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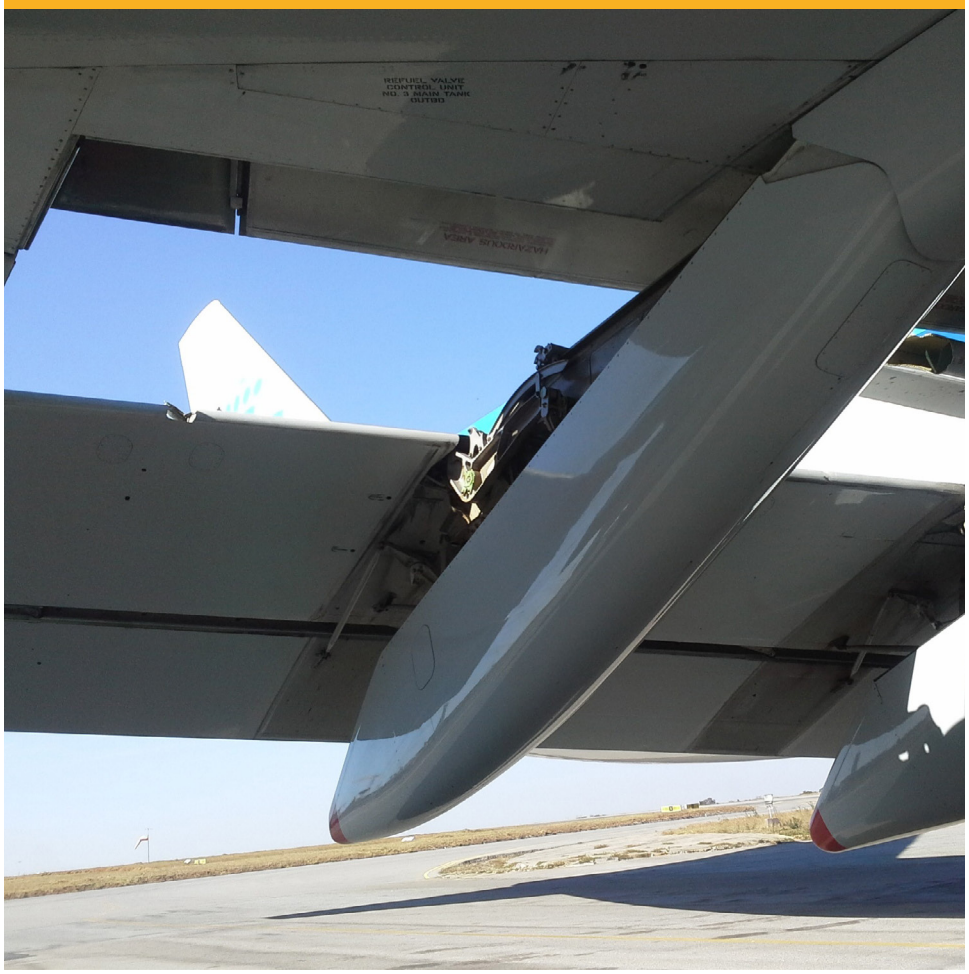
SAFETY BOARD

Loss of flap part, Boeing 747-400



Loss of flap part, Boeing 747-400

The Hague, February 2022

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Source cover photo: Owner of the aircraft

The Dutch Safety Board

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N.B:
This report is published in English, a summary is available in the Dutch language. If there is a difference in interpretation between the Dutch and English versions, the English text will prevail.

CONTENTS

Summary **5**

Abbreviations **7**

General overview **8**

1 Introduction **9**

2 Investigation **11**
2.1 Factual information 11
2.2 Meteorological information 14
2.3 Flight recorders 15
2.4 Tests and research 15
2.5 Organisational and management information 17
2.6 Additional information 20

3 Analysis **22**
3.1 Cause of foreflap separations 22
3.2 Owner's maintenance on inboard foreflap fittings 23
3.3 Measures taken to prevent foreflap fitting failures 24

4 Conclusion **25**

Appendix A. Responses to the draft report **26**

SUMMARY

On 8 July 2019 the Boeing 747-400F, with registration PH-CKA, was flying an ILS approach to Runway 05 at Robert Gabriel Mugabe International Airport in Zimbabwe for landing. While selecting the required position of the flap system, a part of the right wing inboard foreflap broke of and separated from the aircraft. The separation caused a slight rolling motion to the right; the pilots were able to keep the aircraft under control. The pilots continued the approach and landed safety. The broken foreflap part came down in a residential area 5 nautical miles from the airport, close to the approach path and was recovered later. Nobody was injured.

In the past the Boeing 747 series trailing edge flap system design encountered various technical abnormalities such as separating parts of the foreflap and a skewed operation of the flap system. Separating foreflap parts cause a risk of secondary damage to the aircraft and cause a risk to third parties on the ground.

The Dutch Safety Board conducted an investigation that answers the following three questions. What was the cause of the inboard foreflap separation? In what way is this occurrence similar to previous foreflap separations in the Boeing 747 worldwide fleet? To what extent did the measures taken by the owner of the aircraft and manufacturer prevent similar foreflap separations?

The investigation found that the right wing inboard foreflap of PH-CKA failed and partly separated, because of a fatigue crack failure of the foreflap outboard fitting lug. The fatigue crack was caused by pitting corrosion. The pitting corrosion had formed because of moisture that had accumulated between the inside of the foreflap fitting lug and the outside of the fitting lug bearing for over a long period of time. The cause of PH-CKA's inboard foreflap outboard fitting failure is similar to other investigated occurrences concerning inboard foreflap separations, that occurred with the Boeing 747 series aircraft in the past.

The owner of the aircraft's planning of the required maintenance on the inboard foreflap outboard fitting was compliant with Airworthiness Directive 75-20-05. The owner had incorporated Service Bulletin 747-27-2366 (Rev 3), that recommends the visual inspection and lubrication of the foreflap fitting within an interval period of six months, in such a way that an interval period of seven to eight months ensued. The owner had justified this longer interval period by referring to its experience with foreflap fitting anomalies across its Boeing 747 fleet in the past. The European Union regulations concerning continuing airworthiness allow for such an adaptable incorporation of service bulletin requirements into aircraft maintenance programs.

About one year prior to the failure of PH-CKA's right wing inboard foreflap outboard fitting lug, the foreflap outboard fitting lug bearing was replaced during a regular D-check because of migration of the bearing. At that time, it was likely that a progressed form of pitting corrosion was present on the inside of the fitting lug. This corrosion was not discovered during the replacement. Therefore, the Dutch Safety Board emphasises that investigating the cause of anomalies of aircraft parts according to maintenance manuals and by observing standard maintenance practices is vital to ensure system safety.

