

**SERIOUS INCIDENT**

<b>Aircraft Type and Registration:</b>	ATR 72-202, EI-SLG	
<b>No &amp; Type of Engines:</b>	2 x Pratt and Whitney PW124B turboprop engines	
<b>Year of Manufacture:</b>	1990	
<b>Date &amp; Time (UTC):</b>	15 March 2011 at 2130 hrs	
<b>Location:</b>	Near Edinburgh Airport	
<b>Type of Flight:</b>	Commercial Air Transport (Non-Revenue)	
<b>Persons on Board:</b>	Crew - 2	Passengers - None
<b>Injuries:</b>	Crew - None	Passengers - N/A
<b>Nature of Damage:</b>	None	
<b>Commander's Licence:</b>	Air Transport Pilot's Licence	
<b>Commander's Age:</b>	45 years	
<b>Commander's Flying Experience:</b>	TBA	
<b>Information Source:</b>	AAIB Field Investigation	

**The investigation**

The Air Accidents Investigation Branch (AAIB) was notified of the serious incident involving this aircraft by the Air Accident Investigation Unit (AAIU) of Ireland and an investigation was commenced under the provisions of EU Regulation 996/2010 and the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996. In accordance with established international arrangements, the AAIU and

the 'Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile' (BEA) of France appointed Accredited Representatives to participate in the investigation. This Special Bulletin has been published to highlight significant safety issues identified in the early stages of the investigation. The investigation is ongoing and a final report will be published in due course.

---

This Special Bulletin contains facts which have been determined up to the time of issue. It is published to inform the aviation industry and the public of the general circumstances of accidents and serious incidents and should be regarded as tentative and subject to alteration or correction if additional evidence becomes available.

The investigation is being carried out in accordance with The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996, Annex 13 to the ICAO Convention on International Civil Aviation and EU Regulation No 996/2010.

The sole objective of the investigation shall be the prevention of accidents and incidents. It shall not be the purpose of such an investigation to apportion blame or liability.

Extracts may be published without specific permission providing that the source is duly acknowledged, the material is reproduced accurately and is not used in a derogatory manner or in a misleading context.

---

## History of the flight

The aircraft had undergone routine maintenance at an engineering facility at Edinburgh Airport immediately prior to the incident flight.

Everything appeared normal during the crew's pre-flight checks, which included a full-and-free check of the flying controls. The crew were able to visually monitor the roll control surfaces and observe the spoiler operation on a cockpit indication, but could not see the empennage and the aircraft was not fitted with a flight control position indicator.

The aircraft took off at 2122 hrs from Runway 24 at Edinburgh, with the co-pilot acting as the handling pilot. After carrying out a standard instrument departure the crew climbed the aircraft to FL 230 at a speed of 170 kt with the autopilot engaged. As the aircraft levelled and accelerated through about 185 kt, the crew felt the aircraft roll to the left by about 5 to 10° and they noticed that the slip ball and rudder trim were both indicating fully right. The co-pilot disengaged the autopilot and applied right rudder in an attempt to correct the sideslip and applied aileron to correct the roll. He reported that the rudder felt unusually "spongy" and that the aircraft did not respond to his rudder inputs. Approximately 15° to 20° of right bank was required to hold a constant heading with the speed stabilised above 185 kt and a limited amount of aileron trim was applied to assist. Shortly after regaining directional control a FTL CTL caption appeared on the Crew Alert Panel (CAP) and the FLT CTL fault light illuminated on the overhead panel, indicating a fault with the rudder Travel Limitation Unit (TLU). The commander requested radar vectors from ATC for a return to Edinburgh, later declaring a PAN.

The crew carried out the required procedure from the Quick Reference Handbook (QRH). As part of the

