

# **FINAL REPORT**

## **AIRBUS A320, REGISTRATION 9V-TRH FAN COWL DAMAGE DURING TAKE-OFF**

**16 October 2015**

**AIB/AAI/CAS.117**

**Transport Safety Investigation Bureau  
Ministry of Transport  
Singapore**

11 August 2017

## **The Transport Safety Investigation Bureau of Singapore**

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## GLOSSARY

AMM	Aircraft maintenance manual
AMSP	Aircraft maintenance service provider
ATC	Air traffic control
BLO	Base Layover
CIC	Cabin crew in charge
EASA	European Aviation Safety Agency
FO	First Officer
FOD	Foreign object debris
HOD	Hold-open device
IDG	Integrated drive generator
LAE	Licensed Aircraft Engineer
LGCIU	Landing Gear Control Interface Unit

## **SYNOPSIS**

On 16 October 2015, a TigerAir A320 lost the inboard and outboard fan cowls of its left engine during take-off from Singapore Changi Airport.

After being informed by the cabin crew of the loss of the left engine fan cowls, the flight crew levelled the aircraft off at 8,000ft. They checked and noted that all engine parameters were normal. They then decided to return to Changi Airport.

When landing gears were selected down during the approach to land, a Master Warning came on, indicating that the left main landing gear was not downlocked. The approach was discontinued and the flight crew performed the manual gravity extension procedure but the Master Warning still indicated that the left main landing gear was not downlocked.

The flight crew declared Mayday and flew a holding pattern to burn fuel and reduce the aircraft landing weight. Later, the flight crew performed a low fly-past, and engineers on the ground reported that the left main landing gear appeared to be down. Subsequently the aircraft landed without incident.

The Transport Safety Investigation Bureau classified this occurrence as a serious incident.

## **AIRCRAFT DETAILS**

Aircraft type	:	Airbus A320
Operator	:	TigerAir
Aircraft registration	:	9V-TRH
Numbers/type of engines	:	2 x International Aero Engines V2500
Date and time of incident	:	16 October 2015, 2047hrs local time
Location of occurrence	:	During take-off from Singapore Changi Airport
Type of flight	:	Scheduled passenger flight
Persons on board	:	178

# 1 **FACTUAL INFORMATION**

All times used in this report are Singapore times. Singapore time is eight hours ahead of Coordinated Universal Time (UTC).

## 1.1 **History of the flight**

- 1.1.1 On 15 October 2015, the day before the incident, the aircraft had completed a prior flight and was parked at Bay 702 at Singapore Changi Airport for Base Layover (BLO) maintenance. The BLO involved a BLO technician checking the oil level of the integrated drive generator (IDG) of the left and right engines. According to the BLO technician, he checked the right engine IDG first. He lifted the outboard fan cowl on the IDG side to visually sight the oil level before closing it. He proceeded to check the left engine. He closed the fan cowls of the left engine and fastened the latches of the fan cowls after checking the IDGs. He said he was not interrupted while closing the fan cowls.
- 1.1.2 Before signing off the BLO technician's work, the Licensed Aircraft Engineer (LAE) in charge of the BLO performed a walkaround check. As part of the walkaround, the LAE looked at the sides of the fan cowl, he checked that there were no gaps between the surfaces of the fan cowl and the engine nacelle which, from his experience, would indicate an unfastened fan cowl condition. He mentioned that he would normally also squat down and extend his hand to reach under the fan cowl to feel if the latches were secured. However, he did not do so this time. The BLO LAE ended his walkaround check at the front of the aircraft near the nose landing gear. According to the BLO LAE, while in a squatting position at the front of the aircraft, he inspected visually the engines from his position and he did not notice any protrusion of unfastened latches (see paragraph 1.4).
- 1.1.3 The BLO was completed by 0300hrs on 16 October 2015 and the aircraft remained at Bay 702 until its next flight.
- 1.1.4 At 1900hrs, the aircraft was towed to the departure gate to prepare for passenger boarding. The aircraft arrived at the departure gate at 1925hrs. The flight crew was already waiting at the gate and boarded the aircraft when it arrived. The aircraft was scheduled to depart at 2010hrs.
- 1.1.5 The Departure LAE in charge of the departure check arrived at 1940hrs, having just completed a departure job at another gate. The Departure LAE performed a walkaround check prior to releasing the aircraft for departure. According to the Departure LAE, he did not squat to sight the condition of the fan cowl latches. He said that he observed the engines from the nose wheel location and did not notice any protrusions at the bottom of the fan cowl which he said would indicate unfastened latches.