Boeing issued Alert Service Bulletin 747-57A2367 on 15 November 2019 to further improve the reliability and the safe operation of the inboard foreflap and related parts of the inboard trailing edge flap system. This alert service bulletin requires replacement of the inboard foreflap outboard fitting lug at an interval that is well before the expected time of failure. On 30 March 2021, the Federal Aviation Authority mandated with Airworthiness Directive 2021-02-15 the maintenance requirements from Alert Service Bulletin 747-57A2367. This measure as imposed by the airworthiness directive has been incorporated after a prolonged period with various maintenance measures to improve the Boeing 747 inboard trailing edge flap system. The Dutch Safety Board considers that the alert service bulletin requirements and the mandatory compliance as imposed by the airworthiness directive are adequate to prevent future inboard foreflap outboard fitting lug failures. Hence, the Dutch Safety Board does not issue recommendations.

ABBREVIATIONS

AD	Airworthiness Directive
BFU	German Federal Bureau of Aircraft Accident Investigation
CAAZ	Civil Aviation Authority of Zimbabwe
CMM	Component Maintenance Manual
FAA	Federal Aviation Administration
FDM	Flight Data Monitoring
ICAO	International Civil Aviation Organization
KLM	Royal Dutch Airlines
MRO	Maintenance Repair Overhaul
NM	Nautical mile
NTSB	National Transportation Safety Board
SB	Service Bulletin
SOPM	Standard Overhaul Practice Manual
UTC	Coordinated Universal Time
WQAR	Wireless Quick Access Recorder

GENERAL OVERVIEW

Identification number:	2019060
Classification:	Accident
Date, time of occurrence:	8 July 2019, 12.13 UTC
Location of occurrence:	5 NM final Runway 05, Robert Gabriel Mugabe International Airport, Harare, Zimbabwe
Operator:	Martinair Holland
Registration:	PH-CKA
Aircraft type:	Boeing 747-400F
Aircraft category:	Freighter
Type of flight:	Commercial air transport, cargo
Phase of operation:	Final approach
Damage to aircraft:	Moderate
Flight crew:	Two
Passengers:	None
Injuries:	None
Other damage:	None
Light conditions:	Daylight

1 INTRODUCTION

On 8 July 2019 the Boeing 747-400F, with registration PH-CKA, was flying an ILS approach to Runway 05 at Robert Gabriel Mugabe International Airport in Zimbabwe for landing. While selecting the required position of the flap system, a part of the right wing inboard foreflap broke of and separated from the aircraft. The separation caused a slight rolling motion to the right; the pilots were able to keep the aircraft under control. The pilots continued the approach and landed safety. The broken foreflap part came down in a residential area 5 NM from the airport, close to the approach path and was recovered later. Nobody was injured. The aircraft sustained moderate damages to the right aft fuselage.

In the past, the Boeing 747 series inboard trailing edge flap system design encountered various technical abnormalities, which in some cases lead to foreflap separations. These technical problems have been addressed with design improvements and increased maintenance tasks and intervals. The problem with the flap system and foreflap separations, however, continued to occur. Separating foreflap parts cause a risk of secondary damage to the aircraft and cause a risk to third parties on the ground.

At first, this accident was investigated by the Civil Aviation Authority of Zimbabwe (CAAZ), on behalf of the State of Occurrence, according to ICAO Annex 13. As State of Registry and State of the Operator, the Netherlands appointed an *accredited representative.* The investigation was initiated and conducted by the CAAZ. On 21 February 2020, the CAAZ delegated the investigation to the Dutch Safety Board.

The Dutch Safety Board conducted an investigation that answers the following three questions.

1. What was the cause of PH-CKA's inboard foreflap separation?
2. In what way is this occurrence similar to previous foreflap separations in the Boeing 747 fleet worldwide?
3. To what extent did the maintenance measures taken by the owner of the aircraft and manufacturer prevent similar foreflap separations?

This investigation was carried out following the standards and recommended practices as stipulated by ICAO Annex 13. This report follows the standard report format and addresses the cause of the foreflap separation and the prevention measures taken. The investigation into this accident consisted of interviews, technical analysis of flap parts and analysis of the flight data during final approach and investigation reports of similar occurrences and the proposed measures to prevent future occurrences.

The parties concerned with the investigation are KLM Royal Dutch Airlines as the owner of the aircraft and advisor to the Dutch Safety Board, Martinair Holland as the operator and advisor to the Dutch Safety Board, the National Transportation Safety Board (NTSB) on behalf of the State of Design and Manufacture, The Boeing Company as the aircraft

manufacturer and advisor to the NTSB, the Civil Aviation Authority of Zimbabwe (CAAZ) on behalf of the State of Occurrence, and the Dutch Safety Board as the State of the Operator, the State of Registry and the State conducting the investigation.

In Chapter 2 the investigation and analysis of the accident are presented. The conclusions following the investigation and analysis are presented in Chapter 3. Chapter 4 contains the overall conclusion.

2 INVESTIGATION

2.1 Factual information

2.1.1 History of flight

On 8 July 2019 the Boeing 747-400F, with registration PH-CKA, performed a scheduled cargo flight from Tambo International Airport (Johannesburg, South Africa) to Robert Gabriel Mugabe International Airport (Harare, Zimbabwe). The two pilots were the only occupants of the aircraft.

The aircraft flew a non-precision approach to runway 05 to land at the airport. At approximately 5 NM from the runway, at an altitude of 1,995 feet radar altitude and an indicated airspeed of 156 knots, the crew extended the flaps from 20 to 25 degrees. Shortly thereafter, a loud bang was heard in the cockpit and the pilot flying felt a slight rolling motion to the right, which he countered with a fair amount of left aileron. The aircraft remained controllable and it continued on the approach, not deviating from its flight path and adhering to the approach criteria. The crew made a safe landing.

After the aircraft had landed, the post flight inspection revealed that the right half of the right wing inboard foreflap was missing, and that the right aft fuselage was damaged at several places.

2.1.2 Damage to aircraft

The foreflap separation caused moderate damages to the right wing inboard flap system and the right aft fuselage of the aircraft. The right inboard flap assembly was damaged at the foreflap and mid flap sections. The foreflap was partially missing; it was approximately broken in halve. The right hand side of the foreflap had separated and was later recovered. The left hand side of the foreflap was deformed, but still attached to sequence carriage assembly 5, which was also deformed due to the unusual forces exerted (see Figure 1). The mid flap section sustained multiple damages and was beyond economical repair. The separated right hand side of the foreflap caused damages to the right hand aft wing and body fairing, and the right aft fuselage, among other parts. The aft flap was not damaged.

2.1.3 Injuries to persons and other damage

The broken part of the foreflap came down approximately 5 NM from Runway 05 near the extended centreline, close to the town of the Chitungwiza, Zimbabwe. The flap part was approximately twelve foot long and two foot wide. No injuries to persons or damages to property were reported.