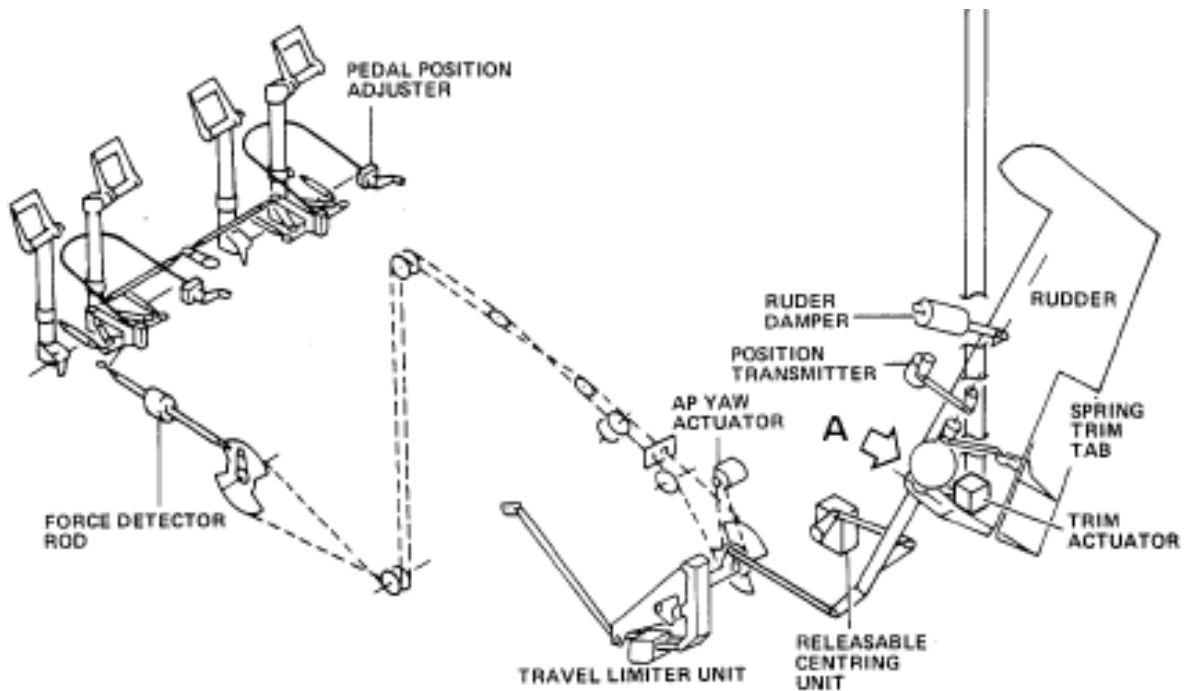
procedure they established that both Air Data Computers (ADC) were operating, before manually selecting the TLU switch to the LO SPD position. The aircraft had at this point temporarily slowed to below 180 kt. The co-pilot reported that on selection of LO SPD more roll control input was required to maintain heading and that roll authority to the right was further reduced. The commander therefore decided to return the TLU switch to AUTO and the required roll control input reduced. The green LO SPD indicator light did not illuminate.

An approach was made to Runway 24, the aircraft was established on the ILS and was normally configured for a full flap landing. The crew added 10 kt to their approach speed, in accordance with the QRH. The co-pilot had to operate the control wheel with both hands in order to maintain directional control; the commander operated the power levers in the latter stages of the final approach. The co-pilot reported that the aircraft became slightly more difficult to control as the speed reduced, but remained controllable.

The aircraft landed just to the left of the runway centreline, whereupon the commander assumed control of the aircraft and applied reverse thrust. Despite the application of full right rudder pedal during the rollout, the aircraft diverged towards the left side of the runway. The commander re-established directional control using the steering wheel tiller. The aircraft was taxied clear of the runway and back to the engineering facility for inspection.

## Rudder Travel Limitation Unit

The rudder linkage on the ATR 72 is a mechanical system composed of quadrants, pulleys, rods and a cable (Figure 1). The rudder pedals are linked to a force detector rod which produces movement of the forward quadrant. A cable loop links the forward and aft quadrants. The