- 1.1.6 During preparation for departure, the First Officer (FO) said he performed a walkaround check as required by company procedures. He visually inspected the engines from two positions (from the main landing gear<sup>1</sup> and from the outboard side of the engine). Accordingly to the FO, he stood at these positions and looked downwards at the fan cowls but he did not bend down or squat to check<sup>2</sup>. He did not notice any latch protrusions. Looking at the sides of the engine, the FO also checked that the fan cowl surfaces were flush with that of the engine nacelle and that there was no gap.
- 1.1.7 The Captain later also decided to perform a walkaround check of the aircraft<sup>3</sup>. However, he only had time to look at the front cargo door and aft cargo hold areas. He did not notice any abnormality in these areas.
- 1.1.8 The aircraft took off at 2047hrs. During the take-off, the Cabin crew-in-charge (CIC) was alerted by a passenger that the left engine fan cowl had fallen off<sup>4</sup>. The CIC made a visual confirmation and immediately informed the flight crew through the interphone.
- 1.1.9 The flight crew checked and noted that all cockpit panel parameters were normal, although a fault message from the Landing Gear Control Interface Unit<sup>5</sup> (LGCIU) No.2 was received during take-off. The Captain asked the CIC to reconfirm what she saw. The CIC reported back that the interior of the engine was visible.
- 1.1.10 The flight crew levelled the aircraft off in a holding pattern at 8,000ft and the Captain stepped out of the cockpit to assess the damage. He observed that the left engine fan cowls were missing and there was no visible damage to the surrounding wing area. He noted that the right engine fan cowls were intact.
- 1.1.11 The Captain returned to the cockpit and he decided to return to Changi Airport. When the landing gears were selected down during the approach to land, a Master Warning came on, indicating that the left main landing gear was not downlocked. The flight crew discontinued the landing, informed Air Traffic Control (ATC) of the situation and requested to return to holding for troubleshooting actions.

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<sup>1</sup> The inspection position at the main landing gear differed from the aircraft manufacturer guidance for exterior walkaround check.

<sup>2</sup> The FO indicated that he was taught during his training not to bend down or squat to check due to risk of possible injury from sharp edges (e.g. vent pipes on the fan cowl) when standing up.

<sup>3</sup> The Captain was not required to do the walkaround check. He checked the front cargo door and aft cargo hold, proceeding back to the cockpit thereafter.

<sup>4</sup> The loss of the fan cowl during take-off was also recorded by a runway camera.

<sup>5</sup> The LGCIU has a role in controlling the operation of the landing gears and the landing gear doors. It does this by sensing the position of the landing gears and the landing gear doors.

- 1.1.12 The flight crew cycled the landing gears and performed the manual gravity extension procedure to extend the landing gears, but the Master Warning remained on. The flight crew declared Mayday and remained in the holding pattern to burn off excess fuel to reduce the aircraft landing weight.
- 1.1.13 Later, the flight crew performed a low fly-past, and engineers on the ground reported that the left main landing gear appeared to be down. Subsequently the aircraft landed at 2318hrs without incident. There was no injury to any person in this incident.

## 1.2 **Damage to aircraft**

- 1.2.1 The left engine's inboard and outboard fan cowls were missing (see **Figure 1**).



Figure 1: Loss of inboard and outboard fan cowls

- 1.2.2 The left engine forward pylon was buckled (**Figure 2**).

