Swearingen SA227-AC Metroliner III, OY-BPH

Contents

Report Information

AAIB Bulletin No: 6/2004	Ref: EW/C2002/12/03	Category: 1.1
Aircraft Type and Registration:	Swearingen SA227-AC Metroliner III, OY-BPH	
No & Type of Engines:	2 Garrett (Honeywell) TPE331-11U-611G turboprop engines	
Year of Manufacture:	1984	
Date & Time (UTC):	24 December 2002 at 0745 hrs	
Location:	Aberdeen Airport, Scotland	
Type of Flight:	Positioning	
Persons on Board:	Crew - 2	Passengers - Nil
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Aircraft and one car destroyed	
Commander's Licence:	JAA Commercial Pilot's Licence with Instrument Rating	
Commander's Age:	40 years	
Commander's Flying Experience:	4,600 hours (of which 2,800 hours were on type)	
	Last 90 days - 120 hours	
	Last 28 days - 40 hours	
Information Source:	AAIB Field Investigation	

Synopsis

On a positioning flight, with the co-pilot as handling pilot, the crew detected a right engine failure shortly after takeoff from Runway 16 at Aberdeen Airport. The commander feathered the right engine but did not raise the landing gear. The aircraft descended and the co-pilot was unable to prevent the aircraft from impacting the ground, some 500 metres to the right of the runway. During the subsequent ground slide, the aircraft entered a public road and collided with a moving car.

Bird remains were found on Runway 16 and evidence was found to indicate that the left engine had ingested birds. There was no indication of any bird ingestion by the right engine and no defect with that engine was identified during the investigation. Lack of adherence to the Joint Aviation Requirements - Operations (JAR-OPS), was identified, relating to the FDR system and to crew training.

Background to flight

The aircraft had been leased in support of a UK mail contract. On 9 December 2002, the aircraft and two pilots had arrived at Aberdeen from Aalborg Airport in Denmark, and had subsequently operated flights within Scotland, in support of the mail contract, until 23 December 2002. During this period, the same two pilots operated together and alternated handling duties for their flights. The co-pilot had a total of 1,300 hours flying experience, of which 275 hours were on type, and he was the holder of a Commercial Pilot's Licence with an Instrument Rating.

History of the flight

At approximately 0630 hrs on 24 December 2002, the pilots arrived by car at Aberdeen Airport. With no requirement for their aircraft to transport mail on this occasion, it was decided to fly directly to their home airport in Denmark. The aircraft had been refuelled the previous day and the total fuel on board of 2,200 lb was sufficient for the flight; with no cargo on board, take-off weight was calculated as 12,000 lb (maximum take-off weight: 16,000 lb). The commander carried out an external inspection on OY-BPH while the co-pilot, who was the designated handling pilot for the flight to Denmark, submitted a flight plan.

The weather at 0720 hrs was reported as follows: Surface wind 150°M/ 12 kt; visibility 2,500 metres in mist; cloud scattered 100 feet agl, overcast at 200 feet agl; air temperature +9°C; QNH 994 hPa. The runway was reported as wet and Low Visibility Procedures (LVP) had been in force at Aberdeen since 0633 hrs.

OY-BPH, callsign 'Birdie Nine Two Four', was parked on Taxiway Bravo and the crew called for, and were given, start clearance at 0736 hrs by 'Ground Movement Control' on frequency 121.7 MHz. Then, following their after-start checks, the crew were cleared to taxi to 'Whiskey Five' for Runway 16 at 0740 hrs. During taxi, the crew were passed and correctly acknowledged the following clearance: "LEAVE CONTROLLED AIRSPACE CLIMBING FLIGHT LEVEL ONE FIVE FIVE SQUAWK SIX TWO FOUR ZERO". Then, at 0742 hrs as the aircraft approached 'Whiskey Five', the crew were transferred to 'Aberdeen Tower' on frequency 118.1 MHz. On the 'Tower' frequency, they were given line-up clearance for Runway 16. At 0743 hrs, the controller transmitted: "BIRDIE NINE TWO FOUR WITH A LEFT TURN DIRECT KARLI CLEAR TAKE OFF ONE SIX SURFACE WIND ONE SIX ZERO ONE TWO KNOTS". The crew correctly acknowledged this clearance. The controller watched the initial movement of the aircraft along the runway before transferring her attention to another aircraft, which was lining up. Shortly after, at 0746 hrs, she transmitted: "OY-BPH REPORT TURNING LEFT" but received no reply. About this time, a telephone message was received in the 'Tower' from a witness in front of the Terminal Building to the effect that an aircraft appeared to have crashed just south of the airfield. This witness had heard a "change in pitch" from the aircraft but had seen no flames prior to it disappearing from his sight: ATC personnel immediately activated their emergency procedures.

