Version 2, issued 27 May 2016

UPDATE TO PRELIMINARY REPORT ON ACCIDENT AT TURØY, NEAR BERGEN, NORWAY ON 29 APRIL 2016, INVOLVING AIRBUS HELICOPTERS H225, LN-OJF OPERATED BY CHC HELIKOPTER SERVICE AS

This report is a preliminary and incomplete representation of AIBN's investigations in connection with the relevant aircraft accident. The report may contain faults and inaccuracies. The final report will be the Accident Investigation Board's official document concerning the accident and investigation.

Aircraft:	
- Type and reg.:	Airbus Helicopters H225, LN-OJF
Serial No.:	2721
Call sign:	HKS241
No. and Type of Engines:	2 x Turbomeca Makila 2A1 turboshaft engines
Date and time (local):	Friday 29 April 2016 at 11:55 hours
Year of Manufacture:	2009
Accident site:	Turøy, Hordaland county, Norway (Pos. 60,45234°N 004,93028°E) Radial/Distance from ENBR: 330°/13 NM
Weather conditions:	METAR ENBR 290950Z 20017KT 9999 SCT018 SCT023 07/03 Q1005 NOSIG RMK WIND 1200FT 19020KT=
Light conditions:	Daylight
Operator:	CHC Helikopter Service AS
Type of Operation:	Commercial Air Transport (CAT), Non-scheduled operations
Persons on board:	Crew - 2 (Fatal) Passengers – 11 (Fatal)
Nature of damage:	Helicopter destroyed
Information Source:	AIBN Field Investigation

All times given in this report are local time (UTC + 2 hours) unless otherwise stated.

Introduction

This update to the Preliminary report is published to disseminate information obtained during the ongoing investigation[1]. The intention is to give a brief update on the progress and findings four weeks into the investigation.

The official investigation team led by AIB Norway (AIBN) met at Airbus Helicopters (AH) in Marignane on 24, 25 and 26 May 2016 with the additional participation, BEA France, AAIB UK, EASA, CAA UK and CHC.

[1] *Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, Art. 2.*

The main purpose of this 3 days meeting was to agree on further investigation of the parts that the AIBN had sealed and sent to Airbus Helicopters, and to discuss a list of possible scenarios that could explain the detachment of the main rotor. The scenarios that are considered as possible initiating events are mentioned at the end of this updated preliminary report.

History of Flight

HKS241 was enroute from Gullfaks B (ENQG) to Bergen Airport Flesland (ENBR). The helicopter was cruising at 2000 ft when the Main Rotor Head (MRH) and mast suddenly detached.

The helicopter impacted on a small island and caught fire. The main wreckage thereafter ended in the sea where it came to rest at a depth of 1-9 meters. The accident was not survivable.

Initial Phase of the Investigation

The CVFDR (Combined Voice and Flight Data Recorder) was salvaged from the tail section of the helicopter the day of the accident. The recorder was taken to the Air Accidents Investigation Branch (AAIB) at Farnborough, UK for read-out. Two days after the accident, both voice and flight data was successfully downloaded.

The main wreckage was recovered from under water and brought to the naval base Haakonsvern the day after the accident. The Main Rotor Head (MRH) and other parts found on land were taken to the same place for preparation, registration and preliminary examination.

According to international Standards and Recommended Practices (ICAO Annex 13), the State of Occurrence shall institute and be responsible for the investigation. AIBN has taken on the responsibility for this investigation and has called upon assistance from France (the State of Design and Manufacture) and the UK AAIB (Air Accidents Investigation Branch)[2]. Le Bureau d'Enquêtes et d'Analyses (BEA) pour la Sécurité de l'Aviation civile is supported by technical advisors from Airbus Helicopters and the Engine manufacturer Turbomeca. From the UK, QinetiQ are contributing with their technical expertise.

In addition, the European Aviation Safety Agency (EASA) is the competent certification Authority for Airbus Helicopters H225 and participates as Advisor to the AIBN. The Norwegian Civil Aviation Authority (N-CAA), the UK Civil Aviation Authority (UK CAA) and the Operator CHC Helikopter Service are also advisors and part of the team.

Initial Examinations

The recordings on the CVFDR showed that everything appeared to be normal until a sudden catastrophic failure developed in 1-2 seconds. The CVFDR recordings ended abruptly at the same time. There are no indications that flight crew actions were a factor in the accident. A spectral analysis of the CVR data has been carried out. There was no obvious indication of an abnormality before the sudden detachment of the rotor head.

On 5 May, all the retrieved parts from the helicopter wreckage were taken from Haakonsvern to the AIBN premises in Lillestrøm, where all parts of particular interest for the investigation have been selected for more detailed inspections/examinations.

The Health and Usage Monitoring System (HUMS/PCMCIA) card was retrieved and has been examined by BEA. The logic of the HUMS system is that HUMS data is saved to the card after the

[2] *ICAO Annex 13 does not preclude the State conducting the investigation from calling upon the best technical expertise from any source. In particular if a State believes that a useful contribution can be made to the investigation or when such participation might result in increased safety.*

helicopter has landed onshore. Thus, data from the accident flight was not available. However, the system also stores some Flight Data parameters that are used for Flight Data Monitoring (FDM). On 12 May, the BEA succeeded in downloading FDM data that extended approximately 13 seconds beyond the CVFDR data. A preliminary analysis was ready a week later. It provides valuable information about the sequence of events and will be analysed further.

On 20 May, key pieces of wreckage were sent to selected laboratories, including Airbus Helicopters, for detailed examination. Detailed examination work continues to focus on the MRH suspension bar assembly, the main gearbox and the main rotor head. Other wreckage parts and components are also being examined in parallel.

Search for Components

Whilst several parts vital for the investigation have been recovered the four weeks since the accident, some key components are still missing. These components are in particular the epicyclical second stage planet gear carrier and parts of the forward suspension bar. A comprehensive search involving both civil and military resources was organised by AIBN until Friday 20 May. Before the next search phase is launched, the intention is to study in detail all information from the searches som far. A refined flight path and mapping of where the different components have been found will be carried out in order to possibly fine-tune a new search for these key components. Please refer to the AIBN web page for additional information on missing components and instructions on how to behave if 3rd parties discover parts from the helicopter.

