Aircraft Type and Registration:	AS350B1 Ecureuil, G-PLME
No & Type of Engines:	1 Turbomeca Arriel 1D turboshaft engines
Year of Manufacture:	1988
Date & Time (UTC):	9 September 1993 at 0710 hrs
Location:	Lesmahagow, nr Douglas, Strathclyde
Type of Flight:	Aerial Work, underslung loads
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - Serious Passengers - N/A
Nature of Damage:	Aircraft destroyed, structure partially collapsed vertically on impact with ground
Commander's Licence:	Air Transport Pilot's Licence (Helicopter)
Commander's Age:	34 years
Commander's Flying Experience:	Total 4,100 hours (of which 650 hours were on type) last 90 days - 106 hours last 28 days - 59 hours
Information Source:	AAIB Field Investigation

The aircraft had been engaged in aerial work, removing sections of dismantled powerline pylons as underslung loads. On the third lift, the aircraft picked up a section of pylon and climbed away steeply to clear an 11kv powerline which was directly ahead. After clearing this, and at a height of about 100 to 120 feet agl, the pilot heard a 'bang' followed by a slight yaw; the ground crew also heard this 'bang' followed by a high pitched whine or whistle. Almost immediately the low rotor RPM warning sounded and the pilot lowered the collective lever as the aircraft descended rapidly. Although he applied collective pitch again to cushion the landing, the aircraft struck the ground with a high rate of descent but little forward speed.

At impact the helicopter's structure collapsed partially in the vertical sense and the pilot, although remaining conscious, suffered a very painful back injury. He was assisted from the wreckage by the ground crew.

Subsequent examination of the aircraft showed that the skid gear had collapsed, resulting in the underside of the cabin structure coming into contact with the ground. The floor structure of the cabin is supported on two main beams which are cantilevered forward from the transmission support structure. The seat structure is formed as a double skinned inverted 'U', with the seat runners on the bottom. The runners for each of the pilot's seats are placed, unequally, one either side of the floor support cantilever. The forces resulting from the sudden arrest of the cantilever on hitting the ground had caused the floor to bow beneath the seat runners and the bottom of the seat structure to fail.

The engine was removed and taken to the manufacturer for strip examination under supervision of the AAIB. This revealed that a single blade from the 2nd stage turbine of the gas generator had separated from the disc. In the turbines of this engine type, individual blades are fixed to slotted turbine discs by a 'fir-tree root'. After separation from the disc, the blade had passed rearwards through the power turbine, damaging or breaking off the outer part of every power turbine blade. The imbalance in the gas generator rotating assembly resulting from the blade loss had been sufficient to break up the rear bearing support structure and cause blade tip rubs throughout the gas generator section of the engine. The damage observed in the engine was sufficient to cause an immediate and complete loss of power.

Examination of the fracture of the blade showed that it had failed initially by fatigue from an origin in the trailing edge side of the aft face of the fir-tree root, at the first serration below the platform (see Figs 1 & 2). The failure had progressed by a fatigue mechanism forwards and upwards from this point until it had penetrated the platform, after which the final separation of the blade had occurred by fast rupture through the remainder of the blade section. Examination of the other blades in this turbine assembly showed that a further 7, of the total of 27 blades, had started to crack at the same location on the fir-tree root and an 8th had a crack starting on the 3rd fir-tree root serration. It was also noted during this examination that the injection wheel was cracked. These cracks were not associated with any material defects or deficiencies and the interpretation placed on these findings by the manufacturer was that the engine had experienced a very large number of operating cycles since overhaul and that the turbine blade set had exceeded its safely useable life.

The Arriel 1 engine is of modular construction and although operators are permitted to change complete modules, all overhauls are performed by the manufacturer. An examination of the CAA engine log book, which constitutes the engine operating record, showed that this engine had been fitted as a manufacturer's overhauled unit on 14 June 1991 and had retained the same gas generator module up to the time of this accident. When an engine is released to service after build or overhaul it has, in the manufacturer's log book, a certificate of available life for each module. This is specified in terms of both operating hours and operating cycles and whichever life limit is reached first determines a module's time of withdrawal from service for overhaul. This certificate takes account of the official declaration by the previous owner of the module with regard to components which have been reused in the overhauled assembly. The manufacturer's log book showed that this engine had passed its acceptance checks at the factory on 28 February 1991 and had an available life of 2,500 hours or 5,104 cycles determined by the gas generator module.

