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COMISIÓN DE
INVESTIGACIÓN
DE ACCIDENTES
E INCIDENTES DE
AVIACIÓN CIVIL

Report A-034/2011

Accident on 19 September 2011, involving an Agusta AB-412 aircraft, registration EC-JRY, operated by FAASA Aviación, S. A., in the municipality of La Peza (Granada, Spain)

GOBIERNO DE ESPAÑA
MINISTERIO DE FOMENTO

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Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident object of the investigation, and its probable causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.5 of Regulation (UE) n.º 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1, 4 and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

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Abbreviations

00°	Sexagesimal degrees
00 °C	Degrees centigrade
ADC	Air data computer
AESA	National Aviation Safety Agency (Spain)
AGL	Above Ground Level
ANSV	Agenzia Nazionale per la Sicurezza del Volo (Italy)
ARO	Airport Reporting Office
ATC	Air Traffic Control
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (France)
CH	Radio channel
cm	Centimeter(s)
CPL(H)	Commercial Pilot License (Helicopter)
CSMU	Crash Survivable Memory Unit
CVR	Cockpit Voice Recorder
EASA	European Aviation Safety Agency
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FDAU	Flight Data Acquisition Unit
FDR	Flight Data Recorder
FL	Flight Level
ft	Feet
ft/min	Feet per minute
GPS	Global Position System
kg	Kilogram(s)
GSM	Global System for Mobile Communications
h	Hour(s)
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
IR(H)	Instrument rating (helicopter)
JAR-FCL	Joint Aviation Requirements – Flight Crew Licensing
KIAS	Indicated airspeed in knots
km	Kilometer(s)
kt	Knot(s)
lb	Pound(s)
LH	Left Hand
m	Meter(s)
m^2	Square meters
MGB	Main gearbox
MTOW	Maximum Takeoff Weight
min	Minutes
mm:ss	Minutes:seconds
N	North
N1	Gas generator revolutions (in percent)
N2	Power turbine revolutions (in percent)
Nr or NR	Main rotor revolutions (in percent)
NTSB	National Transportation Safety Board
P/N	Part Number
psi	Pounds per square inch
RH	Right Hand
RPM	Revolutions per minute
S	Seconds
S/N	Serial Number

Abbreviations

TBO	Time Between Overhaul
TRI(H)	Type rating instructor (helicopter)
TSO	Technical Standard Orders
TWR	Aerodrome Control Tower
UTC	Coordinated Universal Time
V	Volts
VFR	Visual Flight Rules
VHF	Very High Frecuency
VOR	VHF Omnidirectional Radio Range
W	West

Synopsis

Owner and operator:	FAASA Aviación, S. A.
Aircraft:	Agusta AB-412, registration EC-JRY
Date and time of accident:	Monday, 19 September 2011; at 9:25 h[1]
Site of accident:	Municipality of La Peza (Granada, Spain)
Persons onboard:	3; 2 crew member, fatal and 1 passenger, fatal
Type of flight:	General aviation – Other – Ferry flight
Phase of flight:	En route
Date of approval:	28 September 2015

Summary of accident

On 19 September 2011, an Agusta AB-412 aircraft, registration EC-JRY, took off at 08:18 from its base at the Sebastián Almagro Aerodrome in the town of Palma del Río (Córdoba) en route to Alhama de Almería (Almería). Weather conditions during the flight were not limiting to the operation.

The flight took place over two consecutive segments. The first flight (callsign FMA01) was from the aerodrome of departure to the Granada-Jaén Airport. A second flight plan was then activated (callsign FMA02) to the destination in Alhama de Almería. The crew was in contact with ATC during each segment. No emergency calls were made.

During the second leg of the flight plan, the aircraft fell to the ground, causing the wreckage and the surrounding vegetation to catch fire. All three occupants died as a result of the impact.

An analysis of the cockpit voice recorder's sound spectrum revealed a changed frequency for the lower planetary gear on the main gearbox. The examination of the remains of the main gearbox (MGB) allowed investigators to determine that the gears in the lower planetary gear of the MGB failed, resulting in an inability to transmit torque to the main rotor, causing the aircraft to fall to the ground.

[1] Unless otherwise specified, all times in this report are in UTC. To obtain local time, add two hours to local time.

The failure of the lower planetary gear was caused by the lack of lubrication to the gearbox, the origin of which could not be determined due to the effects of the fire on the aircraft.

The effects of the fire on the aircraft required opening different areas of investigation into various aircraft systems, the outcomes of which were either inconclusive or unsuccessful and that prolonged the investigation.