**Figure 1**

ATR 72 Rudder control system

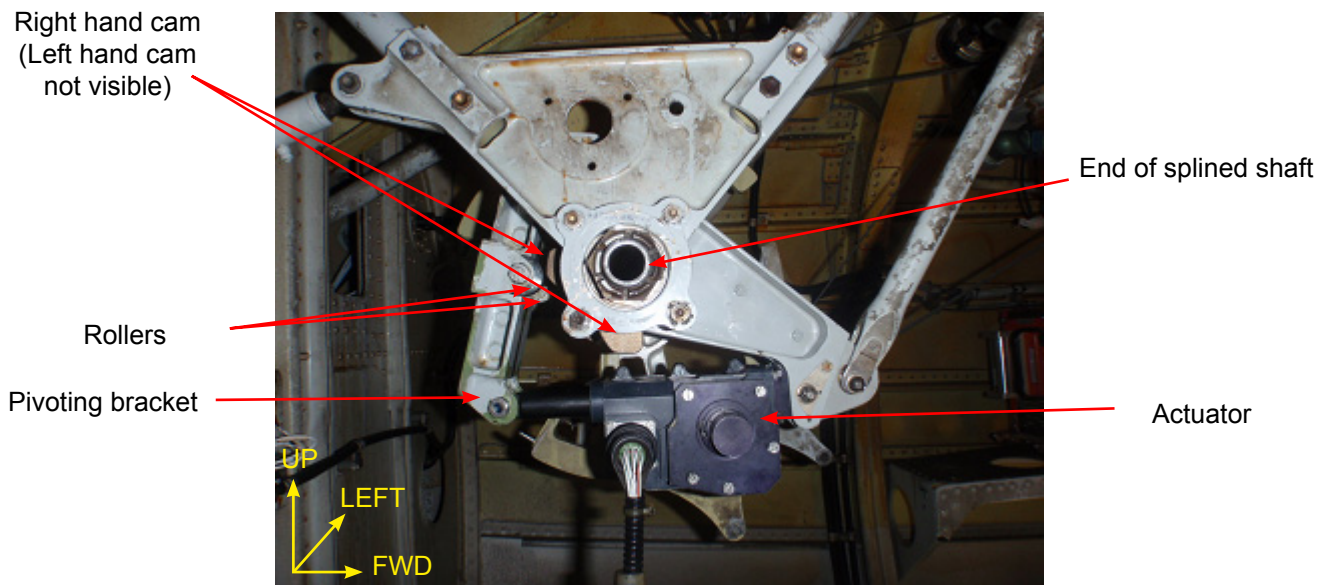
rudder is operated by means of mechanical linkages connected to the rudder rear quadrant shaft.

A Travel Limitation Unit (TLU) is installed on the rear quadrant shaft; this reduces the rudder deflection when the aircraft speed is greater than 185 kt. The TLU system has two positions: in the full authority position, rudder deflection is not limited; in the reduced authority position, rudder deflection is mechanically limited.

The TLU comprises an electrical actuator with two output shafts, two vee-shaped cams mounted on the rudder rear quadrant shaft and a pivoting bracket on which are mounted two rollers. The position of the pivoting bracket and hence the rollers is a function of the actuator extension. When the actuator is retracted, each roller is positioned into the vee groove of its corresponding cam (Figure 2).

In the reduced authority position the actuator retracts, rotating the bracket about its pivot, thereby engaging the rollers in the vee cams and thus mechanically limiting the rudder deflection. In the full authority position the actuator extends, disengaging the rollers from the vee cams such that rudder deflection is no longer limited. A green LO SPD indicator light illuminates in the cockpit when the TLU is in the full authority position.

In normal operation the system is operated in automatic mode and the actuator retracts automatically when both ADCs signal that the aircraft speed is greater than 185 kt. The actuator extends automatically when at least one ADC signals that aircraft speed is less than 180 kt. The duration of the actuator stroke in automatic mode is approximately 15 seconds.



**Figure 2**

#### Rudder Travel Limitation Unit

In standby operation the actuator extension and retraction are controlled via a three-position (HI SPD/ LO SPD / AUTO) selector switch on overhead panel 25 VU. The duration of the actuator stroke in this mode is approximately 30 seconds.

Monitoring of the TLU position is performed by modules 1A and 2A of the Multifunction Computers MFC 1 and MFC 2. The monitoring logic compares the actuator position, as given by a position synchro, with the airspeed signal from the ADCs. In the case of a disagreement, the logic generates a discrete signal to illuminate the FLT CTL fault light on overhead panel 25VU (after 25 seconds have elapsed), triggers a Master Caution alert and illuminates the FLT CTL caption on the Crew Alert Panel (CAP).

