INCIDENT

Aircraft Type and Registration:	Fairchild SA227 AC Metro III, EC-JCU
No & Type of Engines:	2 TPE331-11U-612G turboprop engines
Year of Manufacture:	1987
Date & Time (UTC):	10 October 2006 at 1510 hrs
Location:	Lasham Airfield, Hampshire
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Tyre damage, and all four brakes replaced due to overheating
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	2,150 hours (of which 1,915 were on type) Last 90 days - 210 hours Last 28 days - 70 hours
Information Source:	AAIB Field Investigation

Synopsis

The lightly loaded aircraft commenced the takeoff with its centre of gravity towards the forward end of the permitted range; the co-pilot was the handling pilot. The aircraft did not respond as expected when he attempted to rotate the aircraft and he handed control to the commander. The commander aborted the takeoff and the aircraft overran the paved surface of the runway on to an area of grass stubble.

The investigation found no technical fault that could have contributed to the apparent control problem. Experience had shown that, for this type of aircraft, a large aft control column movement is required during rotation when the centre of gravity is close to the forward limit. Although there was nothing in either pilots' training records that could have had a bearing on this event, the crew was relatively inexperienced and it was considered that this was a factor in the incident. The aircraft has subsequently carried out a number of uneventful takeoffs and responded normally to control inputs.

One Safety Recommendation is made with regards to the flight data recording system.

History of the flight

EC-JCU had positioned from Coventry to Lasham with the two pilots and their personal bags on board. The aircraft had departed from Coventry with a calculated

takeoff weight (TOW) of 12,972 lbs and a calculated centre of gravity (CG) 262 inches aft of the datum, close to the forward limit. The commander was the pilot flying (PF) and the flight was completed without incident. After landing on Runway 09 at Lasham, the commander re-trimmed the horizontal stabiliser to the middle of the takeoff range during the after-landing checks, in accordance with normal procedure. This operation was confirmed by a recording of the aural warning associated with horizontal stabiliser trim operation, as detected by the Cockpit Voice Recorder's (CVR) area microphone on the flight deck.

During the turn around, the aircraft was refuelled to a total of 4,300 lbs of fuel and loaded with 44 lbs of cargo, which was placed in the forward (No 1) cargo bay in the cabin. The crew calculated a TOW of 14,492 lbs for their departure; the maximum TOW was 16,000 lbs. Their calculation was based on an assumed cargo load of 220 lbs in the centre (No 2) cargo bay and 100 lbs of baggage in the aft baggage compartment. They calculated the CG to be 264.5 inches aft of the datum, further aft than for the departure from Coventry, but still within the forward portion of the CG range.

The co-pilot was the PF for the departure from Runway 09 and initiated a rolling takeoff from the runway 'numbers', just ahead of the threshold markings, by setting an intermediate power setting with the brakes off. With the PF monitoring the position of the power levers, the pilot not flying (PNF) trimmed the levers to a takeoff power setting of 87.3% torque. The PNF made the standard operating procedure (SOP) calls at 60 kt and 80 kt, which were confirmed by the PF, and called "V_1" and "ROTATE" at 109 kt and 112 kt respectively. On hearing the commander call "ROTATE", the co-pilot pulled back the control column "a bit". He reported that the aircraft did not respond, so he pulled back the control column "a bit more". The aircraft still did not respond, so the PF returned the control column to its forward position before making another attempt. He reported that he then pulled the control column back half to three-quarters of its full travel. The nose of the aircraft pitched up a small amount but no further. He advised the commander of the problem. The commander took control and, after trying to rotate the aircraft himself, without success, he rejected the takeoff by applying reverse thrust and maximum braking. EC-JCU departed the end of the paved surface and ran on to an area of grass stubble. The commander advised Lasham Air/Ground radio that they and the aircraft were safe, before shutting the engines down. Neither pilot was injured.

