited flight data available from the DFDR showed that the commander's sidestick check lasted between five and six seconds. With the sidestick in the 9 o'clock position both ailerons moved correctly and the roll spoilers on the left wing deployed whilst those on the right wing remained down which was the correct response. When the sidestick was moved to the right of neutral, the ailerons again responded correctly but spoilers 2 to 5 on the right wing did not rise as they should have done. The commander's demand for right roll lasted for less than three seconds. Later, but before the aircraft taxied, the co-pilot also carried out a check of his sidestick in the same manner as the commander. The response of the flight controls was unchanged in that elevator, aileron and left wing spoilers reaction to control demands was normal but again the right wing spoilers did not rise when right roll was demanded. The co-pilot's sidestick check lasted for between six and seven seconds with right roll demanded for less than three seconds. Because neither pilot demanded right roll for three seconds or longer, no fault was detected by the fault warning computer.

Both pilots believed that they had carried out satisfactory flight control checks and both had resorted to selecting manually the desired page on the system/status display. Having taken the trouble to select the appropriate page it seems highly improbable that either pilot would then ignore the display. Moreover, both pilots stated that they had observed flight control response during their independent checks and the commander had observed the flight controls display whilst the co-pilot carried out his own sidestick check. However, since the tests carried out on G-KMAM shortly after the incident showed that the ECAM system was displaying the position of the spoilers in the manner in which the designers intended, other factors must have contributed to the oversight by both pilots.

2.10.3 Flight control check procedures

2.10.3.1 General

The quality of any check depends on the thoroughness of the check procedure and the diligence of the checker. There was no evidence to suggest that either pilot had an inappropriate attitude towards the check but there were areas in which the pilots' flight control checks may have been deficient. These were: distraction; organisation of the check procedure, and training.

2.10.3.2 Distraction

During his check of the flight controls the commander also monitored the movement of the trailing edge flaps. Since the lowering of flap was the co-pilot's responsibility, the commander was not required to monitor flap extension but on this occasion he decided to do so because of the recent flap change. The flap position symbols are on the upper ECAM display whilst the flight controls symbols are on the lower ECAM display. It is possible that by dividing his attention between the upper and lower ECAM displays, the commander missed the spoiler fault. It would have been better for the commander to have informed the co-pilot that he himself would position the flaps after start, or to have deferred his flight control check until after flap extension by the co-pilot. As a result he could have concentrate fully on each separate activity.

2.10.3.3 Organisation of the check procedure

The aircraft manufacturer recommended that the flight control checks were carried out on the move whilst the aircraft taxied out to the runway (see Appendix 6). Doing so requires a reasonably straight section of taxiway because the handling pilot has to release the nosewheel steering tiller in order to move the sidestick and divide his or her concentration between taxiing and the check procedure. This can be done safely because the handling pilot still has limited nosewheel steering authority through the rudder pedals and he or she need not look inside the aircraft as the sidestick is moved; correct control deflection is checked by the non-handling pilot. However, the operator decided to avoid flight control checks on the move by specifying that they would be performed by both pilots as part of their memorised checks after starting engines. The philosophy behind this decision was to provide an uninterrupted opportunity for the flight crew to complete the check thoroughly, in a co-ordinated, logical manner and without the distraction of attending to the needs of safe taxiing.

After starting engines, the commander had little to do before commencing his flight control checks except to talk to the ground engineer to ensure that the nosewheel steering pin had been removed. Therefore, he was able to begin his check whilst the co-pilot was still part way through a series of eight separate checks or actions which preceded his own check of the flight controls. Although the times taken for a commander and co-pilot each to complete their after-start checks will vary from pilot to pilot, the difference in workload is such that a commander would normally finish his sidestick flight control checks before the co-pilot completed the eight actions which preceded his own flight control check. Therefore, commanders would normally carry out their tests of the pitch and roll flight controls unmonitored by co-pilots, and co-pilots would subsequently repeat the tests. Although a commander would normally finish his checks in sufficient time to monitor a co-pilot's check of the controls, he had no active involvement in a co-pilot's check and he was not required to monitor it. The philosophy behind the operator's divergence from Airbus Industrie's procedures was understandable but the airline's re-organisation of the after-start checks diminished co-ordination between the pilots to the point where the checks became independent rather than interdependent.

2.10.4 Human factors

2.10.4.1 Pilot expectations

There are subtle but important distinctions between a check being performed independently by two pilots and one being performed by two pilots simultaneously. Human expectations can affect the quality of an independent check to the point where two people make the same mistake. For instance, if a check has previously been carried out numerous times without any fault being present, it is human nature to anticipate no fault when next the check is carried out. During that check there is the potential to see what is expected rather than what is actually displayed, particularly if the difference is subtle. In this way subtle faults may not be noticed. Other human factors are that if a pilot moves the sidestick to the left and he is used to seeing the aileron symbols move before the spoiler symbols, he will tend to look at the aileron indications before looking at the spoiler indications. If he sees both ailerons move, he perceives that the sidestick is producing roll demands and he may omit to check the spoilers. Secondly, he is less likely to check spoiler movement instinctively if he has little experience of aircraft with roll control spoilers. Thirdly, if he remembers to check the spoilers, he expects the outer four of the five spoiler symbols on the left wing to rise and those on the right wing to remain unchanged; this requires a check of eight individual symbols which span the ECAM display. If his expectations are fulfilled when he moves the stick to the left, he will naturally expect them to be fulfilled when he moves it to the right and a subtle failure of the roll control system which only affects roll control to the right may be overlooked. Finally, if he moves the sidestick in a circular fashion (stirring) without pausing at the four cardinal points, he will see a mix of roll and pitch control movement which tends to saturate his scan. At that point, the only valid deduction may be that the stick is connected to the flight controls.

2.10.4.2 Workload pressure

In operating to Excalibur Airways' normal procedures, co-pilots carried out most of the after-start checks and actions. It is not intended to infer that the commander of G-KMAM showed any impatience during this incident but if a captain did show signs of impatience, or began the challenge and response phase of the 'After-Start' checks before a co-pilot had finished his flight control checks, the co-pilot could be tempted to 'rush' the checks. Moreover, the implied logic behind the non-handling pilot's check of the flight controls as expressed in paragraph 3 of the manufacturer's memo at Appendix 6 could be interpreted to mean that it is not so much a check of the flight controls but more a check of the other sidestick. Thus an Excalibur Airways co-pilot could be tempted into believing that because the commander has already checked the flight control responses and found them correct, he could safely abbreviate his own check to the point where it was sufficient only to ensure that the flight controls actually moved in response to sidestick demands. It is not suggested that this concept was intended or condoned by the operator, nor is it suggested that the co-pilot of G-KMAM abbreviated his flight control check in this way. However, it is possible that in the context of operating an aircraft with a design philosophy of multiple computers to prevent, detect or constrain pilot error, a tendency to place undue reliance on computer fault detection and warning (overtrust) could be prevalent amongst inexperienced or ill informed pilots and the quality of some checks could suffer accordingly. Therefore, whilst maximum use of the computers can enhance safe operation, pilots should be aware that computers have limitations and that safety ultimately depends on thorough pre-flight checks of critical systems. This awareness can best be imparted during conversion and recurrent training programmes which cover the system and human limitations applicable to computer driven flight controls.