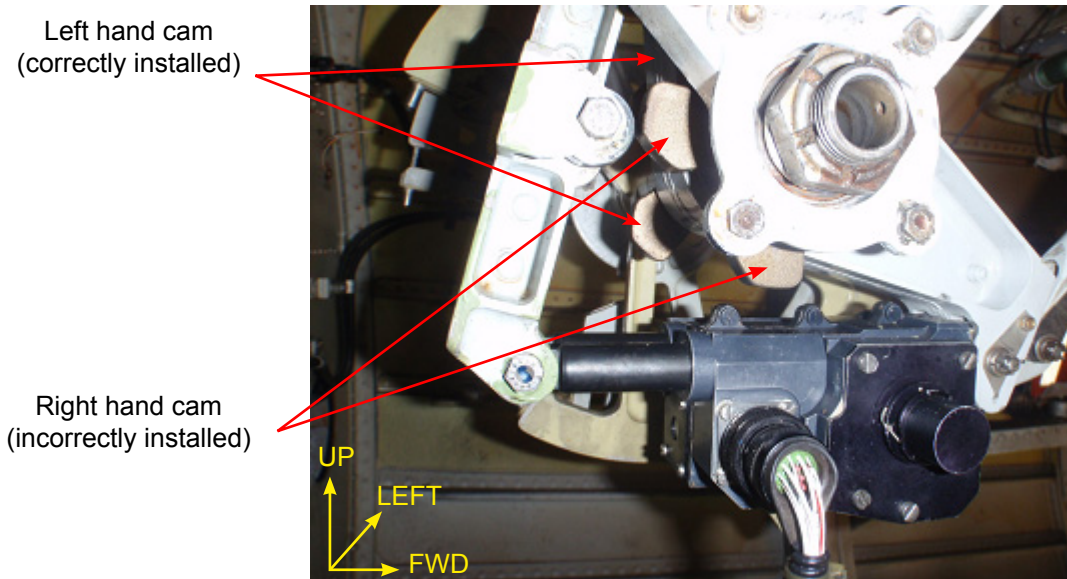
#### Maintenance

During the maintenance input which preceded the incident flight, work was performed on the rudder system which required the disassembly of the TLU mechanism.

During reassembly, the right hand cam was installed in the incorrect orientation. Neither an independent inspection nor an operational test of the TLU system was performed. The incorrect assembly was not identified until the TLU mechanism was inspected by the maintenance organisation after the incident.

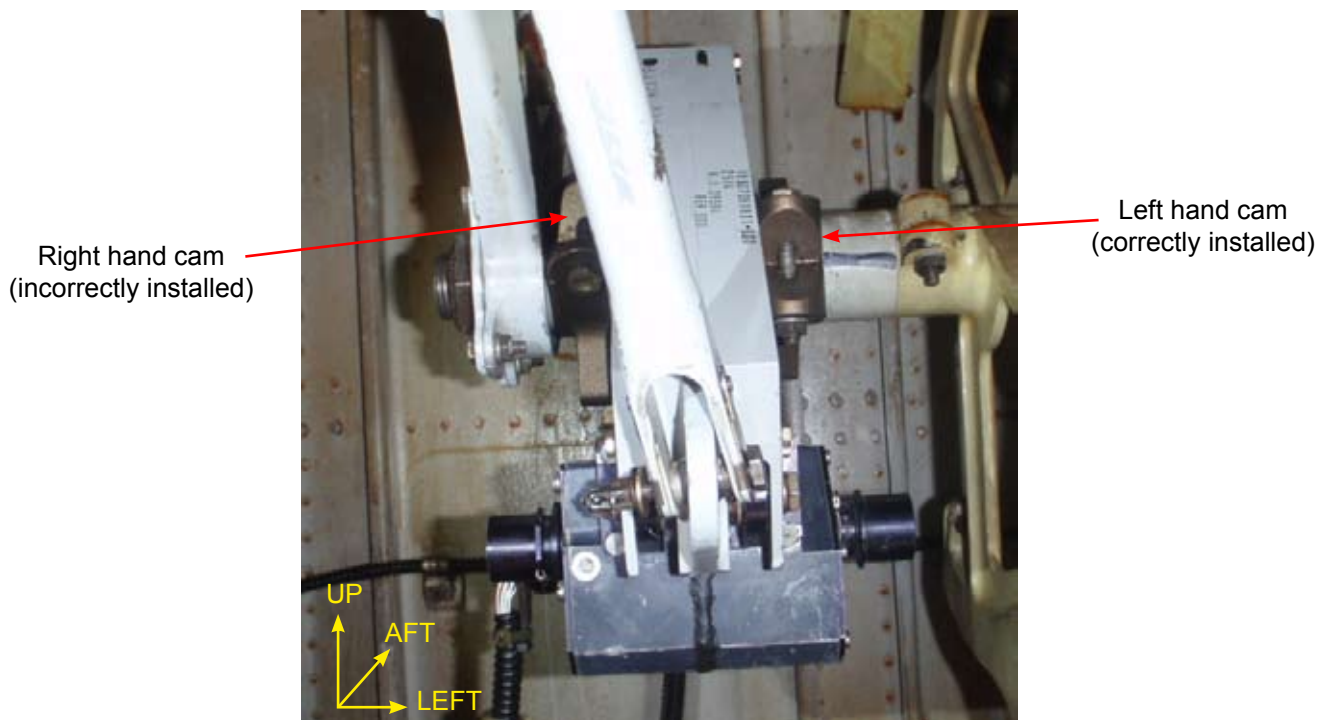
The factors that led to the incorrect installation of the cam and the failure to identify this condition prior to flight are the subject of the ongoing investigation.