The crew of one of the airfield's fire vehicles, which was positioned at a holding point on the north side at the upwind end of the runway, had followed the aircraft when they saw it pass them, at speed but still on the ground. They too reported the aircraft's predicament to the airfield's Flight Information Safety Officer (FISO), who was in the airfield's control tower, near the downwind end of the runway; he had not seen the incident because of the convex nature of the airfield surface.

Although the brakes were hot there was no fire, and the crew exited the aircraft normally. Before leaving the aircraft, the pilots carried out a 'full and free' check of the flying controls and confirmed that the elevator responded normally to flying control inputs initiated from the flight deck. They also confirmed that the horizontal stabiliser was in the middle of the takeoff range, as indicated on the instrument panel.

Damage to the aircraft

There was a deep cut approximately 10 cm long on the No 3 tyre. (The No 3 wheel is the inboard of the two wheels fitted to the right main gear leg.) Following a

subsequent inspection at the aircraft's base maintenance organisation all four brakes were replaced due to wear and suspected overheating.

Personnel information

The commander had flown a total of 2,150 hrs on all types of aeroplane. He had flown 1,915 hrs in the SA227, and 250 hrs of these were as commander.

The co-pilot had flown a total of 585 hrs on all types of aeroplanes; 295 hrs of these were in the SA227. He had completed his training in March 2006.

The pilots had flown together once before, and the investigation revealed nothing in either pilots' training records that related to the handling of the flying controls during the takeoff.

Aircraft information

The Fairchild SA227 AC Metro III is powered by two turboprop engines and is certified for single pilot operation in the cargo configuration.

The elevator is actuated via a closed loop cable system that is connected to the control columns in the cockpit at one end, and to the elevator quadrant, mounted in the fin, at the other. The cables are guided under the floor of the fuselage and through the tail by a series of pulleys. There is no option to disconnect one of the control columns from the cable system manually, as is the case on some aircraft.

The aircraft is trimmed in pitch by an all-moving horizontal tailplane, which is operated through a three-position thumb switch on each control yoke; when either of these switches is moved from its neutral, central position, the pitch trim actuator, in the fin, moves the horizontal tailplane either nose-up or nose-down. In addition, there is a central console-mounted backup switch. An electronic horn sounds intermittently during operation of the pitch trim actuator. The middle 45% of the operating range of the tailplane incidence is the valid range for takeoff. There is a dial in the cockpit which indicates the amount of nose-up or nose-down trim that has been applied. The manufacturer's Before Taxi checklist includes an item on checking the stabiliser trim system before takeoff. Explanatory material advises the crew that:

> *'All takeoffs should be made with the stabilizer trimmed within the takeoff band marked on the trim indicator. When the airplane is loaded to a forward center of gravity configuration, the stabilizer should be trimmed to the nose up end of the takeoff band; for aft center of gravity configurations, the stabilizer should be trimmed to the nose down end of the takeoff band.'*

If the horizontal tailplane is not within the valid range during the takeoff run, a loud continuous electronic alarm sounds. The logic for this alarm requires the pitch trim to be out of the central range, the power levers to be advanced and for weight to be on the wheels.

The aircraft has two systems that provide retardation. The primary method is to select reverse thrust on the engine power levers which changes the pitch angles of the propeller blades. Additional braking is provided by four brakes, one mounted in each of the four main wheels. The brakes on EC-JCU did not have an anti-skid system fitted.

Weight and CG

The TOW and CG position were recalculated using the actual weights and locations of the load. This consisted of 44 lbs of cargo in the No 1 cargo bay; 31 lbs of manuals

and wheel chocks in the nose baggage compartment, and replacing the allowance for 100 lbs of equipment in the aft baggage compartment with the actual figure of 28 lbs for personal bags. The remainder of the equipment had been included in the aircraft's Operating Weight Empty (OWE) and its associated CG index. This gave a TOW of 14,275 lbs and a CG 262 inches aft of the datum; the same CG position that had been calculated for the departure from Coventry. The permitted CG range at that weight is from 260.4 inches to 277 inches aft of the datum.