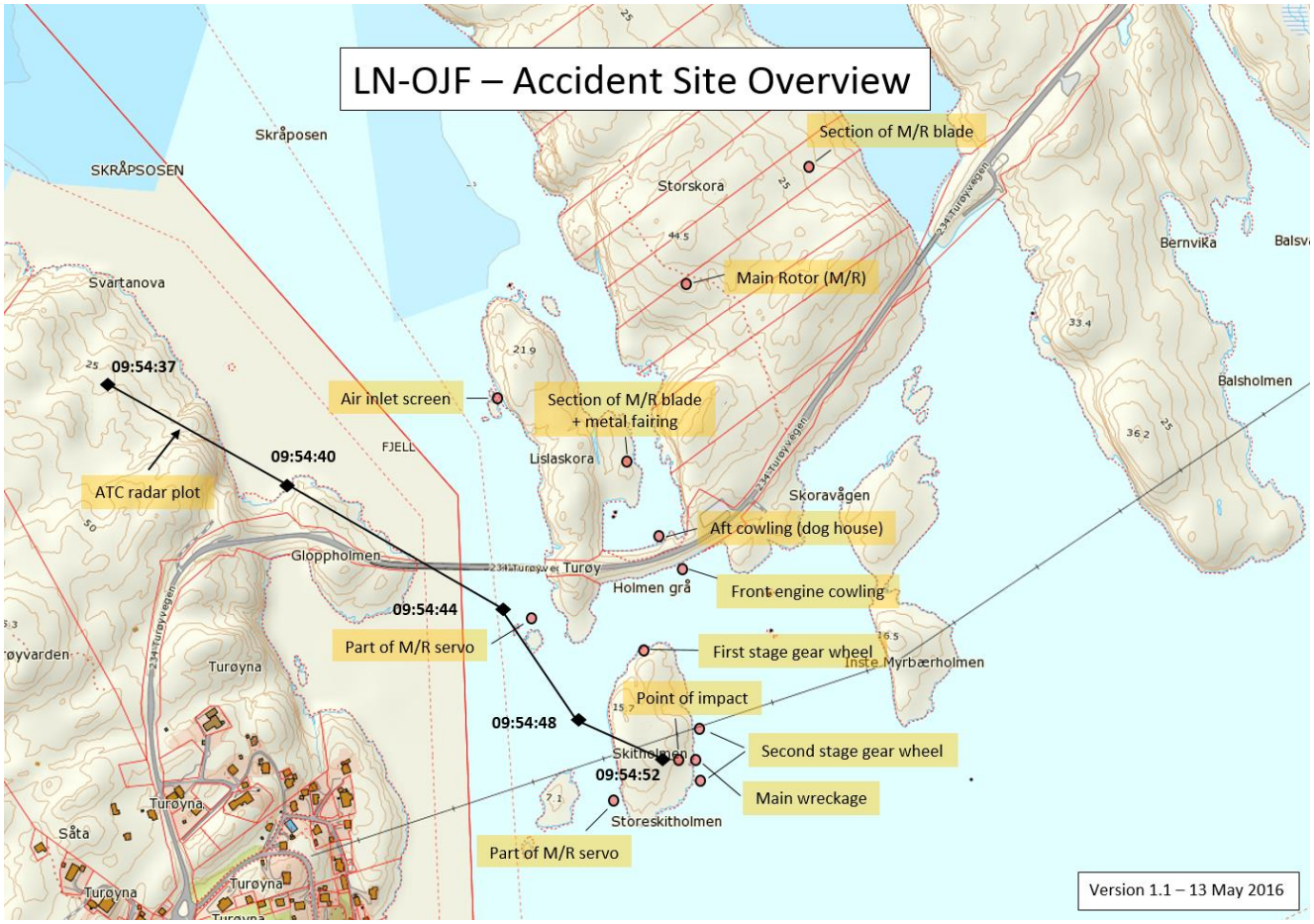

Figure 1: The Accident Site. (Time on ATC Radar Plot is UTC.) Map: © The Norwegian Mapping Authority. Illustration: AIBN

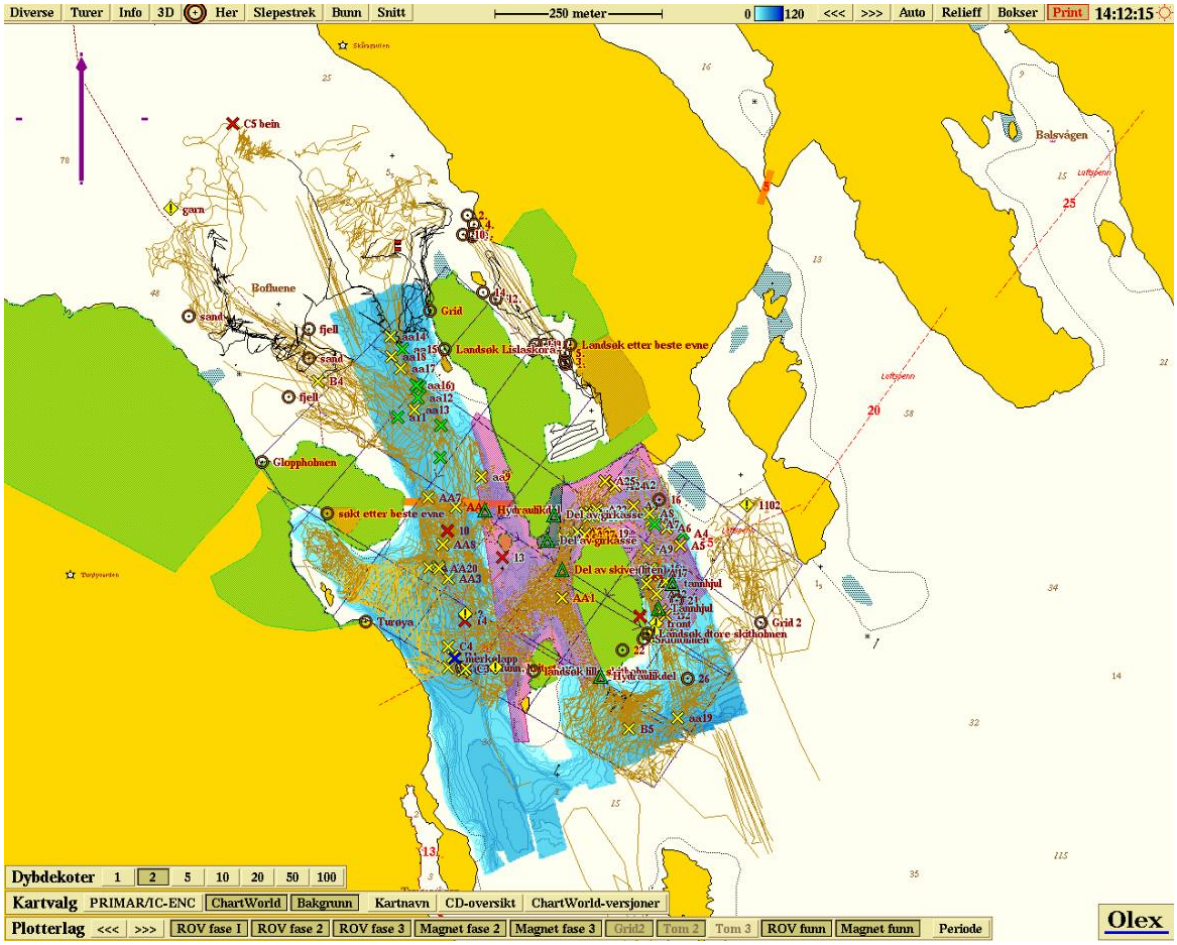

Figure 2: Illustration of underwater search grid.

Samples of retrieved components

Figure 3: MGB Right and left hand aft suspension bars with attachment fittings. Photo: AIBN

Figure 4: Upper forward suspension bar fitting. Photo: AIBN

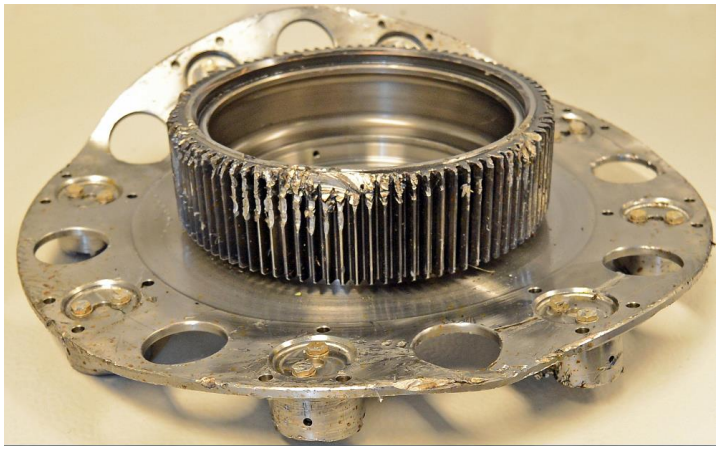

Figure 5: MGB first stage planetary gear carrier. Photo: AIBN

Figure 6: Parts from second stage planet gear. (The fractured gear is placed on top of a sample gear that was not involved in the accident.) Photo: AIBN