2.10.4.3 Training

The co-pilot's previous fixed wing experience had been acquired on Jetstream aircraft which have no cockpit display of flight control positions, no spoilers and no view of the empennage from the flight deck. Similarly, most of the commander's civil flying experience had been gained on Boeing 737 variants which also lack cockpit displays of flight control positions. Therefore, both pilots came to the A320 from a background where the flight control checks were of the 'full and free' type where the words 'full and free' related to movement of the control columns and rudder pedals. On these aircraft corresponding movement of the flight control surfaces is assumed because the surfaces are mechanically connected by fixed linkages which are not normally disturbed between flights. If they are disturbed, duplicate inspections and monitored functional checks are necessary before the aircraft is released for service. The relationship in the A320 between the sidestick and the control surfaces is very different. There is no direct or fixed link and the relationships change depending on the phase of flight and serviceability of the many computers which interact within the 'fly-by-wire' system. Whilst both pilots gained a working knowledge of the system during their conversion training, neither had acquired much experience of 'fly-by-wire' control systems. Consequently they should have been carefully trained on the correct, detailed procedure for checking the flight controls. However, neither pilot could state the authority or origin of his technique and neither had memorised a detailed procedure for checking all the relevant indications on the ECAM flight control system page. With no written procedure to consult in the FCOM, the emphasis of what they each did during their individual checks was left to their own discretion. This situation was a factor which contributed to the incident.

2.10.4.4 Minimisation of human error

This incident demonstrated that it is not sufficient for A320 pilots simply to observe that the control surfaces move in response to sidestick demands; full movement in the correct direction of some surfaces and no movement by other surfaces should be confirmed. If both pilots monitor the flight controls display whilst one exercises a sidestick, the pilot not moving the sidestick is more likely to interpret the display correctly because his expectations of what will be displayed are lower than if he himself moves the stick. If he also reports what he sees and is trained to report the position of all the relevant control surfaces to the handling pilot, it is more likely that a subtle fault will be detected by at least one of them. Consequently, a flight control check procedure which actively involves both pilots has a better chance of detecting a subtle fault than independent checks by each pilot.

The involvement of both pilots and abbreviated verbal reporting of control response was included in the manufacturer's procedure but these aspects had been inadvertently precluded by the operator when devising his own procedure. Moreover, the operator had specified only that the check should be carried out and when it was to be carried out. Excalibur Airways had not provided precise instructions as to how the controls should be checked and no demonstration of an approved procedure had been given during conversion training.
Therefore the AAIB makes Safety Recommendations 94-48 and 94-49:

> Excalibur Airways should review their after-start procedures to ensure that both pilots are simultaneously involved in the first check of the flight controls and should specify the detailed content of the flight control check procedures in their FCOM.

> The Civil Aviation Authority should ensure that A320 type conversion training includes demonstrations of the approved procedures for aircrew checks of the flight controls and the limitations of the fault warning computer with respect to spoiler faults.

2.10.5 Flight Crew Performance During the Flight

2.10.5.1 Takeoff

The initial ground roll phase of the takeoff was unremarkable and the aircraft did not behave abnormally until it became airborne. The co-pilot's initial reaction of making a small stick input to the left to correct for a crosswind was logical, as was his subsequent conclusion that his sidestick might be faulty. On taking control, the commander also applied full sidestick and retained adequate roll control without resorting to the secondary effect of rudder. Despite the difficulty in retaining roll control both pilots reacted appropriately and maintained control of the aircraft.

2.10.5.2 Initial Climb

The initial climb was flown straight ahead to 1,700 feet altitude, the planned flap retraction height. In the absence of any significant capability to turn left the commander wisely decided not to attempt to follow the standard instrument departure which required an early left turn through about 180 degrees. The decision to abandon RT communication on the departure frequency and to declare the inability to turn left to the Gatwick Approach controller on the appropriate frequency was also sensible because the aircraft was heading towards the area where arriving aircraft hold under Gatwick ATC's control. After the initial message made by the co-pilot which stated that the aircraft had a flight control problem and would have to return to Gatwick, the commander took over the RT communication to describe the difficulty in turning left and his intentions. Although neither pilot declared an emergency by using the 'PAN' or 'MAYDAY' prefix, together they ensured that Gatwick ATC were aware of their flight control difficulties and their immediate and further intentions. Gatwick ATC then kept all other traffic clear of the Excalibur flight and provided it with radar vectors to remain inside controlled airspace in visual flight conditions. ATC also informed other crews on the frequency that an emergency was in progress and a second controller assisted with controlling arriving traffic. Thus, although an emergency was not declared using the word 'emergency' or a recognised distress prefix, the crew of Excalibur 259 did ensure that ATC were aware of their control problem and ATC responded in a manner appropriate to the declaration of an emergency. The climb out phase of the flight was well handled by the crew and by Gatwick ATC.

2.10.5.3 Fault Diagnosis

Although there was no voice recording of the pilot's conversation during the flight, in his first transmission to the approach controller, the commander revealed his early thoughts on the cause of the inability to turn left. Although an immediate association between the recent maintenance activity and the control difficulty in roll was a natural and irresistible first assumption, the commander did not study the ECAM flight controls synoptic page. If he had, he would have seen that all the spoilers had failed, that some had failed at zero and that others had failed deflected (ie extended by 2.5 degrees or more). He would then have arrived at a better understanding of the true source of the lateral control problem. The co-pilot did not study the page either; he was fully occupied with informing ATC of their intentions, negotiating clearances for non-standard manoeuvres, answering requests for more information, and assimilating the procedures displayed on the ECAM.

The fact that neither pilot interrogated the flight controls synoptic page on the lower ECAM display seems illogical given that they both observed messages on the upper ECAM display concerning flight control faults. Normally on clearing the STATUS page on the lower display, the affected system synoptic page is automatically displayed, but on this occasion both pilots believed that the page was not shown. There was insufficient evidence to determine whether or not the page was displayed but certainly no deliberate attempt to interrogate it was made. The reason why the pilots did not seek the synoptic page was unrelated to the earlier (and briefly held) assumption that the lateral control problem was caused by the flap change. The omission arose because, at the time of the incident, they were content to trust the ECAM wholeheartedly. This trust was a conditioned response of their training and a reflection of their limited experience on type.

The system designers intended that the ECAM would monitor the aircraft systems, diagnose any faults, inform the flight crew of significant faults at an appropriate stage of flight, and then present them with instructions on how to deal with the malfunction. Almost all the instructions for abnormal or emergency operation of the aircraft in flight were automatically presented on the ECAM as and when they were required, and pilots had only to follow the displayed checklists, item by item, to resolve any difficulties. In this way, the need to refer to written checklists and manuals was minimised.

The operator's training staff had endorsed this philosophy and instilled in its pilots the requirement to adhere strictly to the procedures displayed on the ECAM. Moreover, until this incident, the pilots' experience had been that the ECAM was reliable. Consequently, both pilots trusted the ECAM instructions and followed them implicitly. It was not until the further degradation in roll control as the flaps were lowered beyond position 1, that they realised that the ECAM instructions were inappropriate to their situation. At that stage the commander instigated a search for written material in the somewhat unfamiliar 'Abnormal and Emergency Procedures' section of the FCOM 3.

