Aircraft Type and Registration:	Jetstream 4112, C-FTVN
No & Type of Engines:	2 Garrett TPE 331-14 turboprop engines
Year of Manufacture:	1995
Date & Time (UTC):	7 April 1995 at 0935 hrs
Location:	Prestwick Airport
Type of Flight:	Delivery flight
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to both propellers, main landing gear torque links, gear doors and flap operating arm fairings
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	7,945 hours (of which 1,129 were on type) Last 90 days - 71 hours Last 28 days - 41 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent investigation of components

Following satisfactory pre-start checks the first (right-hand) engine start cycle was initiated. As the engine gained RPM, the green 'gear down and locked' lights turned red, the landing gear warning horn sounded and the gear retracted. The start cycle was cancelled as the aircraft subsided onto the concrete hardstanding. The right-hand propeller was damaged, as were the two lowermost tips of the stationary left-hand propeller. The relatively superficial damage to the airframe included buckled gear doors, crushed flap operating arm fairings, damaged main landing gear torque links and associated pipework. The landing gear selector lever was confirmed as still being in the 'down' position prior to shutting down the aircraft, following which the crew evacuated without any problem.

The subsequent investigation conducted by the aircraft manufacturer quickly identified an electrical anomaly within the landing gear control unit to which the selector lever was attached. The unit was removed from the aircraft and quarantined until the arrival of AAIB and personnel from the vendor company which supplied the unit.

Before the control unit was opened, it was connected to an electrical test box which confirmed the electrical defect. Despite the selector lever being in the 'down' position, it was found that a 28 volt DC signal could be present on the 'UP' and/or 'DOWN' output lines, depending on whether the unit was tilted or shaken. The output lines of the unit are connected directly to the 'UP' and 'DOWN' sides of the double acting solenoid of the hydraulic selector valve in the landing gear system.

The landing gear selector lever is connected to a cammed shaft within the control unit. This in turn operates on a bank of four identical microswitches which provide the landing gear operating and signalling functions. These are: the gear warning horn; the 'position disagreement' light in the selector handle; the baulk solenoid in the control unit (signalled by the left gear 'weight on wheels' switch when the aircraft is on the ground, and which prevents movement of the selector lever to 'UP', unless the solenoid is manually overidden); and finally, the 'UP' or 'DOWN' signal to the hydraulic selector valve solenoid. Each switch is operated by means of a spring loaded plunger emerging from the switch body, and which is in contact with the cam. Upon opening the control unit, it was apparent that no spring loading was present on the plunger of the gear up/down signalling microswitch. The latter was removed from the unit and X-rayed, which revealed that a moving contactor within the switch was apparently lying loose. At this stage it was decided to take the control unit, together with the microswitches, to the DRA Structural Materials Centre at Farnborough for detailed examination and metallographic analysis of the contactor. Two photographs of the landing gear control unit are presented at Fig 1.

Examination of the microswitches

The landing gear control unit was supplied by a UK vendor who in turn sourced it from a US manufacturer. The microswitches were supplied by a separate company. Following the accident to C-FTVN, two more control units with apparently similar faults were located by the UK vendor. One of these had been returned to the vendor following rejection upon receipt inspection at Jetstream Aircraft Limited. None of the failed components had more than 15 flying hours, or about 20 cycles, including landing gear installation and functional checks. In addition to the one failed and three intact microswitches from C-FTVN, the vendor made available the failed microswitch together with an intact one from the rejected control unit. All of these were examined at Farnborough.

The conductive elements, including the moving contact blade, within the microswitch were made from gold plated 0.015 inch thick silver-magnesium-nickel alloy strip. A photograph of the switch is shown at Fig 2, together with a photograph of the failed unit from C-FTVN after the cover had been removed. Operation of the switch occurs when the cam-operated plunger applies a lateral force to the tensioning spring. This causes the blade, the lower end of which is pivoted on a platform on the central ('common') contactor, to 'flip' to its alternate position. Upon opening the switch, it was apparent that the integral loop on the moving contact blade, to which the upper end of the tensioning spring was attached, had failed. This had resulted in disconnection of the spring, which therefore removed the loading on the plunger. It had also liberated the remaining portion of the blade, which was thus free to make random contact with the 'normally open' and 'normally closed' contacts. A sketch is included at Figure 3 which is a representation of how the moving contact blade, with its integral loop, is stamped out of one piece of alloy strip.

