INCIDENT

Aircraft Type and Registration:	ATR42-300, EI-SLD
No & Type of Engines:	2 Pratt and Whitney PW120 turboprop engines
Year of Manufacture:	1985
Date & Time (UTC):	18 January 2007 at 2225 hrs
Location:	London Stansted Airport
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	2,732 hours (of which 2,144 were on type) Last 90 days - 147 hours Last 28 days - 35 hours
Information Source:	AAIB Field Investigation

Synopsis

Soon after takeoff from London Stansted Airport the aircraft developed a yawing motion which persisted as a yawing/rolling motion of varying severity. The yaw damper could not be engaged. An emergency was declared and the aircraft returned to Stansted. No mechanical fault was found which would have caused the motion, although an undetected and intermittent fault affecting components within the rudder control system could have degraded the aircraft's handling characteristics with the yaw damper not engaged, as could a takeoff with the rudder control system incorrectly configured. The nature of the motion and observed control deflections were such that an inadvertent and inappropriate rudder input by a pilot would have been required for the oscillations to persist. Four Safety Recommendations were made, concerning operational advice to flight crews and ongoing serviceability checks for Flight Data Recorders (FDRs).

History of the flight

On the evening of the incident, the aircraft was to operate a series of freight flights, originating and ending at Glasgow Airport. The flight crew of two had been operating the aircraft continuously for some days and had flown it to Glasgow the previous night, arriving at 0145 hrs. Both pilots were adequately rested when they reported at 1600 hrs for their night duty.

Glasgow had been affected by snow and strong winds during the day, and the crew arranged for the aircraft to be de-iced prior to departure in order to clear snow from the aircraft's surfaces. However, there was no ice detected on the aircraft prior to departure, and the surface temperature was reported to be 3ºC. The first flight of the evening, to Stansted, was uneventful apart from an occasional, intermittent and very brief illumination of an amber caution light on the Central Crew Alerting System (CCAS). This situation had reportedly persisted for a few weeks, but the caution was illuminating randomly and only very briefly, so had not been identified. The aircraft landed at Stansted at 2055 hrs.

Forecast strong crosswinds had prompted the crew to load sufficient fuel for a diversion back to Glasgow, so there was no need to refuel for the onward flight to Dublin. With the commander as handling pilot, the aircraft departed from stand at 2211 hrs. On board were the two pilots, 2,800 kg of freight and 300 kg of ballast. The calculated takeoff mass was 15,459 kg, with a maximum takeoff mass of 16,700 kg. The Centre of Gravity (CG) was calculated at 28% Mean Aerodynamic Chord (MAC), slightly aft of neutral.

The aircraft took off from Stansted's Runway 23, with a reported wind from 240º at 14 kt. Almost immediately after becoming airborne, the crew experienced a yawing motion, which developed into a motion described later by them as being similar to a Dutch roll. In accordance with standard flight procedures, the co-pilot attempted to engage the yaw damper after takeoff but it would not engage. The commander told the co-pilot she was having difficulty controlling the aircraft. The aircraft climbed to 3,000 ft above mean sea level (amsl) and maintained approximately the runway heading. When the aircraft was seen by Air Traffic Control (ATC) to be deviating from the cleared 'BUZAD 6R' Standard Instrument Departure (SID), the controller instructed the crew to turn right. The co-pilot informed the controller of the control difficulties and requested radar vectors for an immediate return to the airport. Figure 1 shows the aircraft's ground track, based on recorded radar data.

The aircraft was vectored around a right-hand radar pattern for an ILS approach to Runway 23. The crew

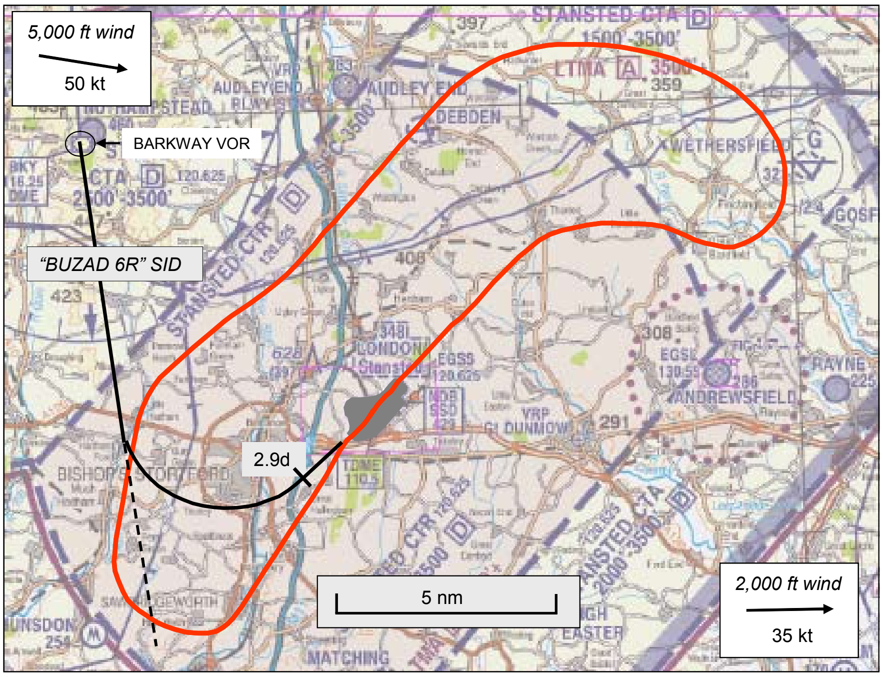

Figure 1

Aircraft ground track, SID and wind data elected not to declare an emergency initially, but did so after reviewing the situation. The commander experienced difficulty in turning right onto final approach and the aircraft flew through the runway centreline. Following further vectoring, the aircraft established on the Runway 23 localiser, but in the process descended inadvertently below the glidepath. This situation persisted until late in the approach, when the crew received configuration warnings related to landing gear and flaps, which were not correctly set for landing. The aircraft continued and landed from a reduced-flap approach at 2241 hrs, after a flight of 15 minutes 24 seconds. The crew did not experience any control difficulties during the rollout phase and were able to taxi normally to the stand.

Flight crew reports

The commander had been flying the ATR 42 and ATR 72 for six years before the incident. She had been with the operator for four years, during which time she had been promoted from co-pilot to captain. Of her 2,144 hours on type, 525 hours had been in command. The co-pilot had also been flying the ATR 42 and ATR 72 for six years. Of a total of 2,700 hours, he had 800 hours on the ATR 42.

The aircraft motion was reportedly confined to a gentle yawing motion initially, producing heading changes of just a few degrees. The co-pilot tried to engage the yaw damper several times but it would not engage, and the commander at first attributed the motion to this fact. As the aircraft drifted to the left of the climb out track, she attempted to turn to the right, but said that only a shallow angle of bank could be achieved with full control wheel deflection to the right. The predominant motion remained one of yaw, which increased markedly during turns. The co-pilot described the motion as if the rudder was being displaced across its full range of travel within a one to one and a half second period, though he did not handle the flying controls at any stage of the flight. The motion varied in severity and, at its worst, was extremely uncomfortable and adversely affected the crew's ability to manage the flight. The crew also reported turbulence associated with relatively strong winds at low levels.

Both pilots reported that turns to the right were difficult. The commander perceived there to be limited, though acceptable, roll control authority to the left, but very restricted authority to the right. She said she was reluctant to use the rudder pedals, as both pilots perceived the problem to be with the rudder, although she stated that her feet remained on the rudder pedals throughout. Neither pilot recalled much, if any, movement of the rudder pedals.

According to the co-pilot, the aircraft motion did improve somewhat with flap 15 extended for landing, which was deliberately selected late on the approach. However, the commander was still having difficulty controlling the aircraft, and instructed the co-pilot to handle the engine and propeller controls for landing, which he did. The final touchdown was controlled and described as smooth, with no control problems on the ground.

