Uncommanded roll, Serious incident on March 20, 2001 at Frankfurt/Main, to Airbus Industrie A320-200

Micro-summary: **This A320 experienced an uncommanded roll to the left.**

Event Date: **2001-03-20**

Investigative Body: **Federal Bureau of Aircraft Accidents Investigation (BFU), Germany**

Investigative Body's Web Site: **http://www.bfu-web.de/**

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Bundesstelle für
Flugunfalluntersuchung

German Federal Bureau of
Aircraft Accidents Investigation

Investigation Report

5X004-0/01
April 2003

Identification

Kind of occurrence:	Serious Incident
Date:	20. March 2001
Location:	Frankfurt / Main
Type of aircraft:	Transport category aeroplane
Manufacturer / Model:	Airbus Industrie / A 320-200
Injuries to persons:	no Injuries
Damage to aircraft:	A/C not damaged
Other damage:	none
Source of Information:	BFU Investigation

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The investigation has been conducted in compliance with the Law relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft (Flugunfall-Untersuchungsgesetz - FlUUG) dated 26. August 1998.

According to the Law, the sole objective of the investigation shall be the prevention of future accidents and incidents. It is not the purpose of this activity to apportion blame or liability or to establish claims.

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Abbreviations

AMM	Aircraft Maintenance Manual
AOC	Air Operator's Certificate
AWL	Aircraft Wiring List
AWM	Aircraft Wiring Manual
BFU	Bundesstelle für Flugunfalluntersuchung
BMVBW	Bundesministerium für Verkehr, Bau- und Wohnungswesen (Federal Ministry of Transport, Building and Housing)
CVR	Cockpit Voice Recorder
ECAM	Electronic Centralized Aircraft Monitoring
EFCS	Electronic Flight Control System
ELAC	Elevator Aileron Computer
FAC	Flight Augmentation Computer
FZE	Flugzeugelektroniker (Aircraft Electronic Technician)
GLB	Ground Log Book
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
LBA	Luftfahrt-Bundesamt (Federal Office of Civil Aeronautics)
MEL	Minimum Equipment List
QM	Qualitätsmanagement (Quality Management)
QMH	Qualitätsmanagementhandbuch (Quality Management Handbook)
QS	Qualitätssystem (Quality System)
ROD	Reliability-Data on Demand
SB	Service Bulletin
SEC	Spoiler-Elevator Computer
SfB	Sammelblatt für Beanstandungen (list of complaints)
SPM	Standard Practices Manual
SSFDR	Solid State Flight Data Recorder
TLB	Technical Log Book
UTC	Universal Time Coordinated
VA	Verfahrensanweisung (Procedural Instruction)
WD	Wiring Diagram

Synopsis

On 21 March 2001 at 18:10 hrs[1], the Federal Bureau of Aircraft Accidents Investigation (hereafter referred to as BFU) was informed of a serious incident at Frankfurt/Main airport.

An Airbus A 320 had departed at 11:00 hrs UTC from runway 18 for a flight to Paris. 115 passengers and 6 crew members were aboard the aeroplane. Immediately following the lift-off the aeroplane assumed a slight bank angle to the left. The commander, who was the pilot flying, tried to correct the attitude by a slight input on the left sidestick. However, the bank angle increased continuously up to approx. 22°. With the commander's call out :"I can't do anything more" the first officer took over the controls with the words "I have control" and pressed the TAKE OVER PUSH BUTTON. The First Officer had already beforehand instinctively tried to counteract the rolling movement with his sidestick.

Controlled by the second autopilot the aeroplane climbed to flight level FL 120 where the crew cautiously analysed the control system. With an input on the left sidestick the aeroplane - after a short shaking and a brief bank angle corresponding to the input - suddenly reacted contrary. The right-hand sidestick functioned normally.

The crew decided to not continue the flight but to return to Frankfurt. The First Officer took over the controls and safely landed the aeroplane in Frankfurt. The aeroplane was than handed over to the maintenance organisation.

Prior to this flight, the aeroplane had already been at the maintenance organisation for two days for repair purposes. On several previously conducted flights had problems occured on one of the two elevator aileron computers (ELAC), which control, among other things, the bank angle. When the computer was replaced, a bent pin, which could not be repaired, was found on the plug of the ELAC no. 1. Therefore the whole plug of the ELAC no. 1 was replaced and rewired. Two pairs of wires were connected inverted, the Command Channel and the Monitor Channel.

The BFU has come to the conclusion that the serious incident is due to the fact that:

- during repair work on the plug of the Elevator Aileron Computer (ELAC) no. 1 two pairs of wires had been connected inverted
- the error remained undetected
- the error was not recognized by the flight crew during the "FLIGHT CONTROL CHECK".

Contributing factors were:

- an unclear and difficult to handle documentation so that a wrong wiring diagram was used
- diversion from the manufacturer's data by the Maintenance Support

[1] Unless otherwise specified, all times are indicated in local time.

- manufacturer's instructions which are not formulated unambiguously
- functional check by the cross checking staff member was carried out incorrectly
- iinsufficient functioning of the quality assurance
- the lack of supervision of the maintenance organisation by the operator
- a quantitatively and qualitatively insufficient supervision of the maintenance organisation and the operator by the supervising authority.
- deficiencies in the "AFTER START CHECKLIST" for the conduct of the "FLIGHT CONTROL CHECK".

1. Factual information

1.1 History of the flight

In Frankfurt the crew performed a scheduled aircraft change. For the crew it was already the third flight whereas the aeroplane was to be used for the first time that day following repair work. Approx. 50 minutes prior to departure the crew was at the aeroplane. In the “TECHNICAL LOGBOOK“ (TLB) all complaints entered had been checked off as settled. The aeroplane had been released for the flight in accordance with the regulations by a “RELEASE TO SERVICE“.

The preparations for the flight were completed on time. After the power plants had been started, prior to taxiing to runway 18, the “FLIGHT CONTROL CHECK“ was conducted by means of the “AFTER START CHECKLIST“. According to the statements of the crew, this check was accomplished pursuant to the valid procedures. During the check no irrecularities were found.

The aeroplane taxied via taxiway “N-South“ to the take-off position of runway 18. During the take-off run no abnormalities were found. During rotation the pilot-in-command noticed an increasing bank angle to the left. He tried to correct the bank angle through an opposite input on the left sidestick, but it grew increasingly larger.

The First Officer reported that he instinctively made an input to the right on his sidestick, which prevented the bank angle from increasing even further, but did not lead to an improvement of the situation. Only after he had pressed the “TAKE OVER PUSH BUTTON“ on his sidestick, he regained full control of the aeroplane and was in a position to restore the normal flight attitude. He switched on the autopilot no. 2 and had the aeroplane climb to flight level 120. At FL 120, the crew cautiously checked the behaviour of the aeroplane control system.

The autopilot no. 2 was switched off and the First Officer checked the aeroplane control system with the right-hand sidestick. The aeroplane reaction was in accordance with the control inputs.

Afterwards the pilot-in-command took over the control. He slowly moved the sidestick to one side and after a short shaking movement the aeroplane unexpectedly moved to the opposite side. When it had become clear that the aeroplane reaction to control inputs on the left-hand sidestick was opposite to the inputs, the flight was discontinued. The First Officer landed the aeroplane safely on Frankfurt/Main airport.

After the delivery of the aeroplane to the maintenance organisation a FLIGHT CONTROL CHECK was carried out in the presence of the crew, during which the symbols of the ailerons on the ECAM monitor first and for a very short moment moved into the corresponding direction, as if everything were alright, before the ailerons moved into the opposite direction.

1.2 Injuries to persons

There were no injuries to persons.

1.3 Damage to aircraft

There was no damage to the aircraft.

1.4 Other Damage

There was no other damage.

1.5 Personnel information

1.5.1 Crew

Pilot-in-command:	41 years/male
Licences:	Airline Transport Pilot Licence (ATPL)
Ratings:	- as a pilot-in-command of single piston engined landplanes up to 2000 kg maximum take-off mass - Instrument rating - as a pilot-in-command of A 319; A 320; A 321 - long-range flight rating - aerobatics rating
aeromedical examination:	fit, without restrictions
Flight experience:	approx. 9 300 hours of which approx. 3 300 hours on A 320
Rest period prior to the flight:	approx. 20 hours
Time on duty prior to the occurrence:	approx. 06:30 hours
Co-pilot:	27 years/male
Licences:	Airline Transport Pilot Licence (ATPL)

Ratings:	- as a pilot-in-command of single piston engined landplanes up to 2 000 kg maximum take-off mass
	- Instrument rating
	- as a first officer on A 319; A 320; A 321
aeromedical examination:	fit, without restrictions
Flight experience:	approx. 2 000 hours of which approx. 1 500 hours on A 320.
Rest period prior to the flight:	approx. 20 hours
Time on duty prior to the occurrence:	approx. 06:30 hours

1.5.2 Technical Personnel

A total of 6 staff members of the maintenance organisation were involved in the repair of the aeroplane.

Aircraft mechanic 53 years/male

employed by the organisation since: 1966

A 320 qualification in accordance with JAR 145 Authorisations and LBA approved internal QM guidelines – Signing for Work Performance / FZE / B2 Airbus /A 320 / all ATA mechanical, Performance of Special Maintenance Processes / Duplicate Inspections (B2) / “Duplicate Inspection following Engine / Flight Control Changes“ / Airbus A 320 (IAE V 2500 and. CFM 56)

Aircraft electronic technician 38 years/male

employed by the organisation since: 1989

A 320 qualification in accordance with JAR 145 Authorisations and LBA approved internal QM guidelines – Signing for Work Performance / FZE / B1 Airbus /A 320 / all ATA electronical, avionics, Certification of Aircraft and Aircraft Components – Issue of CRS / FZE / B1 / Airbus A 320

Aircraft electronic technician 38 years/male

employed by the organisation since: 1991

A 320 qualification in accordance with JAR 145 Authorisations and LBA approved internal QM guidelines – Signing for Work Performance / FZE / B2 Airbus /A 320 / all ATA electronical, avionics, Certification of Aircraft and Aircraft Components – Issue of CRS / FZE / B2 / Airbus / A 320.