1. FACTUAL INFORMATION

1.1. History of the flight

On 19 September 2011, an Agusta AB-412 aircraft, registration EC-JRY, took off from its base at the Sebastián Almagro Aerodrome at 08:18, in the town of Palma del Río (Córdoba) en route to the base in Alhama de Almería (Almería), where it would join the firefighting service located in that town.

The flight took place over two consecutive segments. For the first, a flight plan was filed (callsign FMA01) for the segment from the aerodrome of departure to the Granada-Jaén Airport (hereinafter the Granada Airport). A second flight plan was then activated (callsign FMA02) to the destination in Alhama de Almería without interrupting the flight.

While en route to the Granada Airport, at 08:24, the crew contacted the Seville control center and confirmed instrument flight plan FMA01. At 08:28, ATC cleared the aircraft to point MARTIN on the instrument arrival chart for the Granada Airport. Three minutes later, the aircraft started a climb to FL090 on heading 120°, which it maintained until it started the descent to line up with the VOR radial for runway 09 at the airport.

At 09:01, the aircraft was cleared by the TWR to land on runway 09 at the airport, though the crew requested to make a low approach and continue toward Alhama de Almería. At 09:04, the crew made its next report to the TWR, informing "taking off to Alhama de Almería".

The second flight plan, with callsign FMA02, was activated in flight at 09:05:01 and was executed under visual flight rules. The weather conditions were not limiting for the flight.

The data from the operator's fleet tracking system showed that after flying over the runway at the Granada Airport, the aircraft continued its flight on heading 84° to fly over the municipalities of Santa Fe and Granada. It then flew over the towns of Beas de Granada and Tocón, in that order, in the vicinity of which the data transmission was lost due to the lack of coverage of the GSM (Global System for Mobile Communications) network, which was being used to aid the transmission. At the time the aircraft's heading was 51° and its ground speed was 125 kt.

The aircraft's wreckage was found 2.3 km further ahead, a little over 11 minutes since the activation of flight plan FMA02. The topography was rugged and the wreckage was scattered along a tree-covered hillside at an altitude of 1,250 m.

All three occupants onboard received fatal injuries and the aircraft caught fire as a result of the impact. The smoke from the fire alerted personnel from the forest fire prevention and extinguishing service, who reported to the site, along with emergency services, to extinguish and monitor the area around the wreckage.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal	2	1	3	
Serious				
Minor				Not applicable
None				Not applicable
TOTAL	2	1	3	

1.3. Damage to aircraft

The aircraft was destroyed by the impact with the ground and subsequent fire.

1.4. Other damage

Several trees and grass were affected by the fire. An estimated surface area of 1,000 m^2 was affected.

1.5. Personnel information

The aircraft's flight crew consisted of a captain and a first officer. The captain, in addition to having the required type rating, was also a type rating instructor (H) for the Bell 212/412 type in the operator organization. As for the relationship between the two crewmembers, they had flown together on several occasions and knew the terrain they were flying over. The information examined indicates that both crewmembers had been working for the operator since at least 2009.

The positions of each crewmember in the cockpit were determined to have been as follows: the first officer in the RH seat and the captain in the LH seat.

1.5.1. *Captain*

- Age: 48 years old
- Nationality: Spanish

- Helicopter commercial pilot license (CPL(H)) issued as per ICAO (International Civil Aviation Organization) and JAR/FCL requirements by Spain's National Aviation Safety Agency (AESA):
  - Initial issue date: 06/09/1989
  - Expiration date: 31/06/2013
- Medical certificate: Valid until 09/10/2011
- Ratings valid until:
  - Bell 212/412: Until 30/04/2012
  - Bell 222/230/430: Until 30/04/2012
  - IR(H): Until 31/03/2012
  - Agricultural (firefighting only): 20/05/2013
  - TRI(H), Bell 212/412: Until 14/06/2014
- Flight hours:
  - Total: 5,427 h
  - On the type: 2,352 h
  - Previous 30 days: 6:55 h (5:25 h on the type)
  - Previous 7 days: 2:55 h
  - Previous 24 h: 0:00 h
- Rest: >12 h

1.5.2. *First officer*

- Age: 41 years old
- Nationality: Spanish
- Helicopter commercial pilot license (CPL(H)) issued as per ICAO (International Civil Aviation Organization) and JAR/FCL requirements by Portugal's Instituto Nacional de Aviação Civil - Portuguese:
  - Initial issue date: 24/04/1997
  - Expiration date: 15/04/2015
- Medical certificate: Valid until 27/10/2011
- Ratings valid until:
  - Bell 212/412: Until 31/03/2012
  - IR(H: Until 30/09/2011
  - Agricultural (firefighting only): 14/06/2012

- Flight hours:
  - Total: 3,056 h
  - On the type: 557 h
  - Previous 30 days: 25:35 h (all on the type)
  - Previous 7 days: 14:00 h
  - Previous 24 h: 0:00 h
- Rest: >12 h

1.6. Aircraft information

The Agusta Bell AB-412 is a dual rotor helicopter with a 4-blade main rotor and a 2-blade tail rotor for directional control. It has a fixed, skid-type landing gear.