The failed contact blade from C-FTVN, together with the other failed unit obtained directly from the vendor, were examined under a scanning electron microscope. Both failures were similar in that the fracture faces were intergranular, with no evidence of crack growth prior to failure, and were thus characteristic of mechanical overload imposed by the spring. Certainly one of the failed loops was deformed on its inner edges in a manner indicative of considerable pressure from the spring.

The metallographic analysis showed that the contact material was of the correct composition. Microhardness tests indicated that the mechanical properties were in accordance with the specification.

In order to investigate the possibility that variation in spring tension may have caused higher loads in some moving contact loops than others, tests were conducted to establish spring rates (ie load/extension curves) for all the springs that were available. The results were as follows:

Spring origin	Condition	Extension @ 2N Load (mm)	Spring Rate (N/mm-1)
C-FTVN	Failed	1.16	1.72
C-FTVN	Unfailed	1.2	1.67
C-FTVN	Unfailed	1.2	1.67
C-FTVN	Unfailed	1.24	1.61
Vendor	Failed	1.12	1.79
Vendor	Unfailed	1.2	1.67

As can be seen, the results suggested that the springs from the two failed switches were slightly stronger than the rest of those tested. However, it should be noted that whereas it was a simple matter to remove the springs from the failed switches, the others required considerable manipulation, which may have resulted in some stretching.

The UK vendor of the control unit, at the request of AAIB, obtained additional information from the US microswitch manufacturer, whose products are found in a range of industrial applications as well as aerospace. The contact blades, which are also used in another type of switch, are manufactured in quantities stated to be "millions per year". This was apparently the first reported failure of the switch in service, although the company found a small number of failed units held in stock. The company examined manufacturing records concerning Part Numbers, Serial Numbers and Lot Numbers, and tested several switches from "suspect" Lot Numbers. The switches were operated for more than a thousand cycles, albeit without electrical load, with no failures being reported.

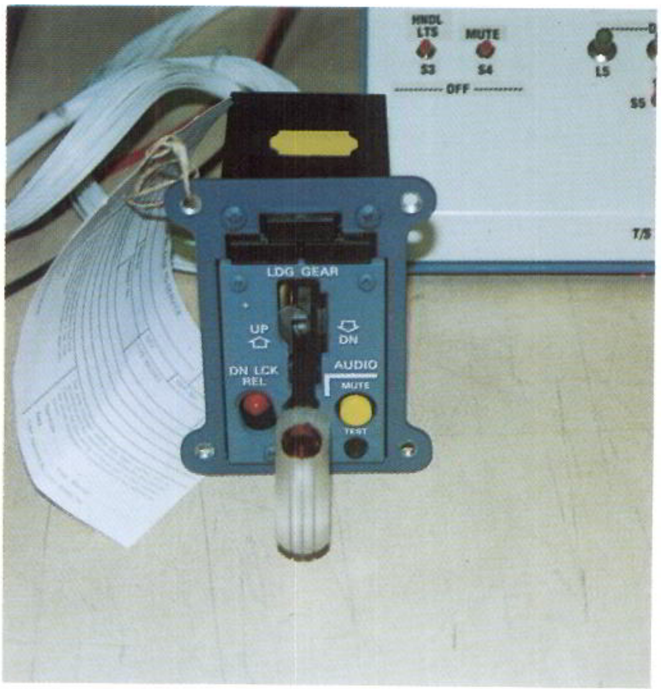
Following their own metallurgical examinations, the manufacturers of the control units and the microswitches have concluded that the failures could be attributed to "the presence of pre-existing cracks, folds, etc resulting from the forming process caused by the condition of the material prior to the forming operation".