Aircraft electronic technician / aircraft mechanic 26 years/male

employed by the organisation since: 1992

A 320 qualification in accordance with JAR 145 Authorisations and LBA approved internal QM guidelines – Signing for Work Performance / FZE / B1 Airbus /A 320 / all ATA electronical, avionics, Certification of Aircraft and Aircraft Components – Issue of CRS / FZE / B1 / Airbus / A 320.

Aircraft electronic technician 31 years/male

employed by the organisation since: 1989

A 320 qualification in accordance with JAR 145 Authorisations and LBA approved internal QM guidelines – Signing for Work Performance / FZE / B2 Airbus /A 320 / all ATA electronical, avionics, Certification of Aircraft and Aircraft Components – Issue of CRS / FZE / B2 / Airbus / A 320

Aircraft electronic technician 32 years/male

employed by the organisation since: 1984

A 320 qualification in accordance with JAR 145 Authorisations and LBA approved internal QM guidelines – Signing for Work Performance / FZE / B1 Airbus /A 320 / all ATA electronical, avionics, Certification of Aircraft and Aircraft Components – Issue of CRS / FZE / B1 / Airbus / A 320.

1.6 Aircraft information

The aeroplane concerned is an Airbus A 320-200, manufactured in 1990.

The aeroplane is equipped with a fly-by-wire system, i.e. all control surfaces (elevator, stabilizer, ailerons and spoilers) except for the rudder are controlled electrically by means of an hydraulic actuator. The hydraulic actuators for the rudder are controlled mechanically. In addition there is a mechanical back-up system for the rudder and the stabilizer. 7 computers are provided for the primary control of the aeroplane:

- **2 elevator aileron computers (ELAC)** for the elevator and aileron control as well as the control of the SECs to control the spoilers (global roll computation)
- **3 spoiler elevator computers (SEC)** to control the spoilers and as standby system for the elevator and stabilizer control
- **2 flight augmentation computers (FAC)** to stabilize the aeroplane flight attitude, e.g. damping of the Dutch Roll effect in flight, support of the roll control by turn coordination, rudder trim coordination in case of engine failure and adoption of rudder travel function depending on speed

Two side sticks in the cockpit, which are not mechanically linked with each other allow manual control inputs by the crew. The movements of the sidesticks are transformed into electrical signals and are transmitted to the corresponding computers. Generally the sidestick being moved out of its neutral

position has priority. If both sidesticks are moved simultaneously, the signals of both sidesticks are added up with the resulting signal being limited by the maximum travel of one individual sidestick.

If one pilot wishes to take over control he will have to press the "TAKE OVER PUSH BUTTON" on his sidestick. If he releases the button within 30 seconds, both sidesticks are equal in priority again and the control signals of both sidesticks will be added up again. If he holds the push button pressed for more than 30 seconds, his sidestick gets priority and at the same time a green light will light up on the instrument panel in front of him whereas on the other side a red light will light up. This priority can be neutralized only by pressing the "TAKE OVER PUSH BUTTON" on the other side.

1.6.1 Case History

Already on 17 March 2001 in Hamburg, ELAC no. 2 failed and was then replaced by a new one. All tests conducted afterwards showed a proper function.

A second error message of the ELAC no. 2 appeared on 18 March 2001 at Frankfurt during taxiing. By briefly pulling the circuit breakers of the ELAC no. 2 the crew made a “RESET“ after which no further error message appeared.

A further error message of ELAC no. 2 appeared in the evening of 18 March 2001 at Moscow Airport, when the powerplants were started. The aeroplane was parked again and engine shut down. As a corrective action ELAC no. 1 and ELAC no. 2 were interchanged. The defect, however, persisted on position 2. Therefore the corresponding circuit breakers were pulled pursuant to the "OPERATIONAL MAINTENANCE PROCEDURE" (OMP) and in accordance with the "MINIMUM EQUIPMENT LIST" (MEL) so that the defect was now on position 1. The return flight was conducted in accordance with the MEL with a functioning ELAC no. 2.

The complaint was entered by the crew into the "TECHNICAL LOGBOOK". At the same day, on 18.03.2001, the aeroplane was delivered to the maintenance organisation in Frankfurt.

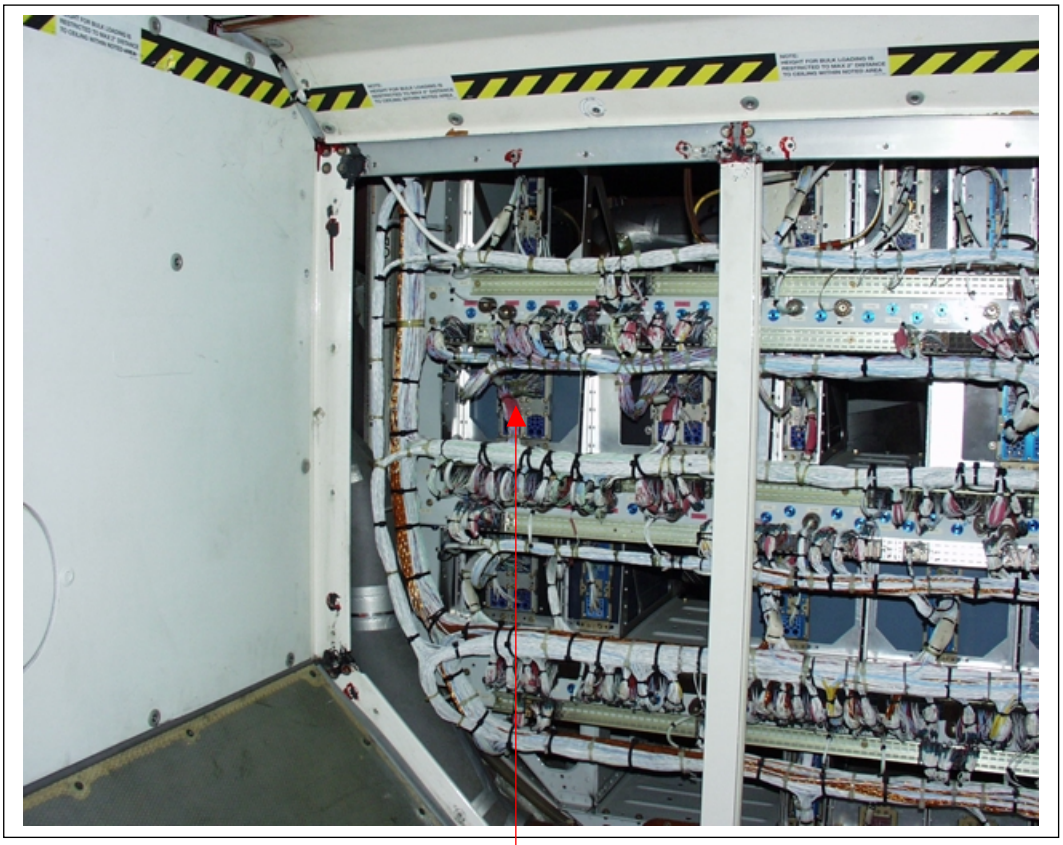
1.6.2 Repair

When the aeroplane was taken over from flight operations, the complaint “failure of the ELAC no. 2“, which the crew had entered into the aeroplane’s Technical Logbook, was erroneously transferred by a maintenance staff member under an incorrect number into the "GROUND LOGBOOK"(GLB).

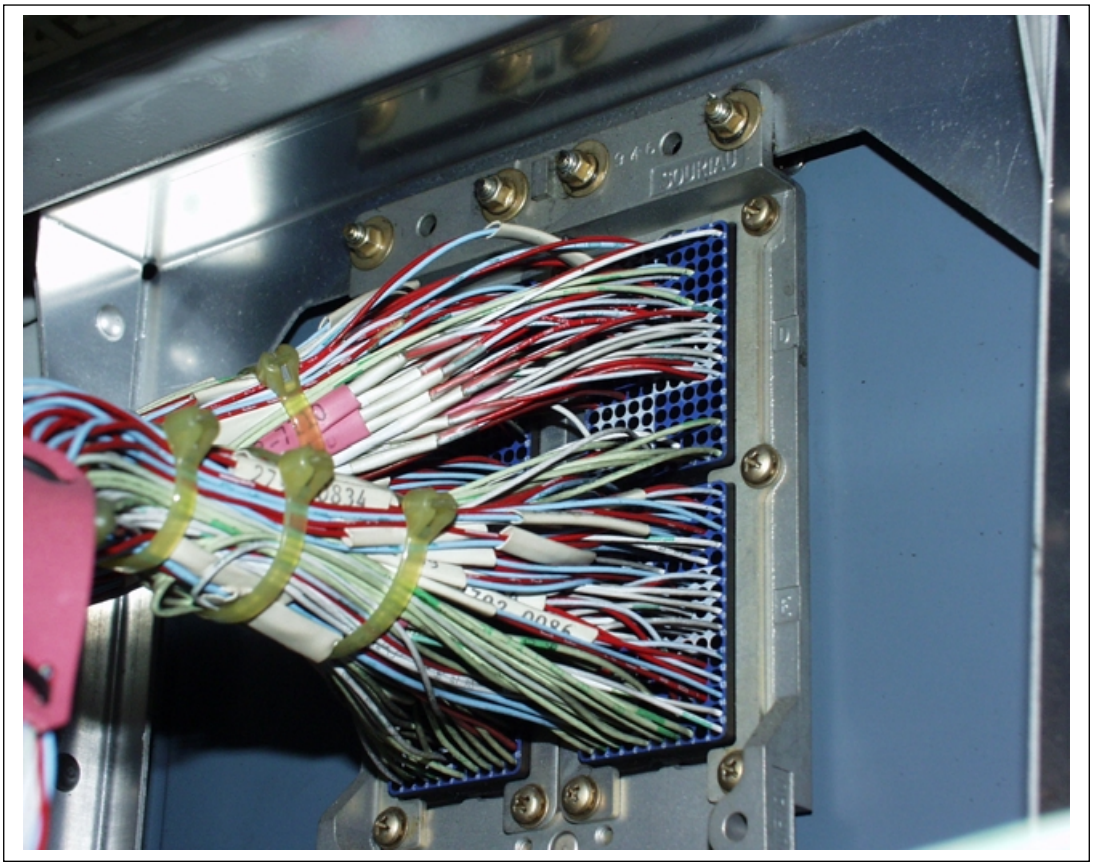
During the error search, which was accomplished during the night shift from 18th to 19th March 2001 a defect in the X-TALK-BUS between ELAC no. 1 and ELAC no. 2 could be localized. It was caused by a bent connection pin (Pin 6K) in the plug segment AE of the socket for the ELAC no. 1.