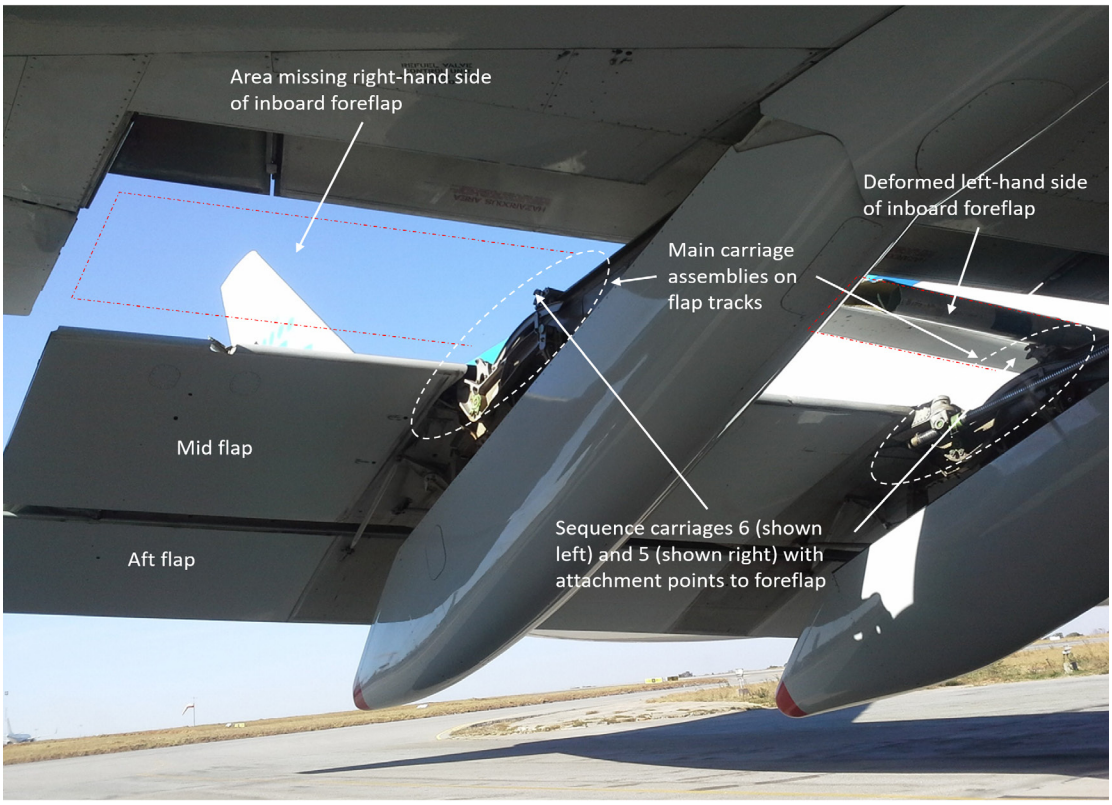

Figure 1: PH-CKA's right wing trailing edge inboard flap system and damage. (Source: owner of the aircraft)

Examination of the recovered right wing inboard foreflap parts revealed that the outboard foreflap fitting had failed (see Figure 2). Visual inspection of the outboard fitting revealed that the lug of the fitting was broken with signs of fatigue and overload failure. It could not be determined when exactly the outboard fitting lug had failed.

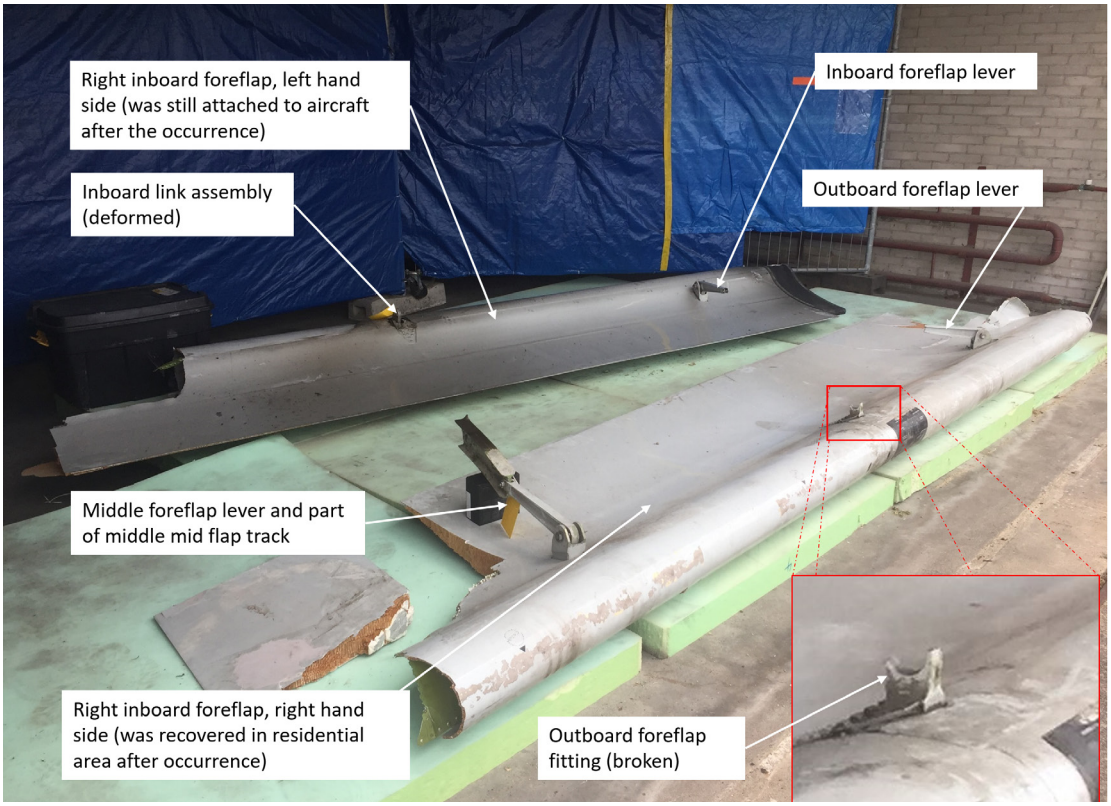

Figure 2: Broken parts PH-CKA's right wing inboard foreflap. (Source: Dutch Safety Board)

2.1.4 Aircraft information

PH-CKA was flying as a cargo configured aircraft. The aircraft had serial number 33694 and was manufactured on 31 March 2003. The aircrafts airworthiness certificate was valid until 31 March 2020.

The Boeing 747-400 flap system provides lift augmentation during phases of flight with relative low airspeeds such as takeoff, approach and landing. The complete flap system consists of leading edge flaps and trailing edge flaps. The trailing edge flaps of each wing consist of an inboard and outboard triple slotted Fowler[1] flap (see Figure 3). The inboard Fowler flap is made up of a foreflap, a mid flap and an aft flap (see Figure 1).

1 Skybrary, Fowler Flap - A split flap that slides rearwards level for a distance prior to hinging downwards. It thereby first increases chord (and wing surface area) and then increases camber.