Other information included the fact that switches are assembled manually, as opposed to an automated process. It is thus possible that there is a variation in the forces applied to the loops in the contact blades by different assembly personnel. Higher forces would result in an attendant risk of overstressing the loops. Furthermore, shorter springs and/or higher spring rates would require slightly higher forces to stretch them enough to attach them to the contacts. There is thus a suggestion that the observed failures were of the 'infant mortality' type, ie only applicable to new units.

Rectification action

Following the accident, the aircraft manufacturer issued an Alert Mandatory Service Bulletin (J41-A32-042) to implement a solution to the problem, which does not affect other Jetstream models. The modification re-routes the 'UP' signal wire from the landing gear control unit via a spare set of contacts in the flight idle baulk time delay relay. The function of the baulk is to prevent power lever movement below flight idle unless at least one of the weight on wheels switches is in the 'ground' position. When these switches attain the 'flight' condition, the time delay relay inserts a three second delay before the baulk is reinstated. Thus in the modified configuration, a spurious 'UP' signal would not, as a result of this modification, reach the hydraulic selector valve unless the weight-on-wheels switches, and hence the time delay relay, were in the 'flight' condition. However, in view of the remote possibility of this modification causing a critical delay in gear retraction in the event of an engine failure on takeoff, a further Service Bulletin will be issued which installs a modified landing gear control unit. This modifies the unit so that two microswitches are used to control gear operation. This results in the system having dedicated 'UP' and 'DOWN' microswitches connected to opposite ends of the double acting solenoid in the selector valve. This is effected by re-assigning the functions of the current UP/DOWN microswitch and the microswitch currently connected to the handle baulk solenoid. A rearrangement of the switch locations has resulted in the UP and DOWN switches being located on separate cams. A failure within either switch causing an uncommanded (and therefore opposing) signal would simply result in a hydraulic lock, ie no change in gear position. This feature has been confirmed by the aircraft manufacturer, using the J41 hydraulic systems rig. The emergency gear extension system is not affected by this modification.

As part of a product improvement exercise, the switch manufacturer has redesigned the switch and changed the process specification for the contactor material. A lighter spring has also been incorporated. In addition, improved quality control procedures have been implemented, including a blade loop pull-out test on production samples. Prior to delivery, each switch will be subjected to 15,000 operating cycles. No failures have been reported with the new switch following an intensive test programme. Pending full production of the new switch, the old type will continue to be delivered to the landing gear control unit manufacturer, but only after the 15,000 operating cycle qualification.