Since this incident, the UK CAA has issued advice which is relevant to the handling of this type of emergency. The advice is contained in its Aeronautical Information Circular (Pink 84) of 1 July 1994 entitled *'In Flight Aeroplane Damage'*. Consequently, a recommendation to publish yet more advice to pilots is inappropriate.

2.10.5.4 First approach

The crew followed the ECAM instructions for a FLAP 3 landing. The instructions were appropriate for total loss of spoilers but they were inappropriate for an approach with superimposed roll control asymmetry. Fortunately the extension of flap was made at a safe height and it was wisely stopped when roll control became further degraded as flap extended. The pilots restored the configuration to FLAP 1 (now slats 18° flaps 0°) and reverted to holding under radar vectors whilst they re-assessed their options.

2.10.5.5 Non-normal procedures

Following the aborted attempt to land with FLAP 3 as recommended on the ECAM, the commander sensibly decided to land with FLAP 1 because roll control authority was more assured with the trailing edge flaps retracted. He asked the co-pilot to obtain appropriate advice and information for this non-standard landing from the aircraft's library but the co-pilot had difficulty in finding the data he wanted.

The information required was contained in two different locations within the 'ABNORMAL AND EMERGENCY PROCEDURES' section of the FCOM 3. Firstly, it was tabulated on page 3 of section 3.02.27 of the 'FLIGHT CONTROLS' sub-section under the heading 'F/CTL FLAPS FAULT/LOCKED' or 'F/CTL SLATS FAULT/LOCKED'. Because there was no malfunction of the flaps or slats, the co-pilot did not consult this page. The second location was on page 3.02.80 of the 'MISCELLANEOUS' sub-section. Being the penultimate page of a section covering about 500 malfunctions with an index spread over 10 pages, and being indexed within a sub-section covering situations which were generally unrelated to flight control problems, it is not surprising that the co-pilot had difficulty finding this page. Fortunately, the commander carried personal copies of the relevant pages from a previous version of the FCOM 3 and had updated the page numbers to reflect the current standard. Producing these eventually enabled the co-pilot to find the current page in the FCOM 3 and extract the appropriate increment to V_{REF} for the FLAP 1 approach and landing.

The design philosophy of the A320 is such that there should seldom be any need to consult the QRH or FCOM which explains why the co-pilot was unfamiliar with the layout of the abnormal procedures sections. Therefore, to maximise their ease of use, the written emergency procedures must be very well indexed with cross references to important pages. The page entitled 'APPR SPD - LDG DIST CORRECTIONS FOR FAILURES' was appropriate to failures of five different systems (Flight Controls, Flaps, Hydraulics, Brakes & Electrics), yet it was not cross-referenced in the index under any of these headings. In view of the importance of this page, the AAIB makes Safety Recommendation 94-50 part 1:

> Airbus Industrie should make the contents of page 3.02.80 of the FCOM 3 more conspicuous in the index of 'ABNORMAL AND EMERGENCY PROCEDURES' and that the contents of this page should be duplicated in the QRH.

Airbus Industrie are considering revisions to the FCOM.

2.10.5.6 Approach planning

The planning for the second, successful approach and landing was satisfactory with one exception; the pilots did not allow for the increase in landing distance appropriate to the double failure. The table on page 3.02.80 listed a factor of 1.30 for the flapless landing and 1.3 for the multiple spoiler fault. The note at the bottom of the page explained the need to take account of multiple failures by multiplying the factors. Thus, although the pilots expected an increase in the normal landing distance of 1.3, the appropriate factor was 1.69. When applied to the landing performance data within the FCOM 2, the required minimum runway length was 1,640 metres. Fortunately Gatwick's Runway 08R has a landing distance available of 2,766 metres and the aircraft was able to use 2,310 metres of it without any embarrassment or danger of overrun.

Being placed at the bottom of the page in italics, the note regarding multiple failures was inconspicuous and unlikely to be read because it appeared below the information sought by the reader. Moreover, since the most probable reason for consulting this page is multiple failure, the information within the text is too important to be relegated to note status. Therefore the AAIB makes Safety Recommendation 94-50 part 2:

> Airbus Industrie should make the note to FCOM page 3.02.80, which explains the need to take account of multiple failures by multiplying the factors, more conspicuous and that it should precede the table of increments.

Airbus Industrie are considering revisions to the FCOM.

2.10.5.7 Abnormal approach diagrams

It was noted that the early pages of the 'ABNORMAL and EMER PROCEDURES' section contained pictorial notes on 'OPERATING TECHNIQUES' for non-standard approaches. There were diagrams for landing with NO FLAPS; NO SLATS; and NO FLAPS AND NO SLATS. However, there were no diagrams for an intentional FLAP 1 or FLAP 2 approach and landing. An intentional approach in CONFIG 1 must be handled in a different manner to a 'NO FLAP' approach yet both may result in landing with the flaps retracted. To avoid confusion and to simplify the planning and execution of such an approach, the AAIB makes Safety Recommendation 94-50 part 3:

> Airbus Industrie should include operating techniques for intentional FLAP 1 and FLAP 2 approaches in the 'OPERATING TECHNIQUES' sub-section of the 'ABNORMAL and EMER PROCEDURES' of the FCOM 3.

Airbus Industrie are considering revisions to the FCOM.

2.10.5.8 Second approach

The commander was offered either runway direction for landing and the emergency services were well prepared to offer assistance without any need for frequency changes or extraneous RT chatter. The second, curved approach was well flown and the commander was free to fly whatever approach path he desired thanks to excellent co-operation from ATC.

2.10.5.9 Landing

Although there was no flight data available from the DFDR, observers all reported that the landing was well judged and well flown by the commander using manual thrust and direct law flight control. The co-pilot did underestimate the correct degradation factor to apply to the normal stopping performance, however, fortunately only a long runway was available and consequently the possibility of opting to use an inappropriately short runway did not present itself.

2.11 Flight Recorders

The investigation of this incident involving G-KMAM was hampered by the lack of good quality DFDR data, under different circumstances such a lack of data could be critical. It is clear that the poor performance of the Loral F800 DFDR was not restricted to this A320 but a common problem on the aircraft type. This is confirmed by the aircraft manufacturers practice of fitting another recorder for all test and certification flights and the experience of other operators and accident investigation authorities.

There is a need for immediate action to address the data loss commonly experienced on the A320 Loral F800 DFDR installation. Mounting of the recorder on a rack as recommended by Loral, which in combination with the F800 meets the requirements of RTCA DO160, has been demonstrated to make a substantial improvement.

The F800 is used on other aircraft types, and whilst AAIB has no firm evidence, there must be a concern that the data quality problem is not peculiar to the A320.

Therefore the AAIB makes Safety Recommendation 94-51:

> The Civil Aviation Authority should require that all A320 aircraft equipped with the Loral model F800 DFDR should be fitted with an approved tray, which provides compliance with the appropriate edition of RTCA DO160, as soon as possible.

Recommendation 94-52:

The Civil Aviation Authority should ensure that data quality on other aircraft equipped with the F800 Digital Flight Data Recorder is acceptable during all phases of flight, and that the mounting system is approved.