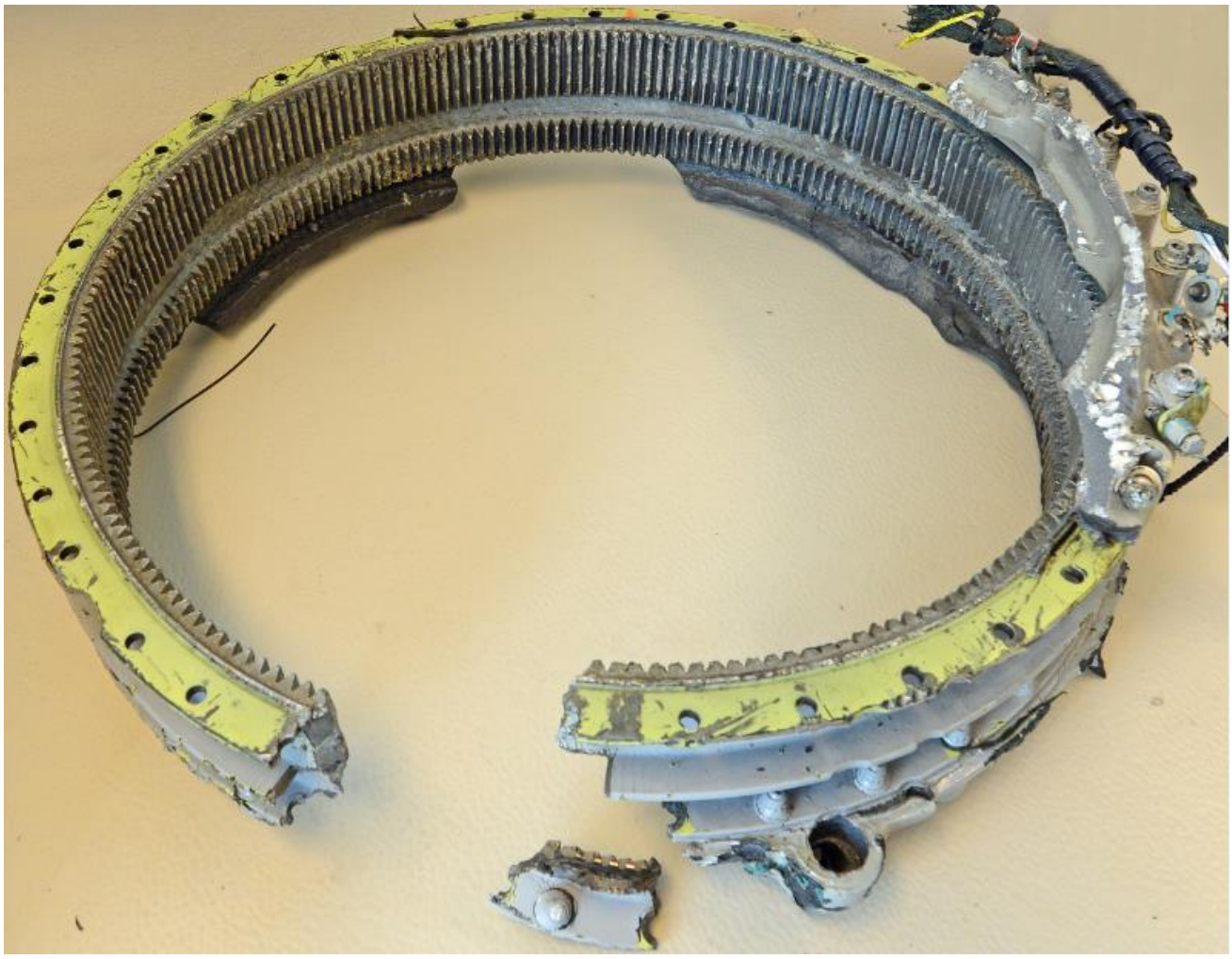

Figure 7: Ring Gear. Photo: AIBN

Figure 8: First stage Sun Gear. Photo: AIBN

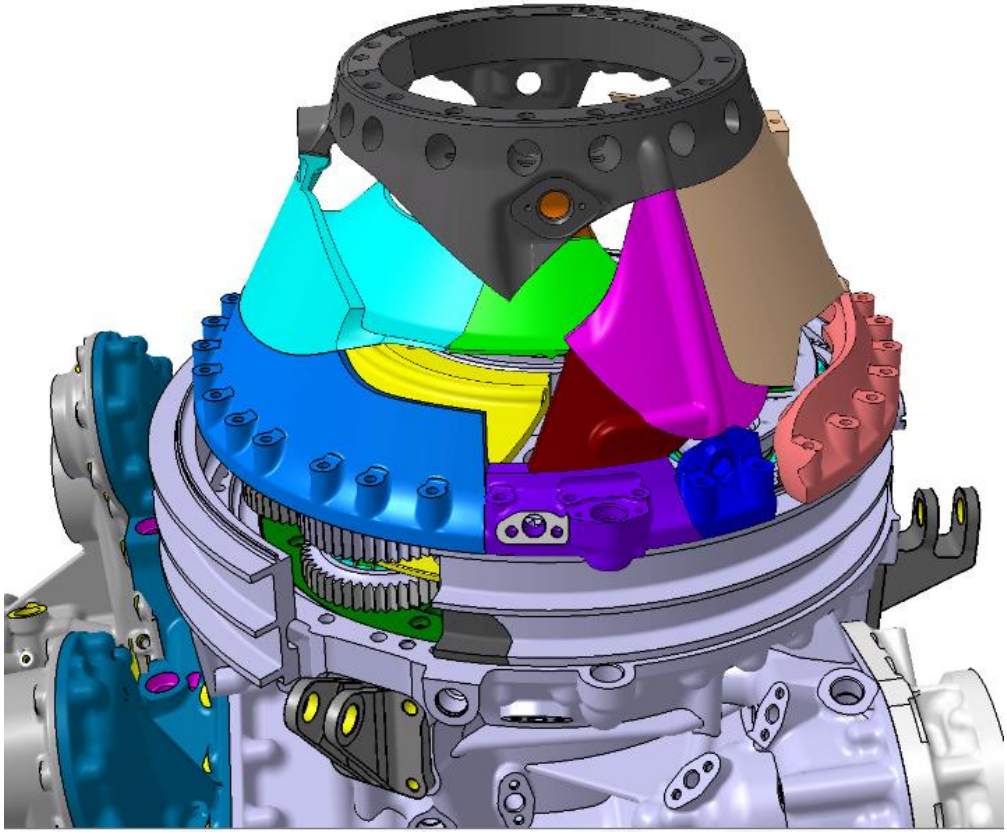

Figure 9: Illustration of how the retrieved fragments of the Conical Housing are pieced together in order to look for break-up sequence/mechanism. Illustration: Airbus Helicopters