The part on Limitations in Section 1 of the Aircraft Flight Manual states that the minimum flight crew is a single pilot flying the helicopter from the RH seat in the cockpit. The LH seat can be used by an additional pilot when dual controls and the first officer's instrument suite are installed. Section 1 also states that the aircraft was configured and certified for Category I IFR (Instrument Flight Rules) operations.

The aircraft's last flight prior to the accident had been five days earlier (14/09/2011) and had been piloted by the same captain.

1.6.1. *Airframe*

Manufacturer:	Agusta Bell
Type	AB-412
Construction number	25803
Registration	EC-JRY
Year of manufacture:	1994
MTOW:	5,400 kg
Total hours prior to 19/09/2011:	4,878 h
Owner:	Fortis Lease Ibérica, S. A.
Operator:	FAASA Aviación, S. A.

1.6.2. *Certificate of airworthiness*

Number:	6074
Renewal date:	30/12/2010

Expiration date:	14/01/2012

Issued with AESA's authorization.

1.6.3. *Engines*

	No. 1 engine	No. 2 engine
Manufacturer:	Pratt & Whitney	Pratt & Whitney
Model:	PT6T-3B	PT6T-3B
Serial number:	CP-PS63379	CP-PS63140
Total hours of operation:	4,766 h	5,014 h
Hours of operation since installation on the aircraft:	789 h	565 h
Cycles:	4,861	3,682

1.6.4. *Maintenance records*

The maintenance records indicate that the aircraft had an approved maintenance program, reference FAA-AB-412-PMA, Edition 2, Revision 2, dated 15 March 2011, approved by the National Aviation Safety Agency. The last 300-hour and 100-hour inspections had been carried out on 10 June 2011, followed by a 25-hour inspection on 7 September of that same year. The number of hours elapsed between the accident and these inspections were 76 and 16, respectively.

As for the two engines, these were being maintained in accordance with their scheduled inspections. The last 300-h inspection of both had been on 24 November 2010, the 100-h inspection on 19 August 2011 and the 25- and 50-h inspections on 7 September of that same year.

The maintenance records and the flight logs indicate that the aircraft did not have any repetitive defects or deferred maintenance items.

1.6.5. *Limitations of the aircraft*

The aircraft limitations given in Section 1 of the Flight Manual indicate that the values for the torque, main rotor RPMs (Nr) and engine RPMs (N2) are as shown in Figure 1.

TRIPLE TORQUE INDICATOR

MAST TORQUE

10 to 81 %	Continuous operation
81 to 100 %	5 minute takeoff range
100 %	Maximum

ENGINE

5 to 58.9 %	Continuous OEI operation
58.9 to 73.2 %	30 minute OEI range
73.2 %	Maximum OEI

TRIPLE TACHOMETER

ROTOR RPM (Nr)

26 to 77 %	Transient ground operation
80 %	Maximum for autorotation below 8000 Lb (3630 kg) gross weight
80 to 91 %	Power off operation below 8000 LB (3630 kg) gross weight
91 to 104.5 %	Continuous operation (power off)
104.5 %	Maximum

ENGINE RPM (NII)

97 %	Minimum
97 to 100 %	Continuous operation
100 to 104.5 %	Operation at or below 30 % engine torque
104.5 %	Maximum at or below 30 % engine torque

Figure 1. Limitations

1.6.6. *Information on the aircraft checklists*

Section 2 of the Aircraft Flight Manual includes the checklists for the walkaround, engine pre-start, engine start, before takeoff and in-flight operations. These contain the following references to the gearbox:

- Visually verify the oil level through the sight glass (walkaround check)
- Check the fill cap is tight (walkaround check)
- Check and reset, if required, the chip detector indicators (pre-start)
- Check and reset, if required, the lights on the "MASTER CAUTION" panel (pre-start)
- Do not increase thrust above flight idle until the oil temperature is above 15 °C (first engine start)
- Check the lubrication pressure (first engine start)
- Check oil pressure and temperature are within limits (second engine start)
- Check oil pressure and temperature are within limits (before takeoff)
- Warning and caution lights off (before takeoff)
- Check gearbox instruments within range (in-flight operations)

1.6.7. *Aircraft performance*

The Flight Manual was used to calculate that, for an approximate weight of 8,614 lb, the climb rate of the aircraft at a speed of 70 KIAS is approximately 2,600 ft/min at the temperature and altitude conditions present in the area where the helicopter was flying before crashing to the ground.