Recommendation 94-53:

The Civil Aviation Authority should ensure that the problems of the F800 when fitted to the A320 are made known to other national regulatory bodies.

The issues raised by the A320/F800 focus on the unusual position of flight recorders in aviation regulation. The specification of recorders and the data to be recorded is regulated by international committees which are a model for international co-operation. However, there are no equivalent procedures or standards for assessing the installed performance of DFDR systems. DFDR installations have become so complex that system serviceability tests are often impractical. The mandatory annual replay is no longer sufficient as a means of determining the serviceability of DFDR installations. This is particularly so because there is no standard by which those carrying out DFDR replays can assess the quality and accuracy of the recovered data. A number of factors exacerbate replay difficulties. Firstly there are no procedures to regulate the suitability and accuracy of DFDR replay equipment or training of replay operatives. Secondly airframe manufacturers are reluctant to release, to third party organisations, the information necessary to decode and reduce the data. Thirdly there is no formal procedure to ensure that DFDR manufacturer or the regulatory authority is made aware of recurring DFDR defects and/or poor performance of specific DFDR installations. Consequently AAIB are recommending CAA to establish minimum standards for the replay organisations.

Therefore the AAIB makes Safety Recommendation 94-54:

The Civil Aviation Authority should introduce procedures in respect of flight recorder replay and maintenance that:

a) Will enable the serviceability of the flight recorder installation to be determined.

b) Will ensure that organisations which undertake the replay, repair and maintenance of flight recorders have formal procedures so as to ensure that they have up to date knowledge of the correct techniques to be employed in such work.

c) Will ensure that sufficient records are kept to alert the Civil Aviation Authority and/or the recorder manufacturer of any short-comings in particular flight recorders.

3 Conclusions

(a) Findings

(1) The right outboard flap was removed and a replacement fitted as an unscheduled maintenance task during the night of 25 August 1994 and the subsequent dayshift.

(2) The aircraft was returned to service with four of the five spoilers on the right-hand wing in the maintenance mode instead of the active mode.

(3) The commander would not have been able to detect visually the spoiler fault during his exterior pre-flight inspection of the aircraft.

(4) As all the spoilers were retracted, the inability of spoilers 2 to 5 on the right wing to respond to roll commands remained dormant until a demand for right spoiler deployment was made.

(5) The failure of spoilers 2 to 5 on the right wing to respond to right roll demand was not noticed by either pilot during his independent functional check of the flying controls.

(6) Excalibur Airways' divergence from Airbus Industrie's flight control check procedures was understandable but the airline's re-organisation of the after-start checks diminished co-ordination between the pilots to the point where the checks became independent.

(7) The degradation in roll control on takeoff was well handled by both pilots.

(8) The indexing of the 'ABNORMAL and EMERGENCY PROCEDURES' section of the FCOM 3 was deficient.

(9) The requirement in the FCOM 3 to allow for multiple failures when calculating increments to apply to normal landing distance was inconspicuous.

(10) The damaged flap removal was carried out generally in accordance with the Maintenance Manual except where tooling deficiencies made this impracticable.

(11) During the flap removal the spoilers were selected to maintenance mode and moved using an incomplete procedure, specifically the collars and flags were not fitted, which constituted a deviation from the Maintenance Manual without design authority approval.

(12) The dayshift engineer either did not observe the spoiler related instructions in the Maintenance Manual, Subtasks 27-54-62-866-060 and 27-54-62-710-051, 're-instate and function spoilers', and the reference on the stage sheets, or did not interpret them to mean that a spoiler reset and function was required.

(13) The engineers whose teams carried out the flap change were well qualified and widely experienced, holding up to ten type authorisations.

(14) The errors made were a result of a belief on the part of the engineers that the practices employed were justified.

(15) The engineers who carried out the flap change demonstrated a willingness to work around difficulties without reference to the design authority including situations where compliance with the Maintenance Manual could not be achieved.

(16) The investigation did not reveal any evidence to suggest that the attitudes and working practices employed by these engineers during the flap change significantly differed from their usual attitudes and working practices.

(17) Local line management did not insist upon a rigorously procedural approach to working practices and total compliance with the Maintenance Manual.

(18) The industry, operators and manufacturers alike acknowledge that although total compliance with approved procedures is a requirement, it is not always achieved.

(19) It is not possible for maintenance staff working on the current generation of aircraft to have enough information about the aircraft and its systems to understand adequately the consequences of any deviation from approved maintenance procedures.

(20) The avoidance of future unnecessary maintenance related accidents with high technology aircraft depends on an attitude of total compliance with approved procedures being developed and fostered within the industry.

(21) The shift handovers took place, for the nightshift engineer, at a time when he could be expected to be tired and with circadian rhythms desynchronised.

(22) These handovers did not achieve the intent of procedures published by the maintenance organisation in that they did not, 'Ensure an adequate handover of the task was provided'.

(23) The stage sheets, which should have provided documentation of the condition of the aircraft at handover and the requirements for re-instatement of all systems disturbed, were incorrect or incomplete.

(24) The stage sheets reflecting the flap removal were reproduced on the correct format and included reference to, 'Fully extend and lock applicable spoilers', and so did indicate that the spoilers had been disturbed during the flap removal.

(25) It could not be established if the original re-fitment sheets contained any reference to the spoiler reactivation and the accepted status of the stage sheets on the incorrect format is unclear; consequently the procedure, of raising the necessary stage sheets to cover the re-instatement of any system disrupted had been compromised, even if the original re-fitment sheets did refer to the spoilers.

(26) The handovers were verbal briefings only in addition to the transfer of the stage sheets and recollections varied, but on neither occasion was the true condition of the spoilers made clear.

(27) The flap function was carried out without either dayshift or duplicate inspecting engineer being aware of the requirement to function the spoilers, although this was the next item in the Maintenance Manual.

(28) The duplicate inspecting engineer sought the requirements for the duplicates and functions from the dayshift engineer rather than consult the Maintenance Manual; this appears to be accepted practice but compromises the independence of the duplicate inspection.

(29) There were differences in the perceptions of the nightshift engineer and the shift foreman concerning the requests for assistance; these were only effective concerning matters essential for the task's completion and could explain why the engineer did not seek design authority agreement to continue the task without using the spoiler collars.

(30) If the engineer is to be able to ensure that the work is carried out without deviation from the Maintenance Manual or other mandatory or company procedures, the industry must ensure that it has in place effective, rapid support, including usable systems for consultation with the design authority.

(31) The Maintenance Organisation's Quality programme was comprehensive and actively supported at the highest level within the company and well promulgated on the shop floor.

(32) 'Quality' was not engineered into the task of changing the flap on G-KMAM.

(33) The aim of the Quality System was to achieve quality engineered into all tasks and this goal would have been well served by the engineers reporting such difficulties and deficiencies as those experienced during this job, however, some features of the Quality System appeared not to be utilised and non-compliant practices were not detected.

(34) The minimum support which was a feature of unscheduled maintenance has the potential to undermine the Quality Programme.

(35) The 0700 hrs Estimated Time to Service originally established was entirely unrealistic, placing unnecessary additional pressure on the engineers to expedite the task.

(36) The nightshift engineer was unfamiliar with the Excalibur A320 Maintenance Manual and its AMTOSS format and found it confusing.