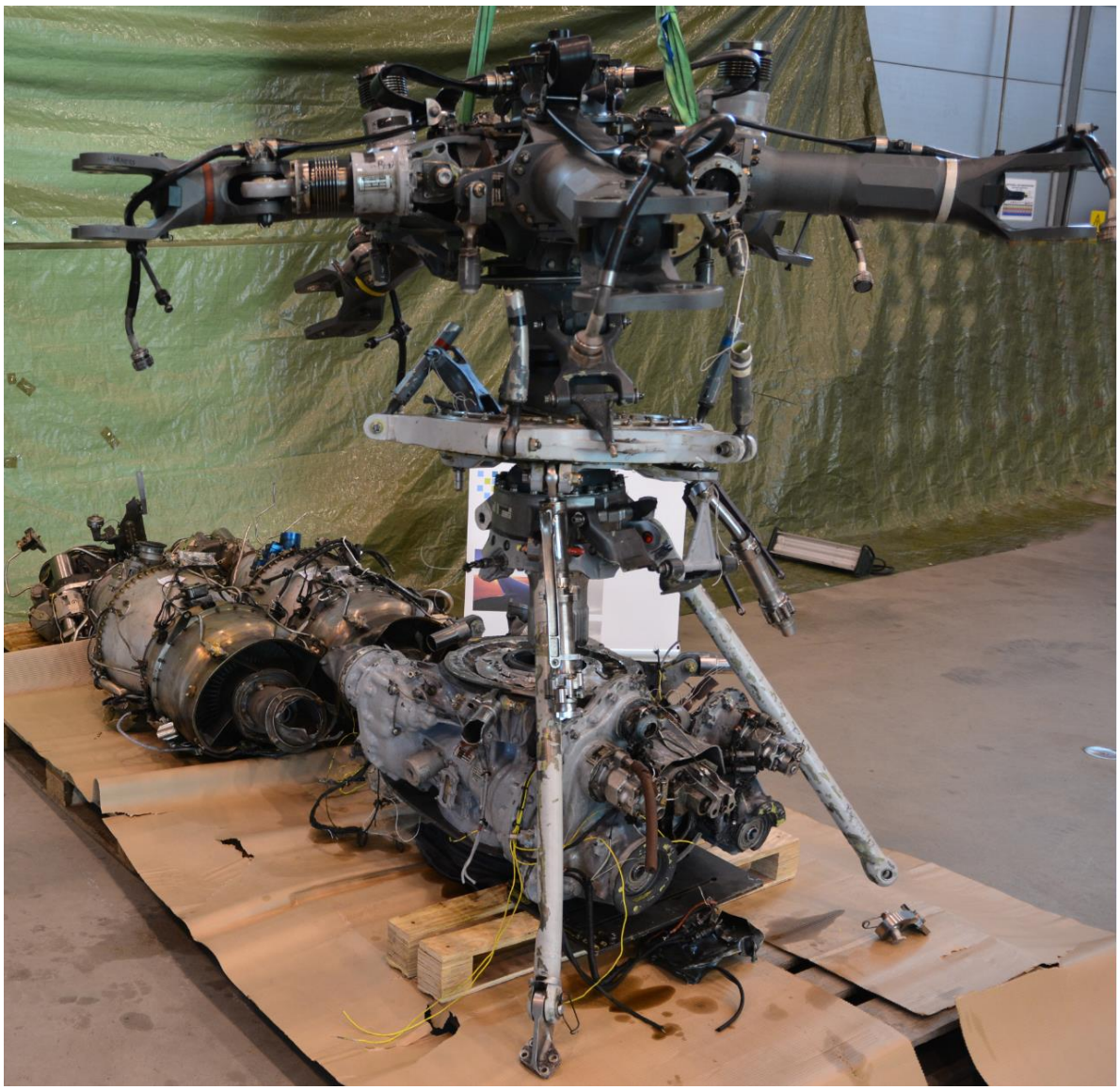

Figure 10: Main rotor head with rotor mast with aft suspension bars and power plants. Photo: AIBN

Further Examinations

The AIBN has collected and secured relevant maintenance documentation. This material is currently the subject of a thorough analysis in parallel with the technical examinations.

Detailed metallurgical examinations have been ongoing since 19 May, but are still at an early stage. So far, these examinations have not identified a conclusive primary cause of the accident.

Preliminary Analysis

The investigation team has discussed a list of scenarios that Airbus Helicopter prepared based on fault tree analysis. At this stage, the AIBN can confirm that the scenarios under consideration include failure of epicyclic module, suspension bar (lift strut) attachment and MGB conical housing.

The investigation is ongoing and updates will follow.

The Accident Investigation Board Norway

Lillestrøm, 27 May 2016

Accident Investigation Board Norway

PRELIMINARY REPORT 1 JUNE 2016

ACCIDENT AT TURØY, NEAR BERGEN, NORWAY ON 29 APRIL 2016, INVOLVING AIRBUS HELICOPTERS H225, LN-OJF OPERATED BY CHC HELIKOPTER SERVICE AS

This report is a preliminary and incomplete representation of AIBN's investigations in connection with the relevant aircraft accident. The report may contain faults and inaccuracies. The final report will be the Accident Investigation Board's official document concerning the accident and investigation.

Aircraft:	
- Type and reg.:	Airbus Helicopters H225, LN-OJF
Serial No.:	2721
Call sign:	HKS241
No. and Type of Engines:	2 x Turbomeca Makila 2A1 turboshaft engines
Date and time (local):	Friday 29 April 2016 at 11:55 hours
Year of Manufacture:	2009
Accident site:	Turøy, Hordaland county, Norway (Pos. 60,45234°N 004,93028°E) Radial/Distance from ENBR: 330°/13 NM
Weather conditions:	METAR ENBR 290950Z 20017KT 9999 SCT018 SCT023 07/03 Q1005 NOSIG RMK WIND 1200FT 19020KT=
Light conditions:	Daylight
Operator:	CHC Helikopter Service AS
Type of Operation:	Commercial Air Transport (CAT), Non-scheduled operations
Persons on board:	Crew - 2 (Fatal) Passengers – 11 (Fatal)
Nature of damage:	Helicopter destroyed
Information Source:	AIBN Field Investigation

All times given in this report are local time (UTC + 2 hours) unless otherwise stated.

Introduction

This preliminary report is published to disseminate new and significant findings from the on-going metallurgical examinations. The report contains one safety recommendation to the European Safety Agency (EASA).

Reference is made to the AIBN preliminary report dated 13 May 2016, which was updated on 27 May (ref. Preliminary Report 27.05.2016). At that time, the AIBN considered three possible failure scenarios: Failure of epicyclic module, suspension bar (lift strut) attachment and MGB conical housing.

Metallurgical Examinations

Detailed metallurgical examinations have been ongoing since 19 May. Several parts from the second stage epicyclic module were retrieved from the accident site. The epicyclic module planet gears are designed as a combined gear and bearing assembly. Figure 1 shows one of eight second stage planet gears.