The attempt to replace the connection pin without replacing the whole plug segment was not successful. A safety spring of the connector pin had come out and could not be inserted again. Therefore it was decided to replace the plug segment AE, but there was a problem, it was no suitable spare plug segment for this series of airplane on stock. Consequently it was decided to replace all four plug segments AA, AB, AD and AE. This meant that in a most confined space approx. 420 assigned connector pins had to be reconnected. As this repair work would take a longer period of time, the aeroplane was taken out of flight operations.

The work started without having a Maintenance Job Order which would have been required according to respective procedural regulations.



Location of the ELAC no. 1 in the Avionic Bay



Rear of the plug with its four segments

It was decided to apply the “ONE TO ONE“ method, i.e. the wires were disconnected one after the other from the old plug and immediately connected to the new one. The work started on 19.03.2001 in the morning shift with the replacement of the plug segments AA, AD und AE. The fourth plug segment AB was replaced in the subsequent late shift. The work was accomplished by adequately qualified aircraft electronic technicians with company internal ratings, so-called B1 and B2 qualifications.

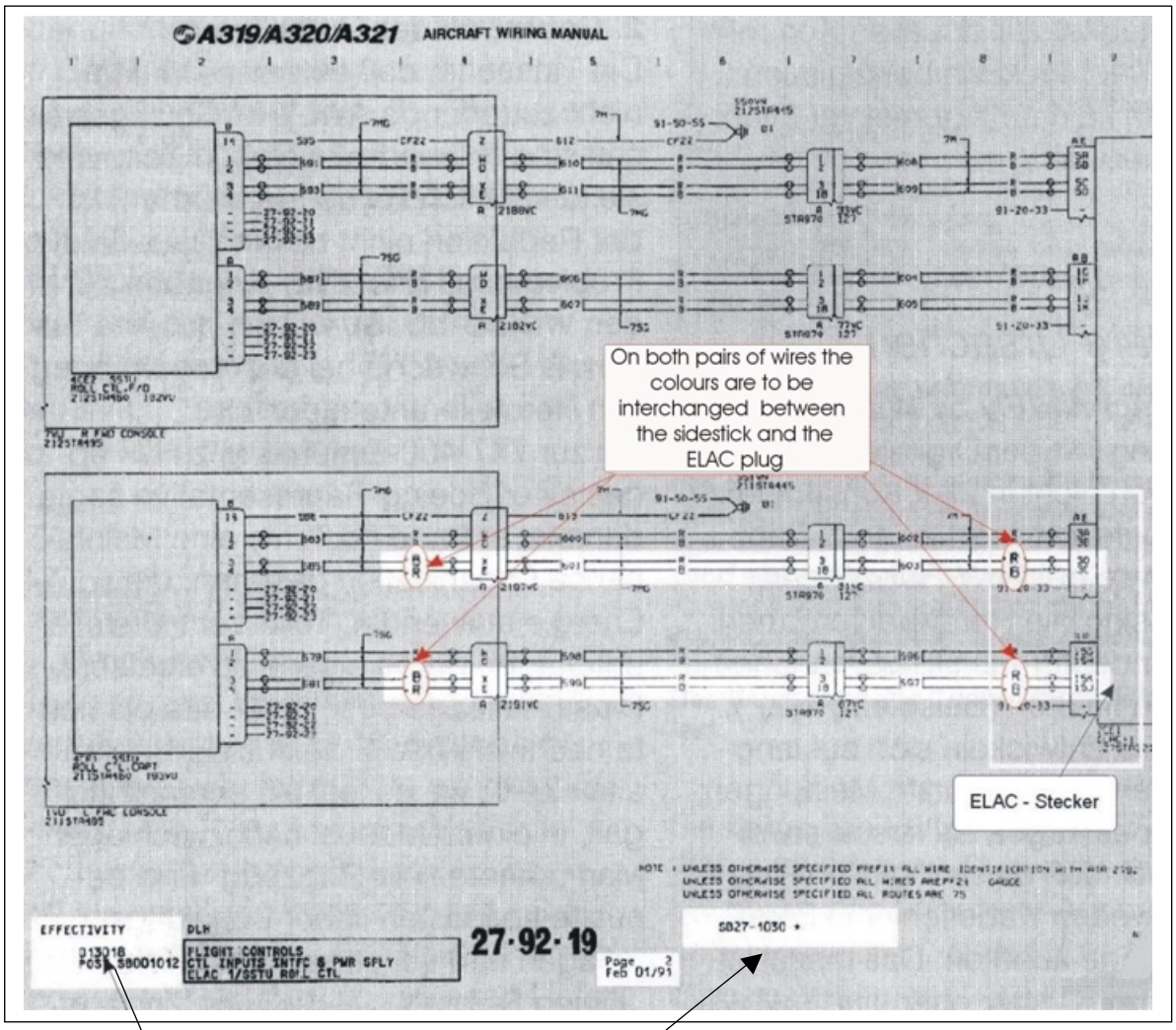
The designation of the positions of the individual pins on the plug segments was defined by an alphanumerical coordinate system. The working basis was the "AIRCRAFT WIRING LIST" (AWL) 91-20-33 and the "AIRCRAFT WIRING MANUAL" (AWM) 27-92-19.

The staff members were not sure which page of the AIRCRAFT WIRING MANUAL was the effective one, as there were two pages which could be applicable for the aeroplane concerned and which could only be assigned on the basis of the accomplished SERVICE BULLETINS (SB).

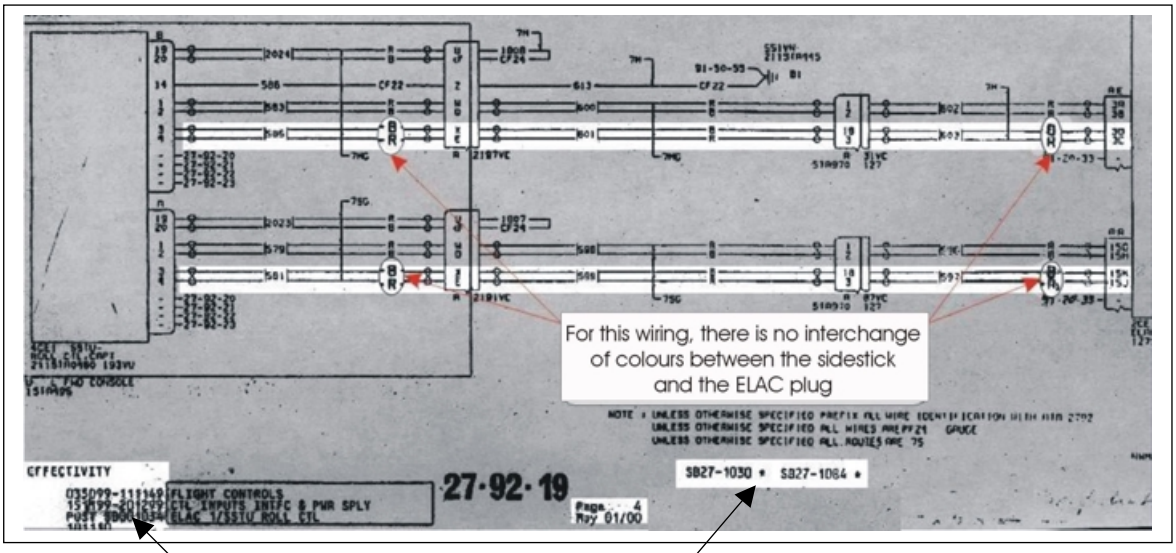
In addition to the serial numbers the aeroplanes are distinguished by the status of their equipment with the validity of the documents for the individual aeroplanes being shown by a consecutive numbering in conjunction with the term "EFFECTIVITY".

Page 2 of the AWM 27-92-19, Feb. 01/91 shows an effectivity range of 013 up to 018 (bottom left). The designation **POST SB001012** below the effectivity range **013018** on the bottom left means that this WD applies only to aeroplanes whose effectivity is within the range of **001 to 012**, if the **SB27-**

1030 has been accomplished; the accomplishment being indicated on the bottom right. The aeroplane concerned had the effectivity 017 and the SB 27-1030 had not been accomplished, therefore page 2 was applicable.



This page is applicable to all aeroplanes with an effectivity range of 013 to 018 and 001 to 012, provided on the latter the SB27-1030 has been accomplished.