View of front of unit

Microswitch plunger operated by roller & lever

Camshaft

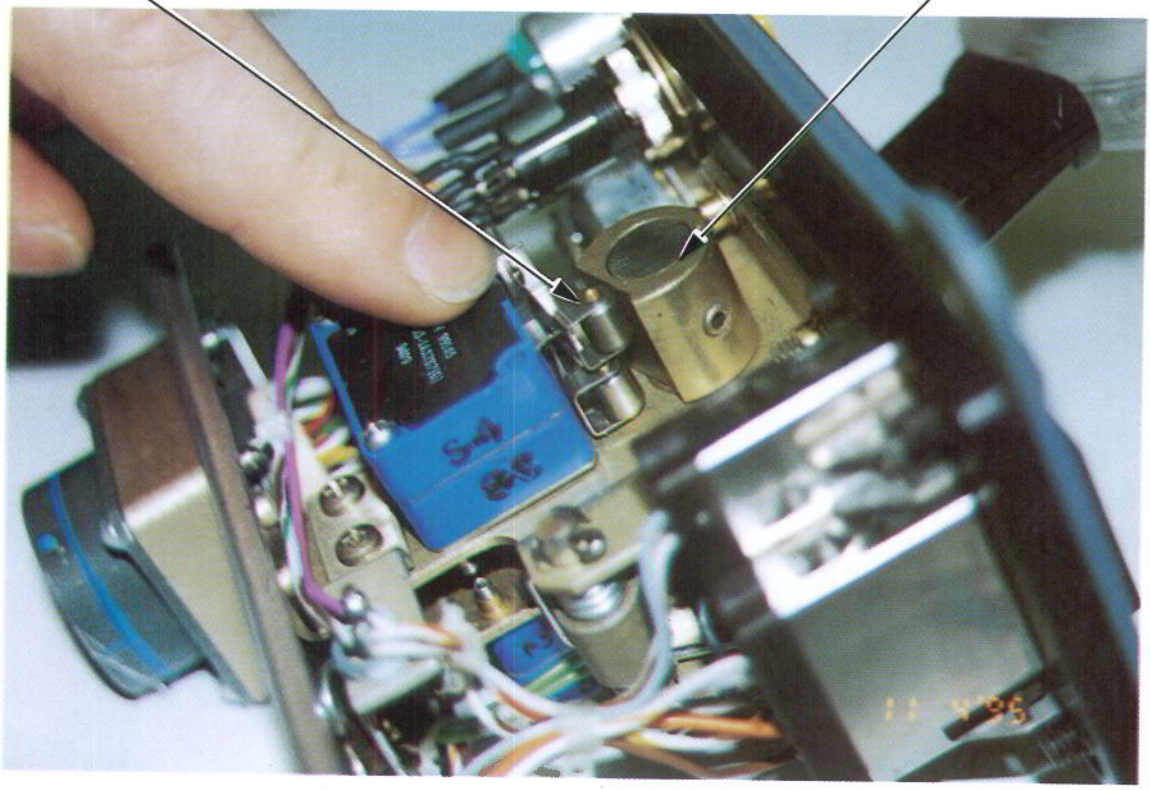


FIG 1 Landing gear control unit

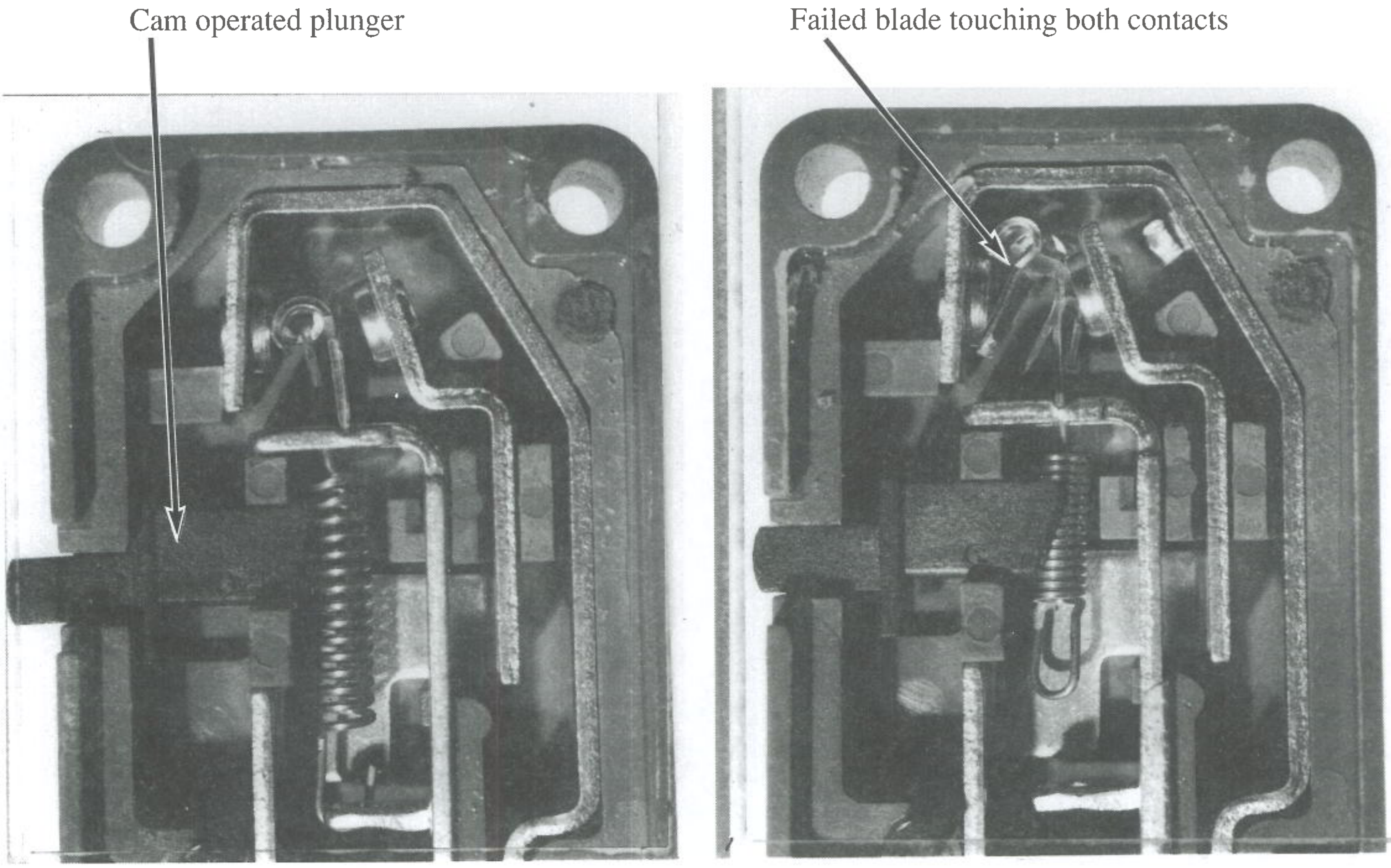