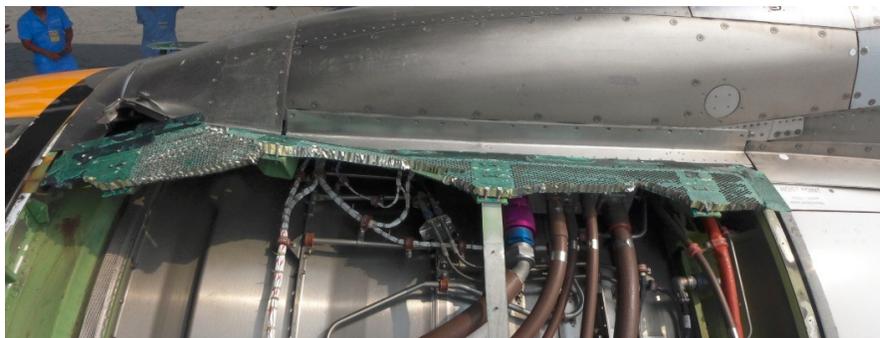


Figure 2: Damage on the engine forward pylon

1.2.3 Debris of the outboard fan cowl was found on the runway. **Figure 3** shows a reconstruction of the debris.



Figure 3: Reconstructed outboard fan cowl

1.2.4 The inboard fan cowl was recovered from the sea by a passing ship. It was essentially in one piece (**Figure 4**). There was a tear across the top near where the fan cowl was attached to the engine forward pylon. The original state of the latches (e.g. fastened or unfastened) could not be ascertained as some degree of latch handling had occurred before the investigation team received the fan cowl.



Figure 4: Inboard fan cowl

- 1.2.5 All the four latches (comprising four hooks at the bottom edge of the inboard fan cowl and four corresponding keepers at the bottom edge of the outboard fan cowl) were recovered. Apart from operational wear, no damages were observed on the four latches (**Figure 5**).

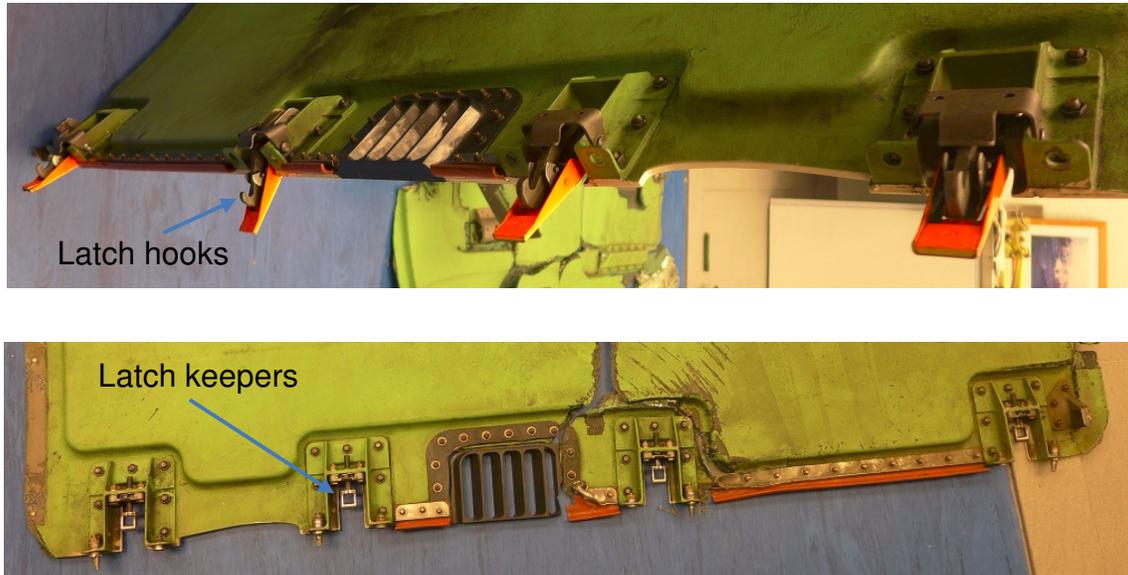


Figure 5: No damage to the hooks and keepers of the latches

- 1.2.6 Some fan cowl debris had lodged into the left main landing gear door, and damaged the proximity sensor on the left main landing gear (**Figure 6**).