(37) The training received by the engineers did not specifically cover reference to the Maintenance Manuals or IPC; the AMTOSS format was not formally taught.

(38) The collars and flags combine together with the Maintenance Manual procedure to create an important safety system which is part mechanical and part procedural; this was not recognised by the engineers and by not complying with the procedural element the safety system was inadvertently negated and flight safety compromised.

(39) The nightshift engineer misunderstood the purpose of the collars and the way in which the spoilers functioned, a misunderstanding due in part to familiarity with other aircraft.

(40) There have been at least three other cases where A320 aircraft have been prepared for flight with a spoiler in the maintenance mode.

(41) The investigation of this incident was hampered by the lack of good quality DFDR data, under different circumstances such a lack of data could be critical.

(42) The poor performance of the Loral F800 DFDR, which was not restricted to this A320 but a common problem on the aircraft type had not been adequately addressed.

(b) Causes

The following causal factors were identified:

(1) During the flap change compliance with the requirements of the Maintenance Manual was not achieved in a number of directly relevant areas:

During the flap removal the spoilers were placed in maintenance mode and moved using an incomplete procedure, specifically the collars and flags were not fitted.

The re-instatement and functional check of the spoilers after flap fitment were not carried out.

(2) A rigorously procedural approach to working practices and total compliance with the Maintenance Manual was not enforced by local line management.

(3) The purpose of the collars and the way in which the spoilers functioned was not fully understood by the engineers. This misunderstanding was due in part to familiarity with other aircraft and contributed to a lack of adequate briefing on the status of the spoilers during the shift handover.

(4) During the independent functional check of the flying controls the failure of spoilers 2 to 5 on the right wing to respond to right roll demands was not noticed by the pilots.

(5) The operator had not specified to its pilots an appropriate procedure for checking the flight controls.

4 Safety Recommendations

The following safety recommendations were made during the course of the investigation:

4.1 The Civil Aviation Authority should formally remind engineers of their responsibility to ensure that all work is carried out using the correct tooling and procedures, and that they are not at liberty to deviate from the Maintenance Manual but must use all available channels to consult with a design authority where problems arise; if full compliance cannot be achieved the engineer is not empowered to certify the work.
[Recommendation 94-41]

4.2 The Civil Aviation Authority should review the requirements for the conduct of duplicate inspections and consider the practicality of requiring the engineer conducting the duplicate inspection to review the task as detailed in the Maintenance Manual so as to come to an independent assessment of the scope of the duplicate inspection.
[Recommendation 94-42]

4.3 The Civil Aviation Authority should require a review of non-Approved Maintenance Schedule tasks which are likely to be encountered several times during the service life of a fleet so as to determine when pre-planned stage sheets should be required. The stage sheet for a task should call up all the relevant requirements of the Maintenance Manual and in particular should include stages for all re-instatements, inspections and function checks. Each such document would include boxes for an authorised signatory at each stage and would also include the Certificate of Release to Service.
[Recommendation 94-43]

4.4 The Civil Aviation Authority, in consultation with operators, should review the procedures for advising engineers of technical information such as Service Bulletins, Airworthiness Directives and other manufacturers' publications.
[Recommendation 94-44]

4.5 Airbus Industrie should amend the A320 maintenance manuals in the flap removal, flap re-fitting and spoiler de-activation chapters, to include specific, clear warnings of the need to re-instate and function the spoilers after de-activation. Similar amendments should be considered for Airbus A330 and A340 aircraft.
[Recommendation 94-45]

4.6 Airbus Industrie should introduce an additional flag and attachment to clip over the hexagon of the maintenance device, to provide clear and independent visual indication of the need to reset the maintenance device, and to amend the maintenance manual procedures accordingly. These actions should be made mandatory by the Civil Aviation Authority for UK operators.
[Recommendation 94-46]

4.7 Airbus Industrie should advise all operators of its 'fly-by-wire' aircraft of the requirement to hold full control deflection for the appropriate period during the flight control checks to allow fault warning computers to inform flight crews of any defects detected, and publish in the A320 Flight Crew Operating Manuals the time taken for a fault warning to be triggered following the failure of a flight control surface to respond correctly to a computer demand.
[Recommendation 94-47]

4.8 Excalibur Airways should review their after-start procedures to ensure that both pilots are simultaneously involved in the first check of the flight controls and should specify the detailed content of the flight control check procedures in their Flight Crew Operating Manuals.
[Recommendation 94-48]

4.9 The Civil Aviation Authority should ensure that A320 type conversion training includes demonstrations of the approved procedures for aircrew checks of the flight controls and the limitations of the fault warning computer with respect to spoiler faults.
[Recommendation 94-49]

4.10 Airbus Industrie should amend the Flight Crew Operating Manuals:

To make the contents of page 3.02.80 more conspicuous in the index of 'ABNORMAL AND EMERGENCY PROCEDURES' and that the contents of this page should be duplicated in the QRH.

To make the note to page 3.02.80 which explains the need to take account of multiple failures by multiplying the factors more conspicuous and that it should precede the table of increments.

To include operating techniques for intentional FLAP 1 and FLAP 2 approaches in the 'OPERATING TECHNIQUES' sub-section of the 'ABNORMAL and EMER PROCEDURES' of the FCOM 3.
[Recommendation 94-50]

4.11 The Civil Aviation Authority should require that all A320 aircraft equipped with the Loral model F800 Digital Flight Data Recorder should be fitted with an approved tray, which provides compliance with the appropriate edition of RTCA DO160, as soon as possible.
[Recommendation 94-51]

4.12 The Civil Aviation Authority should ensure that data quality on other aircraft equipped with the F800 Digital Flight Data Recorder is acceptable during all phases of flight, and that the mounting system is approved.
[Recommendation 94-52]

4.13 The Civil Aviation Authority should ensure that the problems of the F800 Digital Flight Data Recorder when fitted to the A320 are made known to other national regulatory bodies.
[Recommendation 94-53]

4.14 The Civil Aviation Authority should introduce procedures in respect of flight recorder replay and maintenance that:

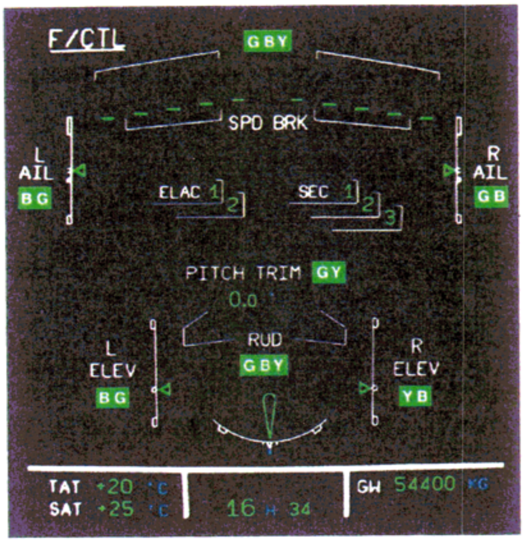
> Will enable the serviceability of the flight recorder installation to be determined,
>
> Will ensure that organisations which undertake the replay, repair and maintenance of flight recorders have formal procedures so as to ensure that they have up to date knowledge of the correct techniques to be employed in such work,
>
> Will ensure that sufficient records are kept to alert the Civil Aviation Authority and/or the recorder manufacturer of any short-comings in particular flight recorders.