Description of the rudder system

The ATR 42 is equipped with a manually operated primary flight control system, which is augmented in the roll axis by hydraulically operated spoilers. The pilots' rudder pedals are connected, via cables, to a spring-loaded servo tab on the rudder trailing edge. The principle of operation is shown in Figure 2. The rudder itself is connected to a Releasable Centring Unit (RCU, also referred to as the 'rudder cam'), the internal springs of which maintain a centring force (approximately 10 kg force at the rudder pedals) towards the trimmed

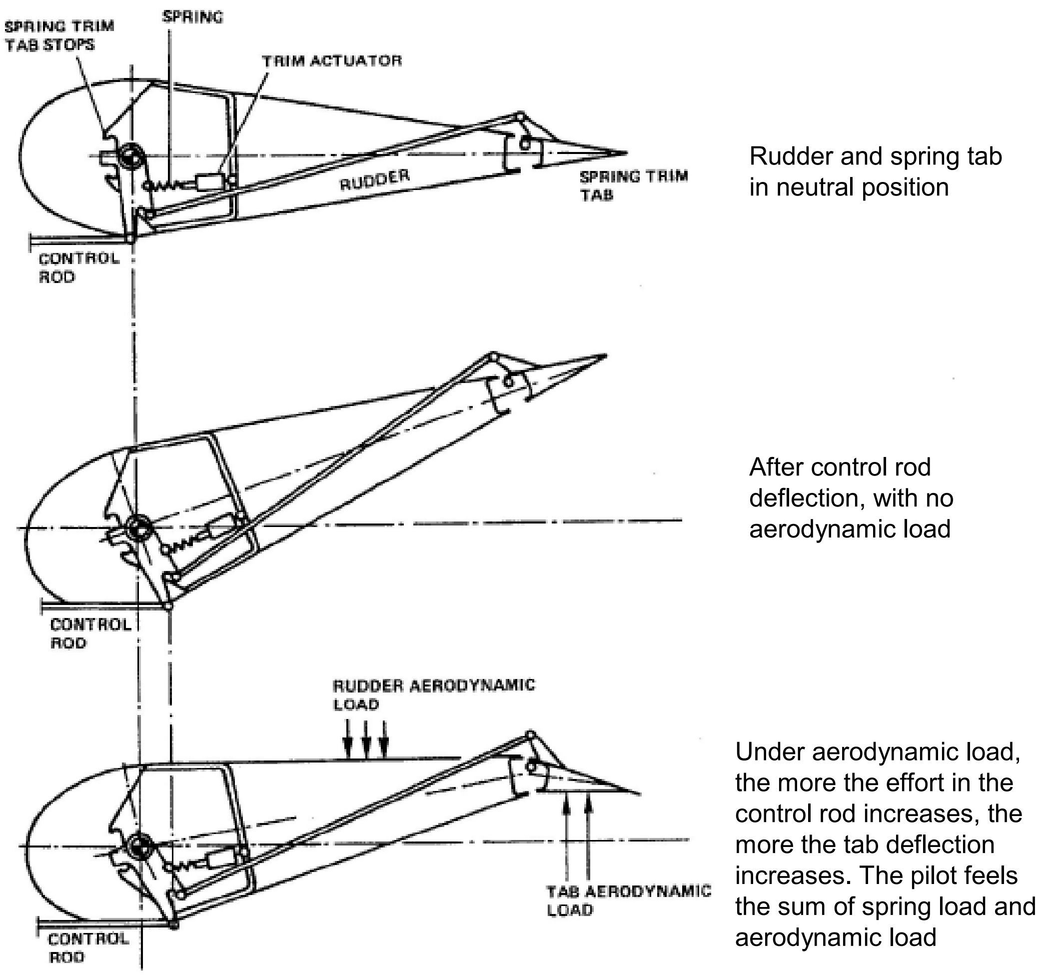

Figure 2

Schematic representation of rudder and spring tab operation

position. The purpose of this device is to improve the aircraft's directional stability, and hence stabilise the Dutch roll tendency, by constraining the movement of the control linkage. The yaw axis control system has no related cautions on the CCAS panel.

An electrically operated trim actuator acts on the same linkage and is controlled from the flight deck pedestal (Figure 3). The design of the rudder trim switch in the flight deck is such that a left or right trim demand also makes an electrical connection to an electromagnetic clutch within the RCU, causing it to release the rudder linkage, thus allowing it to centre on the new trimmed position. The clutch also releases the RCU whenever the yaw damper is engaged. Figure 4 shows a schematic diagram of the system, where it can be seen that both the trim and yaw damper electric inputs to the RCU clutch are routed via a relay (designated Relay 31CG on the diagram). The yaw damper is a function of the Automatic Flight Control System (AFCS), which also controls the autopilot, and is normally engaged shortly after takeoff to provide yaw damping and turn co-ordination. The AFCS computer sends electrical signals to a yaw servo, which acts on a cable drum that is connected to the rudder servo tab control linkage.

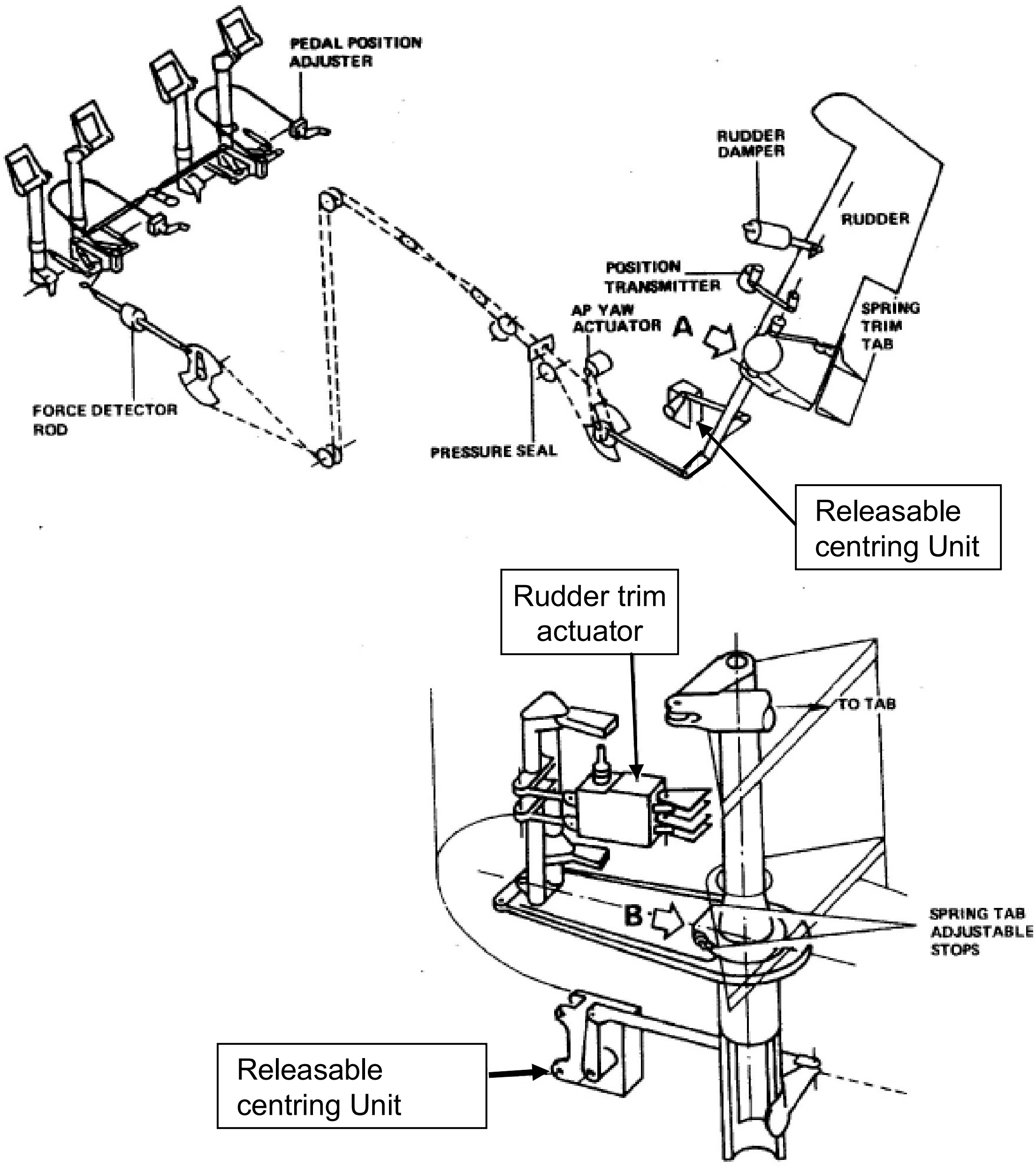

Figure 3

Rudder system layout

A self-contained gust damper is fitted between the rudder and the fin; this is a hydraulic fluid-filled dash-pot that provides a rate-sensitive opposing force to rudder movement. Thus, with the aircraft on the ground (ie with no tab aerodynamic load) a pilot's rudder pedal input would be opposed by the combined forces from the tab spring, the RCU internal springs and the gust damper.

Finally, a force detector rod is provided in the rudder control system below the flight deck floor. This disconnects the autopilot/yaw damper if a load in excess of approximately 30 kg is applied to either rudder pedal.