Aircraft handling characteristics

During the investigation, the manufacturer and another operator of the SA227 were contacted regarding the handling characteristics of the aircraft during takeoff. They confirmed that with a forward CG the handling pilot would be required to pull the control column back a large amount in order to rotate the aircraft and complete the takeoff.

Meteorological information

The weather conditions at the time of the incident were good. The surface wind was from 160º at 5 kt, there was scattered cloud at 1,500 ft agl, the visibility was greater than 10 km, the temperature was 18ºC and the QNH pressure setting was 1014 hPa. Lasham Airfield lies at an elevation of 618 ft amsl.

Performance

Runway 09 at Lasham Airfield is 1,797 m in length and has an asphalt surface. It is unlicensed and, on the basis of balanced field constraints, the values for the Take Off Distance Available (TODA) and Accelerate Stop Distance Available are both 1,797 m.

At the correct weight of the aircraft, and in the ambient conditions, V_1 and V_R were confirmed as 109 kt and 112 kt respectively. The Take Off Distance Required was approximately 500 m less than the TODA.

The commander initiated the rejected takeoff procedure nine seconds after calling "V_1". In nine seconds, at that speed, the aircraft would have travelled a further 498 m beyond the point of the V_1 call. However, since the aircraft was accelerating during this time the distance it travelled after V_1, and before the takeoff was rejected, would have been greater.

Flight recorders

The aircraft was fitted with a 30-minute duration CVR and a 25-hour duration Flight Data Recorder[1] (FDR) that recorded five parameters[2]; these did not include aircraft attitude, pitch trim, control surface or column positions.

Both recorders were removed and replayed at the AAIB. The abandoned takeoff and overrun had been recorded on the CVR and, in addition, the previous approach and landing were also available. The FDR contained the previous 13 flights, plus the abandoned takeoff, but it was found that the recording of airspeed was defective. This is discussed in detail later.

Recorded data

On the previous flight the pitch trim activation tone could be heard during the final approach and landing. After the landing the tone was activated for a further 4 seconds. No further activation was recorded.

During the attempted takeoff from Lasham the Commander called "60 kt", "80 kt", "V_1" and "ROTATE". About 4 seconds after the commander had made the last call the co-pilot advised the commander that the aircraft

Footnote

[1] The FDR was manufactured by L-3 Communications; part number 17M900-274, serial number 729.

[2] Altitude, airspeed, heading, normal acceleration and radio keying.

would not rotate. Three seconds later the engines could be heard to enter the reverse range, eight seconds later the aircraft overran the end of the runway, finally coming to a stop after a further six seconds. About 40 seconds had elapsed from the start of the takeoff roll to the commander calling V_1. At the start of the roll, engine power was initially set at about 80% of the takeoff power setting, before being increased to takeoff power about 8 seconds after the roll had commenced (about 32 seconds before the commander had made the V_1 call).

Due to a fault with the FDR, the airspeed parameter had remained at zero knots during the entire takeoff roll.

FDR airspeed parameter

Analysis of the thirteen previous flights indicated that the recorded airspeeds at takeoff were significantly lower than expected and that, during a number of approaches, the recorded airspeed had reduced to zero before the aircraft had landed. During all of the takeoffs the airspeed was observed to increase suddenly from zero to about 65 kt, always occurring shortly before the takeoff point. The airspeed value then gradually increased during the climb and then stabilised prior to the descent and landing. No airspeed values lower than 65 kt, other than zero, had been recorded at any time.

The FDR was located in the rear section of the aircraft, just forward of the empennage. The FDR obtained both airspeed and altitude parameters by means of pneumatic lines which were connected to the co-pilot's airspeed indicator (pitot) and altimeter (static) lines. Both inputs were connected to the FDR, and internal transducers then converted the pneumatic information to electrical signals, prior to being processed for recording onto the FDR tape. The relationship between pneumatic pressure and electrical output signal is not linear across the transducers' operational range. At speeds below the normal flight envelope of the aircraft, about 100 kt, the transducer is not required to be as sensitive to pressure changes when compared to that at higher airspeeds.