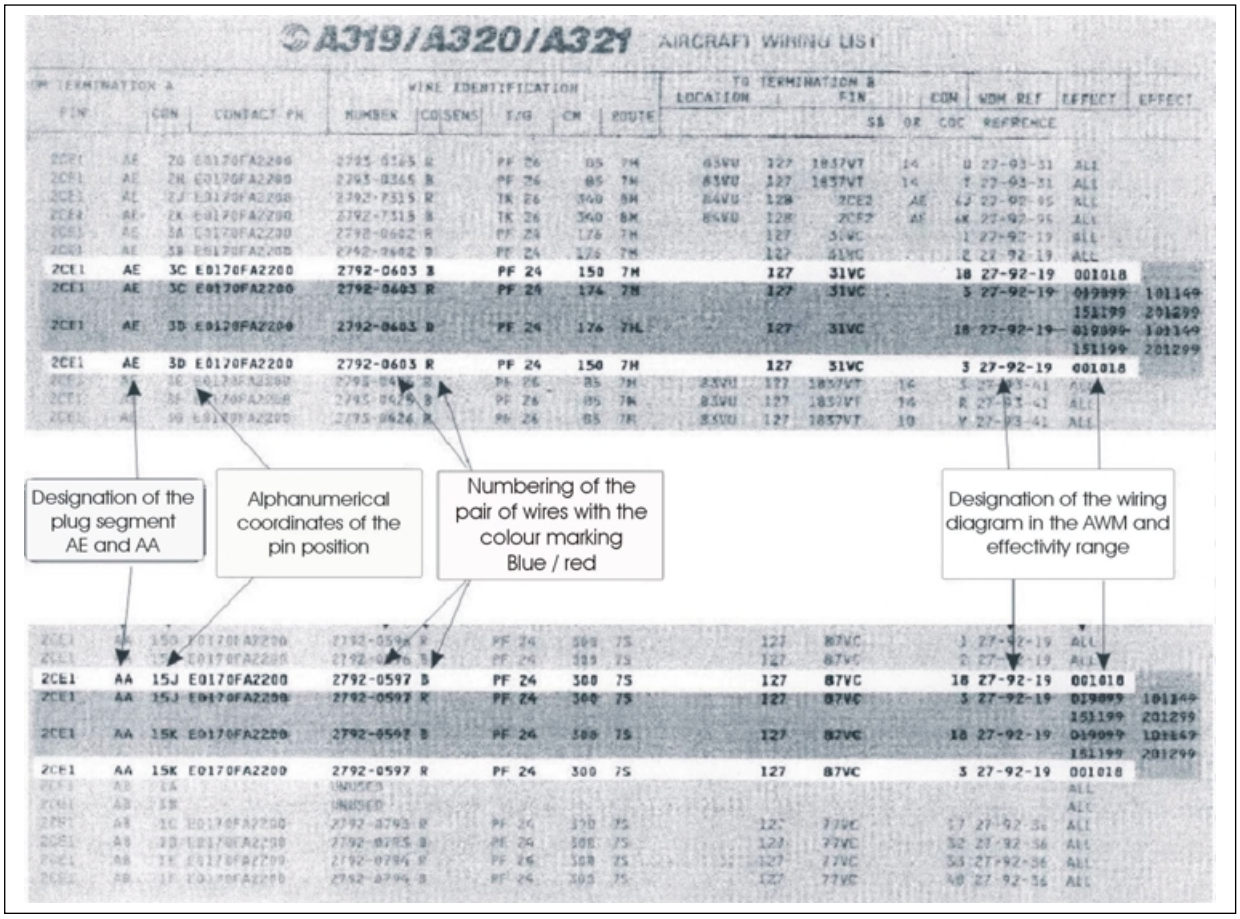


This page is applicable among other things to aeroplanes within an effectivity range POST SB from 001 to 034, provided the SBs listed on the right-hand side have been accomplished.

Page 4 shows the effectivity range from **001 to 034** following the desgination **POST SB**, this means that this range applies only to aeroplanes on which the SBs indicated on this page on the bottom right have been accomplished. Although the aeroplane concerned was within this range, only the **SB27-1084** had been accomplished, but not the **SB27-1030**, thus the page was not applcable to this aeroplane. Erroneously the mechanics thought page 4 to be applicable as the SB 27-1084 had been accomplished on this aeroplane.

On this aeroplane there was a further particuliarity concerning the wiring between the sidestick plug and the ELAC. All pairs of wires consist of a red and a blue wire which are twisted round each other. As can be seen from the AWL the twisted pairs are always assigned in an alphanumerical sequence of the plug segment coordinates in the order **red / blue**, except for the twisted pairs 0603 and 0597 which were - opposite to the normal arrangement - assigned to the pins 3C/3D and 15J/15K in the sequence **blue / red**.

According to an information given by the manufacturer in response to an inquiry, Airbus Industry intend to achieve a uniform wiring for all “fly by wire“ aeroplanes. From a certain type series,on the wiring of the A 320 series was planned to be identical with the wiring of the A 330 and A 340 aeroplanes, an interchange of colours was accepted for a certain transition period. The aeroplane concerned belonged to the transition series as could be seen from the Aircraft Wiring List.



This AWL shows the standard assignment of the pins 3C/3D on the plug segment AA in the area with the dark background. This assignment is applicable to most aeroplanes of the fleet except for the aeroplanes with an effectivity range from 001 to 018, which would have applied also to the aeroplane concerned. For this aeroplane the assignment of the pairs of wires 0603 and 0597 with an interchange of colours blue/red instead of red/blue shown on a white background is effective.

After completion of the reconnection work during the night shift from 19 to 20.03.2001 a functional check was carried out. During this check an error message on the ELAC no. 1 appeared. With the error search a faulty connection of the bridge on the plug segment AA was found and corrected. The mentioned error message, however, did not relate to the original complaint. Afterwards a functional and control system check was conducted simultaneously by an aeroplane electronic technician with a B2 qualification and an aeroplane electronic technician with a B1 qualification.

The functional check was conducted on the right hand sidestick only, although the wiring on the left side was affected as well. The check was carried out using the “AIRCRAFT MAINTENANCE MANUAL“ (AMM). The following instruction had to be adhered to: “***Push the FLT CTL ELAC 1 (2) pushputton switch. – Move the side-stick around in its two axis from stop to stop”.*** Following the functional check, an ELAC system test, a LAND test as well as an EFCS 182 GROUNDSCANNING with hydraulic pressure were done and afterwards the aeroplane was cleared for operation with a “Release to Service“.

All the accomplished work was documented in the copied “Actions“ column of the work done by the previous morning shift.

The action was entered into the „RELIABILITY DATA ON DEMAND“ (ROD), which serves the purpose of recording and evaluating technical processes in the aeroplane, also under the reference number which had been copied incorrectly from the TLB into the GLB, and consequently this complaint and the work accomplished on the aeroplane could later not be found under the actual reference number.

1.7 Meteorological information

The weather information (ATIS) effective for the runway 18 during the period of the serious incident was as follows:

Wind:	070°/ 4 kt
visibility:	more than 10 km
clouds:	FEW 032; BKN 250
temperature/dew point:	04 °C / -04 °C
QNH:	1017; NOSIG

1.8 Aids to navigation

not applicable

1.9 Communications

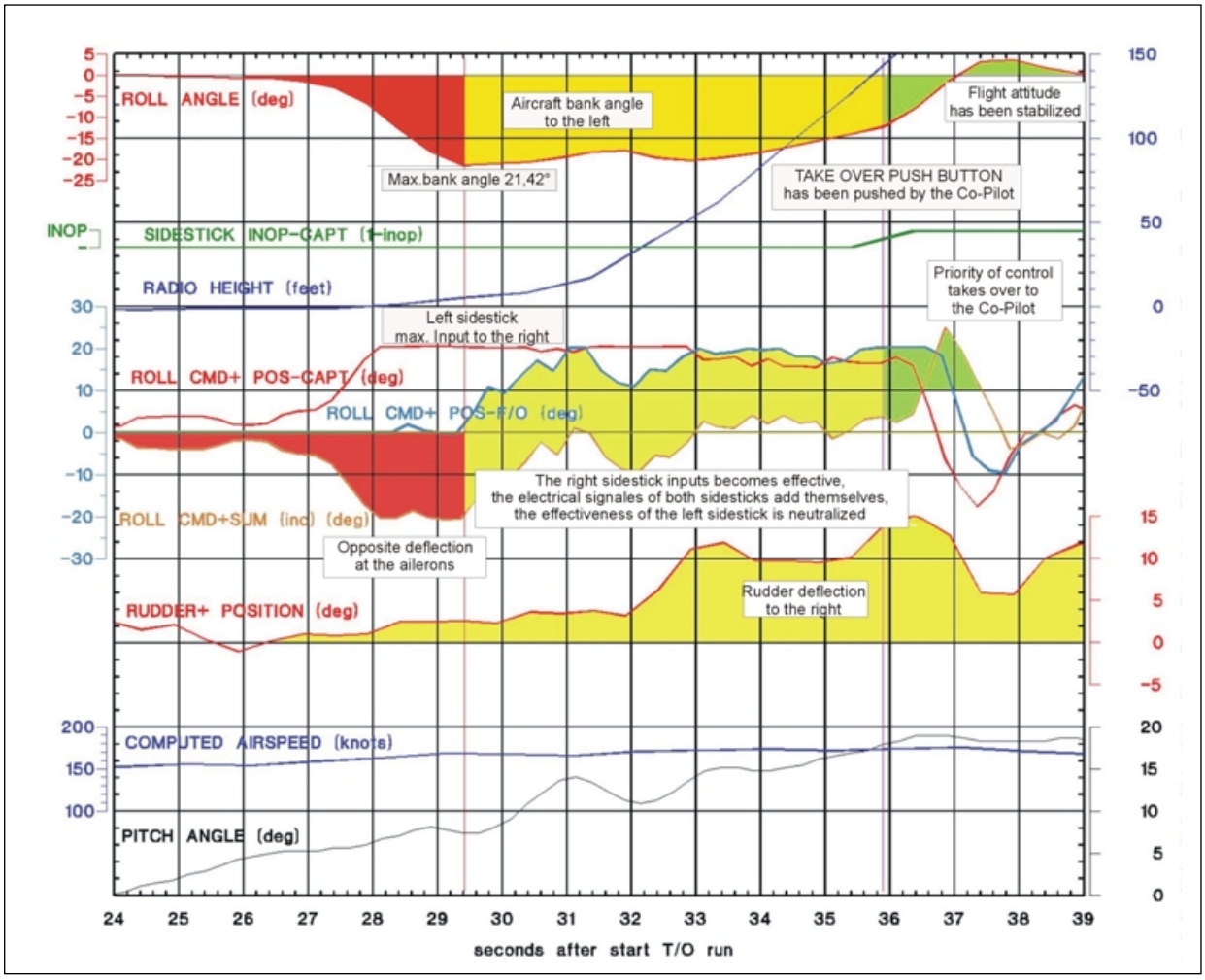
not applicable

1.10 Aerodrome information

The take-off was conducted from runway “West“ at Frankfurt/Main. The concrete runway is used only for take-offs into the direction 180°. The runway is 4000 m long with a width of 45 m.