Prior to takeoff, the RCU must be confirmed as being centred on the trimmed, rudder-centred position. To

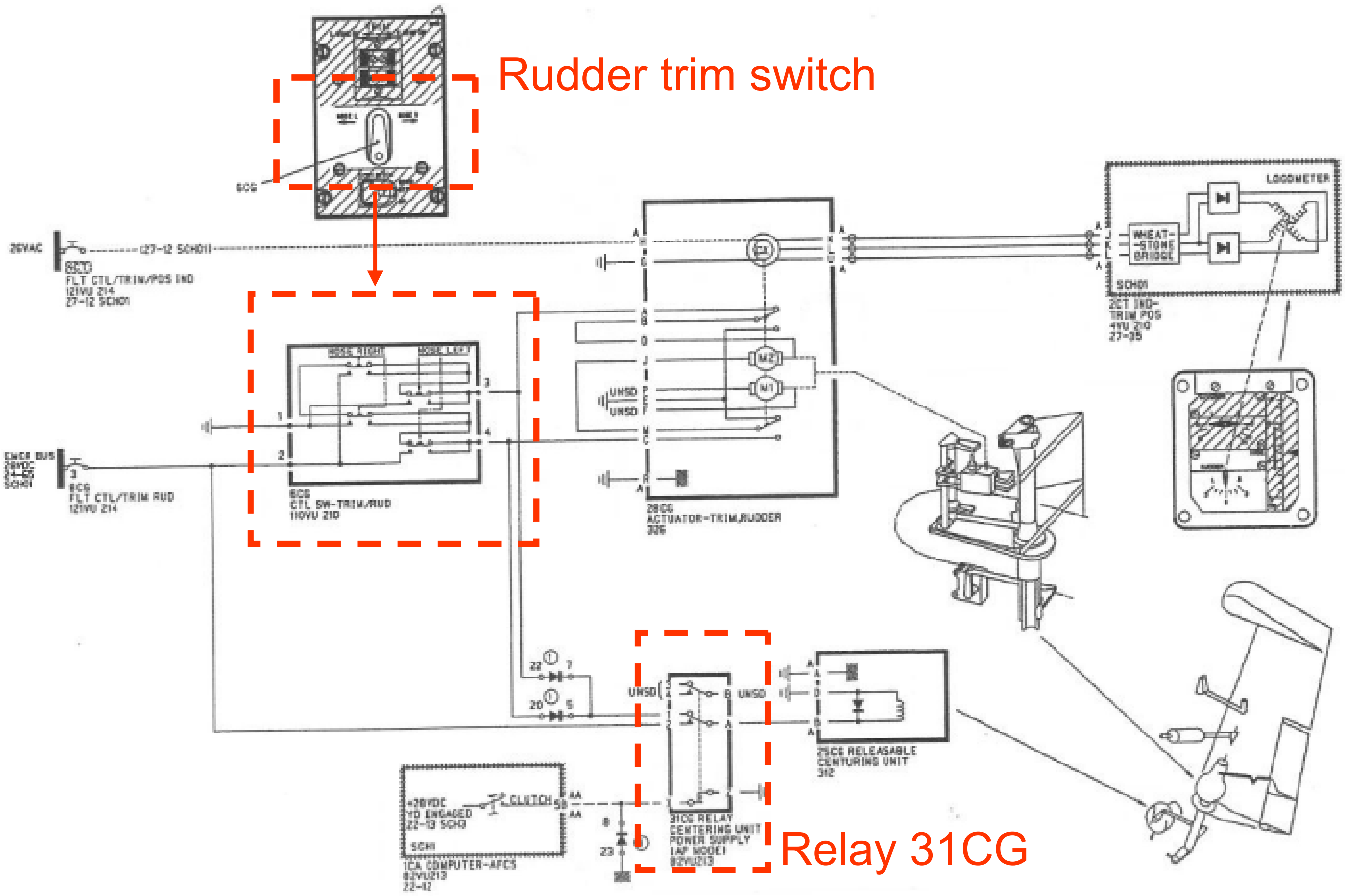

Figure 4

Yaw control schematic

achieve this, the rudder pedals must be centred by the pilot and then the rudder trim switch should be moved momentarily. This ensures that the RCU is centred about the neutral, trimmed rudder position.

Examination of the aircraft

Whilst the crew reports suggested a problem with the rudder system, the opportunity was taken to conduct a function test of the aileron system together with the hydraulically operated roll spoilers. No problems were found. Sufficient panels were removed from the aircraft interior to be able to inspect the rudder control system. With the cables so exposed, the rudder travel, trim operation and cable tensions were checked and found to be satisfactory.

The tail cone was removed, which exposed the base of the rudder and tab, together with the rudder input lever and RCU. All the components were secure and undamaged. It was also noted that the desiccant cartridge on the RCU was showing its normal blue colour (moisture ingress would cause it to turn pink). The gust damper was examined, with no evidence of loss of hydraulic fluid being found. The only untoward feature was a small amount of play in the tab bearing, but the operator's engineering staff noted that other aircraft in their ATR 42 fleet had exhibited similarly worn bearings without any detrimental effect on rudder operation.

Following communications between the operator and the manufacturer, the latter prepared a list of airframe checks to be conducted before the aircraft was returned to service; this involved a structural inspection of the fin attachment area. In addition, a number of components were changed, with the removed items being retained for subsequent testing. These were the AFCS computer, yaw servo, trim switch, RCU and the 31CG relay. Following the inspection of the airframe and installation of the replacement components, the aircraft returned to service, with no further problems being reported.

Examination of components

The AFCS computer and yaw servo were tested, under AAIB supervision, at the manufacturer's UK overhaul facility. The computer was manufactured in 1988 and was not equipped with a fault register. The unit was opened and no evidence of damage or contamination was evident. It was then subjected to a pre-flight software check, during which it was noted that there was a marked 'ripple' on a 5v dc supply that was used throughout the unit. However, it remained within the specification and was attributed to being typical of the power supply board that was used at the time of manufacture. The computer was then subjected to an automated production test, paying particular attention to the yaw damper servo sections of the procedure; no problems were encountered.

The yaw servo was also subjected to a production test; this was successful apart from the motor speed being marginally faster than the specification requirement. This was not considered to have any relevance to the subject incident.

The trim switch, RCU and relay were sent to the overhaul facilities of their respective manufacturers in France. The strip-examinations were supervised, on behalf of the AAIB, by a representative from the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile. The trim switch functioned satisfactorily on test and no significant defects were found during disassembly.

The RCU was manufactured in 1986 and had been modified by the manufacturer in 1988. The use of non-standard screws on the casing suggested that the unit had been overhauled subsequently by an organisation other than the manufacturer. Internally, it was found that the brake pads within the clutch assembly were worn, with some resultant polishing on the friction plates. This in turn had resulted in the override torque being outside the specification when tested. The manufacturer stated that this would have had no effect on normal operation of the RCU. It was additionally noted that some oxidation had occurred within the electrical connector, with the resultant white powder having coated one of the pins. Whilst this was not excessive, there was the possibility of a high resistance which, in extremis, could cause a failure of the RCU clutch to release.

The 31CG relay was tested and found to be satisfactory. It can be seen in Figure 4 that three of the contact pins are unused. The active ones were noted to be blackened as a result of electrical arcing in service but this was stated to be a normal phenomenon and had not resulted in erosion of the contacts.

In conclusion, the examination of these components did not reveal any significant defects that could realistically have resulted in a permanently released RCU. The presence of oxide on one of the RCU connector pins was not considered severe enough to cause problems, but had it done so, the result would have been a failure of the RCU to release when rudder trim was applied or when the yaw damper was engaged.

Radar and radiotelephony (R/T) information

The Stansted radar head provided position, track, groundspeed and Mode C altitude information. Magnetic headings and Indicated Air Speed (IAS) values were derived using wind data for the surface, 2,000 ft and 5,000 ft. The ground track of the aircraft is shown at Figure 1, together with wind and SID data.

Takeoff speed appeared normal, and consistent with a calculated V_2 of 104 kt. The aircraft started to drift to the left immediately after lift-off, but began to correct back towards the runway centreline before the upwind threshold was passed. However, at about 630 m past the upwind end of the runway (2.0 nm from the 'ISX' Distance Measuring Equipment (DME), which was zero ranged to the runway threshold), the aircraft started to drift left again, and from that point flew an almost steady track of 215º. The aircraft levelled at 3,000 ft at 2.4 DME, after which groundspeed began to increase. At the 2.9 DME turn point, the aircraft was heading 225º, tracking 10º left of the centreline and displaced from it by 0.25 nm to the left (south of the centreline).

The IAS increased to between 220 and 230 kt. When the Stansted controller noticed the aircraft was not flying in accordance with the SID, he instructed the crew to turn right to a heading of 360º. The co-pilot acknowledged the instruction, adding "WE'VE GOT A SYSTEMS PROBLEM, WE'RE JUST TRYING TO RESOLVE IT". The turn commenced at 6.4 DME, during which IAS reduced to about 195 kt. When the turn was complete, the aircraft maintained a steady track consistent with a heading of 360º and IAS continued to reduce to about 180 kt. The measured turn rate was 1.824º/sec, equivalent to a rate 0.61 turn. The bank angle required to achieve this turn performance under steady state conditions would have been 17.9º.

The co-pilot transmitted "WE DO SEEM TO HAVE A MAJOR PROBLEM HERE WITH THE FLIGHT CONTROLS, WE WOULD LIKE RADAR VECTORS TO RETURN TO THE FIELD PLEASE". The controller asked if the crew would be able to make a normal approach and the co-pilot said "AFFIRM…NOT A PROBLEM AT THE MOMENT…" When the controller then requested the nature of the problem, the co-pilot replied "…SEEM TO HAVE REDUCED CONTROL IN BOTH AILERON AND RUDDER AT MOMENT BUT WE CAN'T IDENTIFY THE PROBLEM". The controller asked if the crew were declaring an emergency to which the co-pilot declared "NEGATIVE AT THIS TIME". However, after further discussion between the crew about the advisability of declaring an emergency, the co-pilot transmitted "…OUR PROBLEMS SEEM TO BE INCREASING, WE ARE NOW DECLARING AN EMERGENCY".

