Jetstream 4100, G-MAJD

AAIB Bulletin No: 12/2000 Ref: EW/C2000/03/08 Category: 1.1

Aircraft Type and Registration:	Jetstream 4100, G-MAJD
No & Type of Engines:	2 Garrett Airesearch TPE 331-14GR/HR-807H turboprop engines
Year of Manufacture:	1992
Date & Time (UTC):	29 March 2000 at 1400 hrs
Location:	Manchester Aerodrome (Woodford)
Type of Flight:	Post maintenance test flight
Persons on Board:	Crew - 3 - Passengers - None
Injuries:	Crew - None - Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	4,700 hours (of which 325 were on type) Last 90 days - 16 hours Last 28 days - 7 hours
Information Source:	AAIB Field Investigation

History of the flight

The aircraft was one of a group scheduled for a wing splice replacement, in accordance with Service Bulletin J41-57-021, which involved the removal of the wing. It was the second aircraft to undergo the Service Bulletin and the work was carried out by a subsidiary of the aircraft manufacturer.

The pre-take-off checks for the test flight under 'A' conditions included a "full and free" check of the aileron trim. Soon after take off the pilot attempted to trim out a roll bias but it appeared that the initial application of trim made the situation worse. Further roll trim application aggravated the situation and the pilot then realised that the roll trim was operating in the wrong sense. He reversed the trim input, achieving balanced flight and then returned to the airfield for an uneventful landing.

Inspection showed that the aileron trim cables had been wrongly routed around a pair of co-axial pulleys at the wing root and that their connections to the chain, which operates the trim screw jack at the aileron, had been reversed.

Aileron trim system

On the Jetstream 41, roll trim is achieved through a tab on the left aileron. It is a cable operated manual system. The cables exit the pressure hull at station 360.50, abeam the trailing edge of the wing and descend to a pair of co-axial pulleys at the wing root. These pulleys effect a change of direction in the cable run to take them, without further support, along the aft face of the rear wing spar. The cables emerge from the pressure hull one above the other but route under the twin pulleys so that they exit one behind the other. Within the wing the cables route through common, rather than individual, large aperture fairleads. In their passage outboard along the wing they diverge slightly to attach to the upper and lower end fittings of the trim screwjack chain. The cables terminate in nipples, which have different shank lengths and the chain end blocks are sized so that the longer shanked nipple should not be able to be inserted into the shorter of the two blocks.

Pre-flight engineering work

The work was managed by a project leader; a CAA licensed aircraft engineer qualified under his delegated company approval to sign for the work carried out. The project leader controlled a team divided into three groups. Two of the groups worked three consecutive $13^{1}/_{2}$ hour day shifts (including Sunday working) and the third group worked on permanent night shift. The groups maintained a hand-over log. The project leader was present for most of the daytime shift working (2 shifts) and was available at any time on a mobile telephone. In addition to managing the project and manpower allocation within the project, the Project Leader undertook some of the tasks himself, inspected and signed for much of the work. He also had responsibility for signing the Certificate of Release to Service for the aircraft.

A second licensed engineer with delegated company approval, working on contract to the company, was also available. The project leader had requested his assistance full time on G-MAJD but, given the workload assessed for the task, it was deemed that it had been adequately resourced. Consequently, the contact engineer was occupied predominantly with work on an ATP aircraft on which he had responsibility for signing the aircraft's Certificate of Release to Service. He worked on a 40 hour, five day a week schedule with overtime as required on week days and Saturdays. His weekly working hours had totalled about 60 for each of the previous two weeks. He had been periodically called upon to work on G-MAJD and, after the major re-assembly of G-MAJD had taken place, he worked more permanently, but not exclusively, on that aircraft.