For the reduced power take-off roll, with the flaps at ¼, the power was set by the commander. The crew considered that the performance of the aircraft was normal, with no unusual instrument indications. The calculated V_1 and V_R speeds (co-incident at 100 kt) were achieved and called by the commander and, at V_R, the co-pilot rotated the aircraft to a pitch attitude of about 12° to 15° nose-up. As the aircraft left the ground, the co-pilot detected the aircraft 'yawing' to the right; almost immediately, he was also aware of a distinct smell of smoke. He called to the commander that he had an engine failure, called for maximum power and tried to maintain control by corrective aileron and rudder inputs. The commander felt the aircraft roll about 15° to the right and realised that there was a problem with the right (No 2) engine. He reached for both power levers and moved them forward. There were no audio or visual warnings associated with the apparent problem. The commander looked at the EGT gauges with the power levers fully forward and noted that the No 2 engine indicated about 600°C EGT, whereas the left (No 1) engine indicated greater than 650°C EGT (the normal maximum) and that its fuel 'Bypass' light was on. He retarded the No 1 power lever until the 'Bypass' light extinguished and noted the resultant EGT at about 630°C. He did not recall any other abnormal indications on the engine instruments but, later in the investigation, the commander recalled hearing a sound "like a compressor stall from the right engine". About this time, the co-pilot heard the automatic "Bank Angle" voice activate. As the aircraft continued to turn to the right, the co-pilot called that he "couldn't control the aircraft". The commander reached for and pulled No 2 engine 'Stop and Feather Control' but, almost immediately, OY-BPH struck the ground initially with the right wing. The aircraft slid along the surface of a field, through a fence and onto a road, before coming to rest. As it did so, the co-pilot was aware that the aircraft had struck a car, which was now at rest outside the right forward side of the cockpit. The co-pilot saw that the whole of the right wing was on fire and called this to the commander before evacuating out of the left door of the aircraft. As the co-pilot left, the commander pulled No 1 engine 'Stop and Feather Control' and activated both engine fire extinguishers before leaving the aircraft. Outside OY-BPH, the co-pilot went to the car to check if anyone was still inside; as he did so, he saw someone running away. With the intense fire and the car apparently empty, both pilots moved well away from the aircraft. At 0748 hrs, the co-pilot used his mobile phone to advise ATC of the accident and to request assistance.

The local emergency services had been alerted at 0745 hrs by a member of the public, who reported a road accident; by 0753 hrs, the local fire service was on the scene. By 0754 hrs, the first AFS vehicle was on the scene and three further AFS vehicles arrived one minute later. A fifth vehicle arrived at 0800 hrs. The fire was quickly extinguished and the Fire Officer confirmed that all the aircraft and vehicle occupants had been located and that there had been no serious injuries.

Following runway and taxiway inspections, the airport was re-opened at 0954 hrs.

Flight recorder information

The aircraft was equipped with two tape based recorders, a CVR and FDR, and these were located at the rear of the aircraft. Both were heavily sooted but otherwise undamaged. Underneath the avionics rack of each recorder was an associated negative acceleration switch, designed to trip and remove power in the event of a crash. Both switches were found to be in the tripped state.

CVR examination

During replay of the CVR it was apparent that, although the tape transport had been operating during the accident flight, very little audio information had been recorded on the three crew channels and none on the area microphone channel. The problem was traced to an intermittent solder joint on one of the components on the power supply circuit board. The circuit board showed signs of previous component failure with damage sustained through overheating. The intermittent solder joint was on one of the components that had been replaced during previous maintenance action. The inadequate connection had the effect of disabling the generation of the bias signal required for recording and also preventing lower amplitude input signals (eg, the volume of the sounds associated with normal speech) from being written to the tape. A secondary effect had been to inhibit the +18V DC power source that, under normal operation, would have supplied the cockpit located area microphone pre-amplifier. The absence of the area microphone channel and distortion of the three crew channels precluded spectral analysis of the CVR recording with a view to obtaining powerplant information. The only sounds recorded of relevance to the accident flight were three cycles of the GPWS "Bank Angle Bank Angle" alert towards the end of the flight and the subsequent, final impact.