Figure 6: (Left) Fan cowl debris wedged into left main landing gear door  
(Right) Proximity sensor (blue circle) impacted by fan cowl debris

### 1.3 Personnel information

Departure LAE	Male
Age	37
Experience in current capacity	6 years

BLO LAE	Male
Age	32
Experience in current capacity	6 years

BLO Technician	Male
Age	31
Experience in current capacity	1 year 4 months

### 1.4 Fan cowl latches

1.4.1 For the left engine, each of the four fan cowl latches comprises a handle with hook end at the bottom edge of the inboard fan cowl and a keeper end at the bottom edge of the outboard fan cowl.

1.4.2 To fasten the latch, the hook is placed into the keeper and the latch handle is closed flush with surface (**Figure 7**).



Figure 7: Fastened latch with hook into keeper, and handle closed flush

1.4.3 If the latch is not fastened, the latch handle will protrude from the surface (**Figure 8**).



Figure 8: Protrusions due to unfastened latches

1.4.4 In the afternoon of 16 October 2015, the aircraft operator was conducting an orientation tour for a group of interns. The interns visited the incident aircraft at Bay 702 at 1650hrs. Photographs taken by one of the interns showed that at least three of the four fan cowl latches of the left engine were unfastened (**Figure 9**).

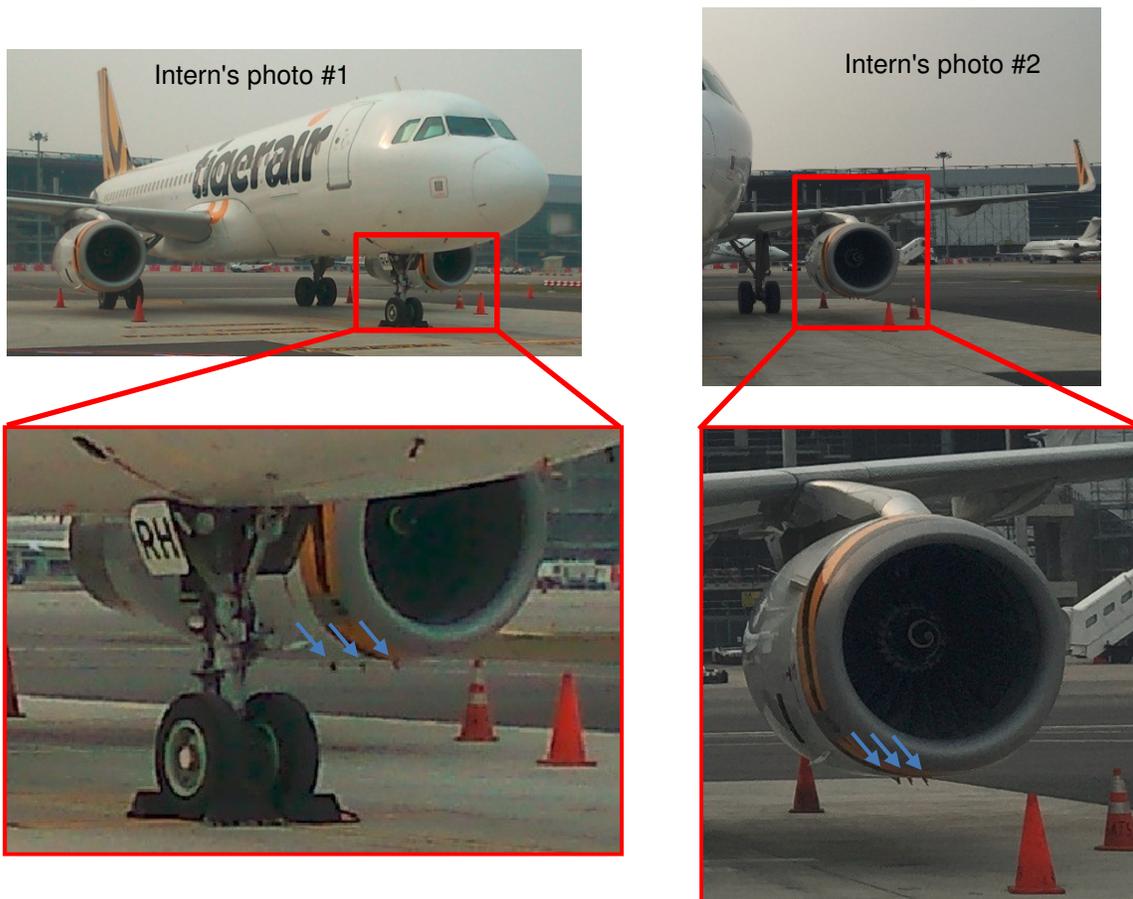


Figure 9: Photographs showing unfastened latches on 16 October 2016

- 1.4.5 Damage to fan cowls in flight when the fan cowl latches were not fastened had happened before. The aircraft manufacturer has introduced a modification for making a hole in the hold-open device (HOD) of the fan cowls which can receive a dedicated red warning flag tool to make an unfastened condition of fan cowls more noticeable (**Figure 10**). This modification was incorporated on the incident aircraft.

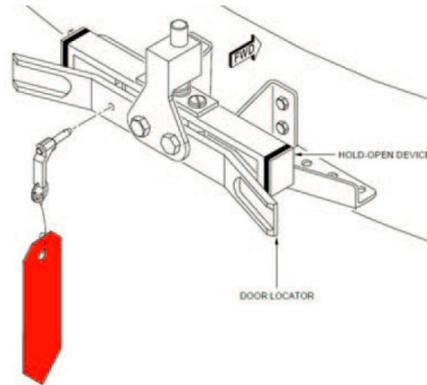


Figure 10: Red warning flag tool in the HOD indicating an unfastened fan cowl

## 1.5 Fan cowl procedures

- 1.5.1 The key actions as prescribed in the aircraft maintenance manual (AMM) to be performed when opening and closing fan cowls were as follows:
- (a) Warning notices to be installed in the cockpit prior to working on the fan cowls
  - (b) Red warning flag tool to be installed in position on the HOD
  - (c) Record in the aircraft logbook whenever fan cowls have been opened or closed