The Arriel 1D Maintenance Manual, Chapter 5-10-03, details the manner in which the time between overhauls (TBO) of the engine should be assessed and the factors which have to be taken into account when assessing consumption of this life in each of the modules. This chapter also states that the cycle consumption rate is affected by different types of operation. There are two ways of calculating the operating cycles of the gas generator module, both of which involve some knowledge of the minimum gas generator speed (Ng) and when it is achieved during any phase of the flight profile. The preferred 'Recommended' method, uses refined data on the variation of Ng; as an alternative there is a 'Lump' method which uses coarse assumptions about the Ng range used and which results in a higher cycle consumption rate.

There are five cyclic life limited components in the gas generator (two compressor wheels, the fuel injection wheel and the discs of the two turbine wheels) and the TBO of any particular module is determined by the component with the lowest remaining cyclic life. This need not be the component with the shortest inherent life but may be a component which has already had part of its life consumed during a previous overhaul life. The manufacturer's log book for this engine showed that, after overhaul, the 2nd stage turbine disc of the subject engine had the lowest remaining cyclic life (5,104).

Although the 2nd stage turbine blades are not stated to have a specific life, the manufacturer's experience and development testing had indicated that these were satisfactory for two lives of their turbine disc which, at the time of overhaul of this gas generator, was 5,300 cycles. The implied life was, therefore, 10,600 cycles. However, as a result of an increase of the turbine disc life to 6,000 cycles, which was promulgated in a manufacturer's Service Letter 1506/92/AR1D/26 of 2 July 1992, the blades were, by implication, deemed satisfactory for 12,000 cycles. The blades used in this particular module had been installed at its initial build and consequently carried a previously recorded usage of 2,258 hours and 4,613 cycles into the overhauled module. Since the time of original construction of this gas generator, a new standard of turbine blade with improved fatigue life has been developed.

The log books and Technical Log information available showed that, since this engine was installed in G-PLME, it had experienced 2,239 operating hours with 2,274 engine starts and 21,542 flights. Using the criteria in the Maintenance Manual and values of Ng for various phases of flight specifically observed during typical operations and estimating a conservatively harsh mix of operational work over the period, a reassessment was made of the cycles used by the operator during the overhaul life of this module. This showed that the module had consumed either about 4,400 cycles calculated by the 'Recommended' method, or 5,500 cycles calculated by the 'Lump' method.

The previous operator who used this module (no longer trading) was understood to engage in a similar mix of operations as the operator of G-PLME. If the cycles recorded by this previous operator had been calculated by the 'Recommended' method and a similar disparity between the cycles estimated by that method and the 'Lump' method is assumed, then this suggests a total utilisation of the 2nd stage turbine blades of about 9,000 (Recommended) or 11,000 + (Lump) cycles. This latter figure is close to the implied satifactory service life of the blades. During the metallurgical examination, the manufacturer established, using a technique they consider reliable, that the turbine blades had run a minimum of 11,820 cycles, evenly divided between the two overhaul lives. Research indicates that this was probably the 'lead' engine in the fleet. in terms of 'cycles' and very high time in 'hours'.

The calculation of cycles consumed consists of two elements: a) a 'Complete' cycle, related to the Start - Power acceleration - Shut Down and; b) a 'Partial' cycle, related to each time Ng decays below 85% between start up and shut down. Thus the gas generator accumulates operating cycles particularly rapidly when there are frequent engine shutdowns or reductions of Ng to ground idle, such as in Air Ambulance or pleasure flight operations, or in cases when there is a large number of power changes, with their concomitant changes of Ng demanded between engine start and shut-down, which is usual when using the helicopter for underslung load operations.

The operator has stated that they believe that, although it is possible for pilots to make specific observations of Ng values for segments of flight to use as data for general application in the cycle calculation formulae, under normal working conditions the pilot's concentration has to be on other features for safety of operation. This makes it difficult to assess how generally applicable the specific observations are in reality when attempting such a sophisticated approach to engine life calculation.