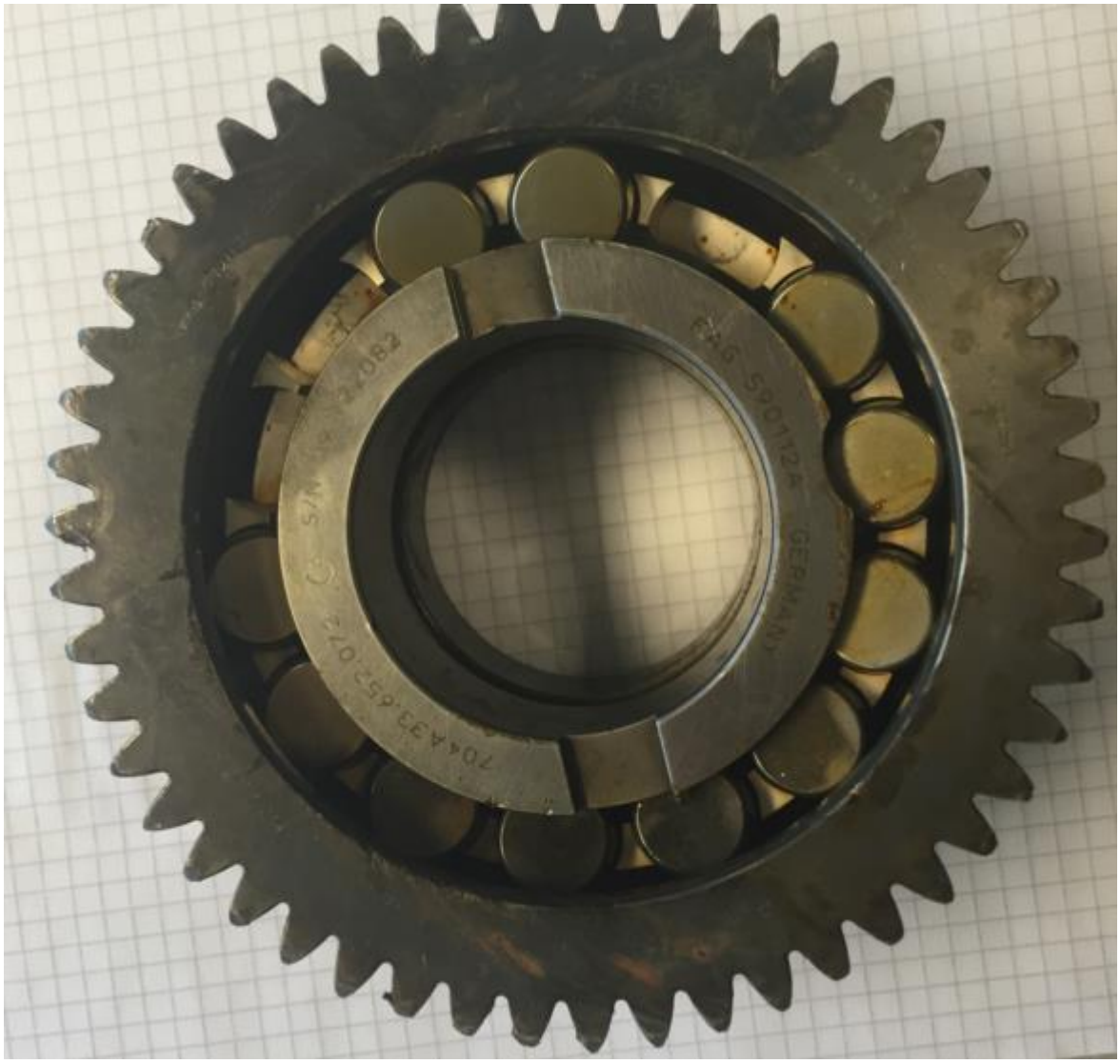

Figure 1: Second stage planet gear (as found with three rollers missing). Photo: AIBN

Planet gears have a double function, acting as a gear on the outside while at the same time functioning as the outer race of a roller bearing on the inside. In order to improve wear resistance it has been given a hard outer surface through a carburization process.

Among the recovered parts were two pieces which together form approximately half a second stage planet gear (ref. Figure 2). Examinations of these parts have revealed features strongly consistent with fatigue. The fatigue appears to have its origin in the outer race of the bearing (inside of the gear), propagating towards the web of the gear teeth. There is sign of spalling in front of the fracture surface.

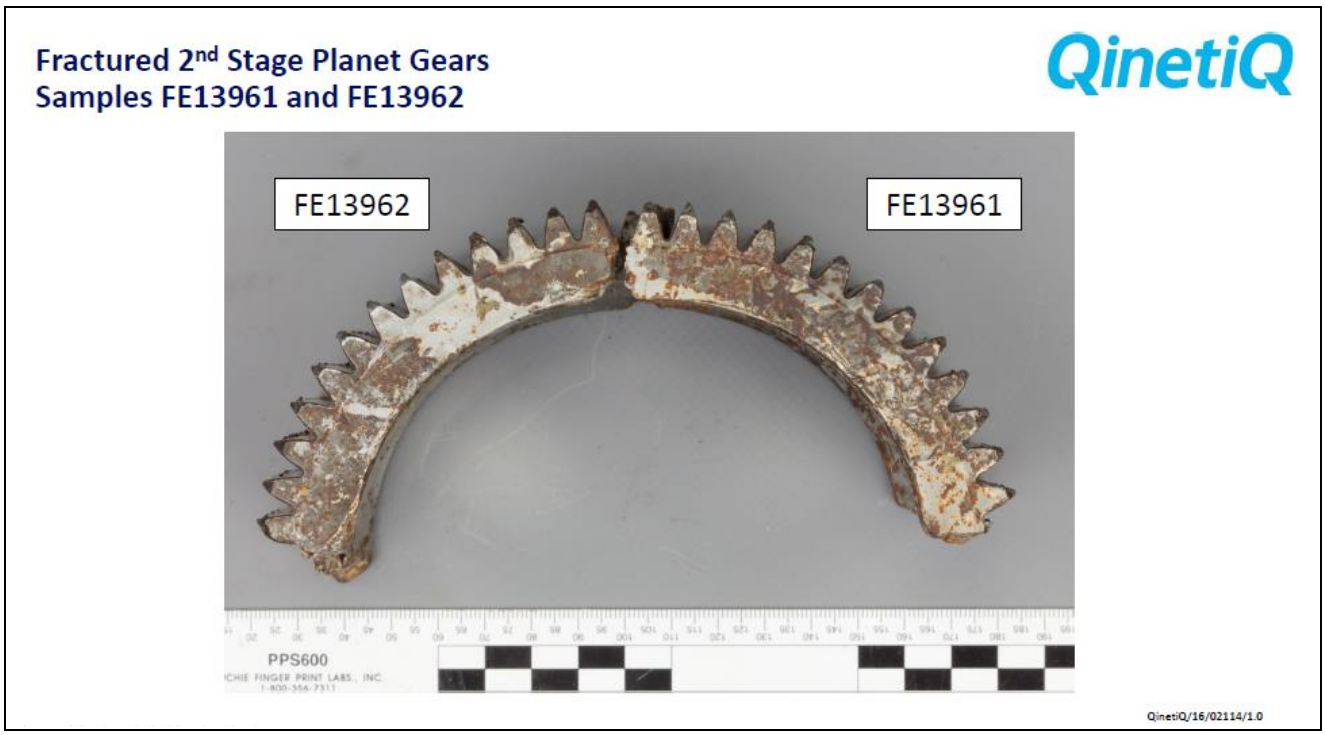

Figure 2: The two pieces of the second stage planet gear prepared for metallurgical examinations. Photo: QinetiQ

The investigation of these particular parts is still ongoing, and thus no photos of the fracture surface are enclosed in this preliminary report. All stakeholders in this investigation have been informed about these significant findings.

Although preliminary, the AIBN considers these findings to be of such significance that it has decided to issue the following safety recommendation to ensure the continuing airworthiness of the Main Gear Box (MGB).

Safety Recommendation

Recent metallurgical findings have revealed features strongly consistent with fatigue in the outer race of a second stage planet gear in the epicyclic module of the MGB. It cannot be ruled out that this signifies a possible safety issue that can affect other MGBs of the same type. The nature of the catastrophic failure of the LN-OJF main rotor system indicates that the current means to detect a failure in advance are not effective.