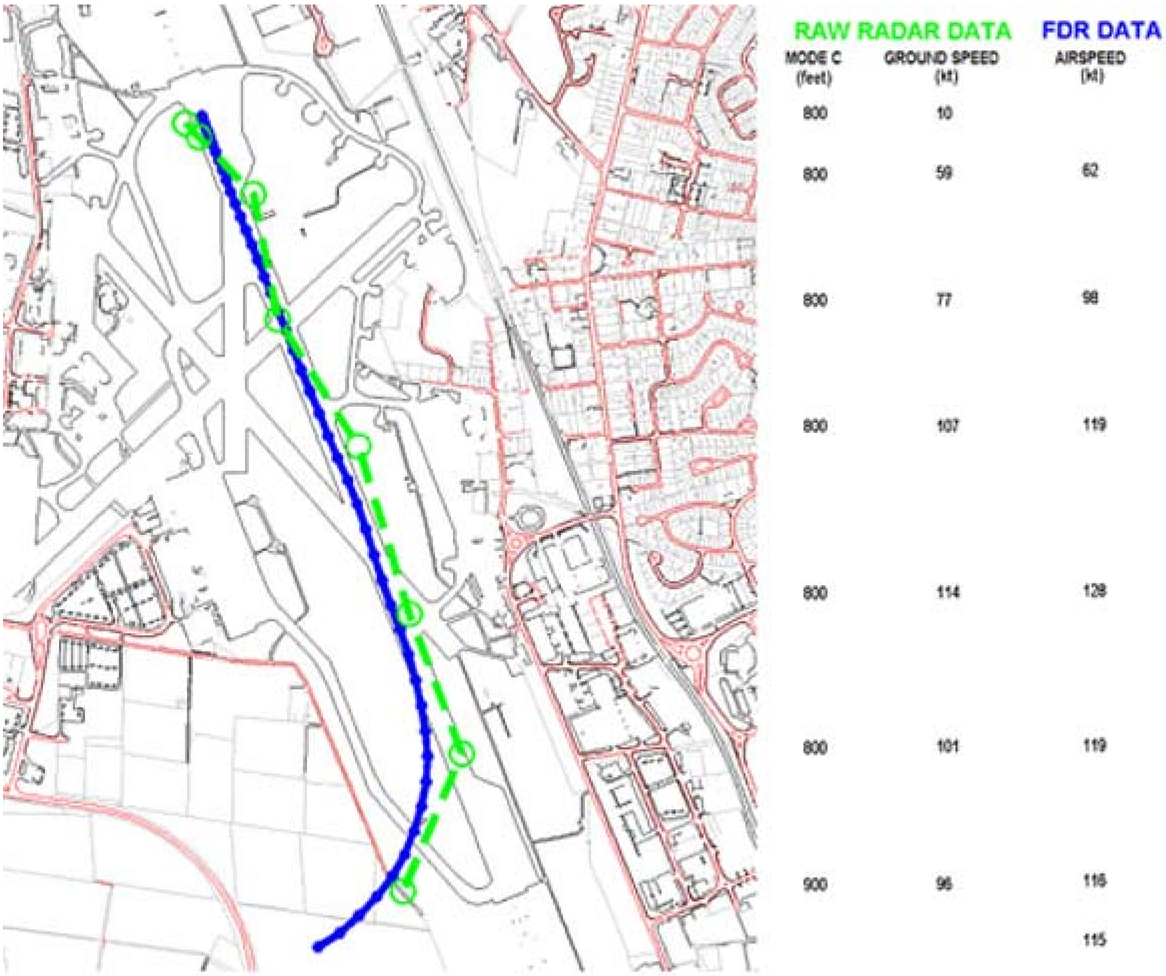
As part of the pre-flight checks, before engine start, the crew should have tested the operation of the CVR by depressing a TEST button on the area microphone control unit, which was located on a panel in front of the right hand seat. With the TEST button depressed, the CVR was designed to write a test tone on all four channels, in sequence. An adequate read-after-write amplitude would have resulted in a satisfactory deflection of the needle on the control unit's test meter. With the aforementioned fault present, the CVR would not have passed this test and this was later confirmed during tests carried out by the AAIB on the CVR.

FDR examination

The FDR was an F800 tape based recorder with integral pitot/static transducers for the measurement of airspeed and altitude. Magnetic heading, normal acceleration, trip, date and push-to-talk were the only other parameters recorded. Upon replay, it was found that the recorder had been developing a fault which the limited built-in test circuitry had been unable to detect. This manifested itself as an intermittent degradation in the recording of all parameters, except heading. Not all of the affected parameters were degraded at the same time so, whereas altitude during the accident flight was consistently incorrect, airspeed (when corroborated against radar data) appeared to have been recorded satisfactorily.

An estimated ground track of the aircraft, based on FDR, CVR, ATC communications and radar, was derived and is shown in Figure 1. A maximum airspeed of 128 kt was recorded by the FDR, and a maximum height achieved by the aircraft of 900 feet was recorded by the secondary radar. This was based on the standard pressure setting of 1013.2 Hpa, which equated to about 100 feet agl.

Radar and FDR data



Radar and FDR data
(Accident to OY-BPH on 24 December 2002 at Aberdeen)

Flight Data Recorder Performance Requirement

The aircraft was operated under JAR-OPS which specifies a minimum performance for flight data recorders. The applicable section for this age and weight category of aircraft is JAR-OPS 1.725 and this requires, as a minimum, the recording of time (or relative time count), pressure altitude, indicated airspeed, heading and normal acceleration. The performance, ie, designated ranges, recording intervals and accuracy limits, of each of the parameters to be recorded, is given in Appendix 1 to ACJ OPS 1.720/1.725. The sampling interval requirement for normal acceleration is stated as being 0.125 seconds, or eight samples per second but, on OY-BPH, this requirement was not met. JAR-OPS addresses non-compliance, with regard to sampling intervals, by stating that reduced performance may be accepted by the certificating authority which, in this instance, was the Danish Civil Aviation Authority (DCAA). The DCAA stated that the operator had made no application for alleviation in this respect.

The FDR fitted to OY-BPH was originally introduced to replace the now prohibited 'scratch foil' type of FDR. The F800 model used an old method of recording, known as ARINC 542 mode, under which only 10 data words were recorded every second and only eight of those were allocated to aircraft parameters. A later version of the specification, ARINC 542A, defines a system using 32 or 64 words per second which allows the recording of normal acceleration at the rates specified in JAR-OPS.

ARINC 542 Mode of Recording on the F800 FDR

The performance associated with the recording of normal acceleration on the F800 FDR, operating in ARINC 542 mode, complied with Technical Standing Order TSO-C51a. The FAA cancelled this TSO in 1995 but the approval to maintain existing equipment (TSOA) was not withdrawn due to the expectation that manufacturers would gradually phase out this old type of FDR.