The crew were instructed to turn right onto 040º. After rolling out of the turn, the aircraft achieved a steady track of 050°, consistent with the heading. A rate of 2º/sec (rate 0.67) was achieved during the turn, which would have required an average bank angle of 19.5º. Following further ATC instructions to turn left to 030º, the aircraft stabilised on a track of 043º. At this point the aircraft had 9º right drift and the IAS had reduced to about 175 kt.

Initially, the turn rate towards finals was noticeably lower and the aircraft flew through the runway centreline. About 40 seconds after starting the turn, the aircraft started a descent to 2,000 ft on ATC instruction. IAS during the initial turn and descent showed an increase, and averaged about 205 kt, with groundspeed reaching between 220 and 230 kt. Between the point that the aircraft turned right from the downwind track and when it levelled at 2,000 ft, the achieved turn rate was only about 1.1º/sec, or rate 0.37, equivalent to about 12º angle of bank in steady conditions.

Accurate IAS values for the remainder of the turn onto finals were difficult to establish. Aircraft IAS appears to have stabilised about 190 kt, with a reduction starting as the aircraft turned through a south-westerly heading (the groundspeed fell more rapidly than the change of relative wind alone would account for). During this period the turn rate increased significantly. Assuming an IAS range of 160 kt to 190 kt, the required bank angle would have been between 19º and 23º. The aircraft stabilised on a heading 35º right of the runway QDM, with an IAS of about 160 kt.

At about 7 nm from touchdown the crew received landing clearance. The radar-derived approach profile is shown at Figure 5. At 5.5 nm from touchdown, ATC instructed the crew to turn left onto 250º, to descend to 1,700 ft altitude and either report established on the localiser or call "visual". The co-pilot reported established and the controller cleared the crew to descend on the ILS. However, the aircraft descended below 1,700 ft before reaching the glideslope and was about 300 ft to 400 ft below it at 4 nm. At about 3.5 nm from touchdown the aircraft started to deviate further below the glideslope until it levelled at about 500 ft above airfield level (aal). It then descended further to about 300 ft aal which it maintained until intercepting the normal approach path at about 1 nm from touchdown.

At about 2 nm from touchdown there was a significant speed reduction below about 160 kt which, from the pilots' reports, would be coincident with the selection of flap 15. Wind reports from ATC showed a fairly steady surface wind from 240º at 16 to 18 kt. After landing, ATC asked if the crew were able to vacate the runway normally. The co-pilot replied "AFFIRM, FULL CONTROL ON THE GROUND".

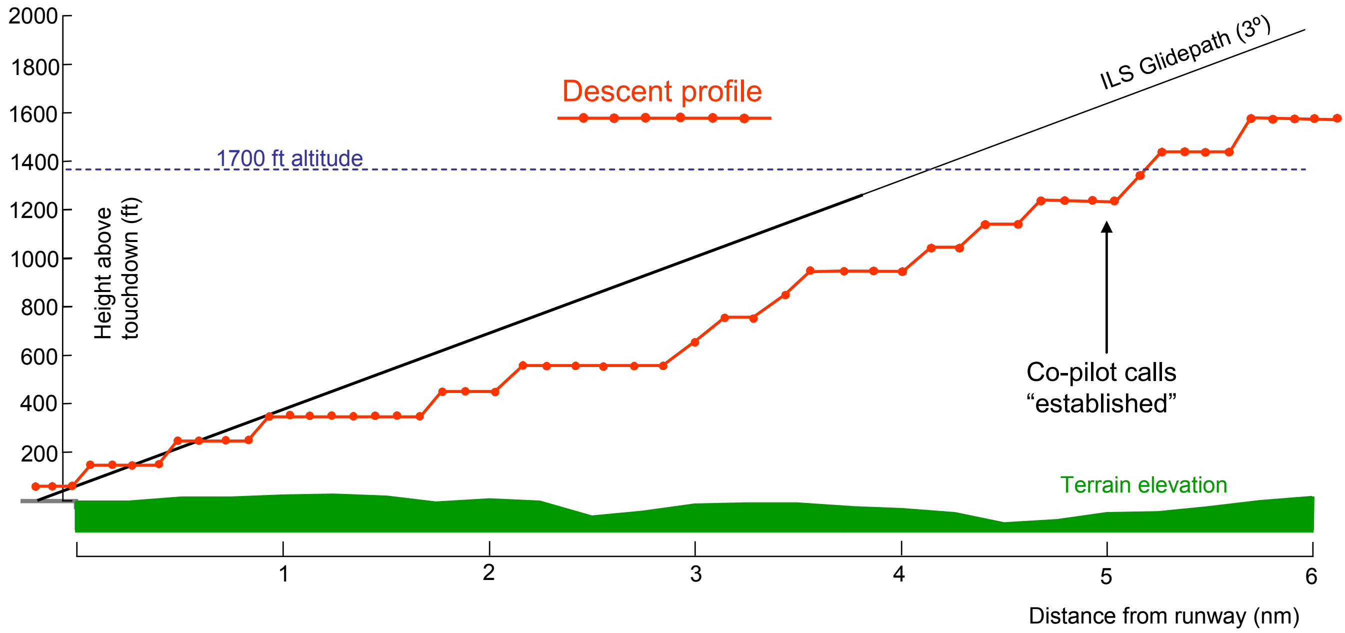

Figure 5

Final approach

Flight recorders

General

The aircraft was equipped with a Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR), capable of recording a minimum duration of 25 hours of data and 30 minutes of audio respectively. In addition, the aircraft was equipped with a Quick Access Recorder (QAR), which would record the same data as that recorded by the FDR. The FDR system recorded a total of 58 parameters which included the position of the rudder, lateral acceleration and the left aileron position. Sampling rates for both the rudder and left aileron position were four per second. The rudder pedal and control wheel positions were not recorded. A plot of the salient FDR parameters is at Figure 6.

The FDR and CVR were removed from the aircraft and replayed at the AAIB. The incident flight, from 'before takeoff' checks to final aircraft shutdown, was available from the CVR. When the FDR was replayed, it was found that only two minutes of the flight had been recorded. Further analysis identified that the 25 hours of data consisted of only partial sections of flight. The operator subsequently replayed the QAR media, but it was found to contain no data. A mechanical fault was later identified with the QAR unit, preventing the media from being correctly inserted.

FDR information

Reliable FDR data became available about 40 seconds after takeoff, as the aircraft was climbing through 1,500 ft, configured with 15° flap, landing gear retracted and the autopilot not engaged. Engine torques and propeller speeds on both engines were stable and power was set at the climb setting. Indicated airspeed was 115 kt. Lateral and vertical accelerations confirmed the turbulent conditions reported by the crew.

During the two minutes of FDR data, significant rudder travel and lateral control inputs were recorded. Soon after the data began, the rudder (which had been displaced to the left) moved right through 11.6º of travel (about 20% of its range), to 6.8º right deflection (Figure 6, Point A), the maximum recorded. Simultaneously, a left roll input was made, and the aircraft reached 6º right bank, also the maximum achieved during the recorded period (Figure 6, Point A). The greatest recorded aileron deflection during the period was 4.5º. The maximum possible surface deflections for the rudder and aileron were +/-30º and +/-14º respectively. At aileron deflections greater than 2.5º the wing spoilers would begin to deploy on the down-going wing.

The next three oscillations shared similar characteristics of rudder motion and lateral control input. On each occasion the rudder moved rapidly from its right deflected position to the left (maximum travel was nearly 13º), in one second or less, accompanied by an opposite roll control input over the same duration. The rudder then returned to the right at a slightly lower rate, with a similarly slower roll input. The period of these oscillations was between 4.3 and 5 seconds.

The applied lateral control input did not always appear to be in response to aircraft rolling motion, particularly during the most significant recorded oscillations. From Point A, the rapid reversal of roll input to the right was initiated when the aircraft was both banked slightly to the right and rolling to the right, a situation repeated during the next oscillation. The initial right bank coincided with the correction back to the runway centreline, after the aircraft drifted left just after lift off. The subsequent left bank resulted in the aircraft stabilising about a mean heading of 225º, which was also the runway heading, and consistent with the ground track seen on radar.