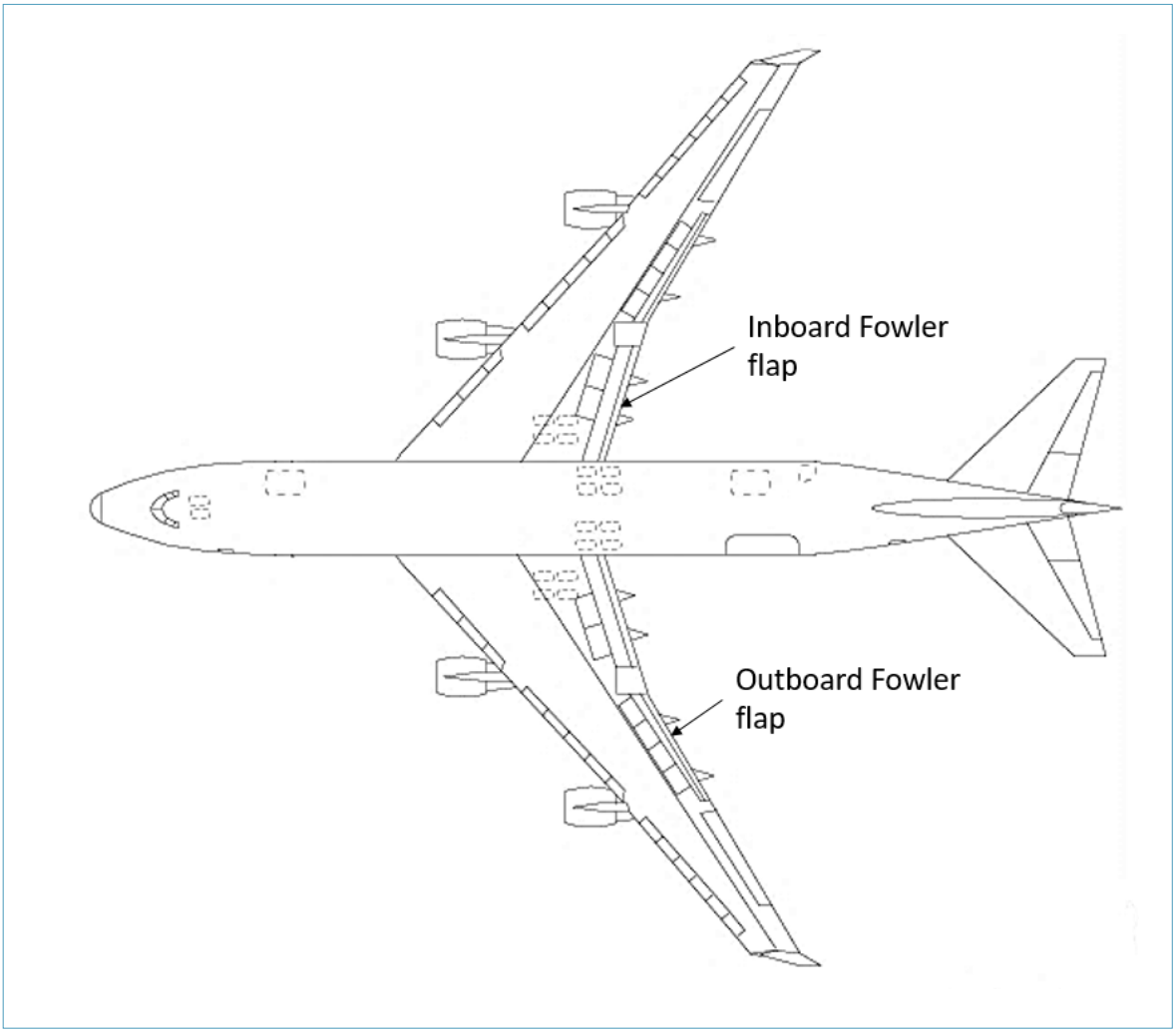

Figure 3: Position Boeing-747-400 inboard Fowler flap system. (Source: The Boeing Company, modified by the Dutch Safety Board)

Depending on the selected flap position, the inboard Fowler flaps are extended by a mechanism moving the sections of the fore, mid and aft flap over two flap tracks. The flap mechanism, with sequence carriages, spaces the three different flap sections. The foreflap is connected with an inboard link assembly onto sequence carriage No 5 and with an outboard foreflap fitting onto sequence carriage No 6 (see Figures 1 and 2). The flap fittings are joined with the sequence carriage assemblies by means of a bearing with bearing ball and bolt (see Figure 6). Besides being connected to the sequence carriage assemblies, the foreflap is also connected to the mid flap via three attachment levers and mid flap tracks that can slide in and out of the mid flap (not shown in Figure 1).

2.2 Meteorological information

The weather conditions during the approach were: winds 170 degrees at 6 knots, visibility more than 10 kilometres, no clouds below 5,000 feet and temperature 25 degrees Celsius.

2.3 Flight recorders

Wireless Quick Access Recorder (WQAR) data was available for analysis. The Flight Data Monitoring (FDM) information of the approach phase of the flight, which was made available through WQAR, was analysed and did not reveal operational deviations related to the occurrence.

2.4 Tests and research

The contracted maintenance organisation performed a metallurgic failure analysis of the outboard foreflap fitting.[2, 3] The examination revealed that the broken foreflap lug had two different fracture fronts (see Figure 4 a). The front side of the lug (see Figure 4 c) was the result of a fatigue fracture. And the rear side, i.e., opposite side of the lug showed an overload failure (see Figure 4 b). This overload failure was the consequence of the fatigue fracture which had caused the lug to open and break.

