SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A330-343, G-VKSS
No & Type of Engines:	2 Rolls-Royce RB211 Trent 772B-60 turbofan engines
Year of Manufacture:	2011 (Serial no: 1201)
Date & Time (UTC):	19 January 2013 at 2333 hrs
Location:	On departure from Orlando International Airport, USA
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 14 Passengers - 311
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to both engines, leading edges and radome
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	13,850 hours (of which 128 were on type) Last 90 days - 135 hours Last 28 days - 75 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was in the initial climb, passing 530 ft agl after takeoff from Runway 35L, when it was struck by birds which impacted the fan blades of the left and right engines as well as the nose of the aircraft. Both engines were damaged and the left engine was shut down by the crew because the engine oil pressure indicated zero. The aircraft returned to Runway 36R and carried out an uneventful single-engine landing. One Safety Recommendation related to the indication of engine oil pressure has been made.

History of the flight

The aircraft was on a scheduled flight from Orlando Airport, USA to Manchester International Airport, UK. The flight crew comprised three pilots: the aircraft commander and two Senior First Officers. All three pilots were present on the flight deck for the departure.

The commander was seated in the left seat and the co-pilot in the right with the remaining pilot seated in the 'jump seat' located behind and between the operating pilots. For the departure, the co-pilot was the Pilot Flying (PF) with the commander as the Pilot Monitoring (PM).

The flight crew carried out the normal pre-flight inspection of the aircraft and the cockpit checks. The departure was to be at night, from Runway 35L in benign weather conditions; visibility was reported as being 10 km with a few clouds at 3,600 ft. The crew briefed the actions to be taken in the event of an abandoned or continued

takeoff as well as the procedure to be followed for an overweight landing. With all the required checks and briefings completed, the aircraft lined up on the runway and commenced the takeoff roll using a flexible takeoff thrust temperature of +46°C.

After takeoff, the landing gear was retracted and the aircraft commenced its climb. At a height of 530 ft, the aircraft suffered multiple bird strikes. There was a loud bang as a bird struck the nose of the aircraft which caused the crew some alarm and this was followed almost immediately by an Electronic Centralized Aircraft Monitoring (ECAM)[1] message indicating a malfunction of the left engine. The crew engaged the autopilots in heading mode and, in line with their departure clearance, selected a heading of 060°.

In accordance with established Crew Resource Management principles, the co-pilot continued to fly the aircraft and the commander analysed the problem with the assistance of the third pilot. There was a significant vibration which was felt through the airframe; indications showed that this was from the left engine. The ENG 1 OIL LO PR (engine one low oil pressure) caption was displayed on the ECAM and the pressure was indicating zero. Following standard operating procedures, this indication required the crew to select idle thrust on the left engine and, because the warning persisted, then select the engine master control to the OFF position and carry out the 'ENGINE SHUT DOWN PROCEDURE'. This was performed by the commander and monitored by the other pilots. The commander informed the tower of the situation with a radio call of "PAN STANDBY CLIMBING RUNWAY HEADING." Tower acknowledged and instructed him to contact the Radar controller on a different frequency.

Footnote

[1] The ECAM indicates to the flight crew abnormal conditions with the aircraft engines or systems.

On initial contact with Radar, the commander prefixed their callsign with "MAYDAY" and he requested a return to the airport. There was already a high volume of RT on the frequency and ATC attempted to assist the crew by keeping the aircraft close to the airport and minimising any manoeuvring. The aircraft levelled at 3,000 ft.

The crew reviewed the situation and, having confirmed that all the ECAM actions had been completed, the Flight Service Manager (FSM) was called to the flight deck and given a NITS[2] briefing. Having briefed the FSM, the commander used the public address system to inform and reassure the passengers. He then downgraded the Mayday to a "PAN" and took control as PF. The crew calculated the landing distance required for an overweight, single-engine landing and ATC offered radar vectors for an ILS approach to Runway 36R but a single orbit was required to allow the crew additional time to complete the pre-landing checks.

The commander confirmed with the other two pilots that all actions had been completed and the aircraft then made the approach to land. Following the uneventful landing the aircraft taxied clear of the runway where the airport Rescue and Fire Fighting Service (RFFS) inspected the aircraft. The crew had intended to taxi to the parking stand but, as the brakes were hot, a tug was used instead. The passengers and cabin crew were kept informed of the situation throughout and, once on stand, the aircraft was shut down and the passengers disembarked normally. The total flight time was 30 minutes.

Orlando International Airport

The area is ecologically diverse and home to many unique and iconic species of reptiles, mammals and birds. It is particularly rich with respect to diversity and

Footnote

[2] Nature, Intentions, Timings and Special Instructions.

abundance of both resident and migratory birds. Many species traverse the airspace frequented by aircraft but only a fraction is hazardous to aviation.