1.11 Flight recorder

The flight data recorder concerned is a solid state flight data recorder (SSFDR) made by Loral-Aviation-Recorders in Sarasota/Florida. Approx. 470 parameters had been recorded. The flight data recordings were stored on a CD and sent to Braunschweig to the BFU for the purpose of evaluation.



The evaluation of the cockpit voice recorder (CVR) was waived as due to the recording duration of 30 minutes, the cockpit voice recordings of the period of the occurrence had already been overwritten.

1.12 Wreckage and impact information

not applicable

1.13 Medical and pathological information

not applicable

1.14 Fire

not applicable

1.15 Survival aspects

not applicable

1.16 Tests and research

not applicable

1.17 Organizational and management information

1.17.1 Operator

On 31.08.1999, the operator was granted an Air Operator's Certificate (AOC) by the Luftfahrt-Bundesamt (LBA) in accordance with JAR-OPS 1.175. One of the conditions to be met for the issuance of the AOC was the establishment of a quality management system (QM) in accordance with JAR-OPS 1.035. *"An operator shall establish one Quality System and designate one Quality Manager to monitor compliance with, and the adequacy of, procedures required to ensure safe operational practices and airworthy aeroplanes."*

The operator has no maintenance organisation of its own, scheduled and unscheduled work is carried out by an external maintenance organisation on basis of a maintenance contract.

The operator put the maintenance organisation in charge of the conduct of the repair work on this aircraft.

Pursuant to JAR-OPS 1.900, the Quality System of the operator must comprise, among other things, the monitoring of the proper accomplishment of all conventionary maintenance actions. This includes also the compliance with the approved procedures.

The Luftfahrt-Bundesamt had on several occasions, last in the scope of the AOC extension, complained that the operator lacked sufficient personnel for the required audits. In view of this fact the maintenance system was approved only subject to conditions.

1.17.2 Maintenance Organisation

The maintenance organisation was granted the JAR -145 approval by the LBA on 23 October 1992. Under the JAR-145 approval the maintenance organisation is obliged to comply with the regulations of JAR-145 and to accomplish the procedures in accordance with the JAR-145 maintenance organisation's exposition approved by the LBA (QM manual parts 1 and 2), the first issue of which was approved by the LBA on 28.10.1992.

Part of this QM manual were, among other things, provisions concerning quality requirements and ratings of the technical personnel in charge of the accomplishment of maintenance tasks and of the staff in charge of the release of aircraft and aircraft component maintenance.

As at that time the JAR-66 had not been completed yet, the Joint Aviation Authorities (JAA) and the Federal Ministry of Transport (BMV) had determined that until the coming in force of JAR-66 the existing national rules should continue to be applied.

At that time the maintenance organisation modified the qualification structure for aircraft mechanics from a three level system (aircraft mechanic I to III) into a two level system with the designation B1 and B2. In cooperation with the LBA additional qualifications were defined to allow a group of persons, which in the beginning was limited in number (approx. 25), to carry out special - highly critical – double inspection (formerly inspection tasks), e.g. following work on the control system. Those

staff members have to undergo special further training and must have gained practical experience. The LBA required the passing of an examination before the examination board for inspectors of aeronautical products.

The designation of the check rating B1 and B2 is a merely internal designation and does not correspond to the designations of Certifying Staff under JAR-66.

According to information obtained from the LBA, the number of the staff members holding a double inspection rating (B2) had increased during the years to 140 staff members at the time of the incident.

1.17.3 Supervision of the maintenance organisation by the Luftfahrt-Bundesamt

The maintenance organisation is subject to approval and supervision by the LBA. The responsibility for the supervision of all four facilities of the organisation and approx. 92 stations lies with one technical inspector of the LBA, who has to supervise besides the company concerned also two other German and three foreign organisations.

The Division U3 of the LBA, Maintenance, has got 12 technical inspectors for the approval and the supervision of 145 aircraft operators, 29 maintenance organisations (9 of which are abroad) and 65 flight training organisations.

Generally one annual audit of 2 to 3 days per facility is scheduled. Supervision in the strict sense of the word takes place only on the level of the regulations and rules as described in the quality management manual.

The quality management manual part 1 and part 2 is a part of the LBA approved quality system of the maintenance organisation concerned. Part 1 mainly defines the administrative items whereas part 2 describes the rules of quality management. The procedural instructions, which are based mainly on the quality management handbook part 2, are subject to checks on a random basis only. Out of the total of approx. 360 effective procedural instructions in the organisation 254 apply to aeroplane maintenance, of which 173 apply to the area concerned in this case.

1.18 Additional information

1.18.1 Documentation

In the following the documents which were available to eliminate the complaint are indicated.

The “AIRCRAFT MAINTENANCE MANUAL“ (AMM) issued by the manufacturer Airbus Industrie as well as the Electronic Standard Practices Manual (ESPM) served as a working basis for the repair of the aeroplane according to the ATA (AIR TRANSPORT ASSOCIATION) Specification no. 100, 29th revision.

In addition the following internal documentation was applied.

- The **Standard Practices Manual of the maintenance organisation (SPM)** contains the procedures for the maintenance of the aircraft of particular customers. Some of the procedures

contained in the SPM are supplements to the existing manuals of the aircraft manufacturers and the maintenance organisation. Others are aircraft manufacturers' procedures modified by the engineering departments of the maintenance organisation.

- **Quality Management Handbook for "qualification requirements and ratings of personnel assuming production tasks".** This handbook describes the system and the responsibilities for the qualification, ratings and the granting of ratings for personnel charged with production tasks in the maintenance of aircraft and aircraft components and in the manufacturing of aircraft components. The responsible accomplishment, inspection and certification of maintenance work on aircraft or aircraft components, of manufacturing of aircraft components as well as their release to service may be effected only by production personnel trained and qualified in accordance with the qualification system described in the QM handbook.

- **Quality management handbook - system and responsibilities for double inspections.** This QM guideline describes the system and the responsibilities for the provision of double inspection in the scope of quality inspections in the maintenance of aircraft, aircraft components and in the manufacturing of aircraft components. Generally it will be sufficient if the staff member who has carried out the work conducts a self-check of his work for compliance with the requirements in the scope of his responsibility. For special tasks an additional double inspection is necessary, which is to be accomplished by a second staff member holding at least the same qualification.

  In the corresponding internal procedure are the requirements for double inspection to be described as easy to handle instruction for the transformation into work paper.

- The associated **procedural instruction** dated 01.04.2000 refers to the a.m. QM manual and describes the system and responsibilities for work on the aircraft control system. Prior to any work on the control system it is to be verified by an aircraft mechanic B2/mechanic III whether the work to be carried out is complex or simple. For complex work the principle of first-check and double inspection is to be applied. The double inspection is to be accomplished by adequately qualified personnel and to be certified in the Technical Log Book (TLB), the Ground Log Book (GLB) and in the list of complaints.

- The **procedural instruction "Confirmation of Work"** contains instructions for the certification of work accomplished. It comprises the certification of maintenance work carried out, the airworthiness release of maintained aircraft and aircraft components relating to the maintenance accomplished as well as the certification of the manufacture of aircraft components in the scope of maintenance or the release under the approval as a production organisation.

- The **procedural instruction "Double Inspection in Aircraft Maintenance"** describes the system and responsibilities for the accomplishment of double inspection in aircraft maintenance and for this refers to the corresponding QM guideline. For work on aircraft and aircraft components quality inspections for the purpose of product quality assurance are to be conducted. For certain actions this requires besides the first-check also a double inspection.

  For the certification of this check it is a general rule that the double inspection is to be conducted by a staff member holding at least the same rating as the staff member who has carried out the first-check.

- The **procedural instruction "Handling of the Technical Log Book"** contains a description of the system and the responsibilities concerning the TLB. According to JAR-OPS 1.915, the op-

erator is obliged to keep a TLB as a part of the aircraft log book system. Among other things the TLB has the following functions:

- recording of maintenance actions accomplished
- confirmation of operator's receipt of the aircraft from the maintenance organisation
- recording of complaints in flight and on the ground as well as recording of the subsequent actions, their certification and release to service
- etc.

For all complaints entered into the TLB the corrective actions must be described and certified in the TLB also. Entries in the TLB must not be changed retroactively.

■ The **instruction for the handling of the "Ground Log Book and the list of complaints"** describes the layout and the system for the handling and filling in of the list of complaints and the GLB. In the framework of aircraft maintenance, these sets of forms are provided to record and to deal with complaints. The correct application allows the systematic recording of complaints and of corrective actions as needed for reliability investigations and error search.