As a result of this investigation, the AAIB has made the two following Safety Recommendations to the CAA:-

93-59 The CAA, in collaboration with DGAC of France, should require all operators of Arriel engines to conduct a critical review of the suitability, related to their particular mix of operations, of the manner in which they calculate and record partial engine cycles for gas generator overhaul life control. The review should be conducted with reference to Turbomeca General Service Letter No.1323/89, Chapter 5 of the Maintenance Manual and in consultation with the CAA and the UK Agent.
(Issued 21 January 1994)

93-60 The CAA, in collaboration with DGAC of France, should review the basis on which Turbomeca has established the current service life of the 2nd Stage Turbine blades of the Arriel 1 engine and consider the need to monitor the consumption of that life by electronic means.
(Issued 21 January 1994)

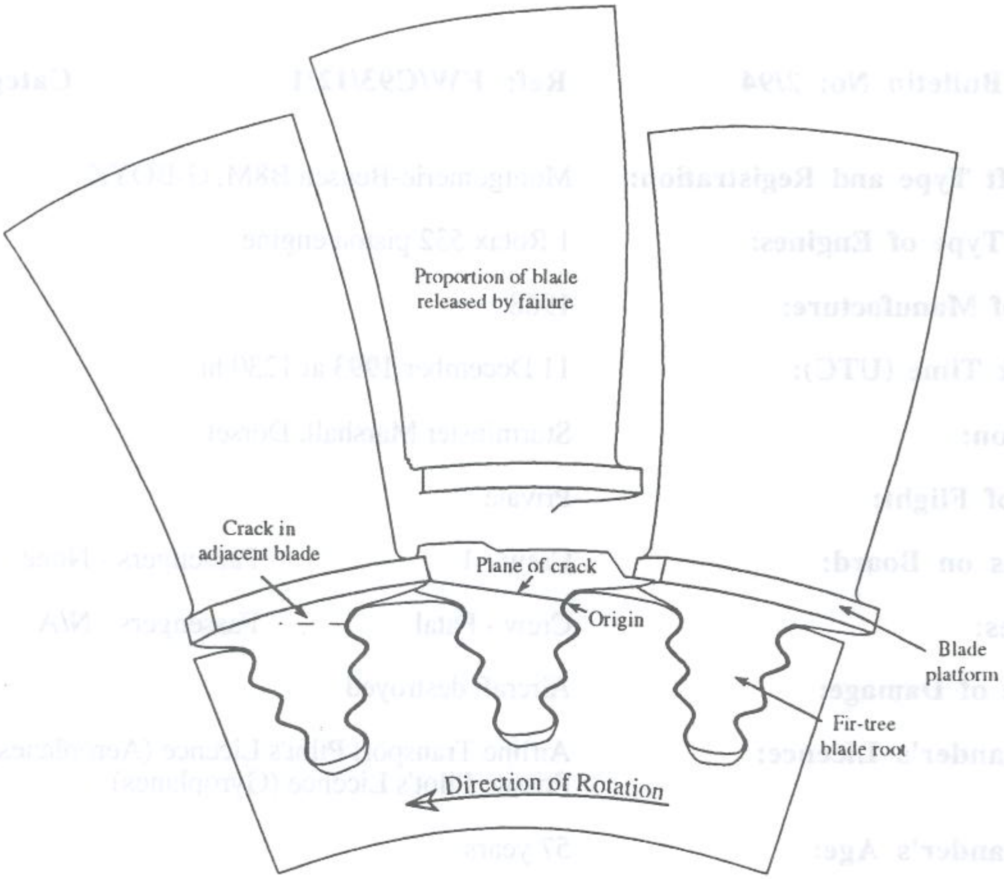

Fig. 1
View on aft side of a segment of Turbine wheel
showing fir-tree root

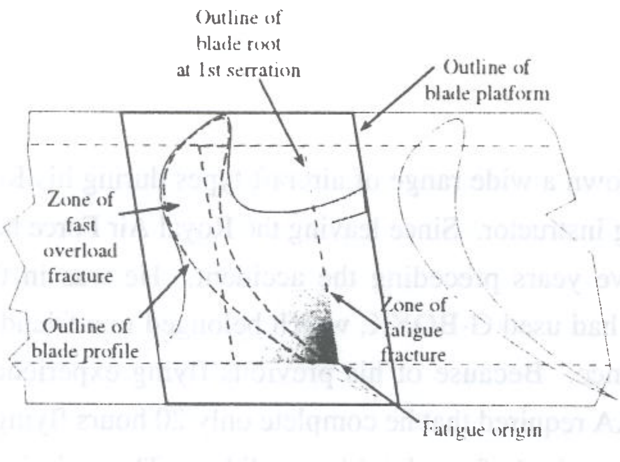

Fig. 2
View looking radially towards the centre of the Turbine wheel
showing progression of fatigue from the fir-tree root.