As part of the work to allow the wing to be removed from the fuselage the aileron trim cables had been removed from the trim actuator chain, withdrawn around the wing root pulleys, coiled up and tied at their exit from the pressure hull. This work was performed by an experienced aircraft fitter working with the maintenance company under sub-contract. When the wing flying control cables had been de-tensioned, the fitter had blocked them at places within the fuselage to prevent them becoming dislocated, had colour coded them and had labelled their coiled ends. After the re-attachment of the wing, when he returned to re-install the trim cables, probably on 23 March, he did not find the labels. He then installed the cables in what he thought was their "natural" routing from their exit from the pressure hull downwards to the pulleys at the wing root and then outboard along the wing's rear spar to the chain at the trim screwjack. The trim cables emerge from the side of the fuselage one above the other and engage the co-axial pulleys one behind the other. He made the wrong selection in routing the cables around the pulleys. (He routed the upper cable around the forward pulley and vice versa.) He then routed the cables to the chain attachments so that they did not appear to cross in their passage along the wing rear spar. (Lower cable off the pulley to lower chain fitting; as the pulleys were angled to keep the cable entry and exit in plane, the forward

pulley appeared to be lower than the aft.) He was unaware that the cable nipples and chain end fittings were sized to prevent mis-assembly and recalled having no difficulty in connecting the cables to the incorrect chain ends. He tensioned the system, let it settle for 24 hours then re-checked the tension and fitted the security devices.

The chain end blocks are sized so that the longer cable end nipple should not fit into the shorter block. The chain end blocks were found to conform to the manufacturing drawings. The drawing of the larger nipple showed it in the pre-swaged condition and so it was not possible to determine whether there had been any non-conformity in the original dimensions of the longer nipple, the swaging process or the design tolerances. The aircraft manufacturer undertook a review of the design and manufacturing of this component which resulted in Service Bulletin J41-27-060.

The initial and duplicate inspections (Item 3, see below) were carried out when both approved engineers were present on Friday 24 March. On that day the contract licensed engineer was also occupied with the release to service of the ATP, for which the operator's aircrew had arrived and were waiting. The checks comprised a visual examination of the system's general condition, correct assembly, security and locking plus a re-check of cable tension. Neither of the engineers saw anything anomalous in the trim cable routing and it did not occur to the project leader that the trim cables could be incorrectly connected. In examining the cable nipple engagement in the chain fittings he merely checked that the roll pins, which lock the nipples in place, were installed. On completion of these checks it was not possible to carry out the functional checks (Item 4) because of other demands on G-MAJD and the other aircraft.

On Monday 27 March, the contract engineer functionally tested and adjusted the engine controls and this occupied him for most of the morning. The project engineer had been working during the weekend and, in the mid-afternoon of Monday, learned that his wife had been involved in a car accident. As she had only been slightly injured, he elected to complete the tasks that he had outstanding before going home. He carried out the functional checks on the aileron, aileron trim and engine controls on his own, using a clinometer to check for flying surface range of movement. This involved setting the control position in the cockpit and walking to the control surfaces to check movement. In performing the check on the aileron trim tab range of movement he did not recognise that its direction of movement was incorrect.

Both engineers then spent some time certifying work that had previously been carried out, including the aileron trim reconnection, to progress the aircraft's release to service. The contract engineer learned from the project leader that he had carried out functional checks on the aileron and aileron trim systems. The contract engineer accepted that without further inspection at the time, signing for the duplicate inspection (see below) and intending to carry out duplicate functional checks later but, in progressing the aircraft's certification and preparation for flight, he overlooked the requirement.

Maintenance documentation

Service Bulletin J41-57-021, a document comprising 88 pages, described a complex scheme of work and, for implementation, it had been transcribed by the company's maintenance planning department onto work cards as a series of separate tasks. The work cards had two columns for clearance stamping, labelled 'AO' (Approved Operator) and 'DUP/FUNC' (Duplicate/Functional). The team had a copy of the Service Bulletin available as a reference document but this was an electronically transmitted copy and it lacked an approval signature. The bulletin and the pack of work cards both contained references to the Aircraft Maintenance Manual (AMM). Where

reference was made to the AMM the relevant section for the aileron trim was 27-15-00. It was found, during the post-incident investigation, that this section did not contain instructions for the installation of the aileron trim cables. It did contain a diagram, labelled "schematic", which showed the cable routings, which were not to scale but were referenced to station numbers. This diagram contained an error in the cable routing but this was not in the area affected by the work on G-MAJD. The diagram had not been included in the Service Bulletin. Since the incident, shortcomings in the AMM have been addressed and a revision issued.