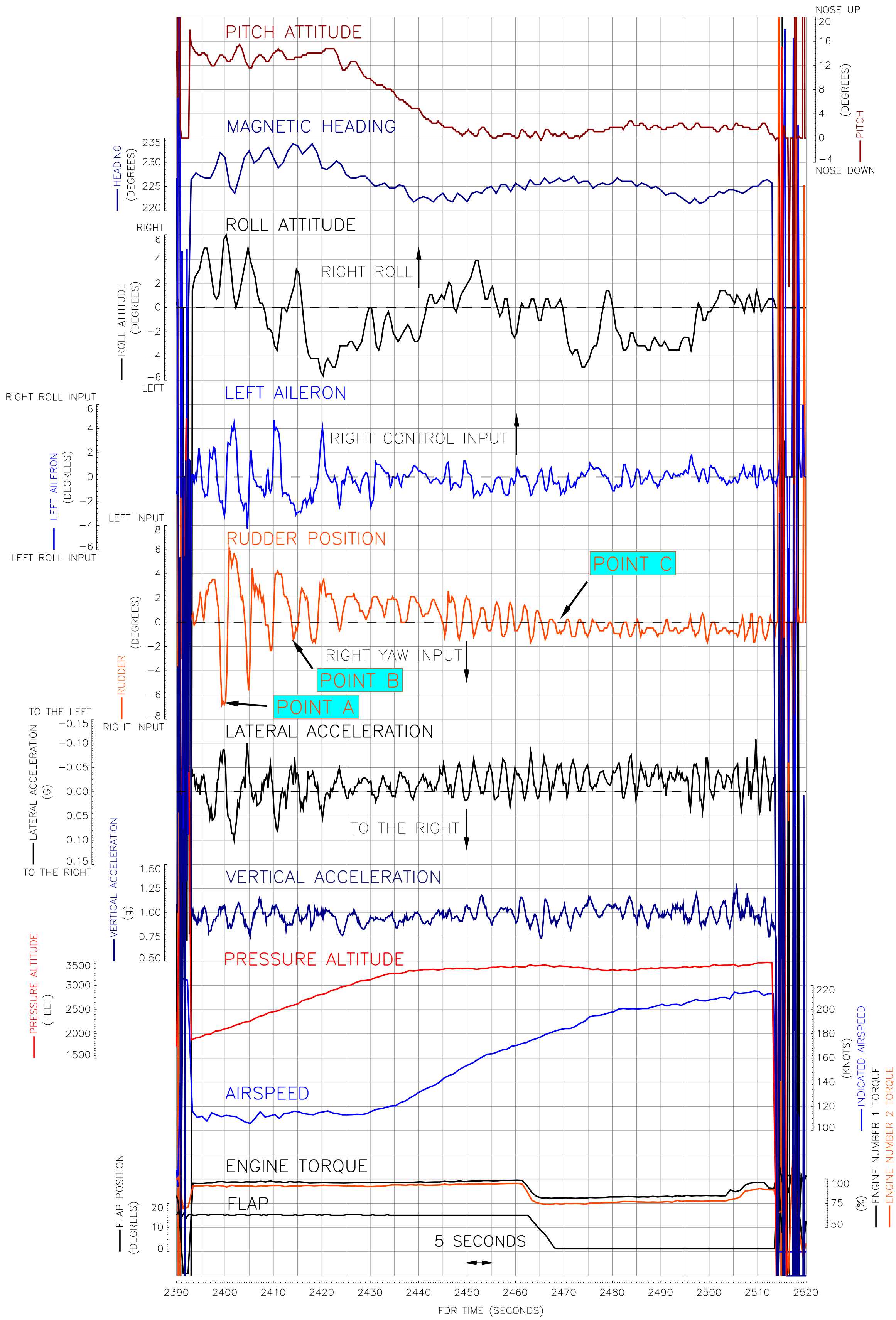

Figure 6

Salient FDR parameters

The oscillation starting at Point B differed from the previous three in that the left roll input was maintained whilst the rudder moved through a similar motion, though with reduced amplitude. On the next oscillation a roll input similar to the earlier oscillations was made, and the rudder travel increased slightly again. A further series of oscillations, with much reduced rudder travel and lateral input, was seen as speed increased with flaps still extended, just before engine power was reduced and flaps retracted (Point C). At this point there was an almost coincident reduction in the magnitude of the rudder oscillations. For most of the remainder of the recording, rudder position movement was small and appeared related to the background turbulence.

CVR information

The CVR recorded the 'before takeoff' checklist and responses, during which the commander confirmed that the flying controls had been checked and the rudder cam was centred. The takeoff phase sounded normal until just after the landing gear was raised, when the commander noted that the heading reference bug was incorrectly set and asked the co-pilot to reset it. Nineteen seconds after the co-pilot's "ROTATE" call, the commander said "WHY IS THE AIRCRAFT GOING LIKE THAT?" Three seconds later, a caution chime was heard and the co-pilot said "YAW DAMPER'S DISENGAGED FOR SOME REASON". The commander replied "YEAH AND THE AIRCRAFT IS GOING FROM SIDE TO SIDE". Ten seconds later, just before the FDR data starts, the co-pilot said "AFCS INVALID". Just after Point A at Figure 6, the commander said "THE AIRCRAFT IS TURNING FROM SIDE TO SIDE". Before the aircraft levelled at 3,000 ft, the co-pilot attempted to engage the yaw damper again. A further audio chime was heard and the co-pilot said "NO IT JUST SAYS AFCS INVALID". When the motion had subsided, 23 seconds before the end of available FDR data, the commander said "ITS ROCKING BUT THAT'S PROBABLY BECAUSE OF THE YAW DAMPER ISN'T IT?" and the co-pilot agreed.

During initial radar vectoring, the commander said "I MEAN WE JUST HAD NO CONTROL WHATSOEVER." The co-pilot said "IT'S JUST THE YAW DAMPER" to which the commander replied "BUT IT'S JUST - THE AIRCRAFT IS IMPOSSIBLE TO CONTROL". Five minutes after takeoff, as the aircraft was flying downwind, the commander commented "IT'S CALMING DOWN A BIT … BUT IT WAS COMPLETELY OUT OF CONTROL". Although the co-pilot indicated on the R/T that the problem was worsening when he formally declared an emergency, the CVR suggested this was not the case. It was done after the crew discussed it and agreed that it was the correct course of action.

During the right turn towards final approach, the commander seemed unsure if the aircraft was actually turning. She asked the co-pilot "AM I TURNING NOW?". He replied "SLOWLY" then "YEAH, YOU'RE NOT TURNING", then a short while later "OK YOU'RE IN THE BANK NOW THAT'S FINE". Later, as the aircraft was being vectored for the approach the commander initiated a discussion about whether the problem could be due to abnormal propeller pitch. Although the co-pilot observed that there had been no unusual engine or propeller indications, the commander became convinced that a propeller pitch problem existed, and continued to refer to it until after landing.

The co-pilot became visual with the runway about 6 nm from touchdown, but the commander did not see it until later when the co-pilot was able to 'talk' her eyes on to it. The co-pilot warned her about the aircraft's height and speed when it began to deviate, and the commander asked him to assist by controlling the power levers as she was again finding it increasingly hard to control the aircraft. After a brief discussion, it was decided to land with a reduced flap setting.

During the approach the Enhanced Ground Proximity Warning System (EGPWS) Mode 5 "GLIDEPATH" alert sounded. In the latter stages of the approach the co-pilot warned "WATCH YOUR HEIGHT", just before the EGPWS 500 ft height call-out occurred, followed immediately by the 'landing gear not down' aural warning and the EGPWS Mode 4 "TOO LOW FLAPS" alert call-out. Co-incident with this, the co-pilot announced that he was lowering the landing gear, and also selected Flap 15. He again warned the commander "KEEP YOUR HEIGHT" (Figure 5 shows that the aircraft levelled at about 500 ft for a time). The co-pilot announced that the landing checklist had not been completed, but confirmed to the commander that the landing gear and flaps were correctly set. The EGPWS "TOO LOW FLAPS" and "GLIDEPATH" alerts continued until touchdown.

Only a single CCAS audio chime was heard which could not be related to a known event. This occurred when the aircraft was nearing final approach, but neither pilot was heard to comment on it.

CVR – Crew Resource Management (CRM) aspects

The event had a significant adverse impact on standard flight procedures and CRM. Although each pilot referred at different times to the problem being associated with the yaw damper's failure to engage, there was no formal troubleshooting or review process, so the Quick Reference Handbook (QRH) was not consulted. There was no briefing for the approach, and no descent, approach or landing checklists were carried out. Although the approach culminated in a reduced flap landing, because this was a late decision the implications were not fully considered beforehand, resulting in the EGPWS flap warning. However, despite the obvious distraction, the crew collectively identified the flight path excursions on final approach (although the actual correction was quite late) and were able to work together in the latter stages when the commander asked for assistance with the engine controls.

Dutch roll

When an aircraft is yawed, it also rolls. This is because of the different airspeeds experienced by each wing, and the consequential imbalance in generated lift. A Dutch roll is a combination of yaw and roll in which the aircraft experiences a continually reversing yawing/rolling motion. The relationship between an aircraft's lateral and directional qualities determine how susceptible it will be to Dutch roll. An aircraft with dominant directional stability will tend to be spirally unstable, while an aircraft with excessive lateral stability will have a greater tendency to Dutch roll. Dutch roll is normally associated with swept wing aircraft (whose tendency to roll with yaw is greater than for comparable straight wing aircraft) and high altitude flight, where aerodynamic damping is reduced.