Maintenance personnel were expected to follow the procedures in the aircraft maintenance manual. However, the AMM did not mention that one should crouch to check the latches.

- 1.5.2 The aircraft maintenance service provider (AMSP) issued a Quality Notice on 2 March 2009 to inform its maintenance personnel of the need to bend down or crouch to confirm fan cowl latches are fastened. The AMSP also issued a Quality Notice on 11 May 2015 to remind its maintenance personnel of the need for aircraft logbook recording whenever fan cowls have been opened or closed and the need for confirming fan cowl latches are fastened. The BLO technician was not a recipient of the Quality Notices and neither was he required to read the Quality Notices.

- 1.5.3 The BLO technician was not aware that the red warning flag tool had to be used when the fan cowls were opened. He was not aware of the key actions for opening and closing fan cowls as described in paragraph 1.5.1 (a)-(c) and he did not refer to the AMM for the fan cowl opening/closing procedure during the BLO prior to the incident flight.
- 1.5.4 There was no aircraft logbook entry recording the opening or closing of the fan cowls during the BLO before the incident flight. The BLO LAE explained that his understanding at that time was that the logbook entry was to create awareness for other maintenance personnel when there was a handover, and that he did not realise at that time that the intent was to include awareness to the flight crew as well. The BLO LAE explained that the check on the oil level of the IDGs of both the left and right engines did not require any follow-up action and the fan cowls were closed immediately after the oil level check, and that he did not make a logbook entry as there was no work performed and there was no issue of a handover to other maintenance personnel.
- 1.5.5 The aircraft manufacturer had provided guidance in its Flight Crew Operations Manual (FCOM) for exterior walkaround check (**Figure 11**) to be performed by flight crew or maintenance personnel. The check was to, among others, ensure that fan cowls are closed and latched before flight. Each engine must be checked from both the inboard and outboard side of the nacelle. The guidance did not mention that one should crouch to check the latches.