FIG 2 Comparison of intact (left) and failed microswitches. Note disconnected spring on failed unit *(Photographs: DRA)*

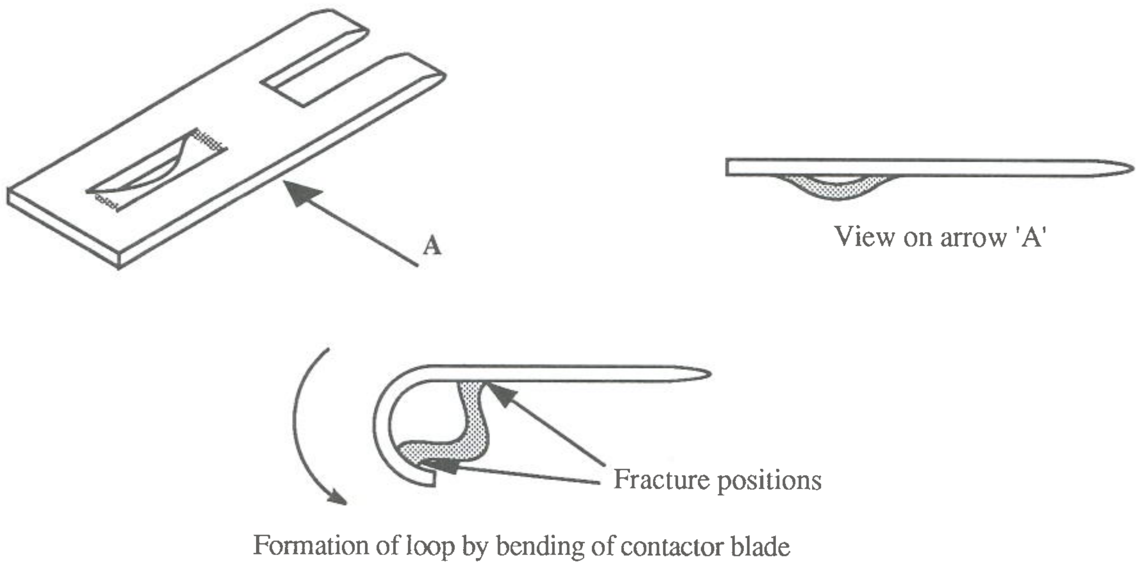


FIG 3 Representation of how contactor blade and integral loop is formed from single piece of alloy strip