[Recommendation 94-54]

David F King
Inspector of Air Accidents
Air Accidents Investigation Branch
Department of Transport
December 1994

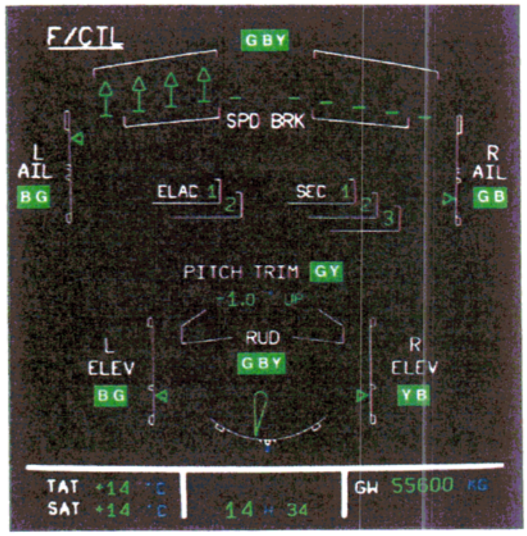
ELECTRONIC CENTRALIZED AIRCRAFT MONITOR (ECAM) SYSTEM DISPLAYS

Note - These photographs are intended to show the relevant spoiler indications. Other control indications are not intended to be representative of the incident.



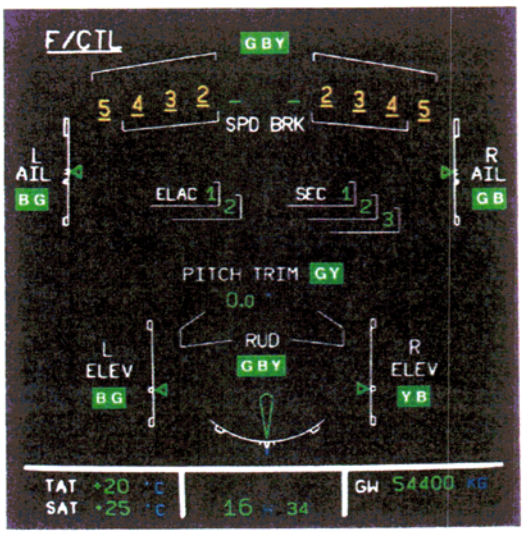
NO ROLL DEMAND
ALL SPOILERS RETRACTED

Retracted spoilers are shown by short horizontal green lines near top of display.



LEFT ROLL DEMAND
SPOILERS ON LEFT WING EXTENDED

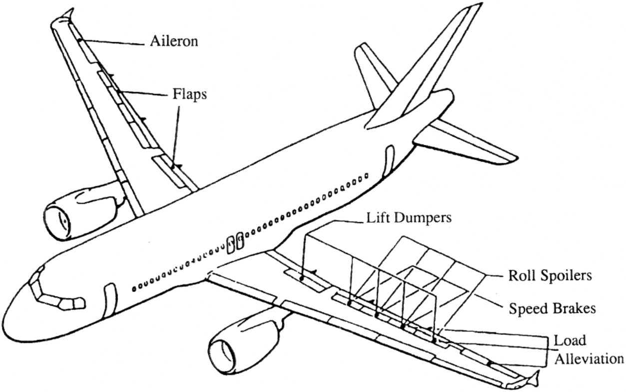
Deployed spoilers are shown by green "fir trees". As there is no disagreement between control demand and spoiler position the indications remain green.



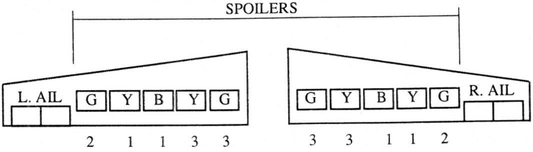
SPOILER DEMAND
NO SPOILER DEPLOYMENT

If an error condition persists for three seconds the spoiler indications change to amber. The corresponding spoilers on the other wing are closed and isolated, and are also shown in amber.

AIRBUS INDUSTRIE A320 FLAP AND SPOILER CONFIGURATION



ARCHITECTURE

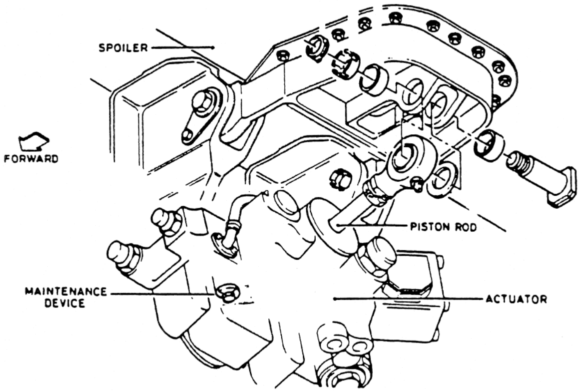


LEGEND

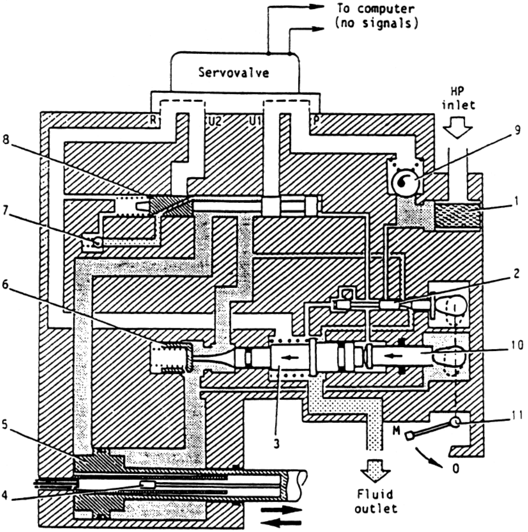
HYDRAULIC SYSTEMS - GREEN (G)
YELLOW (Y)
BLUE (B)

SPOILER ELEVATOR COMPUTERS (SEC)

1 SEC 1
2 SEC 2
3 SEC 3



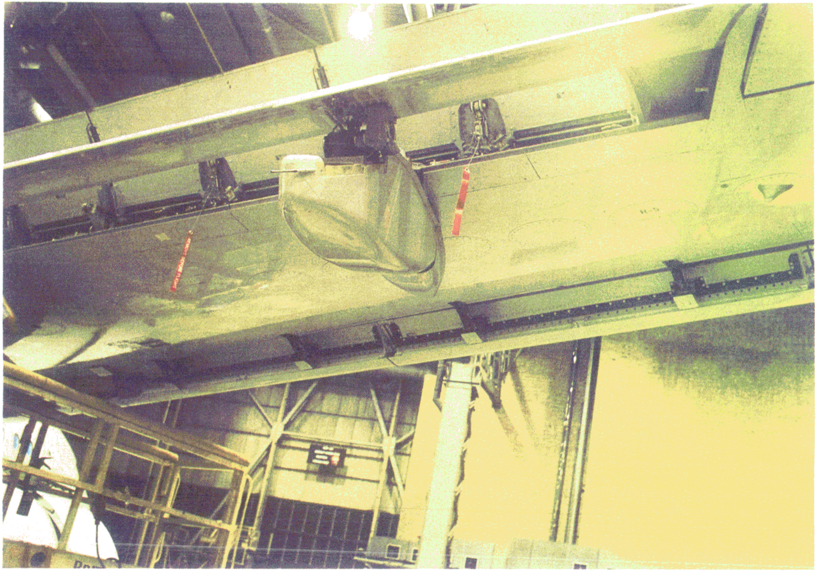
AIRBUS INDUSTRIE A320 DETAIL OF SPOILER ACTUATOR
SHOWING MAINTENANCE DEVICE



1 - Filter
2 - Inhibiting valve
3 - Pusher
4 - LVDT position detector
5 - Piston
6 - Cup valve
7 - LP non-return valve
8 - Mode switching valve
9 - HP non-return valve
10 - Thermal follower
11 - Maintenance device