\* Fan cowl doors.....CLOSED/LATCHED

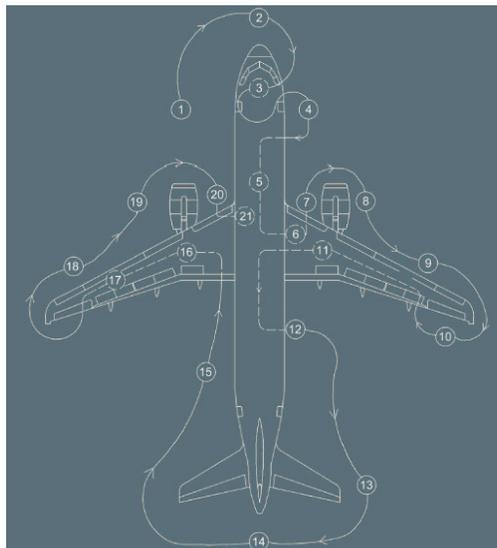


Figure 11: Aircraft manufacturer's instructions on the exterior walkaround check

- 1.5.6 The aircraft manufacturer also published an article in its Safety First Magazine in July 2012 and presented at its forum with operators in March 2014 on the issue of fan cowl loss and the need for crew members performing the walkaround to follow the correct procedure such as positioning themselves at both sides of the engine (e.g. inboard and outboard of the nacelle) and crouching to check that all latches are correctly fastened and that there is no gap around the cowl. The aircraft manufacturer, in an Operators Information Transmission (OIT) on 4 May 2015, highlighted to operators the key actions in the AMM and the information in the Safety First Magazine.
- 1.5.7 The operator in this occurrence did not attend the forum in March 2014 but did receive the forum's presentation material. It also received the OIT. As of August 2015, the operator had been using the version of the AMM which highlights the key actions described in paragraph 1.5.1 (a)-(c).

## 1.6 **Simulated night test**

- 1.6.1 A series of night simulations were conducted to simulate the same night working condition that was experienced on the early morning of the BLO maintenance work at Bay 702 and the night departure of the incident flight.
- 1.6.2 It was observed that, even in night conditions, the airport lighting was sufficient to illuminate the aircraft and its surrounding.
- 1.6.3 The aircraft manufacturer's fan cowl closing procedure required the removal of the red warning flag tool, the depressing of the HOD to allow the fan cowls to close fully and finally the fastening of the four latches from rear to front. It was observed that after depressing the HOD to allow the fan cowls to fully close and prior to fastening the latches, the fan cowl was relatively flushed at the interface with the nose cowl. The existing design of the HOD still could allow the fan cowl to be closed flush at the interface, there was minimal difference in flushness whether latches were unfastened or fastened (see **Figure 12**).