The normal acceleration recording, under ARINC 542, is based on a sequence of data sampling to form a data frame that repeats every second. During the first half-second period of a frame, the accelerometer is sampled five times (samples 1-5) but only the highest value (maximum deviation from 1g) is selected for recording with the remainder being discarded. During the second half-second period, the process is repeated and the accelerometer is sampled a further five times (to give samples 6-10) with the highest value only being recorded. No information is recorded as to which two samples (from 1-5 and 6-10) are selected. The maximum deviation from 1g could be in a positive or negative direction, but only the sign of sample 6 is recorded in the data frame. It is not uncommon during an accident or serious incident for acceleration values to change rapidly and, as sample 6 may not be recorded if it is not the highest value of samples 6-10, it is impossible to determine a time history for normal acceleration using this recording method.

Thus, it can be seen that only two samples (with relatively indeterminate signs) of normal acceleration are recorded every second, as opposed to the eight required by JAR-OPS. This is considered to be unacceptable for the purposes of accident investigation.

It is therefore recommended that:

Safety Recommendation 2004-31

The Joint Airworthiness Authorities should ensure that accident flight data recording systems fitted to aircraft that are required to be fitted with a Flight Data Recorder under the terms of JAR-OPS sample and record normal acceleration data at a rate of no less than eight times per second.

Runway debris

Immediately after the accident, the airport authority conducted a search of the runway. This revealed the remains of four birds concentrated in the area where the aircraft had rotated to its takeoff attitude. This was close to the intersection of Runway 16 with Runway 23, some 550 to 700 metres from the threshold of Runway 16. All the bird remains were found to the left of the runway centreline. After analysis by the Central Science Laboratory in York, it was concluded that the remains consisted of two herring gulls, which have a typical weight of 1,020 gm each, one common gull, typical weight 420 gm, and one black headed gull, typical weight 200 gm. The common gull appeared whole, although only one wing remained of the black headed gull. Large portions of the herring gulls were missing.

The only other piece of debris found on the runway was a piece of braided steel wire, approximately 250 mm long, which was found 190 metres from the threshold of Runway 16. It had the appearance of an electrical bonding lead, but it was not possible to establish if it had originated from the accident aircraft.

Accident site details

The aircraft had come to rest on a road approximately 500 metres to the right of Runway 16 and approximately abeam the end of the runway. The first point of impact was in a field, just outside the airfield boundary, and was identified as having been made by the right wing tip with the aircraft on a track of 255°M. Thus the aircraft had turned to the right by around 95° relative to the runway heading before impacting the ground. The flaps had remained at the take-off setting of Flap ¼.

It was apparent that a section of, approximately, one metre of the outer right wing had broken off as a result of this wing tip contact with the ground. Some 15 metres along track from the initial impact point was a scar made by the right landing gear, with the nose gear impact mark slightly beyond. The yaw induced by the right wing contact with the ground resulted in lateral loads being applied to the nose leg, which was torn from its mountings, and this came to rest to the right of the aircraft track. The aircraft continued, supported by its main wheels and underside of the forward fuselage, until it collided with a hedgerow that bordered the field, approximately 180 metres from the initial impact point. OY-BPH came to rest with its nose halfway across a road beyond this hedge, with the tail of the aircraft in the field. The left wing had struck the trunk of a small tree within the hedge, causing the aircraft to swing to the left as it came to rest. A car travelling on the road had collided with the right side of the forward fuselage. This had not been a severe collision, as only minor impact damage had occurred. The car had been engulfed in flames during the ensuing post impact fire, and this fire had consumed most of the aircraft's right wing, in addition to the inboard left wing and much of the fuselage between the flight deck bulkhead and the tail section. The hedgerow between the field and the road was on a small ridge and it appeared that contact with this ridge had caused the main landing gears to collapse, in a rearward direction, during the final stage of the ground-slide.

Following an on-site examination, the wreckage was recovered to the AAIB at Farnborough for a detailed examination.

Detailed examination of the wreckage

The main thrust of the investigation was directed towards the powerplants, with particular emphasis on trying to establish a reason for the apparent failure of the right engine. This was initially suspected to be the result of a birdstrike.

Fuel analysis

No fuel was found in the aircraft wreckage for analysis. However, samples were taken from the bowser from which the aircraft refuelled on the evening prior to the accident and these were analysed by the QinetiQ Fuel and Lubricants Centre at Pyestock. No abnormalities were identified with these samples, all of which conformed to the specification for Jet A1.

Powerplant description

The TPE 331 is a single shaft engine, comprising a two-stage centrifugal compressor/impeller and a three-stage axial turbine, which drives a four bladed constant speed propeller via a reduction gearbox. In propeller governing mode, the speed of the engine is held constant by the propeller governor, which modulates the propeller blade angles to match load input/output. The pitch changing mechanism is hydraulically operated, using engine oil pressure, towards fine pitch but is mechanically assisted towards coarse pitch and the feather position by means of feathering springs and the action of counterweights mounted on the blade roots. The propeller hub consists of a cylinder and a piston, with the latter connected to a 'crosshead' assembly and into which an operating pin, attached to the base of each propeller blade, engages. This arrangement allows fore and aft movement of the piston and crosshead to be translated into twisting motion of the blades. The piston position, and hence blade angle, is determined by the pressure of the oil to the rear of the piston, opposing the force of the feathering springs in front of it and the effect of the counterweights.