SPOILER ACTUATOR HYDRAULIC SYSTEM
SHOWN WITH MAINTENANCE DEVICE
IN MAINTENANCE POSITION

APPENDIX 5



VIEW ON TRAILING EDGE SHOWING FLAPS AND SPOILERS
EXTENDED, AND COLLARS AND FLAGS IN POSITION

AEROFORMATION TRAINING MEMO 2058 ISSUE 2

Notes:

1. *Text which appears between the two horizontal lines is copied and formatted in a similar manner to the original source. Vertical lines in the left margin were copied from this source.*

2. *In this memo PF is "Pilot Flying" and PNF is "Pilot Not Flying". However, Excalibur Airways had a company standard procedure whereby the commander always handled the aircraft whilst taxying. Therefore, if this memo had been adopted by Excalibur Airways, irrespective of whichever pilot was to carry out the take off, before take off PF would always be the commander and PNF would always be the co-pilot.*

DISTRIBUTION TO: All A320 Instructors
SUBJECT: FLIGHT CONTROL CHECKS

This memo cancels Training Memo 2058

Will instructors please note that the correct method for the time being of carrying out flight control checks on the A320 is as follows:

1. At a convenient stage during taxy : PF applies full travel of elevator, ailerons and spoilers. This check will be called by the **PF** as it is carried out :
   "Full up, full down, neutral, full left, full right, neutral."

   The PF should maintain proper taxi look-out while conducting the F/CTL check.

   The PNF responsibility is to check full travel and correct sense on F/CTL page and calls **"Check"** as each **"neutral"** is called.

2. PF presses PEDAL DISC P/B on nose wheel tiller and applies full left rudder, full right rudder and neutral. PNF monitors travel on F/CTL page as the check is called by PF :
"Full left, full right, neutral"

PNF calls **"Check"** at the neutral call.

PNF physically follow up rudder check with PF to ensure pedals are adjusted correctly.

3. PNF applies full travel of elevator, ailerons and spoilers and checks full travel and correct sense on the F/CTL page.

NOTE : This check is **silent.**

The reason for having to check full travel and correct sense on both sidesticks is to cover for the remote possibility of a mechanical fault restricting full travel in one sidestick and because resolver monitoring tolerances decrease as surface deflection increases, thus a resolver fault at small surface deflections may remain undetected.

Modifications may be made in the future to maintenance procedures so that the above check may be simplified.

EXCALIBUR AIRWAYS' AFTER START CHECK LIST

Extract from Excalibur airways FCOM Volume 3 NORMAL PROCEDURES pages 028 and 029 dated Feb 93

Note: CM1 indicates action by pilot seated on the left (normally the commander)
CM2 indicates action by pilot seated on the right (normally the co-pilot)

AFTER START

- **ENG MODE sel (CM1) . . . . NORM**
  - CM1 turning the ENG MODE SEL to NORM is the signal for the CM2 to commence the AFTER START actions.
  - On ECAM lower display the ENG page is replaced by the WHEEL page.
  - Leaving the ENG MODE at START/IGN position would prevent continuous relight selection on ground (would be supplied at lift off), in addition the ENG page would remain displayed.
  - After start, to avoid thermal shock, the engine should be operated at idle or near idle for at least 2 minutes prior to advanceing the thrust lever to high power. Taxi time at idle may be included in the warm-up period.
  - In order to reduce risk of idle stall/roll back., make sure that pack valves are open before switching on the ENG ANTI ICE or before advancing the thrust levers.
- **GROUND CREW CLEARANCE (CM1). . . . . REQUEST**
  - Request : - NWS by-pass pin removed (MEMO display "N WHEEL STEER DISC" extinguished)
    - Interphone disconnect
    - Hand signal on the left/right side

Note: With the NWS by-pass pin installed, starting the second engine will cause the memo display 'N Wheel Steer Disc' to go amber.

- **FLT CONTROLS (CM1) . . . . CHECK**
- **APU BLEED (CM2) . . . . OFF**
  - APU BLEED valve closes, ENG BLEED valves open
- **APU (CM2) IF NOT REQ . . . . OFF**
- **ANTI ICE (CM2) IF REQ . . . . .ON**
- **GROUND SPOILERS (CM2) . . . . .ARM**
- **RUD TRIM (CM2) . . . . .ZERO**
  - IF RUD TRIM position indication is not at zero, press the RESET pb.

- **PITCH TRIM (CM2) . . . . SET**
  - Set to CG on pitch trim wheel

- **FLAP lever (CM2) . . . . .SET**
  - Set FLAPS for take-off
  - Check position on ECAM upper display
  - If taxiing in slush conditions, keep flaps retracted until reaching the holding point before take off.

- **AUTO BRAKE (CM2) . . . . .MAX**

- **FLT CONTROLS (CM2) . . . . .CHECK**

- **ECAM STATUS (CM2) . . . . CHECK**
  - Check no status reminder on ECAM upper display
  - If status reminder displayed, press the STS pb.

CAUTION

Note: Icing conditions may be expected when OAT or TAT is below +8°C with visible moisture.

- **<u>If the class II message "F/CTL" is displayed on ECAM status page:</u>**

Flight controls priority integrity check must be performed as follows:

1. CAPT sidestick . . . . FULL UP-RH,MAINTAIN
2. F/0 sidestick . . . . FULL DN-LH,MAINTAIN
   - Check on ECAM F/CTL page surfaces at neutral.
3. CAPT TAKE OVER PB . . . . DEPRESS (about 5 sec)
   Check: - Aural "PRIORITY LEFT" message activated
   - F/O reda arrow light on
   - F/CTL page shows surfaces full travel (up right)
4. CAPT TAKE OVER PB . . . . .RELEASE
   Check flight control surfaces at neutral.
5. Repeat check (3) and (4) above with F/O TAKE OVER pb.

MAX SPEED with Slats or Flaps inop

SLATS* \ FLAPS*	0	1	2	3	FULL
0	230 kt (No limitation in clean conf)	215 kt	200 kt	185 kt	177 kt
1, 2	200 kt	200 kt	200 kt	185 kt	177 kt
3, FULL	177 kt	177 kt	177 kt	177 kt	177 kt

APPR SPD and LDG DIST with Slats or Flaps inop

SLATS* \ FLAPS*	0	1	2	3	FULL
0	VREF + 50 at threshold Dist x 1.8	VREF + 45 Dist x 1.8	VREF + 30 Dist x 1.4	VREF + 25 Dist x 1.35	VREF + 25 Dist x 1.35 (FLAP › 3 not allowed)
1, 2	VREF + 25 Dist x 1.3	VREF + 25 Dist x 1.3	VREF + 15 Dist x 1.2	VREF + 10 Dist x 1.15	VREF + 10 Dist x 1.15
3, FULL	VREF + 25 Dist x 1.3	VREF + 25 Dist x 1.3	VREF + 15 Dist x 1.2	VREF + 10 Dist x 1.15	VREF + 5 Dist x 1.1

* SLATS / FLAPS position displayed on UPPER ECAM display.