1.6.8. *Information on the flight controls*

1.6.8.1. Collective control system

The ability to control the lift generated by the rotating blades of the main rotor, thus allowing the helicopter to change attitude in flight, is carried out by means of a system called the collective pitch control system (see Figure 2). This system is controlled by means of a stick (item 12, Figure 2) located to the left of each pilot's seat. Both sticks

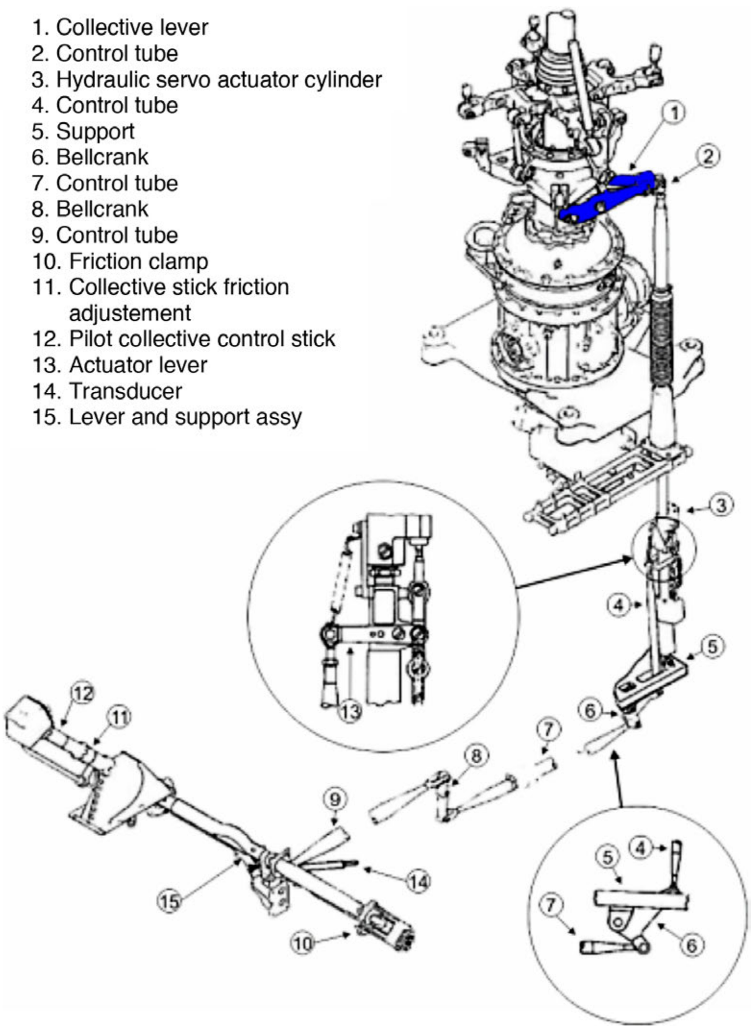

Figure 2. Collective pitch control system

attach to a common shaft, which operates a servo actuator (item 3, Figure 2) through a series of tubes and cams. The servo actuator is connected to the collective lever (item 1, Figure 2), mounted at the top of the main gearbox.

The collective lever (item 1, Figure 3) pivots at the middle and, as shown in Figure 3, connects to the collective sleeve (item 2, Figure 3). As this sleeve rises and falls, this motion is transferred to a rotating hub (item 3, Figure 3) that actuates the pitch links on each main rotor blade (item 9, Figure 3).