Two spring loaded 'start latches' are positioned diametrically opposite each other in the cylinder and retract into their housings under the action of centrifugal force at engine speeds in excess of approximately 25% N1. During a normal engine shutdown, the latches extend into the cylinder as engine RPM reduces, and engage in a circumferential recess in the piston. This prevents the feathering springs pushing the piston to the feathered position during normal engine shutdown and results in the blades being held at an angular position which minimises torque loads during the next engine start.

A Negative Torque Sensing (NTS) system on the engine detects a 'windmilling' condition, ie, when the propeller back-drives the engine, and causes the propeller blades to move towards coarse pitch, minimising propeller drag loads. Thus, the NTS system is designed for drag reduction and is not an automatic feathering system. Feathering must be selected by the crew and this is achieved by pulling the appropriate feathering handle on the flight deck pedestal. This handle is connected to its associated engine by means of a 'teleflex' type cable. When pulled, initial movement of the cable operates a fuel cut-off on the engine, with further movement opening the feathering valve. This allows propeller oil pressure to be vented so that the feathering springs move the piston, and hence the propeller blades, to the feathered position. The fuel cut-off valves can also be operated electrically and are used on engine start-up and shutdown, in order to isolate the engine from the airframe portion of the fuel system.

Examination of the propellers

The propeller assemblies were examined with the assistance of the propeller manufacturer. It was noted that some of the blades could be rotated in their respective hubs, indicating that their operating pins had become detached from the base of the blades. This was consistent with the nature of the impact.

None of the propeller blades bore any obvious evidence of bird remains; however, the blades had been in sustained ground contact during the impact sequence, which could have wiped off any such evidence. Similarly, the post impact fire could have removed or masked any bird remains, particularly on the right propeller.

Disassembly of the propeller hubs revealed no evidence of a pre-impact failure in any of the internal components, although considerable impact damage had occurred. It was found that pistons of both propellers were held on the start latches, ie, corresponding to a blade pitch angle of around 0°. This was initially considered somewhat surprising, especially as the right propeller, reportedly, had been feathered whilst the aircraft was still airborne. However, the manufacturer commented that this situation had been observed in previous accidents and incidents. It was thought that the longitudinal deceleration that occurred when the aircraft struck the ground could have caused the piston to move forward due to the inertial effects of its own mass, away from the coarse pitch position. In addition, the rotational deceleration of the propeller, as a result of the blades contacting the ground, would have caused the angular momentum of the counterweights to act to twist the blades away from the coarse pitch position.

During the impact sequence, the flanges on the crosshead assemblies had come into violent contact with the bases of the propeller blades. At several locations the marks so made were clear enough to define the blade's angular position at ground impact. By this process, it was possible to establish that the left propeller blade angle was around 30°, a typical position for an engine delivering power. No such blade angle could be determined for the right propeller, due to an absence of reliable witness marks.

It was found that with some of the blades, a flange near the blade root had inflicted crush damage to part of the circumference of the hole in the hub unit in which it was located. In the case of the left propeller, the damage was over an arc in the plane of the propeller disc, but on the opposite side to the direction of rotation. This indicated that the blades had been forced against the direction of rotation as a result of torque being applied by the engine to the hub during their initial contact with the ground. In contrast, the equivalent damage on the right propeller was to an arc of the circumference on the aft side of the hub holes. This indicated that the damage was primarily the result of the blades being forced in a rearwards direction following ground contact, with a relative absence of rotational speed.

In summary, the available evidence indicated that at impact the left engine propeller was in a position typical for an engine producing power. The right propeller blade pitch angles could not be determined.

Examination of the engines

Both engines were initially examined with the assistance of the European representatives of the engine manufacturer; subsequently, they were subjected to a strip examination at the manufacturer's facility in the USA. A smear of blood inside the intake of the left engine, together with a characteristic odour, indicated that at least part of a bird had been ingested. This was confirmed by means of a boroscope inspection, which revealed a considerable quantity of burned residue in the first stage nozzles, as well as the more obvious remains of vegetation from the accident site. It was found that one of the first stage impeller blades had been distorted, probably as a result of the bird ingestion, or possibly from other debris ingested during the impact sequence. The right engine showed no evidence of bird ingestion. However, during the boroscope inspection it was observed that the turbine nozzle area was black and sooty in appearance, suggesting either that combustion had been taking place under a fuel-rich condition, or it had been cooler in operation, in comparison with the left engine. On disassembling the combustion sections, no evidence of bird ingestion was found in the right engine but a small amount of residue, including the remains of a burnt feather, was found in the combustion chamber casing of the left engine. Confirmation of bird remains in this engine possibly explained the burning smell observed by the crew immediately after takeoff, as bleed air is taken from the engine second compressor stage, and is fed into the aircraft air conditioning/pressurisation system.

It was found that the left-hand propeller hub could be rotated by hand, without accompanying rotation of the engine. This indicated that a disconnect had occurred in the reduction gearbox drivetrain and, in fact, was found to be a failure resulting from a torsional overload of the high speed pinion input shaft to the reduction gearbox. According to the manufacturer, this is a design shear point and this, in turn, suggested that the engine was developing significant power at the time the propeller blades struck the ground. The fact that no such disconnect had occurred in the right engine corroborated other evidence of the comparative lack of power being generated by that engine.

The oil in both engines was normal in appearance and the filters and gearbox magnetic chip detectors were clear of debris. It was also observed that the fuel cut-off valves, as operated by the feathering handles, were in the 'OFF' position on both engines.

