ACCIDENT

Aircraft Type and Registration:	Lockheed L188C Electra, G-FIJV
No & Type of Engines:	4 Allison 501-D13 turbprop engines
Year of Manufacture:	1961
Date & Time (UTC):	12 October 2006 at 0540 hrs
Location:	Nottingham East Midlands Airport
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Loss of the No 3 engine cowlings and impact damage to the fuselage and No 4 propeller
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	3,477 hours (of which 933 were on type) Last 90 days - 87 hours Last 28 days - 28 hours
Information Source:	AAIB Field Investigation

Synopsis

During taxi prior to flight, the engine cowlings from the No 3 engine detached, causing minor damage to the fuselage and the No 4 propeller. The flight proceeded uneventfully and their loss was only discovered after the aircraft's arrival at its destination; the doors were discovered on a taxiway at the departure airfield. The investigation concluded that the No 3 engine air turbine starter motor casing probably failed after engine start, releasing a rotating clutch assembly into the nacelle, which caused deformation to one of the cowling doors. This in turn allowed propeller wash to enter the nacelle and overstress the door latches attachment structure. Only approximately half of the casing fragments were recovered but none showed any evidence of pre-existing cracking or other defects. The operator, to whom the L188 aircraft type is unique in the UK, has instituted regular inspections of the starter motors to check for defects/cracks.

History of the flight

After an uneventful flight from Nottingham East Midlands Airport (EMA) to Cork, having departed East Midlands at 0540 hrs, one of the ground crew at Cork observed that two engine cowlings were missing from the No 3 engine. After calling their operations department, the flight crew were informed that both cowlings had been found on taxiway Alpha at EMA. The flight crew stated that there had been no abnormal

indications during the engine start sequence, and that the aircraft's handling and engine indications had been normal throughout the flight.

Examination of the aircraft revealed that the No 3 engine air starter motor had failed, components of which were recovered from the engine nacelle; no other damage to the engine or its associated equipment had occurred but impact damage was identified on the No 4 propeller and the fuselage.

Engine starter motor description

Each engine is fitted with an air-turbine starter motor, mounted on the aft side of the propeller reduction gearbox. The starter is attached to the propeller gearbox by a band clamp, which fits over a flange on the unit's case and allows for its rapid replacement. The motor consists of an air-driven turbine which, through an internal reduction gearbox, a clutch unit and output drive shaft, drives the propeller gearbox. The clutch unit prevents the starter motor being 'driven' by the engine when the engine speed exceeds that of the starter output drive. When the engine is running, the clutch unit continues to rotate within the air starter as it is directly connected via the output drive shaft to the propeller gearbox.

Each air starter motor is powered by bleed air from the aircraft's bleed air manifold, which is pressurised by an operating engine or, during ground starting, by an external pneumatic supply. The supply of pressurised air to each engine is controlled by an electro-pneumatic starting valve. When the engine start sequence is initiated, the start valve opens, allowing the bleed air to turn the starter turbine. At 2,200 (engine) rpm, the fuel and ignition systems are activated and the engine accelerates to idle speed. The engine starter remains engaged to assist engine acceleration during this period. As the engine accelerates further, a cut-out switch within the starter is activated at between 8,000 and 8,400 (engine) rpm, which closes the start valve. If this does not occur, a 'starter overspeed' light will illuminate in the cockpit when engine speed exceeds 8,500 rpm. Operational procedures require that, in the event of a starter overspeed warning, the engine must be shut down immediately.

Investigation

The No 3 engine, including the nacelle, had been removed by the operator after the incident and was examined by the AAIB, together with the remains of the starter and the damaged cowlings, at the operator's maintenance facility at Cork. It had been reported that the remains of the cowling latches were still attached to the nacelle. A review of the aircraft's technical log book showed that no maintenance had been carried out on the engine prior to the flight and subsequent tests confirmed that the aircraft's starter overspeed warning system was serviceable. The remains of the starter unit, together with the pneumatic start valve, were the subject of a detailed examination.

The engine cowlings are hinged on their upper edge and held in the closed position on the left and right sides of the nacelle by two latches on their lower edges. Damage to the hinges confirmed that both doors had been torn backwards and upwards before being released from the aircraft. Both latches on each cowling, together with some adjacent structure, had been pulled from the cowling doors. The right door had lost its upper aft corner, the failure surface of which was consistent with it having been struck by the rotating No 4 propeller. The leading edge of the left door had been bent outwards in line with the position of the forward latch, and there was evidence of impact damage to the inner surface of the lower leading edge corner, which had distorted the forward lip

of the cowling. Detailed examination revealed that the mounting structure for all the cowling latches had failed due to an overload condition, and that the latch hooks were undistorted and remained operable.