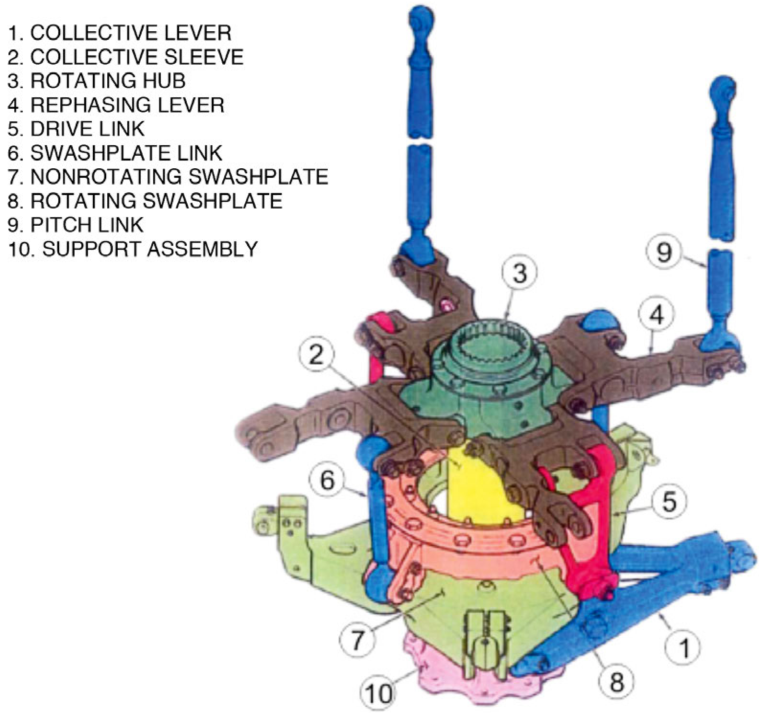

Figure 3. Layout of the collective lever (item 1)

1.6.8.2. Anti-torque control system

The AB-412 helicopter has a main rotor that rotates counterclockwise as seen from above. This causes the helicopter fuselage to yaw right around the mast.

To offset the changes in torque that are generated in the main rotor whenever the collective is raised or lowered, each piloting position has pedals that offer directional control in flight and that counteract the fuselage's rotation while hovering.

The anti-torque control system transfers the inputs from the pedals to a two-blade rotor located at the top right rear of the tail. These blades make it possible to regulate the horizontal force required at all times. This is done by a system that allows changing the pitch of the blades from positive to negative values and passing through a neutral point.

A positive pitch angle tends to move the tail to the right, and a negative pitch angle to the left. If the pitch angle is zero, the tail is not pushed in either direction.

As for the movement of the pedals, from the neutral position, if the right pedal is depressed, the nose turns right and the tail left. If left pedal is applied, the opposite motion results.

Complementing this function is the vertical stabilizer on the tail, which is designed to aid in heading control when its travelling speed is in excess of 55 kt. Below this speed, however, heading control is more difficult, particularly when hovering.

1.6.8.3. Engine control

So as to maintain the helicopter engine's RPM constant, a system is needed to control the engine's output and keep it proportional to the change in resistance caused by the changing pitch of the rotor blades.

This function is basically carried out in the same way as the pitch control of the tail rotor blades, from the pilot's stick, which also transfers its motion through a set of tubes and hinged cams to the fuel control unit and to each engine's governor, such that depending on the position of the stick, the power required by the pilot during the flight can be controlled. Figure 4 shows a diagram of how the stick controls the engines.