The propeller governors were tested on an appropriate rig and were found to perform their governing function satisfactorily.

In summary, the mechanical components of both engines, generally, were in good condition, although some corrosion had occurred in areas that contained the remains of fire-fighting foam. No evidence was found of a pre-impact failure in either engine, or that could explain the loss of power on the right engine.

Engine fuel system examination

The right engine fuel control unit, which had been installed in 1994, was taken to its manufacturer's facility for evaluation. Despite being outwardly affected by fire, it was capable of being run in a test rig. There was no leakage and the calibration check revealed no anomaly that would have caused a loss of engine power. The unit was subsequently disassembled and inspected. No damage or defect was apparent. Other fuel system components from the right engine that were examined included the flow divider and anti-ice solenoid valve. The flow divider apportions fuel to the primary and secondary fuel manifolds; however, when tested, heat damage to the internal components resulted in leakage and erratic performance. Nevertheless, examination revealed that the most critical internal component, a 'bellows' assembly, had remained intact, which suggested that the flow divider was probably operating correctly. The anti-ice solenoid valve would not operate to the closed position when tested. Whilst this could have been an effect of heat in the post-crash fire, it should have been open at takeoff, and thus should not have had any unusual effect on the engine.

'Single Red Line' (SRL) system components

The engines on OY-BPH were equipped with a SRL system. This essentially protects an engine from exceeding EGT or torque limits by signalling a fuel by-pass valve to port excess fuel from the supply to the engine to the return lines. This illuminates a 'Bypass' light, which indicates to the crew that fuel supply to the appropriate engine is being restricted to maintain engine parameters within limits. The SRL system components, consisting of the SRL computers, engine pressure ratio transducers, torque signal conditioners and EGT transducers, were all removed from the wreckage. However, they had all been affected to varying degrees by fire, and were not capable of being tested. Whilst a failure of one of the components could have an effect on engine operation, none would produce a power loss of the magnitude that apparently occurred to the right engine.

Engine maintenance history

The left and right engines had last been overhauled in 1993 and 1994 respectively and, since then, had accumulated total operating times of 5,189 and 4,530 hours respectively. The current operator acquired the aircraft in December 1996. Throughout much of 2002, the aircraft was leased to a Spanish operator before being returned to Denmark in September. In June, the left engine reportedly flamed out after landing and a German maintenance company was tasked with investigating this event. The rectification work included adjustment of the propeller governor, following which the engine ran satisfactorily during a ground test. A few days later, a local (Spanish) company interchanged the fuel cut-off valves between the two engines. Back in Denmark in November, both engines were removed due to reports of low power and torque. Such an event is not uncommon for this type of engine, and is normally remedied by an inspection/repair of the 'hot section'. Both engines were reinstalled, in their original positions, on 10 December 2002, and the aircraft subsequently completed 16 flights prior to the accident.

The exchanging of the cut-off valves suggested that the flame-out incident had not been satisfactorily explained. Although 'rough handling' of the engine controls was put forward as a potential cause of the engine power loss, there was also anecdotal evidence of engines having been shutdown due to uncommanded operation of the shut-off valve. However, the engine manufacturer stated that they were unaware of any such incidents. In the case of OY-BPH, both engine shut-off valves were found in their closed positions, which was consistent with operation of the feathering handles. The valve body from the right engine, together with its integral electrical components, had been almost entirely consumed in the post impact fire, thus no meaningful examination was possible.

Additional information

It was found that a FAA (Federal Airworthiness Administration) Airworthiness Directive (AD) relating to the engine ignition system had not been embodied on this aircraft. AD 2002-01-16, dated 11 March 2002, mandated Fairchild Service Bulletin 227-74-001, dated 8 July 1986. The Service Bulletin introduced an auto-relight system, which is operated via a pressure switch fitted to the NTS dump valve. In the event of negative torque being sensed, such as would occur following a flame-out, the engine igniters are switched on automatically. The aircraft manufacturer was having problems in making timely deliveries of the modification kits to operators of the affected aircraft. In consequence, the Danish national airworthiness authority had allowed a dispensation for this aircraft to operate until such time as the modification kit was available. However, the ignition switches were found, post accident, at the 'normal' position, as opposed to 'continuous' or 'override'. The aircraft's Flight Manual states that these switches should be set to 'normal', unless the takeoff is made with standing water or slush on the runway, when they should be set to 'continuous' or 'override'. At the time of the accident the runway was reported as being wet, but with no standing water.

Fire and survivability issues

In this type of aircraft, fuel is carried in the wings and fed to the engines, via electrically operated shut-off valves, from 'hopper tanks' at the inboard ends of the wing tanks. These tanks are kept full at all times by means of boost pumps.

The nature of the terrain at the accident site had resulted in the aircraft coming to rest in a slightly right wing low attitude. Following the collapse of the main landing gear it is likely that ruptures occurred on the underside of the inboard sections of the wings during the final stage of the ground-slide. Thus fuel escaping from these ruptures, or from fractures in the engine fuel lines, would have run underneath the fuselage from the left wing and joined fuel from the right wing flowing in an outboard direction. This would have accounted for the areas of the aircraft that suffered the most severe fire damage, as described earlier. It is also probable that the boost pumps, which would have continued to operate until electrical power was removed, had exacerbated the discharge of fuel.