Whilst a stable or even neutral Dutch rolling tendency need not present a significant challenge to a pilot, assistance is normally required to prevent the task of piloting such an aircraft from becoming too demanding or tiresome with time. A Dutch rolling tendency usually results from a lack of effective fin and rudder area. If the rudder is allowed to trail downwind in a sideslip, the effectiveness of the fin is reduced and hence the aircraft will be more likely to Dutch roll. In the case of a hydraulically powered rudder, the rudder does not trail downwind in a sideslip, thus increasing the fin's effectiveness. Alternatively, or additionally, a yaw damper can be used to sense developing yaw and apply a corrective rudder input.

The ATR 42 is equipped with a yaw damper. However, as the rudder is not hydraulically powered, it would be prone to trail downwind to some degree if the aircraft were to experience side-slip (thus reducing directional stability) when the yaw damper was not engaged. The RCU is intended to increase the aircraft's resistance to Dutch roll, in this case by keeping the rudder centred about the trimmed position until a threshold force is applied by the pilot to move the rudder. If the RCU fails, or its centred position differs significantly from the aerodynamically trimmed position, the benefits provided by the RCU in terms of directional stability will be lost. In this case, the situation can only be restored if the pilot exercises positive and continuous control through the rudder pedals to ensure that the rudder does not move from its desired, trimmed position.

Certification flight tests

During certification flight tests of the ATR 42, the aircraft's Dutch roll characteristics following simulated RCU failures were demonstrated at altitudes between 7,000 ft and 10,000 ft. The failures considered were a) yaw threshold loss (ie permanent failure of the RCU clutch to engage), and b) rudder threshold centring loss about the trimmed position (ie RCU centred about a position other than the trimmed one).

In both cases the test report noted that Dutch roll could easily be stopped by *'locking the (rudder) pedals with the feet or engaging the yaw damper'*. Both failure cases were classified as 'minor'. Figure 7 depicts, in simplified form, a Dutch roll-induced during flight test with both the yaw damper and RCU disengaged. This is overlaid with the data from the incident flight to allow a direct comparison.

At a meeting between the AAIB and the manufacturer, a flight test department representative described the aircraft's handling qualities in respect of its natural Dutch roll tendency and behaviour in RCU failure cases. It was stated that the ATR 42 will not naturally enter a Dutch roll, which had to be induced and aggravated during test

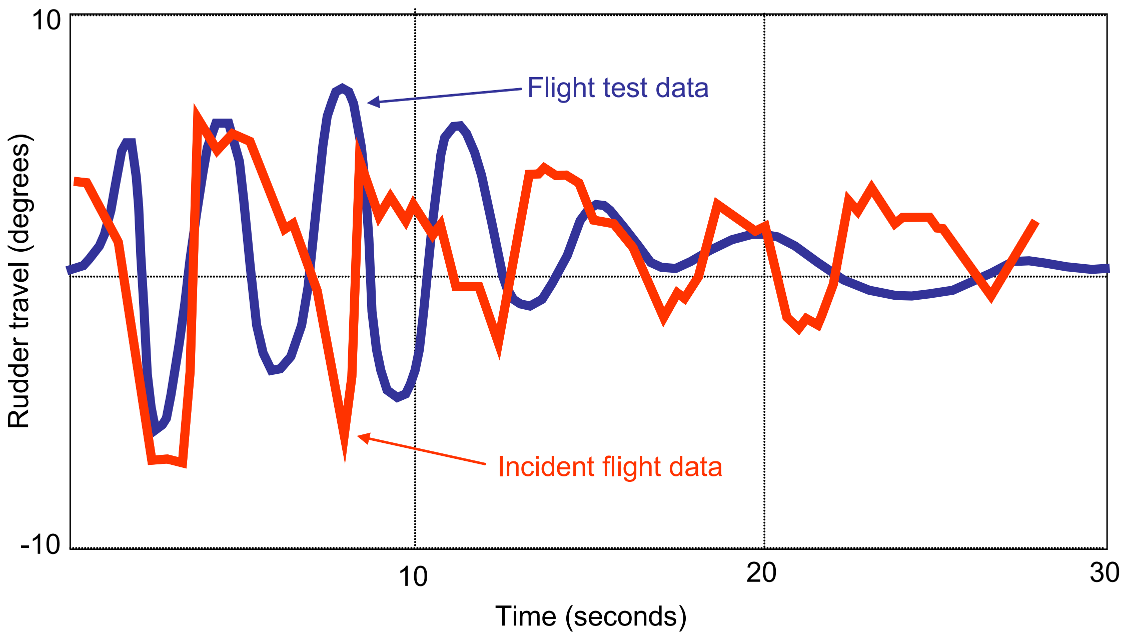

Figure 7

Incident FDR plot overlaid on flight test Dutch roll data flights by positive application of rudder. The Dutch roll motion was more pronounced at aft centres of gravity and with full flap selected, particularly approaching the flap limiting airspeed. However, takeoff flap was not considered to have a significant effect.

The RCU was described as being required only to stop minor yaw oscillations involving small rudder deflections. If the RCU was not correctly centred about the rudder trimmed position for takeoff, it would not significantly affect the aircraft's handling; the test certification paperwork stated that many takeoffs had been made in this condition without a problem, and that Dutch roll, when it appeared, was easily stopped by the actions described above.

Although the observed motion bore some similarities to a Dutch roll, it was not the same. In particular, the uneven and high rates of rudder travel were not natural motions, and the frequency was different. Although coarse use of roll control (involving activation of wing spoilers) would induce yaw, it was considered that the only way in which the rudder could move in the way it did was though the direct assistance of the spring tab, ie by pilot application. It was stressed that the rudder damper also operates during flight, so always acts to limit the rate of rudder travel.

Information to flight crews

A Flight Crew Operating Manual (FCOM) was produced by the aircraft manufacturer and contained information, guidance and procedures for flight crews. Concerning the yaw control system, the FCOM contained four relevant sections: a technical description of the system, a *'procedures and techniques'* section, a *'normal procedures'* section (which included pre-flight system checks), and procedures to be followed in the event of system failures.

The *'procedures and techniques'* section described the purpose and normal use of system features. Concerning the RCU it stated:

> *'The threshold cam automatically synchronises to actual rudder pedal position each time the rudder trim switch is activated. Therefore, before take-off, the rudder trim setting must be made with rudder pedals in neutral position'*

and:

> *'As far as Dutch roll is concerned, yaw damper action (if selected) or RCU are sufficient to adequately dampen Dutch roll oscillations. The rudder should not be used to complement yaw damper action'*

The operator produced its own Standard Operating Procedures (SOPs), based upon those contained within manufacturer's FCOM. They described the before-takeoff check of the rudder and RCU thus:

> *'**CM1**[1] checks full and free rudder movement, left spoiler if visible, and with rudder neutral, centres the rudder cam'*

The FCOM *'Procedures following failure'* section detailed the crew action for an RCU failure in the format shown in Figure 8.

The FCOM also contained a procedure with the title *'AILERON MISTRIM MESSAGE, or EXCESSIVE LATERAL TRIM REQUIRED or ABNORMAL FLIGHT CHARACTERISTICS OF THE AIRPLANE'*. Although one of the conditions for initiating the drill was

Footnote

[1] CM1 – left seat pilot and normally the commander, as in this case.

RUD RELEASABLE CENT UNIT FAIL

ALERT

There is no indication of a rudder releasable centering unit failure other than a dutch roll oscillation tendency

PROCEDURE

RUD RELEASABLE CENT UNIT FAIL

- If YD is available

  YD -- ENGAGE

- If YD is not available

  KEEP THE FEET ON THE PEDALS

Figure 8

FCOM Procedure for RCU failure

'abnormal flight characteristics of the aircraft', the procedure addressed only lateral control problems. The associated actions were to disconnect the autopilot and fly the aircraft manually prior to adjusting lateral trim. There was no information concerning problems with yaw axis control.

Both of the above procedures were also contained within a Quick Reference Handbook (QRH), immediately available on the flight deck. However, the RCU failure drill in the QRH did *not* contain the alert statement:

> *'There is no indication of a rudder releasable centering unit failure other than a Dutch roll oscillation tendency.'*

The manufacturer's Master Minimum Equipment List (MMEL) allowed for aircraft dispatch with the RCU inoperative, provided that the yaw damper was operative and used or, if it was not, for a maximum of two flight legs. The related operational note for the latter case stated:

> *'If the yaw damper is inoperative, PF [pilot flying] will keep his feet on the pedals to be ready to control rudder.'*

Previous occurrence

The manufacturer was aware of only one other similar incident. This 1990 event occurred whilst the aircraft was making an approach to land when the yaw damper disengaged and could not be re-engaged until the AFCS computer had been re-set. During this period, the aircraft rolled ± 15°. The subsequent investigation revealed that a link attaching one of the springs within the RCU had failed.