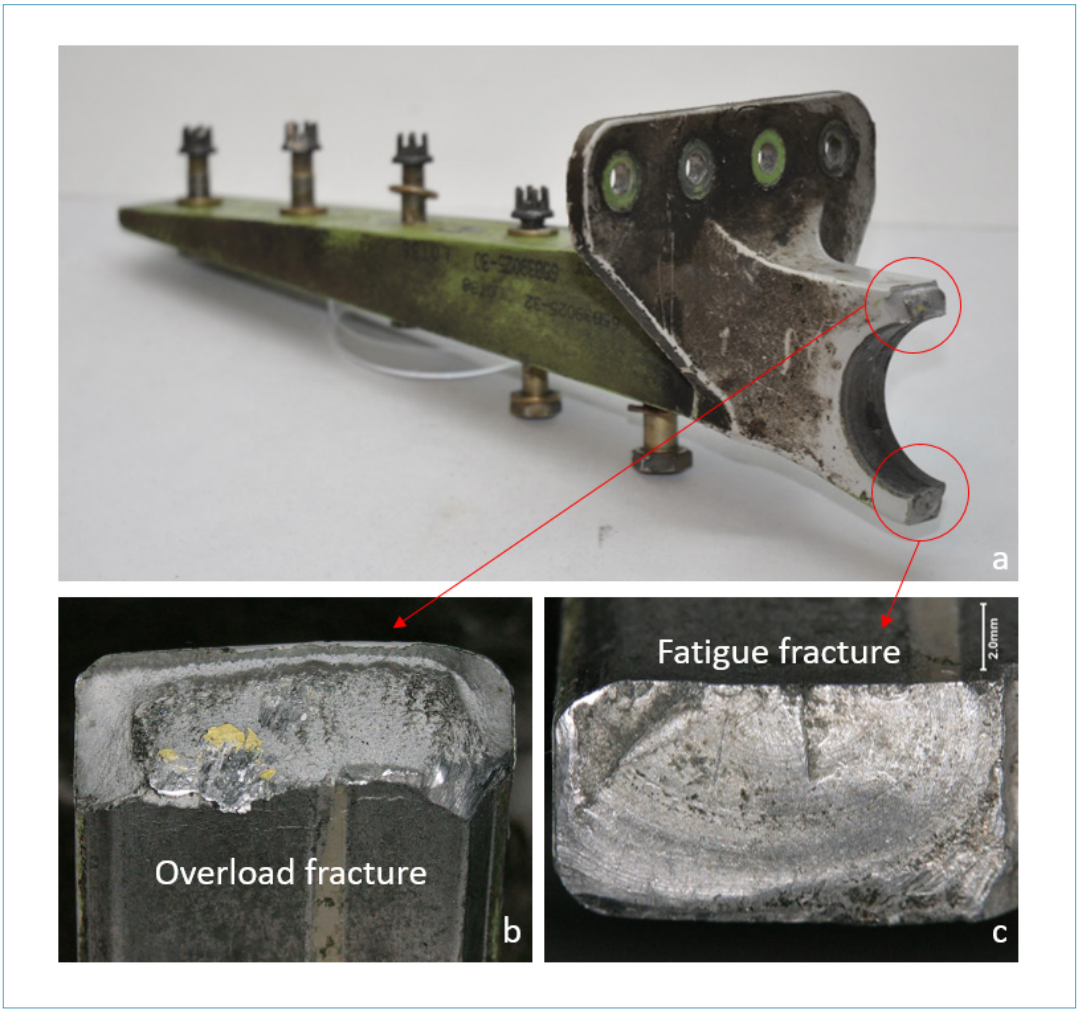

Figure 4: Broken outboard foreflap fitting lug (a), overload fracture (b) and fatigue fracture (c) surfaces. (Source: owner of the aircraft)

2 After approval from Civil Aviation Authority of Zimbabwe.
3 KLM Engineering & Maintenance, Support & Development Group, *Failure analysis of a broken RH inboard flap fitting, Aircraft PH-CKA Boeing 747-400, July 8th 2019*, 2020.

The failure analysis further demonstrated that the inner surface of the foreflap fitting lug had a highly pitted surface area (see Figure 5 a), indicating numerous corrosion points. These corrosion points led to the fatigue fracture that had caused the failure of the fitting lug and of several other fatigue crack fronts (see Figure 5 b). These fatigue cracks reduced the functional area and thus the tensile strength of the fitting lug. When the forces on the fitting lug exceeded the remaining tensile strength, the lug failed at the weakest point, i.e. the most developed fatigue crack front.

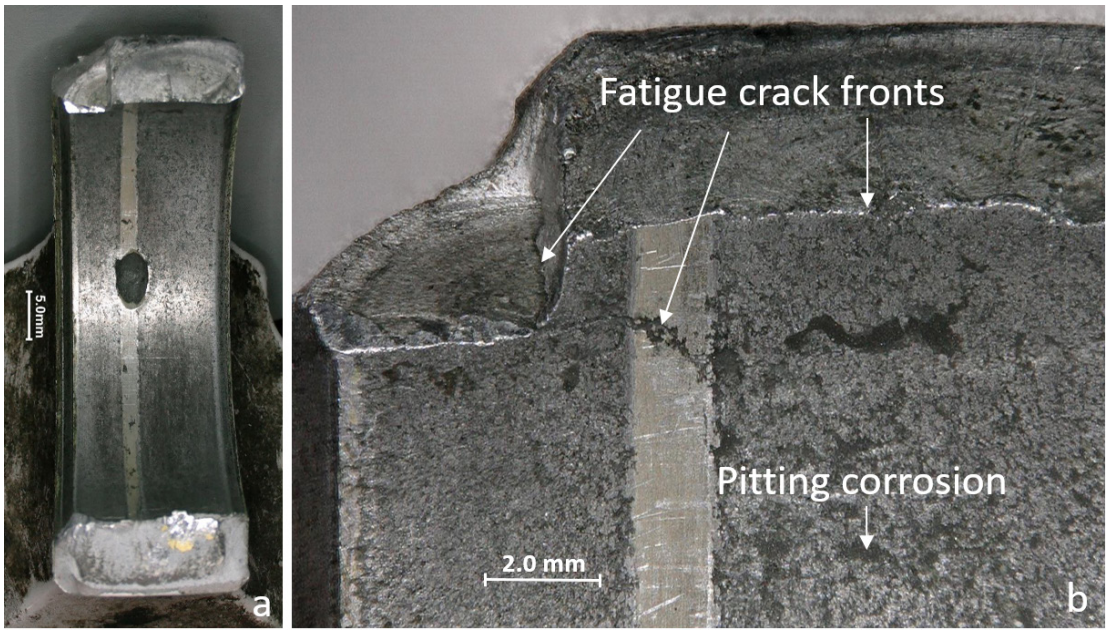

Figure 5: Outboard foreflap fitting inner surface with visible pitting corrosion and close up off pitting corrosion (a) and fatigue crack fronts (b). (Source: owner of the aircraft)

The maintenance organisation's report also stated that the forming of the pitting corrosion on the inside surface of the outboard fitting lug was likely caused by moisture that had entered, and accumulated, in the area between the fitting lug's inner surface and the outer surface of the bearing. The forming of this type of corrosion is a long term process. It is likely that the pitting corrosion on the inside of the right hand side inboard foreflap outboard fitting lug was already present long before it failed. The maintenance documentation showed that the service life at the moment of failure of the foreflap fitting was 16 years. Noted that at the moment of failure, there was no life limit requirement for the fitting established.

The outboard foreflap fitting bearing was still attached to sequence carriage assembly number 6, see Figure 6a. Figure 6b illustrates a close up of the bearing.

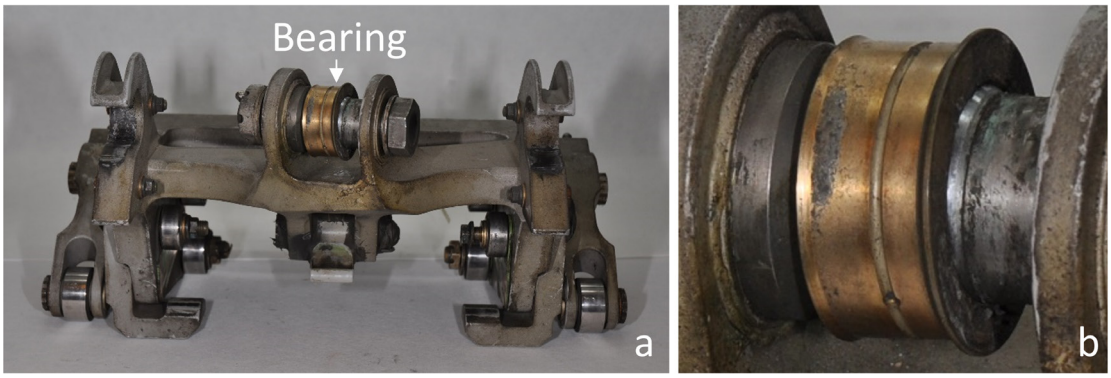

Figure 6: Sequence carriage assembly 6 with outboard foreflap fitting bearing (a) and close up of the bearing (b). (Source: owner of the aircraft)

2.5 Organisational and management information

2.5.1 Relevant airworthiness directives and service bulletins

The Boeing Model 747 series trailing edge flap system has been experiencing abnormalities resulting in foreflap separations as of the 1970ties. These abnormalities are mainly caused by skewed operation of the inboard flap system.[4] Skewed operation of the inboard foreflap may occur when a foreflap sequence carriage is out of phase with the other sequence carriage on a given flap assembly. Skewed operation can be caused by worn or broken centre toggle rollers or by binding of the foreflap track rollers in the mid flap. The loosening and migration may also be the result of insufficient lubrication of the track rollers and fitting lug bearings.