The pneumatic start valve was tested and no faults were identified with its operation. The air starter unit gearbox case had broken up, but sections of the case remained secured to the air turbine containment case by the mounting bolts. The forward section of the case remained attached to the propeller reduction gearbox by the quick disconnect clamp and examination of the case fracture surfaces showed all fractures to have resulted from overloading. It was estimated that approximately 55% of the air starter reduction gearbox casing was recovered.

All of the starter unit's internal components were found within the nacelle. The turbine containment case was intact and detailed examination showed there was evidence of rubbing contact between the air turbine blade tips and the inner surface of the case. The reduction gearing components were intact and undamaged, and all these components were covered with a film of light-coloured oil. The clutch and governor assembly showed clear evidence of rotational damage but, when tested, the clutch functioned satisfactorily. The bearings within the assembly were intact and rotated without restriction.

A review of the aircraft's maintenance records showed that the starter motor had been installed for 3,139 hours prior to this incident; there were no entries in the aircraft technical log relating to this unit since its installation. It was not possible to determine either the total age or operational life of the unit. The Approved Maintenance Schedule for the Lockheed L188C Electra requires that the air starter unit is subject to weekly oil servicing and magnetic chip detector inspections. However, it is considered to be an 'on-condition' item and therefore not subject to scheduled removal, or any other inspections, whilst installed.

Analysis

The flight crew reported that the start of the No 3 engine was normal, with no indication of a starter 'overspeed', and tests confirmed that the pneumatic start valve operated normally. The fact that the cowling latches remained attached to the nacelle after the cowlings had departed the aircraft, and their general condition, confirmed that they had been correctly engaged prior to the incident. The condition of the hinges revealed that both cowlings were lifted upwards and aft, indicating that the latch attachments failed before the hinge attachment structure. The impact damage and deformation to the forward edge of the left engine cowling showed that the cowling had been struck on its inner face with some force, probably by the rotating clutch assembly. Any deformation in this area would have subjected the cowling to increased forces from the propeller wash, increasing the loading on the hinges and latches. It would also have allowed the propeller wash to enter the interior of the nacelle, most likely causing an increase in the ambient pressure, thereby increasing the load on the cowlings. Any increase in engine power, either during taxiing or at the start of the takeoff roll, was likely to have significantly increased the loads experienced by the cowling attachments and probably precipitated the failure of the latches attachment structure.

The satisfactory operation of the clutch unit, together with the apparently normal start of the No 3 engine, indicted that the starter was unlikely to have been 'oversped'. The film of oil found on the gearbox components confirmed that oil had been present in the gearbox, and its appearance indicated that it had not been overheated.

The lack of damage to the reduction gearbox components indicated that the reduction gearing was not rotating with any significant speed when the failure occurred. However, as the starter clutch unit does continue to rotate at considerable speed while the engine is operating, a failure of the gearbox case would allow the clutch unit to be released into the nacelle whilst it had considerable kinetic energy, as indicated by the evidence of rotational damage on the unit.

When attached to the propeller gearbox by the quick disconnect clamp, the majority of the loads acting on the starter unit are carried by the casing and mounting flange. The condition of the air turbine motor and its casing indicated that there may have been some imbalance or misalignment of the turbine rotor prior to the incident, leading to the rubbing of the turbine blade tips on the turbine containment case. It is possible, therefore, that given the likely high levels of vibration experienced by the starter in operation, a crack could have developed in the reduction gearbox casing. If this was so, then it may have occurred in the upper, but missing, portion of the casing, where tensile stresses are likely to be at their highest. A crack in this region would be above the level of oil within the casing and may not have been readily identifiable through a visible oil leakage or excessive oil consumption. In this situation, a crack might progress undetected until it became large enough to precipitate the remaining material to fail in overload and release the internal components of the starter.

Although examination of the recovered fragments of gearbox casing, amounting to approximately half of the unit, failed to identify any sites of crack initiation or progression, the possibility that a significant crack in the starter unit had grown to a critical length prior to the incident, in the casing sections not recovered, could not be dismissed.

Conclusion

Failure of the air starter motor gearbox case on the No 3 engine occurred as the aircraft taxied prior to the flight to Cork, releasing the turbine wheel, reduction gearbox and clutch unit from the motor. The leading edge of the left engine cowling was deformed outwards as a result of an impact on its inner face, probably from the air starter clutch unit, causing it to protrude into the propeller wash. This appeared to have pressurised the interior of the engine nacelle sufficiently to have overloaded the cowlings latch structure, allowing both cowlings to be released. The right cowling was then struck by the No 4 propeller.

As approximately half of the casing fragments were not recovered, the origin of the failure could not be determined with any certainty. However, the most probable cause of the failure of the air starter gearbox casing was the propagation of a crack, which remained undetected until the casing failed due to an overload condition.

Safety action

As a result of this incident, the operator has introduced a repetitive inspection of the air starter units installed on their Lockheed Electra aircraft. In view of the fact that this aircraft type is unique to this operator in the UK, no further safety action is considered to be appropriate at this time.