On the relevant work card which covered the disconnection, reconnection and inspection of the wing flying and engine controls, Item 2, 'Work Required', read:-

"RECONNECT ENGINE, AILERON AND AILERON TRIM CONTROL CABLES IN ACCORDANCE WITH AMM 27-00-00 & 76-10-00"

This statement omitted the AMM reference for the aileron trim control system (Chapter 27-15-00). However, as mentioned above, this chapter did not contain specific instructions on the installation and reconnection of the aileron trim system. In the column headed, 'Work Completed', the project leader wrote, probably on 27 March, "Engine, aileron trim and aileron control cables reconnected satis to AMM refs". The fitter overstamped this entry with his identifying stamp (not signifying clearance of the work) and the project leader placed his stamp in the column headed 'AO' and wrote "N/A" under 'DUP/FUNC'.

Item 3 read,

"CARRY OUT A DUPLICATE INSPECTION OF AILERON, AILERON TRIM & ENGINE CONTROL CABLES."

Under 'Work completed' the project leader wrote, "Initial and duplicate inspections carried out satisfactorily" and stamped under 'AO'. The contracted licensed engineer stamped under 'DUP/FUNC' with his company approval stamp over which he signed with the date (27/3/00) and "DUP". This signified that he was signing for a duplicate inspection not a functional check.

Item 4 read,

"FUNCTIONAL CHECK OF AILERON/ENGINE CONTROL CABLES IN ACCORDANCE WITH AMM 27-10-00, 27-15-00 & 76-11-30"

The aileron trim system is not mentioned in the text although its AMM chapter reference is. The engineers assumed that it was included in this instruction. Under 'Work completed' the project leader wrote, "Functional checks to AMM refs 27-10-00, 27-15-00 & 76-11-30 satis" and he placed his stamp in both the 'AO' and 'DUP/FUNC' columns.

To the Project Leader the items 3 and 4 appeared to contain some repetition and redundancy in their instruction and their provisions for certification. The project leader considered that Item 4 was not necessary as functional checks were implied in Item 3 and duplicate certification provided for in the two stamps under 'AO and 'DUP/FUNC', missing the significance of the contract engineer's entry, "DUP", against item 3.

The Service Bulletin contained the following statement (printed in upper case for conspicuity):-

"2. ACCOMPLISHMENT INSTRUCTIONS

DUPLICATE INSPECTION

WHENEVER ANY PART OF EITHER THE MAIN OR ANY OTHER ASSOCIATED SYSTEM IS DISMANTLED, ADJUSTED, REPAIRED OR RENEWED, THAT PART OF THE SYSTEM THAT HAS BEEN DISTURBED SHALL BE SUBJECTED TO A DUPLICATE INSPECTION FOR SECURITY OF LOCKING DEVICES, FULL AND FREE MOVEMENT, DIRECTION AND TENSION CHECKS AND, FOR AIRCRAFT ON THE BRITISH REGISTER, THE COMPLETION OF THIS WORK SHALL BE CERTIFIED IN ACCORDANCE WITH THE BRITISH CIVIL AIRWORTHINESS REQUIREMENTS, SECTION A, CHAPTER A6-2 OR IN THE CASE OF AIRCRAFT NOT ON THE BRITISH REGISTER, THE EQUIVALENT NATIONAL STANDARD."

BCAR Chapter A6-2, describing the general procedures for duplicate inspection, contains the following:-

"**NOTE:** The inspections prescribed in this Chapter for control systems shall include an inspection to ensure that full, free and correct movement of the controls is obtained throughout the systems relative to the movements of the crew controls. An additional inspection shall be made, when all covers and fairings are finally secured, to ensure that full, free and correct movement of the controls is obtained."

The final sentence in the above note would require a further functional check to that called up in the work cards. Using a non-routine work card the contract licensed engineer called for an inspection of the aircraft in accordance with the operator's Daily Inspection. This method of inspection had not been approved by the maintenance company's maintenance planning department as required by a company procedure. The operator's inspection proforma makes provision for each item in the check to be individually signed for but the check carried out on G-MAJD was certificated en bloc, together with two out of phase items on the non-routine work card. Item 8 of the operator's Daily Inspection is as follows:-

"**Flight Deck**
Disengage control locks and check all flying controls for correct sense and full and free movement. Engage control locks on completion."