In order to resolve the above described anomalies of the trailing edge flap system, Boeing has issued several service letters (SLs) and service bulletins (SBs) from 1972 onwards. In addition, the Federal Aviation Authority issued airworthiness directives (ADs) in relation to the trailing edge flap system anomalies.

ADs and SBs differ in the way operators are required to incorporate the requirements into their maintenance programs. ADs are legally enforceable regulations by the national aviation authorities to correct safety deficiencies in aircraft systems.[5, 6] To ensure the air worthiness of aircraft, operators must comply with the requirements as put forth by ADs, or must accomplish an approved alternate means of compliance with the AD. An SB is the document used by manufacturers of aircraft, their engines or their components to communicate details of modifications which can be embodied in aircraft.[7] SBs intent to improve the reliability of aircraft systems by changing the design or maintenance requirements.

4 Boeing, *Service Bulleting 747-27-2366*, March 22, 2016.
5 EASA, *Air Worthiness Directives*, 2021.
6 FAA, *Air Worthiness Directives*, 2021.
7 Skybrary, *Service Bulletin*, 2020.

Manufacturers of aircraft usually recommend operators to adhere to the requirements as stated in SBs. Operators should incorporate the requirements from a SBs into their aircraft maintenance program based on their utilization of and experience with the fleet.[8] If a modification is a matter of safety, the manufacturer typically publishes an alert SB. Such an alert SB is then usually enforced by an AD. The relevant ADs, SBs and alert SB to the occurrence with PH-CKA are described below.

Airworthiness Directive 75-20-05. On 12 December 1975, the Federal Aviation Authority issued Airworthiness Directive 75-20-05. The AD is applicable to all Boeing Model 747 series aeroplanes. This AD contains several mandatory maintenance tasks, which are related to the various Boeing SBs and bulletins, that will improve the operation of the trailing edge flap system. The specific tasks of this AD are applicable to specific aircraft's, depending on manufacturing date, serial number and modification status.

Service Bulletin 747-27-2366, Revision 3. On 22 March 2016, Boeing issued SB 747-27-2366, Revision 3. This third issue of the original SB (originally issued December 1998) concerns among others, additional and improved instructions for inspection and lubrication of the inboard and outboard foreflap. This SB recommends three work packages with intervals of respectively six, eighteen months and eight years, to enhance phased inspections and maintenance of the foreflap components. Furthermore, Boeing recommended to incorporate the maintenance tasks from this SB into the existing maintenance programs of operators.

Alert Service Bulletin 747-57A2367. On 15 November 2019, Boeing issued Alert SB 747-57A2367, because foreflap separation events continued to occur. This alert SB concerns the periodically replacement of critical parts of the foreflaps and the flap sequence carriage assemblies, and inspections to further improve the reliability of the flap system. More specific, the outboard foreflap fitting is to be replaced within two years or 1,960 flight cycles after publication of the SB. The trailing edge inboard foreflap outboard fitting, thereafter, is to be replaced every six years or 5,880 flight cycles.

Airworthiness Directive 2021-02-15. On 30 March 2021, the Federal Aviation Authority issued AD 2021-02-15. This AD is applicable to all operators of Boeing Model 747 Series, except the 747SP and 747-8 models. This AD mandates the required actions per Boeing Alert Service Bulletin 747-57A2367.

2.5.2 Required maintenance on outboard foreflap fitting

Applicable to PH-CKA's maintenance program of the trailing edge inboard flap system were AD 75-20-05 and SB 747-27-2366 (Rev 3). This AD and SB require various maintenance tasks to maintain and improve inboard trailing edge flap system operation and reliability.

8 EASA, AMC M.A.302(d) *Aircraft maintenance programme*, 2015.

AD 75-20-05 required one lubrication task on the inboard foreflap system of PH-CKA. The reason that only one lubrication task remained was because the manufacturing date and modification status of PH-CKA did not require all tasks from the AD to be accomplished. The required lubrication task had to be accomplished at an interval up to 24 months.

SB 747-27-2366 (Rev 3) (in effect since 22 March 2016) required among others a maintenance task to inspect the inboard foreflap outboard fitting lug for bearing migration. The SB recommended to accomplished this task at an interval rate up to six months. The owner of the aircraft had scheduled the maintenance task on the outboard foreflap fitting with an interval not to exceed 3,400 flight hours. Noted is that the owner's engineering department integrated this relative new maintenance task into the existing maintenance program on 1 August 2016.

Table 1 shows the relevant dates, flight hours and remarks for the accomplishment of the AD 75-20-05 and SB 747-27-2366 (Rev 3) maintenance tasks as part the required A, C or D-checks in the period 2014 – 2019.

Table 1: Foreflap maintenance data

Date performed	Type of check	Maintenance task performed	Cumulative hours	Hours since last
12/11/19	A12		73,898	890
27/08/19	A11	AD 75-20-05 SB 747-27-2366, Rev 3	73,008	826
08/07/19, occurrence with failure of the right wing inboard foreflap, outboard fitting				
14/05/19	A10	AD 75-20-05	72,182	963
26/02/19	A09		71,219	829
18/12/18	A08	AD 75-20-05 SB 747-27-2366, Rev 3	70,390	891
09/10/18	A07		69,499	981
22/07/18	D02, C02, A06	AD 75-20-05 D-check[9] inspection: the right wing inboard foreflap, outboard fitting lug bearing no. 6 was replaced according SOPM 20-50-03.	68,518	673
24/04/18	A05	AD 75-20-05 SB 747-27-2366, Rev 3: the right wing inboard foreflap, inboard link assembly and bearing no. 5 were inspection and replaced.	67,845	917
06/02/18	A04		66,928	901

9 Contracted D-Check maintenance performed by HAECO, Aircraft Maintenance, Repair and Overhaul Service Provider, Xiamen, China.