The FDR was taken for testing to an approved repair agency, where it was confirmed that the FDR airspeed parameter was defective. Under ideal test conditions the FDR started to record an airspeed value of about 30 kt when the actual airspeed reached about 100 kt. At a recorded value of about 65 kt the actual airspeed was about 117 kt. As the airspeed increased the error gradually reduced to a minimum of about 20 kt below that of the actual airspeed.

The altitude parameter was tested and found to be serviceable and a leak test was performed on both the FDR airspeed and altitude transducers, which were both found to be within manufacturer's specifications.

A serviceable unit of the same type was then tested to confirm when it would start to record airspeed. Recording commenced at about 10 kt. Historical records of other similar aircraft installations were assessed and it was found that airspeed recording typically started at about 12 to 14 kt, consistent with the results of the serviceable unit.

Built In Test Equipment

The unit's Built In Test Equipment (BITE) was not capable of detecting a fault of this type, and thus no failure warning would have been indicated by the FDR. To determine a fault of this type, a readout would have been required, followed by appropriate analysis of the recorded data.

FDR annual replay requirement

To determine how long the FDR airspeed recording defect may have been present the operator was asked if

they held records of any previous readouts from the FDR. The operator advised that they had never performed an FDR readout for EC-JCU. Discussions with the Spanish Aviation Authorities highlighted that there was no requirement for an operator to perform a readout of the FDR under JAR-OPS 1 and that no supplemental requirement existed in Spain.

UK legislation has included a requirement to perform a routine readout of the FDR for many years. UK operators are required to preserve a record of one representative flight made within the last 12 months from the FDR and must ensure that the recording system, and those parameters recorded by it, are serviceable. To assist operators in complying with this requirement, the CAA has provided instructions in document CAP 731 "*Approval, Operational Serviceability and Readout of Flight Data Recorder Systems*".

ICAO Annex 6 Part I states 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 provides for the preservation of recordings but it does not include a requirement to perform a routine readout of the FDR. This however differs from JAR-OPS 3 (Helicopters) which does include a requirement to readout the FDR within the last 12 months. Neither JAR-OPS 1 nor JAR-OPS 3 includes a requirement to evaluate the validity of all recorded parameters.

Incident site information

The aircraft had come to a stop in the grass overrun area on a heading of 110°, the nose landing gear was 34 m from the end of Runway 09 and 13.5 m to the right of the runway centre line. There were tyre marks on the runway leading to where all four main wheels went onto the grass. The longest of the tyre marks were over 200 m long, and became progressively less noticeable further back along the runway; it is therefore probable that that the brakes were applied before the marks become visible.

Aircraft inspection

The elevator travelled through its full range, without any hindrance, when operated from either pilot's seat; this concurred with the checks made by the pilots immediately after the incident. The elevator control runs from the control columns to the elevator quadrant in the fin were inspected and no control restriction or evidence of a foreign object was found.

The elevator control system is fitted with a bob-weight to enhance pitch stability and a damper to dampen any sudden movement to the elevators. The damper was found to have leaked slightly and this was removed for inspection. The inspection revealed nothing of significance.

The pitch trim actuator system was inspected and functionally checked. The pitch trim actuator system, including the actuator indication in the cockpit, was found to operate satisfactorily. During subsequent high speed taxi tests the aircraft responded normally to the elevator commands and no restrictions were encountered.

The Air Speed Indicator (ASI) system was checked with calibrated portable test equipment. A leak was detected in the right pitot system and the right ASI under-read the actual speed. However, during the subsequent high speed taxi tests all the ASIs gave consistent readings.