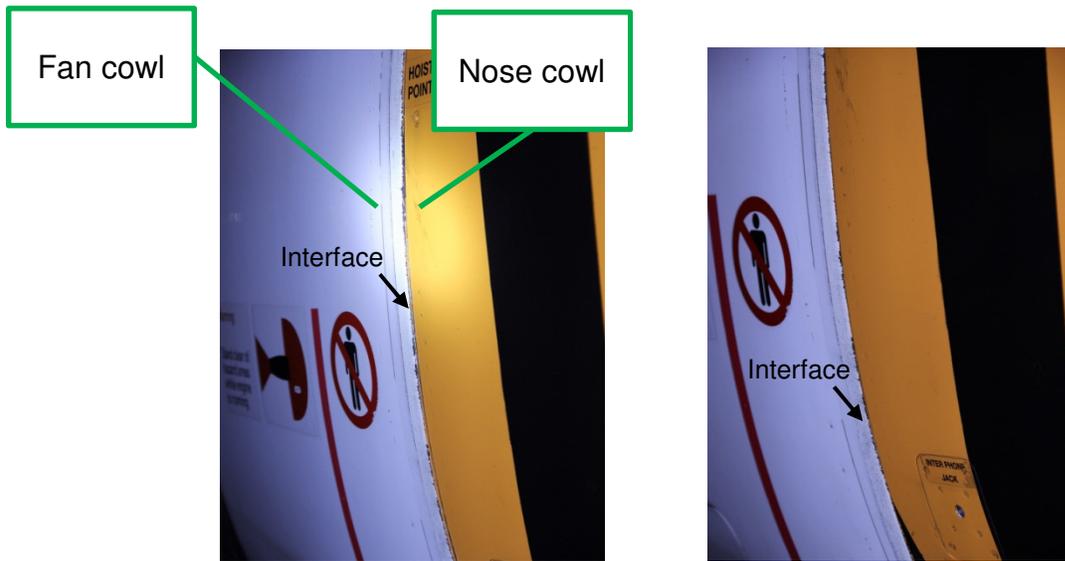


Figure 12: (Left) Flushness at interface when all latches are not fastened  
 (Right) Flushness at interface with all latches fastened

1.6.4 With the fan cowls were closed, latches that were unfastened and protruding could not be seen at certain locations from the engine (particularly when viewed from a standing position). The curvature of the engine nacelle obscures the latches even when they are unfastened, making it difficult to sight the protruding latch handles<sup>6</sup>.



Figure 13: (Left) Unfastened latches can barely be seen from a distance (side of engine)  
 (Right) Unfastened latches cannot be seen when standing next to engine

<sup>6</sup> It was recommended by the aircraft manufacturer that the personnel performing the inspection should position themselves at both sides of the engine and crouch to check that all latches are correctly fastened and that there is no gap around the cowl.



Figure 14: Unfastened latches cannot be seen at any point from the main landing gears to the engine

- 1.6.5 While it might be possible to notice latches that were unfastened from the front of the aircraft at positions around the nose landing gear (i.e. some distance away from the engine) (see **Figure 15**), the silhouette of the engine drain mast might obscure the protruding latches.



Figure 15: Unfastened latches can barely be seen from the nose landing gear location

## 1.7 Foreign object debris (FOD) detection system

- 1.7.1 FOD constitutes a hazard to aircraft and can cause aircraft damage if not detected and removed. The aerodrome operator supplemented its daily runway surface inspections with a FOD detection system to detect the presence of debris on the runway. The system uses multiple panning cameras along the stretch of the runway to capture the presence of possible FOD.
- 1.7.2 When a suspected FOD is detected, the FOD detection system will alert an operator on duty. The duty operator will view the image of the suspected FOD to ascertain if it is really an image of a FOD, and arrange for the FOD's removal as necessary.

- 1.7.3 After the incident flight took off, the FOD detection system detected the presence of a FOD on the runway at 2048hrs. However, the limitation of the image resolution was such that the duty operator interpreted the image as that of a runway ground light and not a FOD. The FOD detection system gave four more alerts but the duty operator determined that there was no FOD.
- 1.7.4 At 2144hrs, the sixth alert provided a better image and the duty operator determined that there was a FOD. ATC was alerted and an aerodrome maintenance vehicle was dispatched to recover the FOD, which turned out to be fan cowl debris from the incident aircraft.