The main batteries were located in compartments in the wing roots and had suffered significant fire damage. As this area had been disrupted during the ground-slide, there would have been scope for the battery leads, or the cables feeding the boost pumps, to short out on the airframe, thus providing a potential ignition source.

The crew exited the aircraft via the main door located on the left side of the forward fuselage immediately aft of the cockpit bulkhead. The fact that the door opened with apparent ease indicated that little or no structural distortion had occurred to that part of the fuselage during the accident sequence.

Operational information.

Three runway inspections had been completed on the day of the accident, prior to the departure of OY-BPH. The last was instigated at 0555 hrs and the airfield operations officer reported to ATC at 0616 hrs the runway as being: "Wet full length and serviceable". During the inspection, the operations officer had noted the presence of gulls and took action to make them disperse. Following his report to ATC, he continued his airfield inspection and noted that the birds had not returned, before completing the inspection at 0705 hrs. Between then and the departure of OY-BPH, at 0743 hrs, there had been four aircraft movements, two of which (one arrival, one departure) were fixed wing aircraft which had used Runway 16. None of these had experienced a bird strike.

During the investigation, interviews with the pilots of OY-BPH revealed the following information:

1. The crew completed the normal company check lists prior to flight. This included a satisfactory check of the CVR prior to engine start, a successful check of the NTS systems (see Note 2 below) after engines start, and a satisfactory check of the Stall Avoidance System (SAS) while taxiing to the runway.

   Note 1. The Flight Manual (FM) requires that both NTS systems are serviceable for flight.

   Note 2. The NTS check involves moving the power lever forward with the propeller RPM lever set to low, and ensuring that each engine will govern at the propeller governor low setting. Thus, in reality, the check only ensures that oil pressure is available for the NTS system, as opposed to checking the NTS system itself.

2. The co-pilot, as the designated handling pilot, gave a standard emergency brief whilst taxiing to the runway. This included the actions to be taken in the event of an engine failure after V_1 and these were in accordance with the procedures detailed in the aircraft FM.

3. Neither pilot saw any birds or was aware of a bird strike during the takeoff.

4. During the takeoff, the commander's feet were 'covering' the rudder pedals. Following the apparent engine failure, he was aware of some, but not full corrective rudder being applied.

5. The commander did not raise the gear after takeoff because his perception was that there was no positive rate of climb.

The aircraft FM contained the following procedure for an engine failure during takeoff, with the takeoff continued above V1:

'1. TAKEOFF POWER SETTING CHECK

NOTE: Commanding high propeller blade angle by keeping the power lever of the inoperative engine well forward will reduce windmilling propeller drag in the event that NTS failure accompanies engine failure.

2. VR Speed ROTATE

(CLIMB AT V2 SPEED)

3. LANDING GEAR (AFTER LIFTOFF) UP

4. ENGINE STOP AND FEATHER CONTROL (failed engine) PULL

5. FLAPS (at acceleration altitude (defined as 400 feet agl) and V2 +5 KIAS) UP

6. MAX CONTINUOUS POWER (AT VYSE (single engine best rate of climb)) SET

(CLIMB AT VYSE)'

Based on the aircraft weight, the FM figures for take-off speeds were as follows: V_1 was 100 kt, V_R was 100 kt, V_2 was 109 kt and V_{YSE} was 126 kt.

As detailed in the aircraft FM, the take-off flight path consisted of 4 phases (segments). In phase one, both engines are assumed to operate normally to V_1 where one engine fails and the takeoff continues on one engine. The phase ends at 35 feet above the runway surface at V_2. The second phase is a constant V_2 climb from 35 feet and ends at 400 feet above the runway. The landing gear is fully retracted at the start of this phase, flaps remain at 1/4, and the propeller on the inoperative engine is windmilling in the NTS mode. The third phase is an acceleration at 400 feet from V_2 to V_{YSE}; the flaps are retracted at V_2 + 5 kt, the inoperative engine is feathered and take-off power is maintained on the operative engine until V_{YSE} is obtained. The final phase is from 400 feet to 1,500 feet above the runway surface at V_{YSE} and with maximum continuous power set.

In the ambient conditions, the FM indicated an expected rate of climb of 820 feet per minute during the second phase.

Although both pilots were qualified on the aircraft type, each worked for a different parent company. The company with the mail contract employed the co-pilot, but the aircraft and commander had been leased from a different company. Both pilots had completed the appropriate training for the aircraft type in accordance with JAR-OPS for their respective companies. Additionally, the commander stated that he had carried out a satisfactory line check on the co-pilot during the flight from Denmark to Aberdeen Airport on 9 December 2002. His company's understanding was that this complied with the JAR-OPS requirements. A check was made with the national authority of OY-BPH to ascertain if the training of the co-pilot was in accordance with JAR-OPS 1.945 (conversion training) and JAR-OPS 1.965 (recurrent training and checking). The national authority stated that any change of operator for a pilot required the completion of a full conversion course. This had not been carried out.

In accordance with the national regulations of the state of registration of the aircraft, a blood sample was taken from each pilot after the accident. Analysis of these samples confirmed that there was no evidence of any alcohol, drugs or any toxic substance, which may have caused or contributed to the cause of the accident.