The AIBN therefore recommends that EASA take immediate action to ensure the safety of the Airbus Helicopters H225 Main Gear Box.

The investigation is ongoing and updates will follow.

The Accident Investigation Board Norway

Lillestrøm, 1 June 2016

PRELIMINARY REPORT 28 JUNE 2016

ACCIDENT AT TURØY, NEAR BERGEN, NORWAY ON 29 APRIL 2016, INVOLVING AIRBUS HELICOPTERS H225, LN-OJF OPERATED BY CHC HELIKOPTER SERVICE AS

This report is a preliminary and incomplete representation of AIBN's investigations in connection with the relevant aircraft accident. The report may contain faults and inaccuracies. The final report will be the Accident Investigation Board's official document concerning the accident investigation.

Aircraft:	
- Type and reg.:	Airbus Helicopters H225, LN-OJF
Serial No.:	2721
No. and Type of Engines:	2 x Turbomeca Makila 2A1
Year of Manufacture:	2009
Date and time (local):	Friday 29 April 2016 at 11:55 hours
Location:	Turøy, Hordaland county, Norway (Pos. 60,45234°N 004,93028°E) Radial/Distance from ENBR: 330°/13 NM
Type of Operation:	Commercial Air Transport (CAT), Non-scheduled operations
Weather conditions:	METAR ENBR 290950Z 20017KT 9999 SCT018 SCT023 07/03 Q1005 NOSIG RMK WIND 1200FT 19020KT=
Light conditions:	Daylight
Operator:	CHC Helikopter Service AS
Persons on board:	Crew - 2 (Fatal) Passengers - 11 (Fatal)
Nature of damage:	Helicopter destroyed
Information Source:	AIBN Field Investigation and metallurgic examinations

All times given in this report are local time (UTC + 2 hours) unless otherwise stated.

Introduction

This fourth preliminary report is published to disseminate findings from the ongoing investigation. Previous reports have been issued 13 May, 27 May and 1 June 2016.

Since the previous report further examinations into the three different failure modes – suspension bar (lift strut) attachment, main gearbox and conical housing have been performed.

At this stage of the investigation, the AIBN finds that the accident most likely was the result of a fatigue fracture in one of the second stage planet gears. What initiated the fatigue fracture has not yet been determined.

Main gearbox history

The main gearbox (MGB) was received from Airbus Helicopters after modification, inspection and repair before it was installed in LN-OJF 15 January 2016. At the time of installation, the MGB had accumulated 1 080 hrs since new. At the time of the accident, it had accumulated approximately 1 340 hrs since new.

Main gearbox examinations

The AIBN started the metallurgical examinations on parts from the epicyclic module 6 May (ref. Figure 1 and 2). More detailed metallurgical examinations have been ongoing under AIBN supervision at QinetiQ, Farnborough, UK since 19 May. Airbus Helicopters have participated in these examinations, as well as performing separate examinations in Marignane, France.

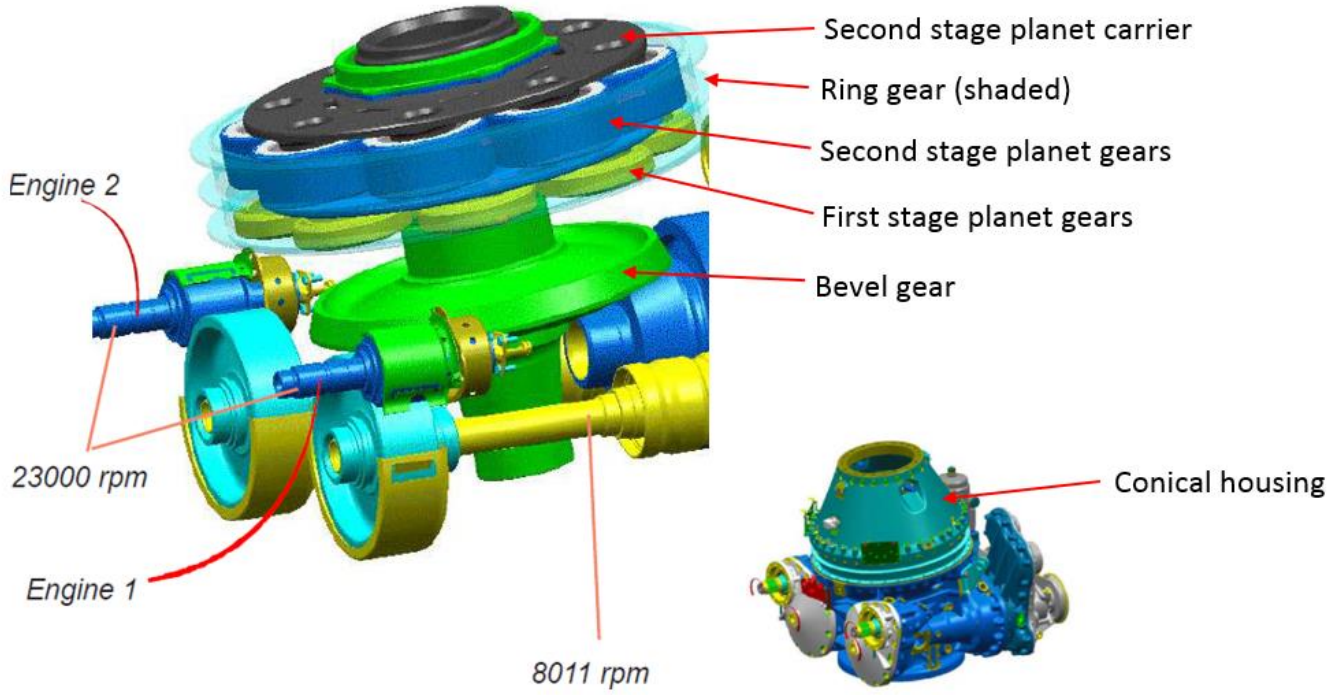

Figure 1: Main power transmission layout with main module (bottom) and epicyclic module with ring gear and two stages of planet gears (top). Conical housing shown in figure to the right. Source: Airbus Helicopters

Figure 2: Planet gear parts from second stage epicyclic reduction gear module. (The fractured gear is on top of a sample gear that was not involved in the accident.) Photo: AIBN

The planet gears are designed such that they act as a gear on the outside while functioning as the outer race of a roller bearing on the inside. In order to improve wear resistance the gears have been given a hard surface through a carburization process. This process also imposes a compressive stress to suppress surface fatigue cracks.