## 2 DISCUSSION

### 2.1 Fan cowl latches

- 2.1.1 Evidence shows that at least three of the four latches of the fan cowl of the left engine were not fastened four hours before the incident aircraft took off. Detailed inspection on the recovered latches (inboard fan cowl hooks and outboard fan cowl keepers) showed no damage on the connecting surfaces, and the damage was solely on the fan cowl structure. This would indicate that there was no mechanical failure or structural damage on the latch hooks and keepers, and would suggest that all latches were likely to be unfastened at the time of take-off.
- 2.1.2 With fan cowl latches not fastened, the airflow generated during the aircraft's flight would tear off the fan cowls.
- 2.1.3 As mentioned in paragraph 1.1.2, the BLO LAE "checked that there were no gaps between the surfaces of the fan cowl and the engine nacelle which, from his experience, would indicate an unfastened fan cowl condition." And as mentioned in paragraph 1.1.6, "the FO also checked that the fan cowl surfaces were flush with that of the engine nacelle and that there was no gap." It is not known how such flushness assessment has become an acceptable way of ascertaining that the fan cowl latches are fastened, in lieu of bending down or crouching to bring eye level low enough to confirm latches are fastened. The simulation test (paragraph 1.6.3) showed that a fan cowl with unfastened latches could still appear flush with the engine nacelle. Such a flushness assessment is not a method recommended by the aircraft manufacturer.
- 2.1.4 The BLO technician was not aware of the key actions to be performed in the aircraft manufacturer's instructions for opening and closing fan cowls. The workaround procedure adopted by the BLO LAE, the Departure LAE and the FO differed from the procedure provided by the aircraft manufacturer.
- 2.1.5 It is also found from the simulation test that, at a distance away from the engine, the unfastened latches could be difficult to detect as the curvature of the engine nacelle could obscure the view of the latches.
- 2.1.6 It is not a reliable method to determine if the fan cowl's latches had been fastened properly by trying to judge from a distance whether there are protrusions of the latches. The lighting condition and the angle of view may make the judging difficult. The silhouette of the engine drain mast may also obscure the outline of protruding latches.
- 2.1.7 In short, a better way to ascertain whether the fan cowl latches are fastened is to squat down low enough to sight the latches.

2.1.8 It is noted that, although the aircraft manufacturer has emphasised the need to bend down or crouch to check that latches are fastened in its Safety First Magazine, this requirement is not mentioned in the aircraft manufacturer's FCOM for exterior walkaround check.

## 2.2 Master warning

2.2.1 Fragment from the outboard fan cowl impacted the left main landing gear proximity sensor. The damage to the proximity sensor resulted in the erroneous Master Warning indicating that landing gear was not downlocked.

## 2.3 FOD detection system

2.3.1 The resolution of the cameras at the time of the incident did not support effectively the task of interpreting camera images for the purpose of ascertaining the presence of FOD.

### 3 SAFETY ACTIONS

*During the course of the investigation and through discussions with the investigation team, the following safety actions were initiated by the aircraft operator, the aircraft maintenance service provider, the aerodrome operator and the aircraft manufacturer.*

- 3.1 The European Aviation Safety Agency (EASA) issued an Airworthiness Directive (AD 2016-0053) on 14 March 2016 to modify the fan cowls such that a special key had to be used to unlatch the fan cowls, the key cannot be removed unless the fan cowl front latch is safely closed.
- 3.2 Following the incident, the aircraft operator issued a Flight Staff Instruction to emphasise the requirement for flight crews to bend or squat down when inspecting latches from either side of the engine.
- 3.3 The aerodrome operator is currently in the process of upgrading the FOD detection system to incorporate higher definition cameras, so as to enable better quality images and more accurate interpretation by the duty operator. The aerodrome operator expects the upgrading to be completed in September 2017.
- 3.4 Following the incident, the AMSP drew again the attention of its maintenance personnel to the Quality Notices of 2 March 2009 and 11 May 2015 to remind its maintenance personnel on the need for aircraft logbook recording whenever fan cowls have been opened or closed and to bend down or crouch to confirm latches are fastened. It has also re-emphasised the importance of following the aircraft manufacturer's instructions for opening and closing fan cowls during daily briefings with its maintenance personnel. Regular checks on logbooks are also conducted by the AMSP to ensure compliance with the Quality Notices.

### 4 SAFETY RECOMMENDATIONS

*A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.*

It is recommended that:

- 4.1 The aircraft operator remind its flight crew personnel that fan cowl flushness with nacelle is not a reliable method for checking that fan cowl latches are fastened. [TSIB Recommendation RA-2017-028]

- 4.2 The aircraft maintenance service provider remind its maintenance personnel that fan cowl flushness with nacelle is not a reliable method for checking that fan cowl latches are fastened. [TSIB Recommendation RA-2017-029]
- 4.3 The aircraft manufacturer emphasise, in its maintenance documentation on exterior walkaround check, the need for inspection personnel to bend down or crouch to bring eye level low enough to confirm latches are fastened. [TSIB Recommendation RA-2017-030]