Discussion

Although the investigation was hampered by the lack of FDR data, which might have provided information on engine handling and behaviour, the available evidence from the crew and the initial examination of the aircraft at the accident site, pointed to a major loss of power in the right engine.

As a result of the discovery of dead birds close to the point of lift-off on the runway, and a section of braided wire found near the start of the take-off roll, consideration was given as to whether the these had been factors in the accident. The braided wire was not identified as having originated from OY-BPH. There was conclusive evidence that the left engine, which had continued to run, had ingested parts of birds, but no such evidence was found with the right engine. Nevertheless, the crew were adamant that there was a power loss from the right engine and were not conscious of any power reduction from the left engine. The technical examination of the left engine and its propeller assembly revealed evidence of damage consistent with this unit delivering a high level of power at impact. The examination of the right engine and propeller revealed all damage to be consistent with a low, or no, power condition at impact, consistent with either a genuine loss of power or as a consequence of the commander pulling the 'Stop and Feather' control immediately before impact. However, an exhaustive examination of the right engine revealed no evidence of anything that could have caused a failure.

Therefore, the items found on the runway were not considered to have been causal or contributory factors in the accident.

The crew's recollection of the event included a low EGT indication, at 600°C. This suggested that either the engine might have flamed out, should they have only momentarily looked at the indication as the engine was cooling down, or that the engine was operating at reduced power for an undetermined reason. Flame out could have occurred due to a number of reasons, including, for example, water contamination of the fuel. However, analysis of the bulk supply samples proved negative and, moreover, there were no reports of contaminated fuel from other operators at Aberdeen Airport. Ingestion of ice or water could also have resulted in a flame-out, although this is considered unlikely due to the conditions not being conducive to the formation of engine icing, the lack of significant standing water on the runway, and the absence of heavy precipitation. However, it could not be completely discounted and, if flame-out had occurred, the non-incorporation of the FAA mandated auto-relight system would have reduced the possibility of an immediate relight.

Approximately six months before the accident, the left engine had failed during a landing roll-out whilst the aircraft was being operated in Spain. This failure was never satisfactorily explained although, at one stage, the fuel cut-off valve came under suspicion. The valves were interchanged, according to the records, so that the unit that had been fitted to the left engine was installed on the right engine, at the time of the accident. Whilst a stray electrical signal causing the valve to close would certainly result in the engine flaming out, rumours that such events had occurred were not substantiated by the engine manufacturer.

In summary, the left engine experienced a bird strike, but with no apparent power loss, and the extensive technical examination could not identify any reason for a loss of power on the right engine.

Although an engine failure during takeoff after V_1 is a serious emergency, the aircraft was at a relatively light weight and, even with an such a failure, the crew should have been able to fly OY-BPH safely away. However, if other factors had been involved, the margins for safe flight would have become more critical. These other factors could have included incorrect operation of the NTS system and/or a failure of the feathering system on the right engine, a concurrent power loss from the left engine, or the crew not handling the emergency effectively.

There is no doubt that the left engine had been producing power at impact, but a definite conclusion could not be made as to the blade pitch angles of the right propeller. From the evidence of the commander and the propeller examination by the manufacturer, it is probable that the right propeller was close to the feather position at ground impact. The functionality of the NTS and feathering system could not be determined but, as noted earlier, the pre-flight NTS check actually only ensured that oil pressure was available for this system, and did not check the operation of the whole system.

With the evidence that only the left engine had ingested birds, there was a possibility that the left engine was not producing maximum power, although the crew considered it was operating normally. The commander could remember that he compared the engine EGT indications, once he had pushed both power levers forward, and recalled that the left EGT was indicating greater than 650°C with the 'Bypass' light on. He then retarded the left power lever until the 'Bypass' light went out, following which the EGT indicated about 630°C. This retardation of the power lever was not required, as the function of the 'Bypass' system is to reduce the fuel flow in order to keep the engine parameters within limits. This reported retardation could, however, have resulted in a lower engine power than was possible within the available limits, possibly with an associated reduction in EGT. While it remains a possibility that the left engine may have experienced a transient power reduction as a result of the bird ingestion, it is likely that the commander's action in retarding the left power lever resulted in a more significant reduction of power.

To maintain straight flight, following an engine failure, it is vital to apply sufficient corrective rudder input to maintain the wings essentially level and minimise the drag due to sideslip. In the case of OY-BPH, there was a constant turn to the right before ground impact. The commander's recollection was that left rudder had been applied by the co-pilot, but not to full deflection. The amount of rudder deflection required depends mainly on the airspeed and the difference in engine power but, with the wings not level, more deflection was obviously required, and was available. Greater use of rudder would have reduced the overall drag of the aircraft, with consequent improvement in the aircraft's performance. Furthermore, following an engine failure, the second segment climb requirement is to climb from 35 feet to 400 feet at V_2 with the landing gear selected to up. The commander did not raise the gear because he did not observe a positive rate of climb. However, evidence from the FDR was that a maximum airspeed of 128 kt was achieved and, as this was some 19 kt higher than the V_2 speed, it indicated that the aircraft had a capability to climb which was not being used.

These last three factors may have combined to reduce the climb capability of the aircraft to zero and, in that situation, the decision to not raise the gear was correct. However, all these factors were influenced by inappropriate crew actions. Although both pilots had flown together before, the lack of adherence to JAR-OPS conversion requirements may have been partly responsible for their actions during the emergency.