In addition these forms contain blocks for the certification of the corrective actions accomplished, may serve as a basis for the subsequent entering of the data into a digital system for the administration of complaints and meet the requirement for the production of evidence pursuant to the provisions for JAR-145 maintenance organisations.

1.19 Useful or effective investigation techniques

Special investigation techniques have not been applied.

2. Analysis

2.1 Operator

JAR-OPS 1.890 specifies operators' responsibility for maintenance. In accordance with JAR-OPS 1.900, Subpart M, operators are obliged to monitor that maintenance contracts are complied with. For this purpose an audit plan, which has to be approved, must be submitted to the LBA once a year. According to the investigations of the BFU, the operator had not audited the maintenance organisation and thus the quality system of the operator was not in a position to recognize systematic faults with the procedural organisation in time. The quality system of the operator is obliged to monitor the maintenance organisation, to supervise, assess and, if necessary, to demand the quality of the work performed.

The fact that the malfunction had not been recognized during the flight control check by the crew is due to the fact that the ailerons had only been checked for full deflection, as described in the check list, but not for the correct direction of deflection. The BFU have issued a corresponding safety recommendation to the operator concerned and to the LBA for operators of fly by wire aeroplanes to amend their check lists accordingly; such an amendment is also in compliance with the recommendations given by the manufacturer.

On the basis of the investigation the BFU assume that the immediate and prudent action of both flight crew members at the time of the incident had prevented an accident. The philosophy of a **flat cockpit hierarchy** between both pilots which is taught and practised in the operator's fleets may have decisively contributed towards the prevention of an accident.

On the part of the manufacturer there was an attempt to explain the fact that during the flight control check following the delivery of the aeroplane to the maintenance organisation the ailerons moved correctly for a short time before they deflected in the opposite direction. The conditions on which this explanation was based, however, existed neither on the ground nor in the air.

2.2 Maintenance Organisation

After the conversion to JAR-145 the maintenance organisation had successively transferred the inspection tasks. These had previously been reserved to the inspection organisation, into the production sections in the scope of a transition programme continuously communicated to the LBA.

JAR-145 does not define precise criteria for the qualification of maintenance personnel, but requires only a qualification system to be specified in the maintenance organisation's exposition.

For personnel in charge of the release of aircraft and/or the maintenance of components, JAR-145 required at that time the application of national regulations until the coming into force of JAR-66. In the Federal Republic of Germany have never been national requirements for certifying staff. Articles 104 through 111 of the Personnel Licencing Order, which was effective at the time of the incident, only describe the qualification requirements for inspectors of aeronautical products, whose tasks pursuant to the Approval of Aeronautical Products Order only consisted in technical inspections, i.e. a sub-quantity of maintenance tasks. According to national aviation regulations the release certification of maintenance work was at that time reserved to persons "authorized to sign" who were not necessarily also inspectors of aeronautical products as for that has never been a legal basis either.

When the first JAR-145 approvals were issued to JAR-145 organisations it would have been necessary to amend the Approval of Aeronautical Products Order, in order to preclude problems of interpretation. This synchronous amendment of the Approval of Aeronautical Products Order was omitted at that time, meanwhile the Approval of Aeronautical Products Order is no longer effective.

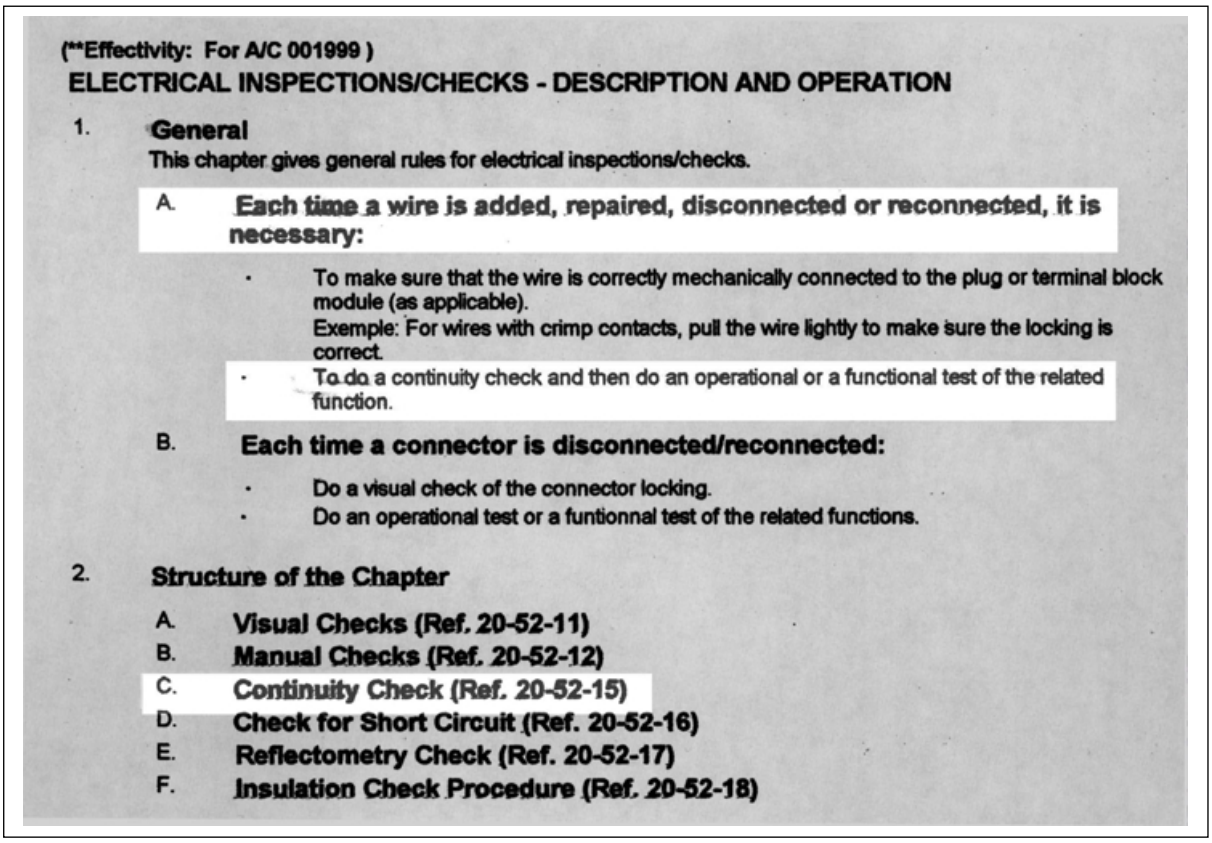
There were several shortcomings concerning the organisation and the accomplishment of work as well as the quality assurance of the responsible maintenance organisation.

The elimination of this technical complaint was a complex action on the control system, as defined in the relevant procedural instruction. Prior to starting repair work on 19 March 2001 a maintenance job order would have had to be established which describes the work, the checks and the documentation have to be made. This maintenance job order was established on 20.03.2001, after the had already started, indicating a certain carelessness in the realization of the prescribed working procedures.

In the morning shift on 19 March 2001 an aircraft electronic technician holding a B2 qualification was to replace the plug segment AE according to the "ONE by ONE" method with the assistance of an aircraft electronic technician B1. During this action it was determined that the new segment (AE) was incompatible with the three remaining segments of the plug. The possibility to find a fitting plug segment within an adequate period of time would generally have been an alternative, but for internal reasons another decision was made. If only the segment AE would have had to be replaced

only the pair of wires 0603 of the monitor channel could have been interchanged on this segment, the pair of wires 0597 of the Command Channel on the segment AA would have remained untouched and with a high probabiltiy an error message would have appeared on the display of the electronic centralized aircraft monitoring system (ECAM).

The reconnection of more than 420 pins of the whole plug was connected to a high risk of errors. Thus it would have been necessary to measure each individual wire (continuity check) as required by the manufacturer's instruction AMM 20-52-10 for major actions on the control system. In reply to the enquiry of the mechanics to staff members of the Maintenance Support Department, whether each individual wire should be measured, this action was orally cancelled with reference to the SPM of the organisation. The reason stated for this decision was the technical experience from practice that the functional test to be performed after completion of the work would reveal wiring errors. Erroneously the SPM of the organisation left this decision to the discretion of the staff members of the Maintenance Support. Following the occurrence this condition was immediately corrected.



(**Effectivity: For A/C 001999)

ELECTRICAL INSPECTIONS/CHECKS - DESCRIPTION AND OPERATION

1. General

This chapter gives general rules for electrical inspections/checks.

A. Each time a wire is added, repaired, disconnected or reconnected, it is necessary:

- To make sure that the wire is correctly mechanically connected to the plug or terminal block module (as applicable).
  Exemple: For wires with crimp contacts, pull the wire lightly to make sure the locking is correct.
- To do a continuity check and then do an operational or a functional test of the related function.

B. Each time a connector is disconnected/reconnected:

- Do a visual check of the connector locking.
- Do an operational test or a funtionnal test of the related functions.