The aircraft manufacturer's flight safety department carried out an investigation, which included an examination of the Service Bulletin and the work cards which had been supplied to the engineering team to implement the repair. The investigation revealed a number of discrepancies in relation to the company's published procedures, in the both the Service Bulletin and the pack of work cards and other documentation that had been raised to support this work leading to a number of recommendations being made. Some other deficiencies where instructions were not clear or were illogically presented were also pointed out.

The number of job cards covering the work had been reduced from 50 for the first aircraft to be modified to 16 for G-MAJD. More work was covered by each card and separate work items often contained multiple tasks (eg Worksheet 13, Item 3, duplicate checking of three different systems) with provision for only one signature for operative or duplicate/functional checking. This was contrary to the relevant company procedure.

Following the incident the aircraft operator inspected the sister aircraft that had been the first to be reworked to SBJ41-57-021. It was reported that the aileron trim cables were found to be wrongly routed around the wing root pulleys but they had been correctly attached to the actuator chain and the trim system, therefore, worked in the correct sense. The operator reported three other assembly defects related to the work carried out under the Service Bulletin:-

1 An electrical harness was incorrectly routed (there being no reference in the AMM).

2 An aileron trim pulley guard had a mismatched nut and bolt which were noted to be 'finger-tight'

3 A fire extinguisher pipe, which would have been disconnected during SBJ41-57-021, was found to be only loosely re-connected.

A further discrepancy was noted which was outside the area affected by the Service Bulletin:-

A split pin missing from a castellated nut on a pulley bolt.

Summary and conclusions

In the documentation which had been produced to regulate the work on G-MAJD there were a number of discrepancies related to the disconnection and reconnection of the aileron trim cables. This material was at times incomplete, illogically presented and deficient in supporting information. The engineers and fitters appear, however, to have used their own knowledge of what was needed, using the work cards as a guide, and do not appear to have sought out any supporting information in the references. Some of the discrepancies, therefore, became irrelevant to the outcome. However, the system available to them for certifying their work, though it could have been interpreted in a way which would have met the requirements for certification, proved to generate some confusion and did not impose on them the discipline of accounting for and certifying the individual and distinct tasks.

The project leader was working long hours, combined management, operative and inspection duties and had been continuously on call. His supporting contract licensed engineer, although working normal, non-shift hours was regularly working overtime hours beyond his shift and on Saturdays. His duties were also split between projects with responsibility for Release to Service on the other aircraft.

A sequence of events can be traced which led to the cross connection of the trim controls and the release of the aircraft for flight, each one of which contained the potential to prevent this serious incident:-

1 The fitter who installed the aileron trim cables did not refer to instructions. (No written instructions existed but a schematic drawing was available in the referenced AMM.)

2 The fitter assessed cable routing, wrongly, by appearance.

3 The built-in mechanical protection against mis-assembly was ineffective.

4 In carrying out their duplicate inspections of this work the project leader and contract engineer did not consider the possibility that the cables could be misconnected.

5 The project leader decided to finish tasks in hand, including the functional check of the aileron trim, after he had heard that his wife had been slightly injured in a car accident.

6 The project leader carried out the controls functional check alone.

7 The project leader did not identify that the aileron trim moved in the wrong direction.

8 The contract engineer did not carry out a duplicate functional inspection of the aileron controls.

9 Contrary to company procedures, the worksheets included multiple tasks under one set of signatures which obscured accountability and made certification less specific.

10 The project leader misinterpreted the requirements for inspection and functional checking of the flying controls as presented on the work cards and misunderstood the certification entry made by the contract engineer for inspection of the system.

11 The non-routine work card calling for a Daily Inspection to the operator's proforma to be carried out before the post maintenance test flight had not been approved by maintenance planning.

12 The Daily Inspection, which required a check of all flying controls for correct sense, was carried out by the same personnel who had already inspected the flying controls and who did not, again, detect the mis-rigging of the aileron trim control.

Following the investigation by the manufacturer's flight safety department, the design and manufacture of the aileron trim chain end blocks, to nipple attachments were subject to review. In addition, shortcomings of the maintenance documentation were addressed and so no Safety Recommendations are made.