Date performed	Type of check	Maintenance task performed	Cumulative hours	Hours since last
21/11/17	A03		66,027	960
05/09/17	A02	AD 75-20-05 SB 747-27-2366, Rev 3	65,067	801
20/06/17	A01		64,266	954
05/04/17	A12		63,312	948
17/01/17	A11	AD 75-20-05	62,364	835
02/11/16	A10		61,529	887
23/08/16	A09		60,642	837
20/06/16	C01, A08	AD 75-20-05	59,805	546
13/04/16	A07		59,259	895
26/01/16	A06		58,364	824
10/11/15	A05	AD 75-20-05	57,540	819
01/09/15	A04		56,721	881
08/06/15	A03		55,840	992
10/03/15	A02	AD 75-20-05	54,848	804
30/12/14	A01		54,044	1086
23/09/14	A12		52,958	806
18/07/14	A11, C06	AD 75-20-05	52,152	---

Maintenance documentation

Relevant to the inspection of and replacement of the inboard foreflap outboard fitting lug are the *Standard Overhaul Practice Manual (SOPM) 20-50-03 Rev.135 Bearing and Bushing Replacement* and the *Component Maintenance Manual* (CMM) 57-52-31.

2.6 Additional information

2.6.1 Similar foreflap failure occurrences

In the past, incidents and accidents with the Boeing 747 (B747) series trailing edge inboard foreflap system have occurred. The Safety Board has compiled a list of occurrences in which foreflap separation occurred as of 2009.

- On 11 May 2019, at Guam, USA, a B747-400 lost parts of its foreflap. Investigation is pending. The investigation of the event at Guam was still ongoing on the day of publication of the report of the foreflap occurrence with PH-CKA.

- On 16 September 2018, at Frankfurt/Main Airport, Germany, a B747-428F lost parts of its right inboard foreflap during landing. The investigation concluded that the flap fitting was destroyed by extensive fatigue failure, which had originated from a corrosion cavity.
- On 27 July 2015, at Delhi Airport, India, a B747-400F lost its entire left inboard foreflap during the landing roll. The investigation concluded that not accomplishing SB 747-27-2366 by the operator was a causal factor. This resulted in the fracture of a foreflap inner attachment link (outboard) or the carriage attachment lug (inboard) leading to subsequent separation of the foreflap. The exact cause could not be determined, because the foreflap parts that had been shipped for investigation were lost.
- On 8 October 2014, at Frankfurt/Main Airport, Germany, a B747-400F lost part of its left inboard foreflap. There was no secondary damage. A fatigue fracture of the outboard foreflap fitting was the reason why the foreflap partly had separated. The fatigue crack was caused by corrosion.
- On 19 May 2013, at Atlanta Hartsfield-Jackson Airport, USA, a B747-400F lost its right inboard foreflap during final approach. The cause was a failure of the right inboard foreflap (outboard) fitting due to fatigue and bearing anomalies on the sequence carriages
- On 17 May 2010, at Miami Airport, USA, a B747-400F lost a section of its foreflap while on approach. The aircraft was, due to the separated foreflap, substantially damaged. A fatigue failure of the right wing foreflap outboard fitting was the cause.
- On 8 May 2009, at Frankfurt/Main Airport, Germany, a B747-400F lost its foreflap during the landing roll. The aircraft was severely damaged with punctures in the fuselage and a damaged tail section. The investigation concluded that the flap attach fitting was destroyed by an extended fatigue fracture. It started in all probability with a corrosion depression.

A more detailed historical account and technical description of these anomalies can be found in the accident investigation reports: BFU AX001-09[10]; BFU EX007-14[11] and BFU18-1394-AX[12] of the German Federal Bureau of Aircraft Accident Investigation (BFU).

10 German Federal Bureau of Aircraft Accident Investigation (BFU), *BFU AX001-09*, 2018.
11 German Federal Bureau of Aircraft Accident Investigation (BFU), *BFU EX007-14*, 2018.
12 German Federal Bureau of Aircraft Accident Investigation (BFU), *BFU18-1394-AX*, 2020.

3 ANALYSIS

3.1 Cause of foreflap separations

3.1.1 PH-CKA's outboard foreflap fitting failure

The maintenance organisation's metallurgic failure analysis of PH-CKA's broken right wing inboard foreflap outboard fitting determined that a progressed form of pitting corrosion and fatigue fracture was the root cause of the foreflap fitting failure. The failure of the outboard fitting caused the foreflap to come lose, move upwards and backwards into the airstream, then break in half and separate from the aircraft. The separated part caused subsequent damage to the aircraft.

The analysis further stated that the pitting corrosion was caused by moisture that had been present between PH-CKA's inboard foreflap outboard fitting lug inner surface and fitting lug bearing. For moisture to enter and pitting corrosion to form on the inner surface of the fitting lug, play between the fitting lug and the bearing must have been present. Once pitting corrosion has started, the inner surface of the fitting lug gradually loses material which in turn increases the play, causing more moisture to enter. Because the forming of pitting corrosion is a long term process, it is likely that the pitting corrosion on the inside of the fitting lug was already present before the replacement of the fitting lug bearing of PH-CKA in July 2018.

According to SB 747-27-2366, the play, loosening and migration of foreflap fitting bearings may be related to skewed operation of the foreflap in flight or poor lubrication of the fitting lug bearing.[13] Skewed operation or poor lubrication were not identified as causal factors with the foreflap fitting failure of PH-CKA by the maintenance organisation's failure analysis. Nevertheless, the manufacturer had indicated that because of the flap system's complexity, it is difficult to determine the actual cause of a partial foreflap loss and that skewed operation may contribute to the initiation of a fatigue crack.[14] The skewed operation causes high stress loads on the fitting lug and fitting lug bearing. Therefore, the Safety Board remarks that skewed operation of the flap system as a contributing factor to the failure of the foreflap fitting lug, should not be ruled out entirely.

3.1.2 Similar outboard foreflap fitting failures

PH-CKA's failure mode of the right wing inboard foreflap fitting as described in Paragraph 3.1.1 shows a similar corrosion and fatigue failure mode of the foreflap fittings as they were found in the occurrences listed in Paragraph 2.6.1.

13 Boeing, *Service Bulleting 747-27-2366*, March 22, 2016.
14 Boeing, *Fleet Team Digest, 747-FTD-57-10002, Partial Loss of Wing Inboard Trailing Edge Fore Flaps – PDA*, July 2021.

Noteworthy is that of these occurrences, the service life of the outboard foreflap fittings at the moment of failure, was approximately between eleven and sixteen years. The service life of PH-CKA's fitting was sixteen years, showing correlation with the mentioned failure time period. Altogether, the foreflap separation occurrence with PH-CKA shows a similar causality with previous foreflap separations.

3.2 Owner's maintenance on inboard foreflap fittings

The owner of the aircraft incorporated the maintenance tasks from AD 75-20-05 and SB 747-27-2366 (Rev 3) in its regular maintenance cycle/planning. The AD 75-20-05 required a lubrication task which had to be accomplished at an interval rate of up to 24 months. The owner performed this maintenance task at an average interval of approximately seven months In the period 2014 to 2019. The owner complied with the mandatory requirements from AD 75-20-05.

Furthermore, the owner's engineering department integrated SB 747-27-2366 (Rev 3) maintenance tasks into the existing maintenance program on 1 August 2016. The maintenance task that required a detailed inspection and lubrication of the outboard foreflap fitting and bearing was scheduled to be performed with an interval not to exceed 3,400 flight hours. This interval of 3,400 hours led to an actual inspection interval period of seven to eight months.[15] The SB recommended a maintenance interval not to exceed six months. With the interval period based on aircraft hours as determined by the owner, the recommended interval period of six months was exceeded by one to two months. The owner's rationale to deviate from the SB recommendation was that their experience with twenty one foreflap fitting replacements across their Boeing 747 fleet in the past, justified a longer interval. The European Union regulations concerning continuing airworthiness allow operators to incorporate service bulletins based on their experience with their fleet.