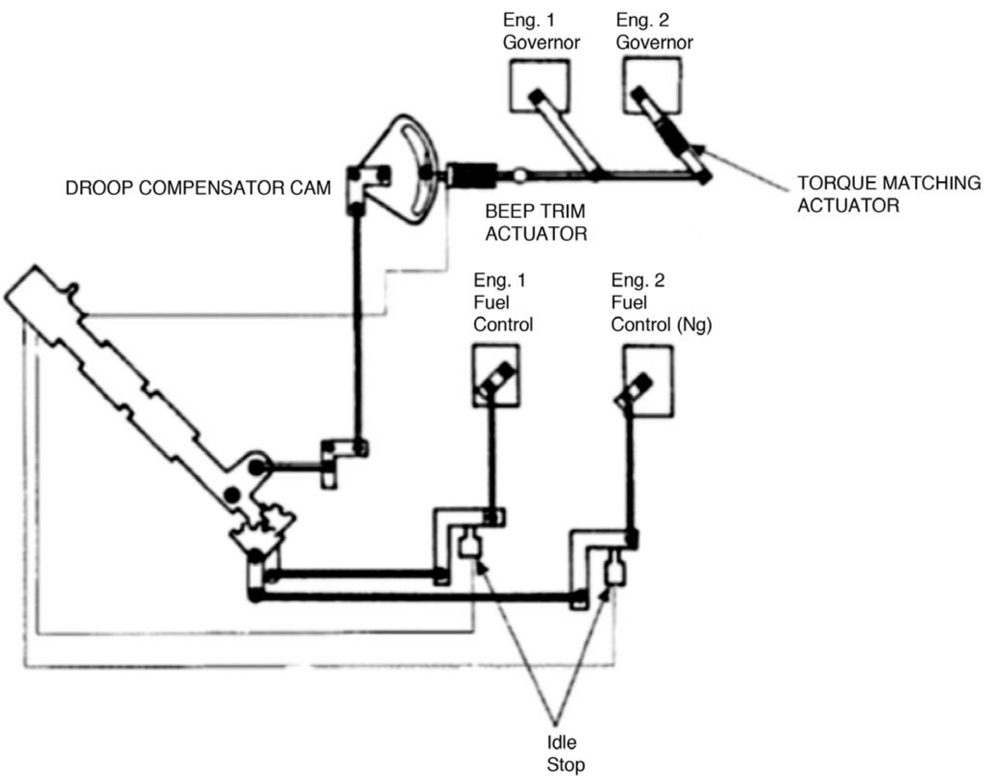

Figure 4. Engine control diagram

The power is requested through the collective control (when operating with automatic fuel control) and is regulated such that regardless of the engine's operating regime, the main rotor RPMs (Nr) are maintained at 100%. This is done by having each engine's control systems maintain engine RPMs (N2) at a constant 100%.

1.6.8.4. Information on the collective lever

The collective lever on this aircraft has part number 412-010-408-101 on the 412/412EP models of helicopter manufactured by Bell Helicopter and AgustaWestland.

On 27/09/2011 and 12/12/2011, Bell Helicopter[2] issued two service bulletins, no. 412-11-148, when this part experienced fatigue fracture caused by a residual stress produced during the manufacturing process. The bulletin affects aircraft included in three groups of serial numbers, and calls for the inspection of the lever every 100 hours and replacement if cracks are found.

AgustaWestland also published a technical bulletin, BT 412-131, with identical instructions on 21/11/2011.

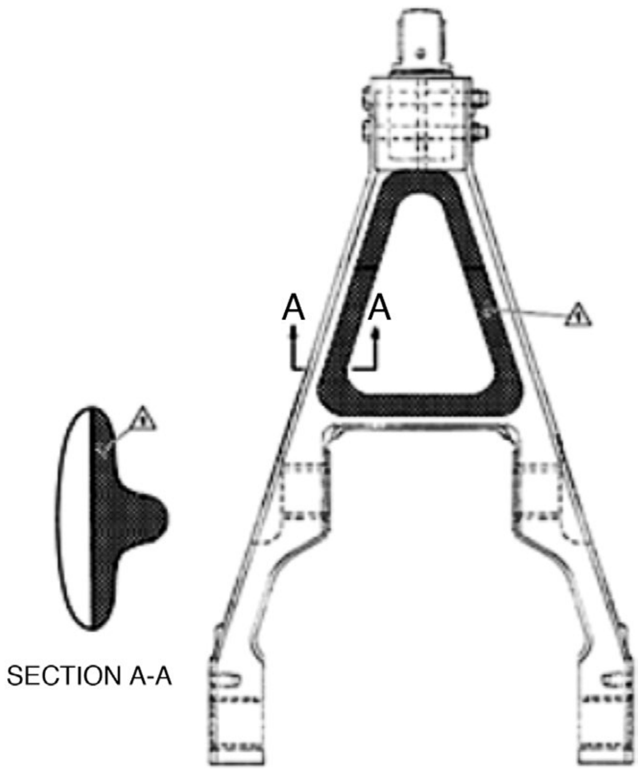

Figure 5. Collective lever

[2] There is record of at least two events, in April 2006 and July 2010, where the collective lever failed.

Finally, on 22/12/2011, the European Aviation Safety Agency compiled the information from both manufacturers and issued Airworthiness Directive no. 2011-0247, which includes all the serial numbers of the AB412 and AB412EP aircraft manufactured by AgustaWestland. See Appendix 1.

Figure 5 shows a diagram of the collective lever and the potential location of the cracks.

1.6.9. *Main gearbox*

The main gearbox is located in the central part of the helicopter fuselage. It is used to transfer, change and reduce the number of RPMs supplied by the powerplant to drive the main rotor mast. It also supplies power to the tail rotor drive system, to its own lubrication system and to all the hydraulic systems. Figure 6 shows an overview of the MGB.

As this diagram shows, the rotations of the main and tail rotors are mechanically linked in the transmission system such that at the maximum 6,600 RPMs at the input pinion to the main gearbox, the maximum main rotor RPMs are 324 and the maximum tail rotor RPMs are 1,660. In other words, the tail rotor turns about five times faster than the main rotor; therefore, any percentage increase (decrease) of main rotor RPMs results in the same percentage increase (decrease) in the tail rotor RPMs.