The rudder rear quadrant shaft on which the cams are mounted is a splined shaft; a master locating spline ensures correct alignment of all components. Teeth on the internal bore of the cams correspond to the profile of the splined shaft, with a missing tooth in the position of the master spline. During reassembly, the orientation of right hand cam was transposed through 180° (such that the inboard face of the cam was facing outboard). As the missing tooth on the cam is not located centrally between the two cam lobes, but is offset by



**Figure 3**

Travel Limitation Unit with right hand cam incorrectly installed – rudder in neutral position  
(Note that the lobes of the right hand cam are not aligned with the lobes of the left hand cam and that the right hand roller is facing the upper lobe of the right hand cam)



**Figure 4**

View looking aft on Travel Limitation Unit with right hand cam incorrectly installed - rudder in neutral position

approximately 19° to one side, the incorrect installation of the right hand cam resulted in the right hand cam no longer being symmetrically aligned with the left hand cam (Figures 3 and 4).

### Documentation

The Aircraft Maintenance Manual (AMM) task *'Removal and Installation of the TLU Mechanism Assembly'* does not highlight that it is possible to install the cams in the incorrect orientation. This AMM task requires an operational test of the rudder TLU to be performed following reassembly.

The AMM task *'Operational Test of the Rudder TLU'* checks that rudder pedal travel is not limited when the TLU is in the full authority position; and that rudder pedal travel is limited when the TLU is in the reduced authority position. It also checks that the TLU mechanism responds correctly to the speed signals from each ADC. A test switch in the cockpit can be selected to send a high speed signal to the TLU actuator during ground testing. When a Press-To-Test (PTT) button is depressed the TLU actuator retracts to the reduced authority position, thereby simulating the automatic activation of the TLU mechanism. Both rudder deflection and rudder pedal travel are limited accordingly.

### Post-incident investigation and testing

During the investigation it was established that the cams could be fitted incorrectly on the splined shaft. Incorrect fitment of one or both cams meant that the vee grooves of the cams would no longer be aligned with the rollers on the pivoting bracket.

It was demonstrated that with the right hand cam installed in the incorrect orientation, it presented a restriction to the travel of the corresponding roller. When the TLU was activated, this situation prevented both rollers from

engaging in the vee groove of the cams and caused an uncommanded rudder input and corresponding rudder deflection.

When the AMM operational test was performed with the right hand cam incorrectly installed, rudder pedal travel was found to be restricted in an asymmetric sense. A FLT CTL fault light was generated only if the PTT button was depressed for a minimum of 25 seconds. The AMM task does not state how long the test button should be depressed.

### Discussion

This incident and the subsequent investigation and testing demonstrated that it is possible to incorrectly install the cams on the rear rudder quadrant shaft. In this incident, the right hand cam was installed in the incorrect orientation and neither an independent inspection nor an operational test of the TLU system was performed. The incorrectly installed right hand cam was not detected prior to releasing the aircraft to service. When the TLU system automatically activated as the aircraft accelerated through 185 kt, the right hand roller encountered resistance as it came into contact with the upper lobe of the incorrectly installed cam, rather than slotting into the vee groove. This caused an uncommanded rudder input and associated control difficulties.

Testing also demonstrated that this condition may be identified during the operational test of the TLU system as follows: (1) by detection of an asymmetric restriction of the rudder pedals and/or (2) if, after depressing the PTT button for more than 25 seconds, the FLT CTL fault light illuminates.

The manufacturer is not aware of any previous reports of the cams being incorrectly installed. The AMM does not highlight that it is possible to incorrectly install the cams.

For these reasons, the following Safety Recommendations are made:

**Safety Recommendation 2011-010**

It is recommended that ATR immediately informs all operators of ATR aircraft equipped with a Travel Limitation Unit that it is possible to install the cams on the rear rudder quadrant shaft in the incorrect orientation.

**Safety Recommendation 2011-011**

It is recommended that ATR amends all relevant Aircraft Maintenance Manual tasks to include a warning to highlight that the cams on the rear rudder quadrant shaft can be installed incorrectly.

**Safety Recommendation 2011-012**

It is recommended that ATR amends the Aircraft Maintenance Manual task '*Operational Test of the Rudder Travel Limitation Unit*' to state that: (1) the test should be carried out for a minimum of 30 seconds and (2) should an asymmetric restriction of the rudder pedals be detected or if the FLT CTL light illuminates, further inspection of the TLU system should be conducted.

**Safety action**

The aircraft manufacturer intends to take the necessary actions in response to these Safety Recommendations by 22 April 2011.