FDR system fault

System description

The FDR system consists of three primary components; the FDR, a Flight Data Acquisition Unit (FDAU) and a Flight Data Entry panel (FDEP). The purpose of the FDAU is to acquire and process information from the various aircraft systems and sensors before transmitting data to the FDR to be recorded. On the ATR 42, the

FDAU also computes the engine target torque, which is displayed on the engine torque indicators on the flight deck. The FDEP is located in the flight deck, towards the rear of the centre instrument pedestal. Its primary purpose is to indicate the status of the FDR system. This is accomplished by illuminating two integral indicators if the FDR, FDAU or FDEP fail. As is common in most FDR installations, there is no associated aural warning or indication on the CCAS panel should the FDR system fail. A test of the system can be readily accomplished by activating a switch in the flight deck.

As well as each component part of the FDR system having a Built In Test (BIT) function, the system also incorporates a 'loop back' check of the aircraft wiring between the FDAU and FDR. In the event that data is sent to the FDR but not recorded, a fault will be indicated on the FDEP. Failure of the FDR to record may be due to electrical power loss, loss of the incoming data signal from the FDAU or an internal fault in the FDR itself. The FDEP fault indicators will remain illuminated for the period that a fault is detected, but will extinguish if the fault subsequently clears. The system does not provide a historical log of failures.

In normal operation, the FDR system is electrically powered prior to flight. The FDAU and FDEP are powered from a separate source through one relay. If, during normal operation, the FDAU/FDEP relay failed such that power was removed from the FDAU and FDEP, both units would stop functioning, rendering the FDR system inoperative. In this case, the FDEP fault indicators would not illuminate, as the status function would also be inoperative. However, the fault would result in the loss of the target torque parameter (provided by the FDAU). Both the aircraft manufacturer and operator advised that the loss of the parameter would be readily identifiable during normal operation of the aircraft.

FDR system defect

The FDEP fault indicators were confirmed as being serviceable and both the FDR and FDAU were replaced. The replacement FDR was a different model from the one installed at the time of the incident, recording data into a solid state memory rather than a magnetic tape. Shortly after the aircraft had returned to service, the operator performed a readout of the FDR which revealed that the defect was still present. The FDR was replaced again and the FDAU/FDEP electrical relay was also replaced; subsequent readouts of the FDR and QAR indicated that the fault was no longer present.

Although the fault cleared after the FDR was replaced a second time, it is unlikely that both the incident and first replacement FDRs were defective. The first replacement unit was of a different type from the FDR installed during the incident, making it unlikely to have developed a similar fault. As the replacement FDAU had not been further disturbed when the fault eventually cleared, it is probable that the FDAU installed at the time of the incident was also serviceable. If the FDAU/FDEP relay had failed, the loss of the target torque indication for a considerable period of time would probably have been detected by flight crews. No such loss of indication was reported. It was therefore unlikely that the system fault was due to a defective FDR, FDAU or FDAU/FDEP electrical relay.

The fault was most likely to have been a result of an intermittent electrical connection, which was resolved during the second FDR replacement. A loss of the data signal from the FDAU to the FDR, or FDR electrical power would have resulted in the FDR stopping. As it was unlikely that the FDAU/FDEP relay had been the cause of the defect, it can be assumed that a system fault indication on the FDEP would have been present. Based on the FDR data, a fault would have been indicated for prolonged periods of time during at least the previous 25 hours of aircraft operation, both on the ground and in flight. The operator advised there had been no associated reports of a FDR system defect prior to the incident. The last readout of the FDR had been performed in July 2005 and no defects were found.

Regulatory requirements

The readout requirement for EI-SLD had been set by the Irish Aviation Authority (IAA) at once every two years. However, some of the operator's other ATR 42 aircraft had readouts conducted at intervals of 12 months. The operator advised that the difference arose because the previous operator of these aircraft modified the recording systems and specified 12 month readouts for some of them. The operator has now aligned the fleet readout period at 12 months.

The Standards and Recommended Practices (SARPS) contained in ICAO Annex 6 Part I stated that an annual readout of the FDR should be performed and that a complete flight from the FDR should be examined in engineering units to evaluate the validity of all recorded parameters. JAR-OPS 1[2] provided for the preservation of FDR recordings but it did not include a requirement to perform a routine readout of the FDR. This differed from JAR-OPS 3 (applicable to helicopters) which did include a requirement to readout the FDR within the last 12 months.

On 1 October 2007, the AAIB issued the following Safety Recommendation in response to FDR deficiencies identified during the investigation of a runway overrun accident involving a Fairchild SA277 AC Metro III, registration EC-JCU:

Safety Recommendation 2007-60

It is recommended that the European Aviation Safety Agency require operators to conduct an annual operational check and evaluation of recordings from FDRs to ensure the continued serviceability of the system. The annual check should require, as a minimum, a readout of the FDR and an evaluation of the data, in engineering units, in order to establish compliance with recording duration, error rates and validity of all recorded parameters.

The European Aviation Safety Agency (EASA) responded on 14 November 2007 stating that:

'Consideration is given as to making these provisions part of the relevant European regulations.'

The status was identified as 'open' by EASA, and remains so at the time of writing.

In addition to the annual readout, ICAO Annex 6 Part I addressed the requirement for a routine check of the FDR system Built-in-Test (BIT) thus:

'Prior to the first flight of the day, the built-in test features on the flight deck for the CVR, FDR and Flight Data Acquisition Unit (FDAU), when installed, should be monitored.'

JAR-OPS 1 partially addressed this requirement, referring operators to EUROCAE document ED55 for the FDR check, but the applicability was only for aircraft first issued with a Certificate of Airworthiness (C of A) after 1 April 1998. The C of A for EI-SLD was first issued in 1985. It should be noted that JAR-OPS 1 was compliant with ICAO with regards to a requirement for a daily check of the CVR when one is fitted.

Footnote

[2] JAR-OPS contains the operational requirements for European Joint Aviation Authorities operators engaged in Commercial Air Transport operations.

The operator carried out a Flight Data Monitoring (FDM) programme on its ATR 42 fleet, supported by data from the QAR. The FDM programme was performed on a voluntary basis as the aircraft was less than the 27,000 kg mass limit specified by JAR-OPS 1. The last available QAR data was from 11 October 2006. Data from between 2004 and 2006 was analysed, with no evidence of a recording defect.

Analysis

General

The limited FDR data supported the crew's reports that the aircraft was subject to an unusual motion which combined yaw and roll, and which varied in severity throughout the flight. However, the recorded data as a whole suggested that there was more flight path control available than the crew perceived or recalled. It is not certain that the recorded oscillations were representative of the motion at its most severe, but the crew's remarks on the CVR during the FDR data period suggest that it was.

The motion was clearly such that it interfered with the crew's ability to manage the flight and to troubleshoot the problem. It ultimately resulted in an unstable final approach which generated EGPWS warnings. Although the aircraft's behaviour caused the crew the most concern, its contribution to the unstable final approach must be seen as the most significant aspect of the incident.

Crew recollections

Some of the co-pilot's responses to ATC and the delay in declaring an emergency were at variance with the commander's comments about the aircraft being out of control, although both pilots were in agreement that the motion was very uncomfortable. The commander recalled that the aircraft could only just be made to turn right with full right lateral control, but this was not supported by the recorded data. The FDR data showed that the aircraft was capable of responding to lateral control input, but that the input itself was reversing relatively quickly from one direction to another, apparently in direct opposition to the yawing motion. The aircraft's heading during the recording period stabilised on the runway heading, which was maintained without significant lateral inputs. The aircraft therefore drifted left of the departure track not because of restricted control authority, but because the heading did not take into account the effect of the wind.

The turn rates seen on radar (which were nearly all to the right), were generally equivalent to moderate angles of bank. The notable exception was the initial turn towards finals, but the CVR data suggested that the angle of bank increased in response to the co-pilot's remarks, so it is more likely that this was due to pilot input rather than reduced control authority. This was at the same time as a descent was starting which, given the degree of control difficulties the commander reported, could have lead to an inadvertent reduction in turn rate as she concentrated on the vertical flightpath. The aircraft was flying at a relatively high groundspeed at this stage which, combined with the effect of the wind, meant that any prolonged reduction in applied bank would have caused the aircraft to fly through the runway centreline, as occurred.

After the flight, both pilots said that they had assumed they were dealing with a rudder problem but, apart from brief references to the yaw damper soon after takeoff, neither voiced this during the flight. In the case of unusual control problems it may be desirable to hand over control of the aircraft for a while when safe to do so, to gain the second pilot's view of the problem which could assist with troubleshooting. This action has the added advantage that, if the handling pilot is inadvertently influencing the situation, this may be detected. As the co-pilot did not handle the controls in this case, his perception of the problem must have been influenced by the commander's description.

Aircraft oscillations

The co-pilot recalled that the yaw damper would not engage after takeoff, and on the CVR stated that the yaw damper had "…DISENGAGED FOR SOME REASON", a remark accompanied by an audio chime. This was after the commander had made her initial comments about the aircraft's motion, so it is uncertain whether the yaw damper engaged for a short while only or not at all. Initial selection of the yaw damper may have been delayed whilst the co-pilot reset the heading reference bug at the commander's request. If this had been the case, and the yawing motion had become established before the yaw damper selection was made, there could have been erroneous or inconsistent air data inputs to the AFCS computer, which would account for the AFCS INVALID message and failure of the yaw damper to engage. Rudder movement alone would not have inhibited yaw damper engagement, unless it was associated with high pedal forces.