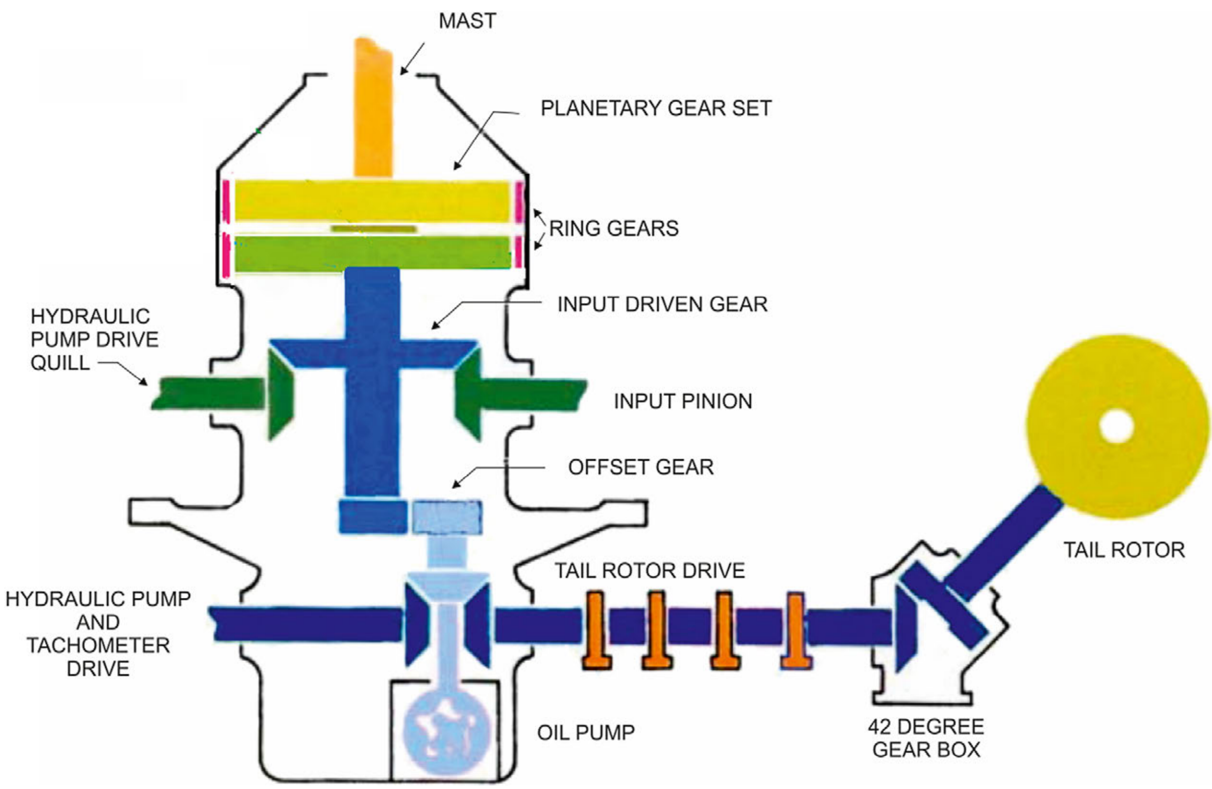

Figure 6. Main gearbox

1.6.9.1. Traceability and maintenance of the main gearbox

The main gearbox installed in the helicopter was manufactured by Bell Helicopter Textron and has part number 412-040-004-109 and serial number A108.

It was installed in the aircraft for the first time in May 1994. A 2,500 hour special scheduled inspection was later conducted at AgustaWestland's facilities with 2,437 run hours on the MGB before being reinstalled on the same helicopter in August 2000.

At the time of the accident it had 4,878 h and there were 122 h remaining before the 5,000-h overhaul.

According to the maintenance program of the MGB, there are 25-h and 300-h/180-day inspections whose tasks include a check of oil levels, corrosion, damage, leaks, overall condition, filters, tubes, chip detectors and so on.

The program also includes a task to be carried out halfway through the TBO/Annual check that includes changing the lubricating oil (specification DOD-PRF-85734) and external oil filter.

The aircraft's maintenance documentation showed that this work had been carried out.

1.6.9.2. Main gearbox lubrication system

The main gearbox has its own lubrication system (see Figure 7), which is in operation whenever the gearbox is turning. The system includes the following components: a wet sump with a sight glass, a pressure pump, an oil cooler regulated by a thermostat, internal and external filters, oil temperature and pressure sensors and an assembly of pipes connecting the components.

The oil is stored in a sump located at the bottom. The oil is injected through a filter and pressurized by a pump when the rotor starts turning. A sight glass shaped like two circular windows located in the passenger cabin is used to check the oil level during the walkaround inspection.