The Greater Orlando Aviation Authority has a comprehensive wildlife management plan which includes reptiles and mammals as well as birds. A detailed report is produced annually and covers the Air Operations Area (AOA) which is essentially the area within the boundaries of the airport perimeter. It is 1,604 hectares (3,963 acres), and includes four parallel runways with the associated taxiways, parking areas, terminal buildings and maintenance areas. The predominant habitat is artificial prairie composed of dry, sandy soils sporadically covered with various grasses, sedges and asters. Approximately 5% of the AOA habitat comprises retention ponds, lakes and drainage canals.

The goal and responsibility of wildlife personnel and airfield operations is to reduce the probability of wildlife aviation conflicts. Their primary objectives are:

- Continual identification of species most hazardous to aviation operations.
- Identifying, eliminating or reducing attractants and activities that entice birds and wildlife to areas where they may cause a strike or interfere with aircraft operations.
- Create and maintain a hostile environment for birds and wildlife on the Air Operations Area.

In order to fulfil the task, the wildlife personnel consist of a Biologist and two Wildlife Specialists who patrol the airfield daily and implement the airport's Wildlife Management Plan. In addition, Airfield Operations have personnel on duty 24 hours a day, 7 days a week, trained to respond to, and alleviate most wildlife/aviation conflicts.

However, as the annual report notes:

> *'There are no products, procedures, or technologies proven to eliminate bird strikes. Concentrating efforts on those hazards with the highest probability of impacting aviation was and continues to be the most effective strategy. Identification and characterization of the most significant wildlife hazards was determined by evaluating and comparing historic data, (strike and wildlife report) which depicted hazards by species, time of year, time of day, and location on the airfield. This provided a basis for practical allocation of personnel and resources'.*

During 2011 there were 317,020 aircraft movements. 115 aircraft were struck by birds of which arriving aircraft accounted for 72% of the strikes. The majority of strikes (44%) occurred on Runway 17L/35R, 22% on Runway 17R/35L, 22% on Runway 18L/36R and 12% on 18R/36L. Approximately 66% occurred on the eastern airport complex which is considerably less developed than the western complex (Figure 1).

Flight recorders

The aircraft was equipped with a 25-hour duration Flight Data Recorder (FDR), a 120-minute Cockpit Voice Recorder (CVR) and a Digital ACMS Recorder (DAR). A record of the entire incident flight was available from the recorders. Salient parameters from the FDR and DAR included the engine low oil pressure warning[3] from the Flight Warning Computer (FWC), engine

Footnote

[3] The FWC is provided with three low oil pressure signals per engine. The EEC unit from each engine provides two signals which are derived from the raw outputs from the engines two oil pressure sensors. The third signal is provided by a "hard-wired" low oil pressure switch. If the FWC determines that two or more of the inputs indicate low oil pressure, the LO OIL PR message will be displayed on ECAM and the low oil pressure parameter on the FDR will be set for the respective engine.

Figure 1

Orlando International Airport

untrim[4] oil pressure from the Engine Interface and Vibration Monitoring Unit (EIVMU) and engine N_1 shaft vibration for each engine. Figure 2 illustrates salient parameters during the period between takeoff and engine shutdown.

The aircraft took off from Orlando International Airport Runway 35L at 2333 hrs (1833 hrs local). The takeoff roll was uneventful, but at a height of approximately 530 ft during the climb out, there was a loud bang, which was almost immediately followed by the activation of the master warning and ENG 1 FAIL and ENG 1 LO PR captions being displayed on the ECAM. The left engine N_1 shaft vibration increased from 0.4 to 10 units[5], which is the maximum range of the parameter, EGT increased by 10°C to 771°C and all three engine shaft speeds, N_1, N_2 and N_3, increased slightly and a series of rapid and erroneous fluctuations in the left engine untrim oil pressure were also recorded. The right engine N_1 shaft vibration also increased from 0.2 to 1.8 units at this time.

Almost immediately, the commander (PNF) confirmed the ECAM indications and the left engine thrust lever was retarded to the idle position. He declared a "PAN" to ATC which was then upgraded to a "MAYDAY". As the left engine speed reduced, the N_1 shaft vibration level also reduced to 0.1 units and the untrim oil pressure normalised. The PF increased the right engine thrust to the TOGA position, before the shutdown procedure for the left engine was completed. The total time from initial warning to shutdown was 1 minute 46 seconds.

Footnote

[4] Engine oil pressure displayed on the ECAM SD display is provided by the EEC as a validated signal. The validated signal is derived by first selecting the highest raw oil pressure value from each of the engines two pressure sensors. An average is then taken over 1.8 seconds before the value is then trimmed to "mapped" oil pressure data for N3 shaft speed ranges when the aircraft is on the ground and in the air. The FDR and DAR record the averaged oil pressure signal, prior to the trimming function being applied.