An RCU fault could have contributed to the motion, although no significant defects were found with the unit and there had been no similar events involving this aircraft reported beforehand. Although thought unlikely by the manufacturer, the oxidation that had occurred within the RCU electrical connector could possibly have caused a failure of the RCU clutch to release when commanded by a trim or yaw damper command. However, as the RCU clutch would normally be engaged during initial climb out anyway, it is unlikely that this was a contributory factor, provided the RCU was centred correctly.

Had the RCU *not* been correctly centred prior to takeoff, the benefits in terms of Dutch roll stabilisation afforded by it would have been lost or reduced, depending on how far the actual RCU datum was from the aerodynamically trimmed position. The commander correctly replied to the before-takeoff checklist item so it must be assumed the check was carried out correctly. However, if the RCU clutch had failed in a permanently engaged state sometime before this, the checklist actions would not have been effective and the RCU would have remained at whatever datum it had adopted beforehand, which may not have been appropriate for takeoff.

If this was the case, it would have introduced a continuous centring force towards a non-trimmed position as well as reducing the aircraft's resistance to Dutch roll. The fact that positive rudder inputs would have been required during the slightly crosswind takeoff roll may have masked this until the aircraft was airborne. A failure of the clutch to disengage when commanded would also account for the failure of the yaw damper to engage.

At the altitudes, configurations and airspeeds concerned in this incident, the aircraft would not have had a significant natural Dutch roll tendency. Certification flight tests had been conducted at higher altitudes where Dutch roll was more likely and had shown that the aircraft would readily recover once appropriate action was taken by the pilot. Any failure of the RCU would not have caused the motion if the commander had taken the action of preventing rudder pedal movement by firmly placing her feet on the rudder pedals, although this was not adequately described in the flight manuals. Had she left the pedals free, and a Dutch roll had developed, it would not have generated the rudder movement seen on the FDR data, although coarse lateral control inputs would have produced a secondary yaw effect.

If the aircraft had become airborne in a slight slip (as it would for a crosswind takeoff), with the RCU not centred and in turbulent conditions, it is conceivable that these conditions would have initiated yaw oscillations before the co-pilot was able to engage the yaw damper (which he may not have attempted immediately due to the commander's instruction to reset the heading bug). However, the subsequent rate and amount of rudder movement (which were not natural and were unlike that seen during certification flight tests) could only have been generated by the servo tab. Given that the rudder control system was examined and found serviceable after landing, the driving force could only have been supplied by one of the pilots. It is therefore likely that the motion was due, at least in part, to a pilot-induced oscillation (PIO).

Prevention and recovery actions

With the widespread use of reliable and sophisticated yaw dampers on modern aircraft, Dutch roll has become a phenomenon which is possibly less well understood by today's flight crews than those of earlier generation transport aircraft. Thus, it is important that correct information is available to crews and that they be aware of the correct recovery actions should the protection afforded by modern aids be lost. Although the purpose of the yaw damper is likely to be well understood by flight crews, that of the RCU may not. RCU failure cases were regarded by the manufacturer as 'minor', and so not the subject of detailed training.

Although the flight test report stated that Dutch roll could be easily stopped by *'locking the pedals with the feet',* this advice did not appear in any of the normal flight operations or training documentation. The RCU failure actions merely stated 'KEEP FEET ON THE PEDALS', which did not adequately describe the full corrective action. In flight, crews would normally refer to the QRH in abnormal or failure situations. An average crew, dealing with an unusual aircraft motion would be most likely to consult the lengthily titled QRH item *'AILERON MISTRIM MESSAGE, or EXCESSIVE LATERAL TRIM REQUIRED or ABNORMAL FLIGHT CHARACTERISTICS OF THE AIRPLANE'.*

It was therefore recommended that:

Safety Recommendation 2008-017

ATR should amend the ATR 42 Quick Reference Handbook (QRH) and Flight Crew Operating Manual (and those of other ATR types if similarly affected), to include in the Releasable Centring Unit failure actions the requirement that pilots must lock the rudder pedals by the feet to prevent unwanted rudder pedal movement. The revised RCU failure actions should be incorporated (or referred to) in the QRH actions concerned with abnormal flight characteristics of the aircraft.

Aircraft dispatch with both the RCU and yaw damper inoperative was allowed under the provisions of the manufacturer's MMEL, although such operations were limited to two flight legs. This would be to enable an aircraft to be flown to a maintenance base for rectification. However, the operational note that the pilot keep his feet on the rudder pedals 'to be ready to control the rudder' did not reflect the actual requirement that the pilot should keep his feet firmly on the pedals and prevent unwanted rudder pedal movement. It was therefore recommended that:

Safety Recommendation 2008-018

ATR should amend the ATR 42 Master Minimum Equipment List (and that of other ATR types if similarly affected), for dispatch with both RCU and yaw damper inoperative, to more accurately describe the pilot action required to positively prevent unwanted rudder pedal movement.

Final approach

The crew made an early decision to return to Stansted, so there was not a great deal of time to diagnose the problem and prepare for the approach. Each pilot had made brief reference to the yaw damper (or lack of it) causing the motion, but there was no further discussion about the likely cause until on approach, and so the QRH was not referred to. The CVR showed that little preparation was carried out prior to the approach, although the co-pilot was heard to confirm that the navigation aids were correctly set. Although there had also been no discussion or briefing about the approach or landing configuration, it was agreed late in the flight that a reduced flap setting would be used.

The aircraft's vertical profile was satisfactory until just prior to the final approach, when the aircraft descended below 1,700 ft and below the glide slope. It is therefore likely that it was the commander's high workload at that point which affected her ability to accurately control the flightpath, despite the co-pilot prompting her to correct the deviation. She would have been aware that the aircraft and crew were not ideally prepared for the approach, and the uncertainty that still existed about the problem would have added to the stress of the situation. This was further compounded by the problems getting established on the localiser, and a perceived need to establish visual contact with the runway much sooner than was actually required.

As the aircraft descended though 1,000 ft aal, its flight path began to deviate further below the glideslope, until the co-pilot and EGPWS together warned of the low height. By this stage the commander had become convinced that the problem was due to a propeller pitch malfunction, which she continued to refer to until after landing, and which presented a further distraction at a critical phase of flight.

It is likely that the fatiguing and confusing nature of the motion, the short time available and the attempt to gain an early visual sighting of the runway contributed to the unstabilised approach. Although the crew had eventually decided to extend flaps at a relatively late stage, late selection of gear and the possibility of aggravating the motion so close to the ground was not discussed. It also left inadequate time to complete the landing checklist.

Flight data recorder defect

The absence of reliable FDR data for the whole flight hampered the investigation process. The IAA required the operator to carry out a readout of the FDR every two years. The ICAO Annex 6 requirement was for an annual readout, but there was no associated JAR-OPS 1 requirement. This deficiency was addressed by AAIB Safety Recommendation 2007-60. In reply, EASA agreed to give consideration to incorporating the provisions of the EUROCAE document (which met the ICAO requirements) into European regulations. At the time of writing, the EASA response was classed as 'open'.

It was therefore recommended that:

Safety Recommendation 2008-019

The European Aviation Safety Agency should, when considering AAIB Safety Recommendation 2007-60, include in its deliberations the FDR deficiency identified in this investigation and the adverse effect this had on the investigation process, with a view to expediting any remedial actions.

It is probable that the FDR system fault was present for some time, yet there was no requirement to monitor the FDR system BIT. Contrary to the SARPs contained in ICAO Annex 6, Part 1, no daily check of the CVR, FDR or Flight Data Acquisition Unit (FDAU) is required by JAR-OPS 1.

It was therefore recommended that:

Safety Recommendation 2008-020

The European Aviation Safety Agency should require that, prior to the first flight of the day, the built-in test features on the flight deck for the Cockpit Voice Recorder, Flight Data Recorder and Flight Data Acquisition Unit, when installed, should be monitored to ensure correct operation.

Conclusion

The cause of the aircraft's motion could not be positively identified, but it was not a natural motion and so must have been due, in part at least, to inappropriate control inputs by one of the pilots. It is possible that the RCU was not correctly centred on the trimmed, rudder-centred position before takeoff. An intermittent failure of the RCU clutch to disengage may have led to the aircraft taking off with the RCU incorrectly centred, which would have prevented yaw damper engagement as well as making the aircraft more prone to a Dutch roll-type oscillation.

At its worst, the motion was severe enough to significantly impair the crew's ability to operate and manage the aircraft. The crew considered an immediate landing to be the preferred option, though this reduced the time available to troubleshoot the problem and to prepare themselves and the aircraft for the approach. Ultimately this contributed to an unstable approach which generated unsafe configuration warnings.