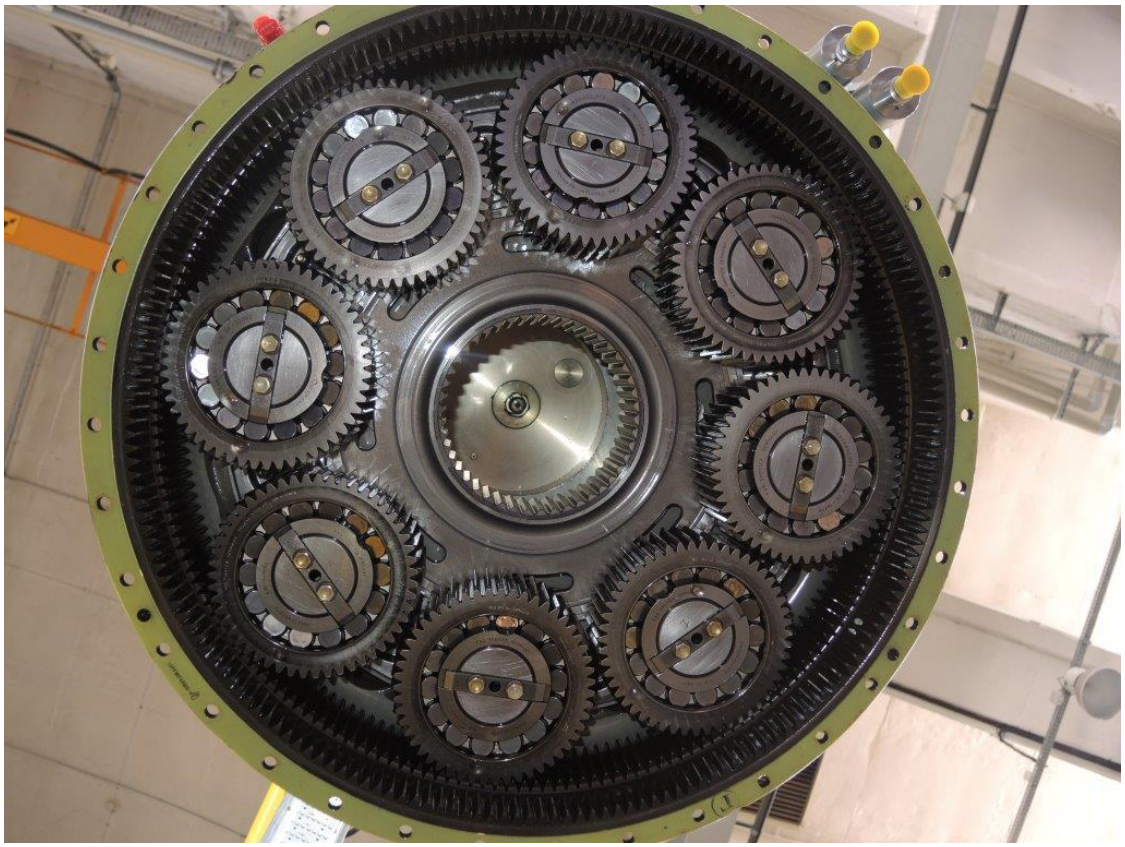

Figure 3: Eight second stage planet gears as fitted on the carrier inside the ring gear, seen from below (first stage gears and carrier is not shown). Photo: AIBN

Two pieces of the recovered parts have been of particular interest. Together they make up approximately half of a second stage planet gear P/N 332A32.3335.07, S/N 10-1292 (ref. Figure 4). Examinations of these parts show that one of the fracture surfaces can be described as being close to 100% fatigue (ref. Figure 5).

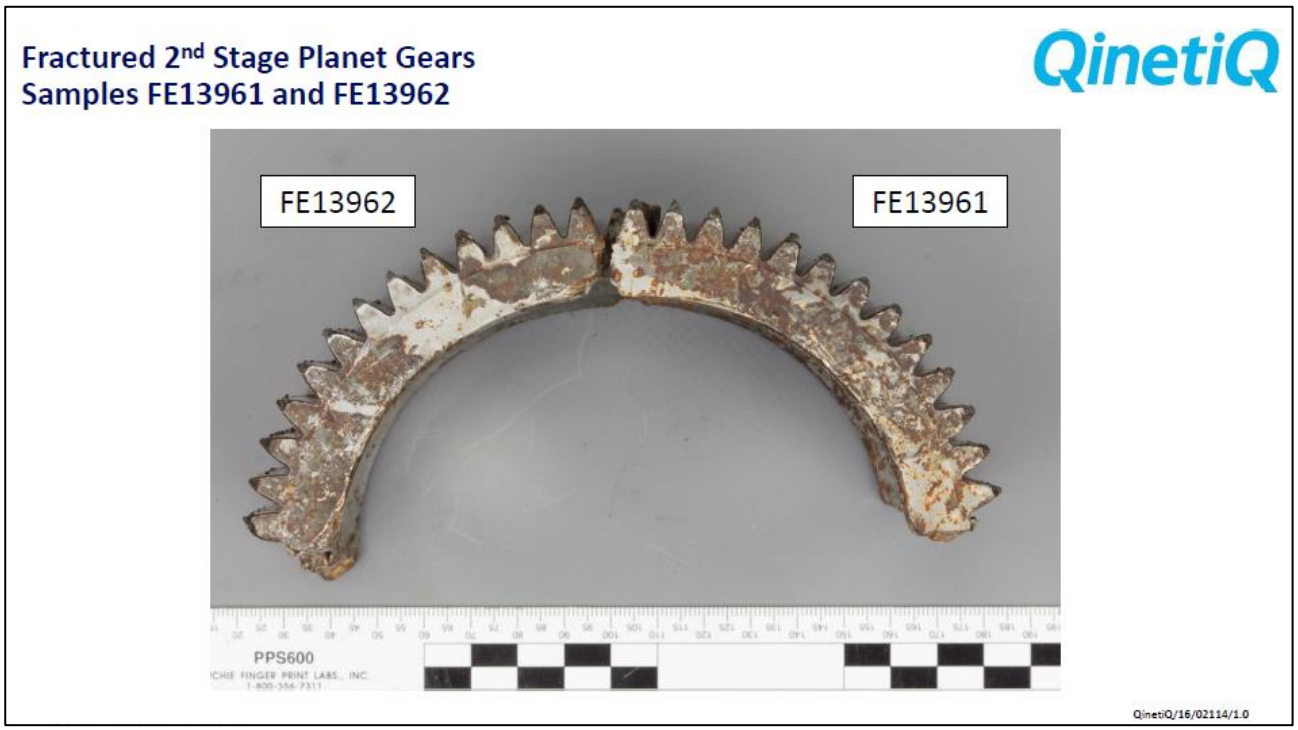

Figure 4: The two pieces of the second stage planet gear prepared for metallurgical examinations. The fracture surface with fatigue is to the right in the figure. Photo: QinetiQ