Footnote

[5] ECAM displays an advisory message if the N_1, N_2 or N_3 shaft vibrations increase above 3.3, 2.6 and 4.0 units respectively.

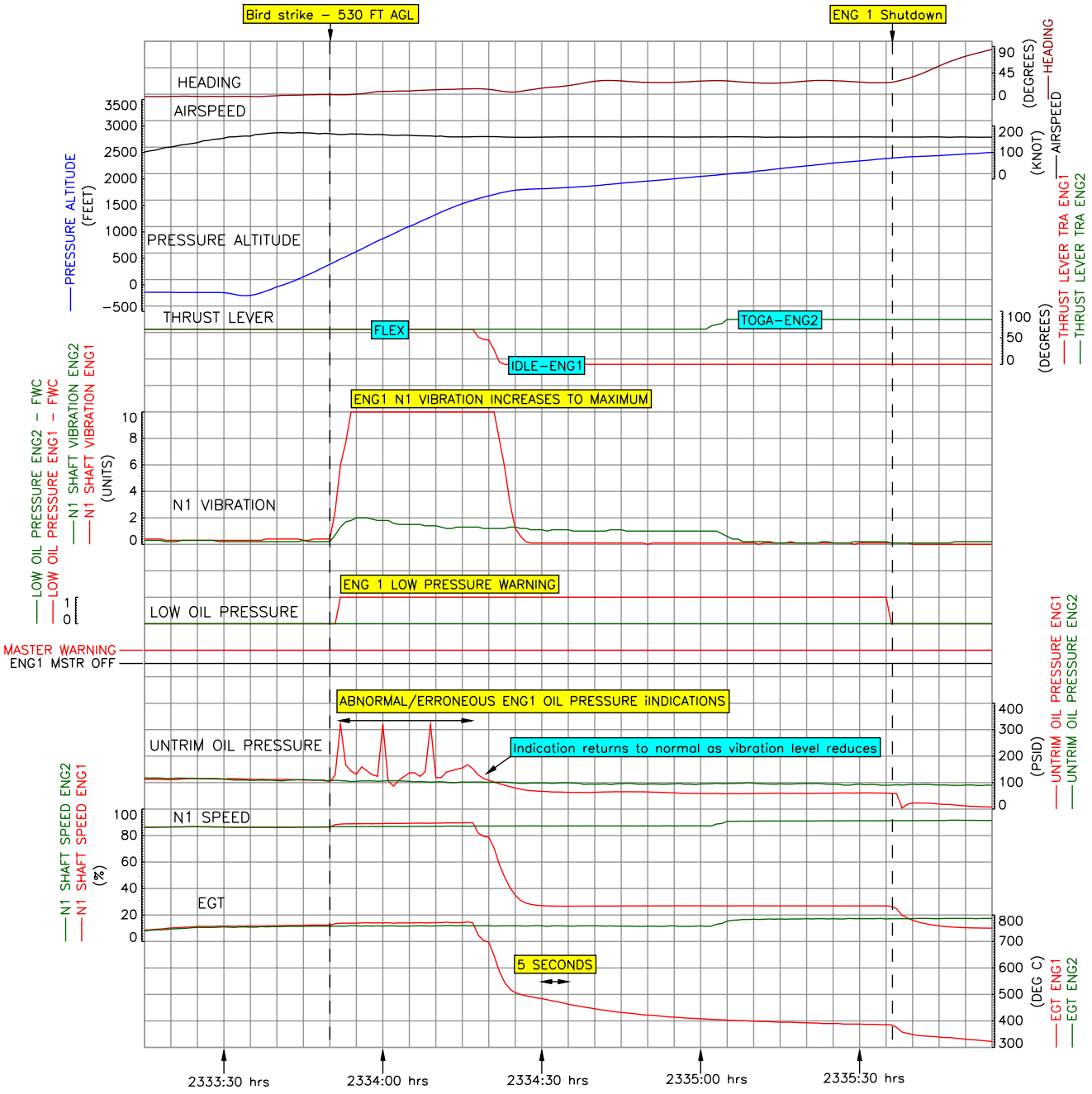

Figure 2

Data recorded between takeoff and engine shutdown

The aircraft levelled at 3,000 ft and MCT (Maximum Continuous Thrust) was selected on the right engine. The maximum recorded right engine N_1 shaft vibration during the flight was 2 units (below the ECAM N_1 shaft vibration advisory message trigger which is 3.3 units).