2. Structure of the Chapter

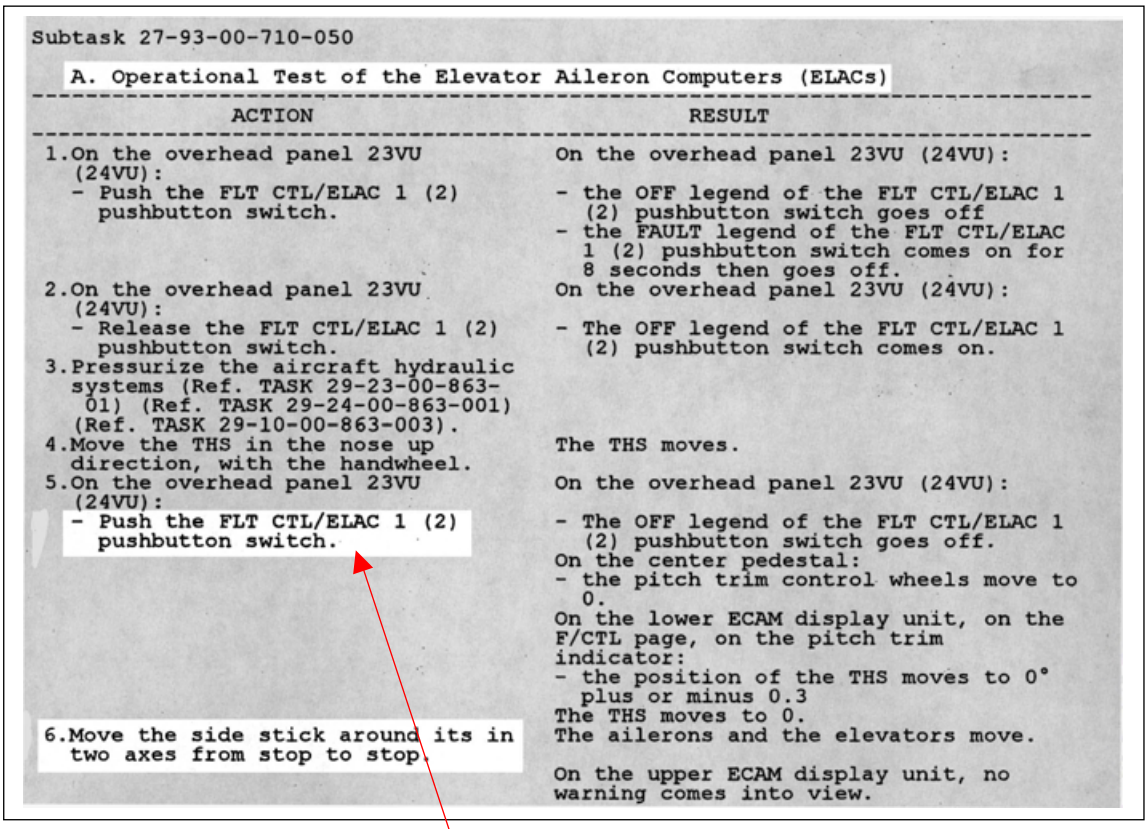
A. Visual Checks (Ref. 20-52-11)
B. Manual Checks (Ref. 20-52-12)
C. Continuity Check (Ref. 20-52-15)
D. Check for Short Circuit (Ref. 20-52-16)
E. Reflectometry Check (Ref. 20-52-17)
F. Insulation Check Procedure (Ref. 20-52-18)

In the Standard Practices Manual the procedure which would have had to be applied in this case is unambiguously established. This provision could have been cancelled only in writing in the form of an engineering order. In the opinion of the BFU the omission of the continuity check was not allowable with regard to the severity of the actions on the control system.

It was also inadmissible to perform the functional check and the control system check simultaneously, they would have had to be carried out independently of each other. The person who had conducted the double inspection and thus was the last to have the chance to find the interchanged connection had not been informed sufficiently about the previous work flow. Presumably it was not

known to him that the staff members of the late shift had by direction of the Maintenance Support not measured the reconnected wires, as actually required.

As a further omission, the control system test and the functional test were made only from the right-hand sidestick and not from both sidesticks and a comparing visual check of the control surfaces of the aeroplane was waived completely.



Subtask 27-93-00-710-050

A. Operational Test of the Elevator Aileron Computers (ELACs)

ACTION	RESULT
1.On the overhead panel 23VU (24VU): - Push the FLT CTL/ELAC 1 (2) pushbutton switch.	On the overhead panel 23VU (24VU): - the OFF legend of the FLT CTL/ELAC 1 (2) pushbutton switch goes off - the FAULT legend of the FLT CTL/ELAC 1 (2) pushbutton switch comes on for 8 seconds then goes off.
2.On the overhead panel 23VU (24VU): - Release the FLT CTL/ELAC 1 (2) pushbutton switch.	On the overhead panel 23VU (24VU): - The OFF legend of the FLT CTL/ELAC 1 (2) pushbutton switch comes on.
3.Pressurize the aircraft hydraulic systems (Ref. TASK 29-23-00-863-01) (Ref. TASK 29-24-00-863-001) (Ref. TASK 29-10-00-863-003).	
4.Move the THS in the nose up direction, with the handwheel.	The THS moves.
5.On the overhead panel 23VU (24VU): - Push the FLT CTL/ELAC 1 (2) pushbutton switch.	On the overhead panel 23VU (24VU): - The OFF legend of the FLT CTL/ELAC 1 (2) pushbutton switch goes off. On the center pedestal: - the pitch trim control wheels move to 0. On the lower ECAM display unit, on the F/CTL page, on the pitch trim indicator: - the position of the THS moves to 0° plus or minus 0.3 The THS moves to 0.
6.Move the side stick around its in two axes from stop to stop.	The ailerons and the elevators move. On the upper ECAM display unit, no warning comes into view.

The fact that the manufacturer's instruction in the AMM 27-93-00-710-050 ***(-Push the FLT CTL ELAC 1 (2) push button switch - Move the side-stick around in its two axis from stop to stop.)*** was not unambiguous, was the reason why the test was conducted only from the right-hand sidestick. The a.m. instruction of the manufacturer had meanwhile been changed at the suggestion of the maintenance organisation and now requires mandatory tests from both sidesticks.

The question of the BFU staff members why the tests had been conducted from the right-hand sidestick which was not concerned was answered with the statement that it did not matter which sidestick was used. As both ELACs were connected to each other possible faults of the one or the other ELAC would surely be indicated. This statement indicates lacking system knowledge of the mechanics.

Severe errors in the conduct of the first check and cross-checks arose. Presumably the aircraft mechanics involved who carried out the checks underestimated the significance of the previous action. There is no other explanation for the fact that the cross checking staff member had conducted the required cross-check using the working documents which where aboard the aircraft and had already been used by the staff member having conducted the first check, although according to the regulations he would have had to use his own impartial documents. Obviously the impor-

tance of the cross-check to this repair had not been realized. In this case not the workflow but the independence of the cross check was the crucial factor.

The repair organisation quality system required pursuant to JAR-145 had proved to be insufficient in this case. In addition it has become obvious that in this case there are deficits in the accomplishment of prescribed procedures and in the necessary system knowledge of the staff members.

2.3 Documentation

Since the reference number was mixed up when the complaint was copied from the TLB into the GLB, the previous maintenance action could not be found initially in the “RELIABILITY DATA ON DEMAND“ immediately following the occurrence. Even though this error is not directly related to the cause of the confusion of the pairs of wires it indicates that the quality system did not work optimally.

A complicated and complex documentation system which thus is difficult to handle increases the risk of mistakes. The 173 procedural instructions valid for the area concerned contain many cross references making handling considerably more difficult. It was very time-consuming to find out which procedural instructions were relevant to the tasks to be performed.

In the past, the maintenance organisation made great efforts to establish an internal documentation, which exists parallel to the manufacturer’s documents and like them has always to be kept up to date. Diversions from the manufacturer’s documents have in this case resulted in actual mistakes.

The aeroplane manufacturer classified the occurrence as a maintenance error, which will not lead to changes in aeroplane design. The ambiguous instruction in the AMM was amended on the insistence of the maintenance organisation immediately following the occurrence.

Towards the BFU the manufacturer justified the problem of the colour interchange red/blue - blue/red between the side stick connector and the ELAC plug with the objective of obtaining a uniform wiring of all fly by wire aeroplanes A 320, A 330 and A 340 which previously had differences. This applies to a certain A 320 transition series, which includes the aeroplane concerned. This particularity involves an increased risk of errors. In the opinion of the BFU, the manufacturer should have more plainly and more emphatically pointed out this particularity.