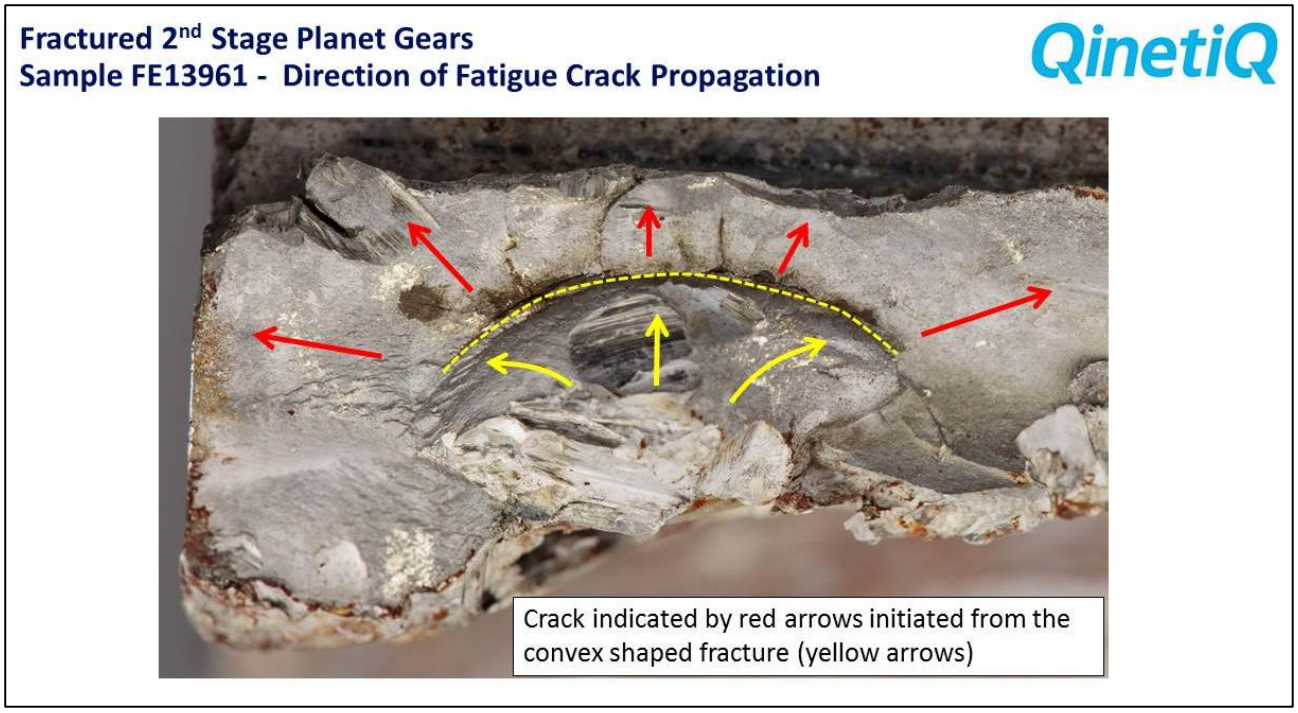

Figure 5: Close-up of the fracture surface initiated on the inner surface (outer race). Multiple cracks propagating from major crack around convex fracture surface. Photo: QinetiQ

The fatigue appears to have its origin in the outer race of the bearing (inside of the gear), propagating towards the web of the gear teeth. In order to examine the fatigued part before performing any destructive testing, the piece was inspected using x-ray computed tomography (CT)

scans. The scans showed several cracks below the surface of the outer race. One crack runs below the surface between areas of surface damage (spalling) (ref. Figure 6).

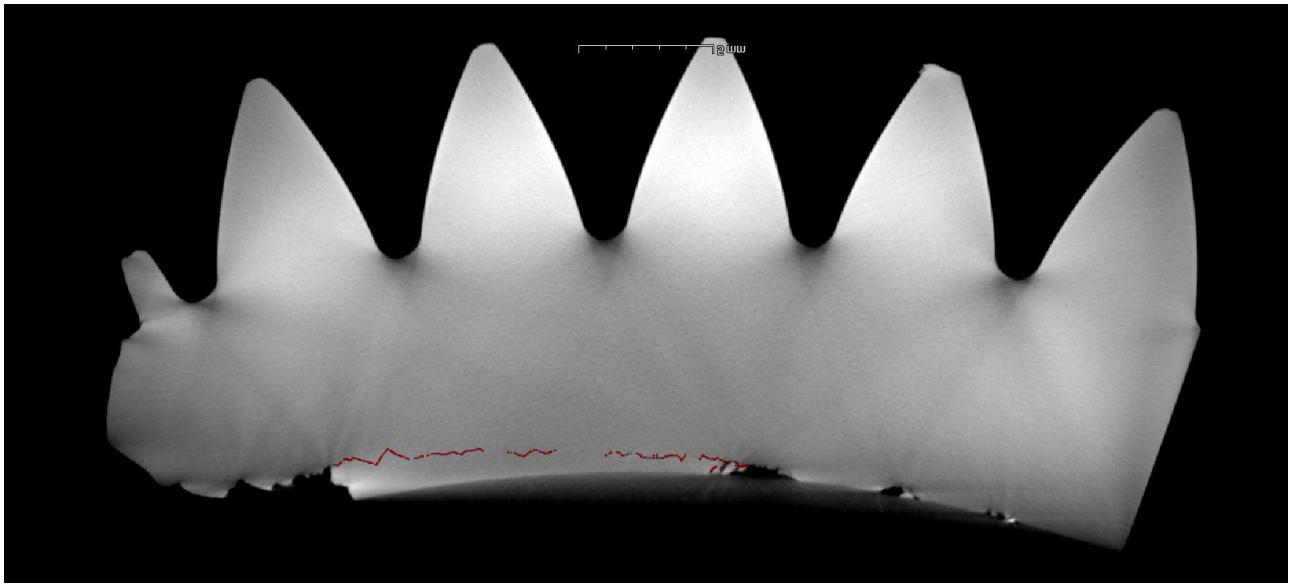

Figure 6: An example from the CT scan showing a subsurface crack propagating from the right hand spalling all the way to the left. The red colour is a frame-by-frame mapping performed by hand to highlight the crack. Photo: University of Southampton

Growth of a fatigue crack requires repeated load cycles, for example through rotation of a gear or a main rotor start/stop cycle. More work is required both to understand the propagation rate and the origin of the observed fatigue cracks, but at present, the AIBN finds it most likely that the fatigue fracture of this planet gear subsequently resulted in loss of the main rotor. It is considered unlikely that this fatigue crack propagated as a consequence of a structural break-up of another component.

An essential design philosophy regarding a possible failure inside the epicyclic module has been that propagation of a crack would be suppressed by the compressive surface stress. Thus a crack in the surface area should grow outboard and create spalling that would produce magnetic debris, which will be detected on the magnetic plugs (chip detectors). The optional HUMS[1] is an additional means for detecting developing degradation.

This issue was discussed in connection with the accident to an AS332 L2 Super Puma (G-REDL) in Scotland in 2009, and measures were taken to improve the detection of spalling. No findings indicate any malfunctions to the magnetic debris detection system on LN-OJF, or fail to follow procedures for visual inspection and checks before flight. Neither are there any records of magnetic debris findings from inspections made since the gearbox was installed on LN-OJF in January 2016.

The observed failure mode in this investigation seems to differ from what was expected or foreseen during certification. AIBN believes that a sub-surface crack has propagated without creating a significant amount of magnetic debris from spalling. Also, the HUMS appears unable to identify symptoms of such degradation in the epicyclic module.

It appears that the fracture of the failed second stage planet gear on LN-OJF has propagated in a manner which is unlikely to become detected by existing mandatory or supplementary systems for warning of an imminent failure.

Even though some differences are observed when comparing the LN-OJF accident with the G-REDL accident, the fatigue fractured planet gears, however, show clear similarities.

[1] *HUMS, Health and Usage Monitoring System, is mandatory for offshore operations in the North Sea*

Other examinations

Scenarios under consideration as part of this investigation have included failure of a suspension bar attachment or failure of the MGB conical housing as the initiating event. The investigation activities since the previous report do not suggest that either of these scenarios were the initiating event.

Further investigations

An important issue will be to seek to determine the origin of the fatigue fracture and the mechanisms behind its growth.

The AIBN is aware that the gearbox was involved in a road accident during transport in 2015. The gearbox was inspected, repaired and released for flight by the manufacturer before it was installed in LN-OJF in January 2016. Whether there is a link between this event and the initiation and growth of a fatigue fracture, is being investigated.

AIBN will also look into the follow-up of safety recommendations issued after the Super Puma accident in Scotland in 2009 (https://www.gov.uk/aaib-reports/2-2011-aerospatiale-eurocopter-as332-l2-super-puma-g-redl-1-april-2009).

Extensive sea and land searches have been ongoing since the accident, and findings essential for the investigation have been made. There are still some important components that are missing, but parts key to the investigation have been recovered. Further sea search will be considered.

The investigation is ongoing. Further updates are expected to be less frequent from this point, and will only follow if there are significant new findings.

The Accident Investigation Board Norway

Lillestrøm, 28 June 2016