Estimation of speed during the takeoff run

With no valid speed data recorded by the FDR, the speed reached during the takeoff roll was estimated. Three estimates were made, and all used the simple

principle that the distance travelled is the area under a speed versus time curve. The length of the runway, the approximate position of the aircraft at the start of the takeoff roll, and the distance travelled beyond the runway were all known. The times for the initial advance of the power levers, the further advance of the power levers, the calls made by the commander for "60 kt", "80 kt", "V_1" and "ROTATE", and the times when the aircraft went onto the grass and stopped, were derived from the CVR.

All three estimates assumed that the deceleration over the grass was linear, and hence the aircraft's speed was estimated to be 23 kt when it left the runway and entered the grass run-off area.

The three estimates were as follows:

a) Pessimistic estimate
   If a linear acceleration and deceleration are assumed and the liner acceleration is assumed to start when the power levers are first advanced (thus maximising the assumed acceleration phase), then the estimated maximum speed during the takeoff roll is 114 kt.

b) Optimistic estimate
   If a linear acceleration and deceleration are assumed and, the liner acceleration is assumed to start when takeoff power is set (thus reducing the assumed acceleration phase) then the estimated maximum speed during the takeoff roll is 134 kt.

c) More realistic estimate
   In reality, the acceleration was probably not linear since the aircraft was already rolling when the power levers were fully advanced. Also, as the speed increases, the rate of acceleration starts to decrease, mainly due to the total drag on the aircraft increasing non-linearly with speed. Hence in reality the speed versus time curve is a gentle S shape, with the acceleration being greatest at approximately half the rotation speed.

   The speed versus time curve was taken from a similarly sized turbo-prop and both axes were scaled so that a good fit with the speeds and times from the pilots' calls on the CVR was obtained. This resulted in the estimate for the maximum speed being around 125 kt.

Analysis

No fault was found with the aircraft that could have contributed to the co-pilot's perception of the aircraft's lack of response to aft control column movement or to the commander's concern for a possible control malfunction. The aircraft began the takeoff roll from a point close to the start of the runway. The pitch trim was set in the middle of the takeoff range but the aircraft's CG was close to the forward limit; this would have exaggerated the need for a large aft movement of the control column during rotation, in order to complete the takeoff. The co-pilot, who was relatively inexperienced, did not achieve the response from the aircraft that he was expecting when he initially pulled back on the control column.

On taking over control, the commander was presented with a possible control malfunction and little time in which to make a decision as the end of the runway was approaching rapidly. After a short time assessing the situation, he rejected the takeoff. However, due to the acceleration of the aircraft after the "V_1" call, the aircraft would have travelled approximately 535 m beyond the point on the runway at which that call had been made.

That, and the need to stop from a speed in excess of V_1, resulted in the aircraft overrunning the paved surface of the runway by 34 m.

A slight leak was detected in the right pitot system and the right ASI under-read the actual speed. However, during the subsequent high speed taxi tests all the ASIs gave consistent readings. It was thought that the lack of an under-read during the taxi tests, and presumably during the incident takeoff attempt, was due to a greater volume of air being available which was not available with the test equipment. In this incident, any under-reading of the ASI is unlikely to be a factor since the elevator would appear to be more effective than the reading on the instrument would imply since the aerodynamic force increases with the square of the speed.

Estimates of the speed indicated that the maximum speed achieved during the rejected takeoff was approximately 125 kt. No airspeed value greater than zero was recorded by the FDR during the incident; however, whilst reviewing previous takeoffs it was noted that the recorded value jumped from zero to about 65 kt, at which point the actual airspeed was about 117 kt. It can, therefore, be inferred that the maximum airspeed achieved during the rejected takeoff was probably less than 117 kt.

Following an extensive technical examination the aircraft was released for a test flight; it completed an uneventful takeoff and reacted appropriately to flight control inputs, and has continued to operate normally since.

Reliable FDRs are an essential component of effective accident investigation and in order to address the anomalies found in JAR-OPS, the following Safety Recommendation is made:

Safety Recommendation 2007-060

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.