Preservation of flight recordings

The operator's procedures addressed the need to preserve the CVR record following an incident or accident in accordance with the requirements of EU-OPS 1.160 '*Preservation, production and use of flight recorder recordings*'. However, the operator did not have the same procedures in place for the FDR. Although the incident flight record was still available, the FDR had been allowed to operate for a further 20 hours before it was disabled, resulting in the majority of the previous flight record being overwritten. On this occasion, the loss of data did not impede the investigation, although under different circumstances a loss of FDR data may prove significant.

The operator has advised that it intends to update its FDR preservation procedures in line with that for the CVR. In light of this, the AAIB considers that a Safety Recommendation on this subject to the operator is unnecessary.

Trent 700 oil pressure monitoring

Oil pressure monitoring is provided by three sensors, two oil pressure transducers mounted on the left side of the engine fan case and an oil pressure switch mounted on the gearbox-driven oil pump. Oil is supplied to the pressure transducers through a series of rigid and flexible pipes which are secured to the Integrated Drive Generator (IDG) oil pipes, IDG cooler, support raceways and other pipes on the fan case. The transducers provide oil pressure readings to the Electronic Engine Controller (EEC) at a rate of 5Hz which are then processed and transmitted to the aircraft systems. The oil pressure switch provides a signal directly to the aircraft systems in the event of loss of oil pressure. The aircraft systems will generate a low oil pressure message in the event that any two of the three oil pressure sensors indicate low oil pressure.

To protect the engine's bearings in the event of an lubrication system failure, the oil pump failure logic in the EEC will be activated if it detects both transducer outputs to have a negative differential pressure of between 10 psi and 30 psi within a three-second period. When the failure logic is activated, the EEC overwrites the oil pressure values being transmitted to the aircraft systems with a ZERO value. This results in the aircraft systems generating the ECAM low oil pressure warning and an oil pressure reading of 0 psi is displayed on the respective engine instrument display. The EEC remains latched in this condition until the EEC resets during engine shutdown. Thus even if the oil pressure recovers or stabilises, the ECAM message would remain illuminated and the oil pressure indication to the crew would remain at zero until such time as the engine is shut down.

Previous events

The engine manufacturer provided information which indicated that there have been seven previous events where high vibration resulted in the generation of an low oil pressure message. Of these seven events, five resulted in subsequent precautionary engine shutdowns on the Trent 700 fleet. One event was caused by a combination of incorrect support clipping of the pressure transducer oil feed lines and high engine vibration due to ice formation on the fan. One event was triggered by a bird strike and the remaining five events were caused by IDG failure.

Initial investigation of these events by the manufacturer suggests that vibration generated by a failing IDG,

or higher than normal engine vibration, can produce fluctuations within the oil pressure transducer or its supply lines of sufficient magnitude and duration to trigger the EEC oil pump failure logic. The behaviour of the oil pressure monitoring system during high vibration events continues to be investigated by the engine manufacturer.

The Trent 800, which has a similar lubrication and oil pressure monitoring system, has the two oil pressure transducers mounted in a different location on the engine which does not require the oil supply lines to be secured to the IDG. Additionally, the Trent 800 oil pressure is not set to zero if negative pressure differentials are transmitted from the transducers. There have been no reported low oil pressure events due to high vibration on the Trent 800 fleet.

Investigation

Examination of the aircraft in Orlando revealed impact damage to the radome, the left engine nose cowl, three fan blades fitted to the left engine and two fan blades fitted to the right engine. No defects were identified with the engine oil system. Analysis of the bird remains recovered from the engines indicated that the birds were probably Ring-necked Ducks, of between 1.5 lb and 2 lb in weight, and that each engine had ingested one bird.

After confirming the serviceability of both engines, the damaged fan blades and the left engine nose cowl were replaced. The aircraft completed an uneventful ferry flight back to the UK where the left engine was removed for overhaul. Inspection of the engine after removal confirmed that the pressure transducer oil supply lines were secured and routed correctly.

Safety action taken

Following previous events, the engine manufacturer notified all Trent 700 operators of the possibility that high fan vibration or an IDG failure may trigger the EEC oil pump failure logic, which would result in an oil pressure reading of zero being presented to crews. They also alerted operators and overhaul facilities of the possibility of occurrence through incorrect pipe support clipping.

In these communications the engine manufacturer advised operators that two solutions were being progressed to address the issue: a modification of the EEC oil pump failure detection software and a modification of the oil pressure measurement system hardware to reduce sensitivity to vibration. However, the engine manufacturer has not provided the AAIB with indicative timescales for the introduction of either of these two modifications and, as a consequence the following Safety Recommendation is made:

Safety Recommendation 2013-015

It is recommended that Rolls-Royce plc modify the oil pressure indication and failure detection systems of the Trent 700 engine to minimise the possibility of an activation of the Electronic Engine Controller oil pump failure logic as a result of high vibration or an Integrated Drive Generator failure.