Example : Flaps locked between position 0 and 1 with slats at zero :
MAX SPEED : 215 kt
VREF + 45 LDG DIST × 1.8

F / CTL ALTN LAW

Refer to FCOM 3.04.27 for flight characteristics.
With AP engaged A / C is controlled by FMGC (AP mode)
(PROT LOST)
All protections except maneuver protections are lost.
Depending on the failure, static stability may be introduced.
- MAX SPEED .... 320 KT
(320/.77 if dual HYD SYS LO PR)

Speed is limited to 320 / .82 or 320 / .77 for dual hyd failure due to loss of high speed protection
- SPD BRK (if L or R elev. fault) .... DO NOT USE

STATUS

MAX SPEED .... 320 KT
(320/.77 if dual hyd sys lo pr.)
SPD BRK (if L or R elev. fault) .. DO NOT USE

ALTN LAW : PROT LOST
APPR PROC :
- FOR LDG .... USE FLAP 3
- GPWS LDG FLAP 3 .... ON
- APPR SPD .... VREF + 10
- LDG DIST .... X 1.15

● **if no AP engaged :**

WHEN L/G DN : DIRECT LAW
At L/G extension control reverts to direct law in pitch as well as in roll.
Refer to DIRECT LAW proc.

● **if AP engaged :**

WHEN L/G DN AND AP OFF : DIRECT LAW
If AP is disengaged :
- *before L / G extension, flight control alternate law is active*
- *after L / G extension, flight control direct law is active.*

Refer to DIRECT LAW proc.

INOP SYS
ATT LIMIT
OVSPD LIMIT
ALPHA LIMIT

F/CTL L (R) ELEV FAULT

F/CTL ALTN LAW (PROT LOST)

Note : Since, in case of L (R) elevator failure, the pitch control through elevator is lost in the ELACs, it is performed by the SECs in alternate law.
This is not the case if R elevator is lost due to the failure of B + Y hyd circuits : pitch normal law remains active in ELAC.

MAX SPEED .... 320 KT

Speed is limited due to loss of high speed protection

– SPD BRK .... DO NOT USE

STATUS

MAX SPEED .... 320 KT	INOP SYS
– SPD BRK .... DO NOT USE	ATT LIMIT
ALTN LAW : PROT LOST	OVSPD LIMIT
WHEN L/G DN : DIRECT LAW	ALPHA LIMIT
At L/G extension, control reverts to direct law in pitch as well as in roll. Refer to DIRECT LAW proc	L (R) ELEV
CAT 1 ONLY	AP 1 + 2

F/CTL SPLR FAULT

Loss of one or more spoilers

– SPD BRK (if SPLR 3 + 4 affected) .... DO NOT USE

Do not use speed brakes if only surface n° 2 is operative to avoid undesirable pitch up moment.

If spoilers 4 or 5 is affected LAF is degraded.

Note : If SPLR 1 FAULT and heavy vibrations are felt use FLAPS 3 for landing

STATUS

● **if SPLR 3 + 4 affected**	INOP SYS
SPD BRK .... DO NOT USE	SPLR (affected)
LDG DIST See GND SPLR FAULT below	

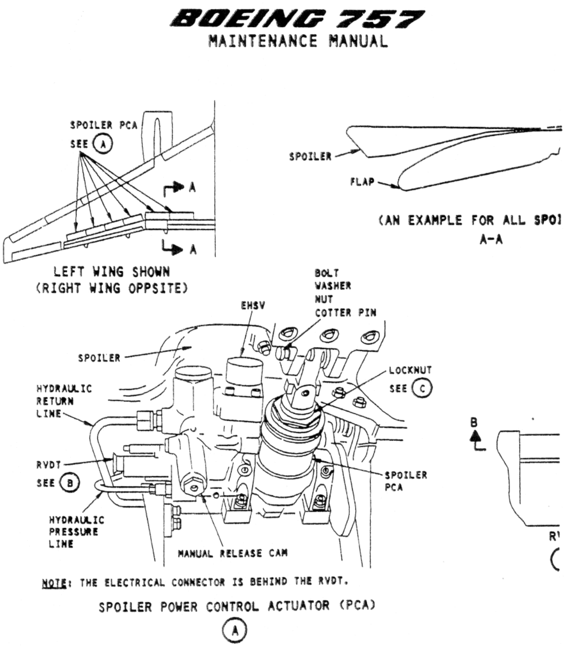
A320 FLIGHT CREW OPERATING MANUAL	ABN and EMER PROCEDURES	3.02.80	P 15
	MISCELLANEOUS	REV 18	SEQ 001

APPR SPD – LDG DIST CORRECTIONS FOR FAILURES		APPR SPD INCREMENT		LDG DIST MULTIPLY BY
		VLS	VREF	
FTL CTL	ONE SPLR FAULT (except n°5)	–	–	1.1
	TWO SPLR FAULT	–	–	1.1
	Three or more SPLR FAULT	–	–	1.3
	SEC 1 or 3 FAULT	–	–	1.1
	SEC 2 FAULT	–	–	Negl.
	Two or three SEC FAULT	–	–	1.3
	STAB JAM / L + R ELEV FAULT	–	10	1.15
FLAPS	FLAPS < 1 : Slats < 1	–	50	* 1.80
	Slats ≥ 1	–	25	1.30
	1 ≤ FLAPS < 2 : Slats < 1	–	30	1.40
	Slats ≥ 1	–	15	1.20
	2 ≤ FLAPS < 3 : Slats < 1	–	25	1.35
	Slats ≥ 1	–	10	1.15
	FLAPS ≥ 3 : Slats < 1	–	25**	1.35**
	1 ≤ Slats ≤ 3	–	10	1.15
	Slats > 3	–	5	1.10
HYD	BLUE or GREEN or YELLOW	–	–	1.1
	GREEN + BLUE	–	25	1.5
	GREEN + YELLOW	–	25	2.1
	YELLOW + BLUE	–	–	1.3
BRK	ANTI SKID	–	–	1.5
	BRK RELEASE	–	–	1.2
ELEC	EMER ELEC CONFIG / DC BUS 1 + 2	–	–	1.55
	DC BUS 2	–	–	1.3
	DC ESS BUS / AC BUS 1	–	–	1.1

* Maintain VREF + 60 down to 300 ft, then reduce speed to reach VREF + 50 at runway threshold.

** FLAPS > 3 and SLATS < 1 not allowed

Note : *For multiple failures, affecting landing distances if LDG DIST increase coef is not given, multiply the coefs associated to the single failures.*



BOEING 757 SPOILER POWER CONTROL ACTUATOR

Printed in the United Kingdom for HMSO
Dd 300459 C6 1/95 310803 52/31859