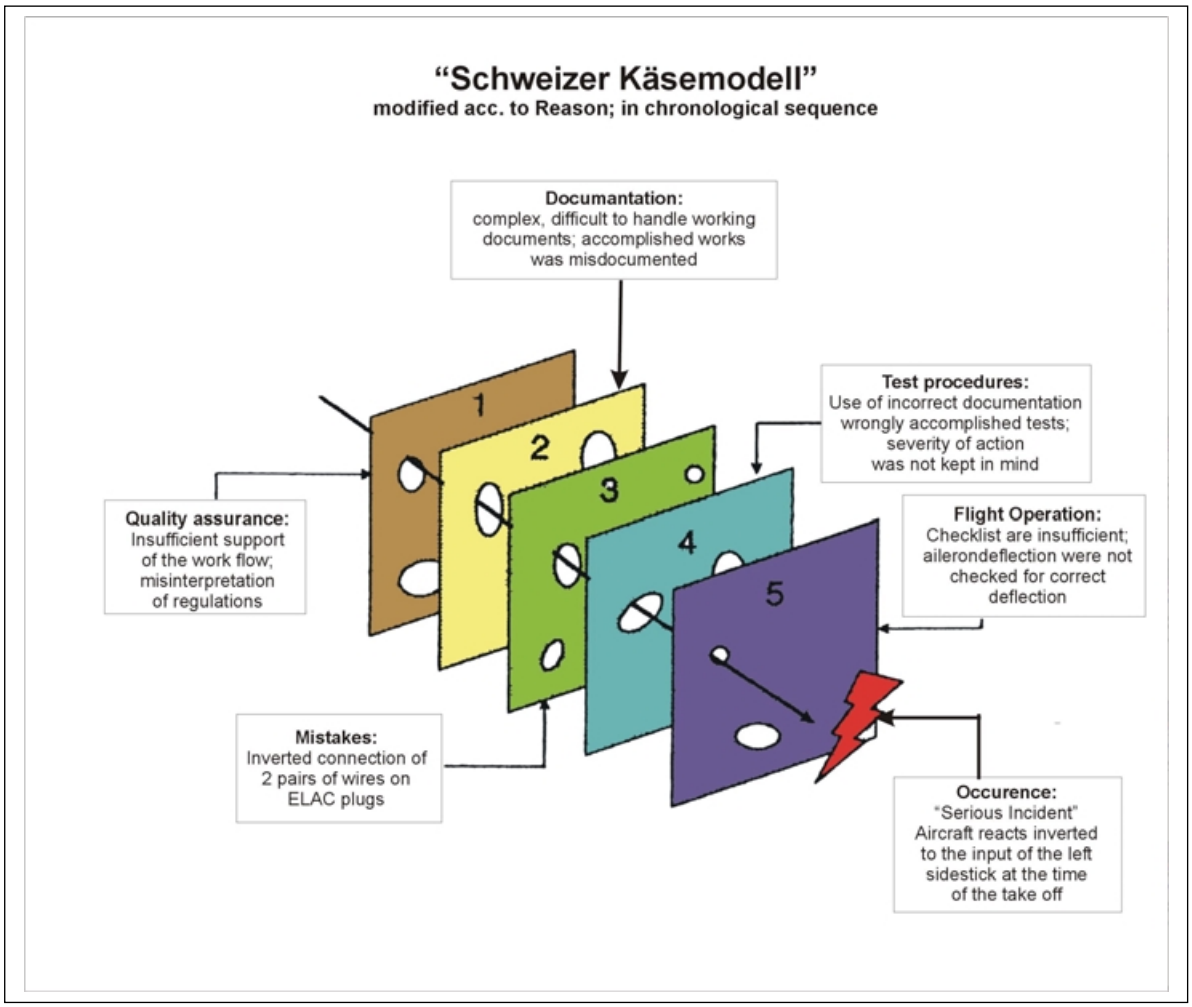
2.4 Supervision by the LBA

The depth of supervision as could be achieved by the technical inspectors of the LBA led to a condition in which deficiencies in the organisation and accomplishment of work and in the quality assurance with the operator as well as with the maintenance organisation had not been recognized. It does not seem to make sense that such a large organisation as in this case falls within the purview of only one technical inspector of the LBA who is also responsible for several other organisations.

For reasons of capacity, the technical inspectors are not in a position to check the organisations more thoroughly. Especially in the organisation concerned plenty of internal provisions had been compiled in the course of the years, the contents of which were not sufficiently known to the technical inspectors. Up to February 2001 only one technical inspector of the LBA was responsible for the operator as well as the maintenance organisation, now this task is shared by two LBA staff members, which, however, still seems to be insufficient.

2.5 Illustration of the causal chain

The investigation has revealed that numerous factors have contributed to this occurrence. The causal chain was never interrupted. In order to illustrate this the Swiss Cheese Model according to Reason was modified in to a chronological sequence.



3. Conclusions

3.1 Findings

- The maintenance organisation is certified by the LBA and has been working under JAR-145 since 1993.
- The entering of the incident into the Ground Log Book and into the "Reliability-Data on Demand" (ROD) under an incorrect reference number shows a lack of care.
- The complicated design of the damaged pin (6K) on the plug segment AE of the ELAC # 1 did not allow a repair in confined space.
- The decision to replace the whole plug was a consequence of the fact that a suitable spare part was not on stock.
- The decision to reconnect the wires of the whole plug involved a high risk of errors.
- The decision which pages of the Aircraft Wiring Manual were applicable was very difficult to make on the basis of the accomplishment or non-accomplishment of SBs on this aeroplane.
- The prescribed interchange of colours within the pairs of wires 0603 and 0597 between the sidestick and the ELAC plug was not realized by the mechanics probably because of the complicated documentation.
- The work of the late shift on the plug segment AB was inadmissibly entered into the same field of the GLB in which already the work of the morning shift on the plug segments AA, AD and AE had been copied, instead of being entered into a separate column.
- The malfunction “PITCH TRIM FAULT“ which had occurred during ground scanning after completion of the work was not related to the confused wires.
- The technical personnel was adequately licensed to accomplish the work.
- The qualification of the B2 or the mechanic III personnel having attended a one day additional training course to obtain the cross-check rating cannot be equated with the qualification of an inspector of aeronautical products or of certifying staff under JAR-66.
- The cross checking staff member did not carry out an independent cross-check as he had incorrectly used the documents of his colleague who had done the previous work.
- The measuring of the individual wires was considered unnecessary by Maintenance Support and therefore omitted.

- The duplicate inspections, i.e. functional check pursuant to the AMM and control system check pursuant to the Job Order was conducted incorrectly due to the fact that the provisions were not unambiguous.

- Contrary to the instructions not all of the inspection modes available were used for the checks.

- Due to deficiencies in the quality system of the maintenance organisation, errors in the organisation and the accomplishment of work remained undetected.

- The operator had not performed the audits in the maintenance organisation required by JAR-OPS thus the deficiencies in the maintenance organisation could not be realized.

- The LBA had not recognized deficiencies in the quality system of the operator and the maintenance organisation.

- The flight crew of the A 320 was adequately licensed to conduct the flight.

- After start-up of the powerplants, the lateral control of the aeroplane was checked in accordance with the “AFTER START CHECKLIST“ only for full deflection but not for the correct direction of deflection.

- During lift-off the aeroplane assumed a slight bank angle to the left. The attempt to counteract this tendency was not successful due to the left sidestick being incorrectly connected. The bank angle even increased to approx. 22°.

- The First Officer took over the control of the aeroplane and immediately restored the normal flight attitude.

3.2 Causes

The BFU has come to the conclusion that the serious incident is due to the fact that:

- during repair work on the plug of the Elevator Aileron Computer (ELAC) no. 1 two pairs of wires had been connected inverted
- the error remained undetected
- the error was not recognized by the flight crew during the “FLIGHT CONTROL CHECK“.

Contributing factors were:

- an unclear and difficult to handle documentation so that a wrong wiring diagram was used
- diversion from the manufacturer’s data by the Maintenance Support
- manufacturer’s instructions which are not formulated unambiguously
- functional check by the cross checking staff member was carried out incorrectly
- iinsufficient functioning of the quality assurance
- the lack of supervision of the maintenance organisation by the operator
- a quantitatively and qualitatively insufficient supervision of the maintenance organisation and the operator by the supervising authority.
- deficiencies in the “AFTER START CHECKLIST“ for the conduct of the “FLIGHT CONTROL CHECK“.

4. Safety Recommendations

4.1 Immediate Actions

As an immediate action the BFU issued the following safety recommendation to the LBA and to the aircraft operator concerned:

Recommendation no. 09/2001

The procedures and checklists for all fly by wire aeroplanes should be amended in such a way that during the flight control check attention is paid to the correct direction of movement of the ailerons and roll spoilers as recommended also by the manufacturer.

4.2 Actions during the investigation

4.2.1 Internal actions by the maintenance organisation

Due to the serious incident a series of internal immediate actions were initiated in order to preclude as far as possible that such an occurrence will happen again. A large number of medium and long-term actions have mostly been realized already in the course of investigation. They shall contribute to the creation of new working conditions and human relations as well as to the bulding up of a more distinct sense of responsibility.

- As an immediate action an instruction has been issued that the functional and control system checks on fly by wire aeroplanes must always be performed from both sidesticks. The Standard Practices Manual (SPM) as well as the Job Cards have been amended accordingly. Airbus Industrie have been requested to correspondingly amend unclear wordings in the “AIRCRAFT MAINTENANCE MANUAL“. The staff members involved in this process have received instruction.

- Within the scope of the short-term actions mainly internal processes, quality assurance procedures and the rules for the documentation of maintenance actions have been checked and modified. The continuation training of the staff members has been intensified.

- Within the scope of medium term actions an improved familiarization of newly employed personnel with all necessary operational procedures has been achieved and accordingly documented. The exchange of information should be improved. An anonymous reporting system similar to that in flight operations has been installed, in order to allow staff members to complain about inacceptable requirements or technical and other conditions without taking a risk of personal disadvantages.

- The long term objective is a positive change in the attitude to work and working ethics intended to lead to an improved working culture.

4.2.2 Actions of the Luftfhart-Bundesamt (Federal Office of Civil Aeronautics)

To improve the situation of the supervision of the operators' maintenance systems the LBA in agreement with the BMVBW has shifted the emphasis of work to the supervision of the approved maintenance systems. This action which is at the cost of other tasks is for the present limited until mid 2003.

At the same time additional funds for personnel have been requested and promised for the budgetary year of 2003.

4.3 Safety recommendations following the completion of the investigation

Recommendation no. 05/2003

The actions initiated by the Luftfahrt-Bundesamt should be continued for an unlimited period beyond the year 2003 in order to achieve a permanent qualitative and quantitative improvement of the audits to be performed with the aircraft operators and the maintenance organisations.

Recommendation no. 06/2003

The aircraft operator should provide the organisational and personnel conditions in order to ensure compliance with the quality requirements for the maintenance of aircraft in the maintenance organisation in accordance with the requirements of JAR-OPS 1.035 (Subpart B) in conjunction with JAR-OPS 1.890, 1.895, 1.900, 1.905 (Subpart M).

Recommendation no. 07/2003

The systerm of the procedural instructions in the maintenance organisation should be amended and re-arranged so that procedural instructions are clear, unambiguous and readily findable for all users.

5. Enclosures:

The enclosures have been included in the text.

Braunschweig, 19.05.2003

Bundesstelle für Flugunfalluntersuchung (Federal Bureau of Aircraft Accidents Investigation)

by order

Müller

Investigator-in-charge

The following BFU staff members have contributed to the investigation:

J. Reuß

A. Thiel