One of the inspection tasks of SB 747-27-2366 (Rev 3) is to perform a detailed visual inspection of the exterior of the fitting lug and the fitting bearing as they are assembled. The SB does not instruct to inspect the inside of the fitting lug for corrosion. The fitting lug bearing in its position in the fitting lug prevents such a visual inspection for corrosion. As such, the maintenance tasks from SB 747-27-2366 could not detect nor prevent corrosion on the inside of the fitting lug.

The maintenance documentation indicates that outboard fitting lug bearing No 6 of the foreflap fitting was found migrated and replaced during a regular D-check[16] inspection on 22 July 2018; this was one year prior the failure of the fitting lug. After this replacement, the bearing was inspected and lubricated according to the SB, five months later in December 2018. This SB inspection did not reveal any discrepancies on the fitting lug or bearing. The fitting lug failed seven months later in July 2019.

15 During A-checks on 5 September 2017, 24 April 2018 and 16 December 2018.
16 Contracted D-Check maintenance performed by HAECO, Aircraft Maintenance, Repair and Overhaul (MRO) Service Provider, Xiamen, China.

During the above mentioned D-check in July 2018, a general visual inspection of the right wing inboard trailing edge flap system revealed that the outboard fitting lug bearing No 6 was migrated. This finding led to the replacement of the bearing that was mentioned earlier. The maintenance worksheet that described the work performed, does not contain remarks about the condition of the inner surface of the fitting lug. The documentation neither shows that further investigation was performed in order to find the cause of the bearing migration nor, does it show that the foreflap fitting was within technical specifications. The non-routine maintenance worksheet raised by the maintenance repair overhaul (MRO) organization had the SOPM 20-50-03 annotated as the procedure to replace the bearing. The SOPM 20-50-03 provided the work steps for the removal and installation of bearings. Yet, instructions to visually inspect parts of the foreflap fitting and bearing for defects and if needed, to use additional inspection methods to further investigate anomalies were provided in CMM 57-52-31. It should be noted that maintenance has to be performed according to the instructions of the maintenance manual, such as an SOPM or CMM and by observing standard maintenance practices.

3.3 Measures taken to prevent foreflap fitting failures

On 15 November 2019, which is after the incident with PH-CKA, Boeing issued alert SB 747-57A2367 to further improve the reliability of the trailing edge flap system. This alert SB requires operators to periodically replace specific parts of the trailing edge flap system. For the inboard foreflap outboard fitting specifically, a replacement interval of every six years or 5,880 flight cycles is required. This replacement time interval is well before the eleven to sixteen years failure time period of the foreflap outboard fitting, as also mentioned in Paragraph 3.1.2. Therefore, the periodic replacement of the inboard foreflap outboard fitting as required by alert SB 747-57A2367 is deemed an effective preventive measure, according to the Dutch Safety Board.

The owner of the aircraft started to implement the requirements of Alert SB 747-57A2367 on 2 December 2019. The owner's maintenance documentation[17] showed that the maintenance program was adjusted to be adhere to the Alert SB 747-57A2367 as of 28 February 2021. On 30 March 2021, the FAA published AD 2021-02-15, that mandates all applicable actions from Alert SB 747-57A2367.

17 Air France/KLM Engineering and Maintenance, *Operator Requirement Proposal No: 744-57-25692-KL Rev 2*, 26 February 2021.

4 CONCLUSION

The right wing inboard foreflap of PH-CKA failed and partly separated, because of a fatigue crack failure of the foreflap outboard fitting lug. The fatigue crack was caused by pitting corrosion. The pitting corrosion had formed because of moisture that had accumulated between the inside of the foreflap fitting lug and the outside of the fitting lug bearing for over a long period of time. The cause of PH-CKA's inboard foreflap outboard fitting failure is similar to other investigated occurrences concerning inboard foreflap separations, that occurred with the Boeing 747 series aircraft in the past.

The owner of the aircraft's planning of the required maintenance on the inboard foreflap outboard fitting was compliant with Airworthiness Directive 75-20-05. The owner had incorporated Service Bulletin 747-27-2366 (Rev 3), that recommends the visual inspection and lubrication of the foreflap fitting within an interval period of six months, in such a way that an interval period of seven to eight months ensued. The owner had justified this longer interval period by referring to its experience with foreflap fitting anomalies across its Boeing 747 fleet in the past. The European Union regulations concerning continuing airworthiness allow for such an adaptable incorporation of service bulletin requirements into aircraft maintenance programs.

About one year prior to the failure of PH-CKA's right wing inboard foreflap outboard fitting lug, the foreflap outboard fitting lug bearing was replaced during a regular D-check because of migration of the bearing. At that time, it was likely that a progressed form of pitting corrosion was present on the inside of the fitting lug. This corrosion was not discovered during the replacement. Therefore, the Dutch Safety Board emphasises that investigating the cause of anomalies of aircraft parts according to maintenance manuals and by observing standard maintenance practices is vital to ensure system safety.

Boeing issued Alert Service Bulletin 747-57A2367 on 15 November 2019 to further improve the reliability and the safe operation of the inboard foreflap and related parts of the inboard trailing edge flap system. This alert service bulletin requires replacement of the inboard foreflap outboard fitting lug at an interval that is well before the expected time of failure. On 30 March 2021, the Federal Aviation Authority mandated with Airworthiness Directive 2021-02-15 the maintenance requirements from Alert Service Bulletin 747-57A2367. This measure as imposed by the airworthiness directive has been incorporated after a prolonged period with various maintenance measures to improve the Boeing 747 inboard trailing edge flap system. The Dutch Safety Board considers that the alert service bulletin requirements and the mandatory compliance as imposed by the airworthiness directive are adequate to prevent future inboard foreflap outboard fitting lug failures. Hence, the Dutch Safety Board does not issue recommendations.

APPENDIX A

Responses to the draft report

In accordance with the Dutch Safety Board Act, a draft version (without recommendations) of this report was submitted to the parties involved for review. The following parties have been requested to check the report for any factual inaccuracies and ambiguities:

- Civil Aviation Administration of China
- Civil Aviation Authority of Zimbabwe
- European Union Aviation Safety Agency
- HAECO Xiamen
- Human Environment and Transport Inspectorate
- KLM Royal Dutch Airlines
- Martinair Holland
- Ministry of Infrastructure and Water Management
- National Transportation Safety Board
- The Boeing Company

The responses received, as well as the way in which they were processed, are set out in a table that can be found on the Dutch Safety Board's website (www.safetyboard.nl). The responses received can be divided into the following categories:

- Corrections and factual inaccuracies, additional details and editorial comments that were taken over by the Dutch Safety Board (insofar as correct and relevant). The relevant passages were amended in the final report.
- Not adopted responses; the reason for this decision is explained in the table.

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