The pressurized oil is sent to an internal filter, after which it exits through a pipe to the external loop. A small part of the oil is used to lubricate the bearing on the tail rotor shaft. The remaining oil goes to the relief and thermal bypass valve. If the oil is cold, the thermal bypass valve directly routes the oil to the external oil filter without going through the oil radiator. If the oil is hot, it is routed to the oil cooler, where a thermostatic valve regulates the oil cooling. Once cooled, the oil is sent to the external filter.

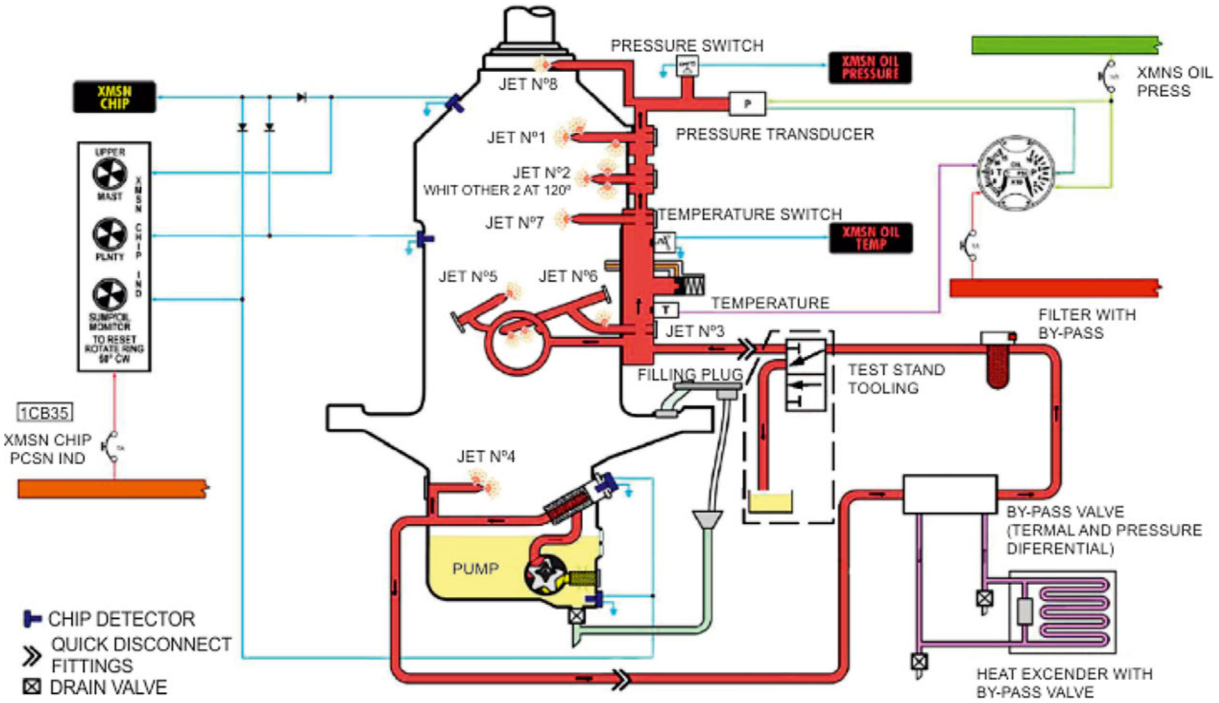

Figure 7. Lubrication system

The external filter cleans the pressurized oil and sends it to a header on the external lubrication system. This system has a red pop-up indicator that is activated if the external filter is clogged and is being bypassed. This filter bypass indicator has to be checked daily during the walkaround inspection.

As soon as the pressurized oil enters the header, part of it goes directly to lubricate the main bearing on the input shaft. A pressure relief valve located at the entrance to the manifold is set to maintain the correct oil pressure in the lubrication system.

Several oil jets located at different levels in the gearbox take pressurized oil from the header and supply it to bearings and gears inside the gearbox. The atomized oil in the entire internal gear assembly is drained to the sump for reuse.

A temperature sensor provides a transmission oil temperature reading to a gauge on the instrument panel (Figure 8), and a switch gives a warning light (XMSN OIL TEMP) if the temperature exceeds a limit. Both devices are located at the entrance to the header.

An oil pressure sensor provides a transmission oil pressure reading to a gauge on the instrument panel (Figure 8), and a switch gives a warning light (XMSN OIL TEMP) if the pressure drops below a limit (30 psi). Both devices are located at one end of the header.

The main gearbox is also protected by a chip detector system that warns the pilot if metallic particles are detected in the gearbox or in the lubricating oil. The system includes three chip detectors (one at the bottom of the sump, one below the planetary gears and

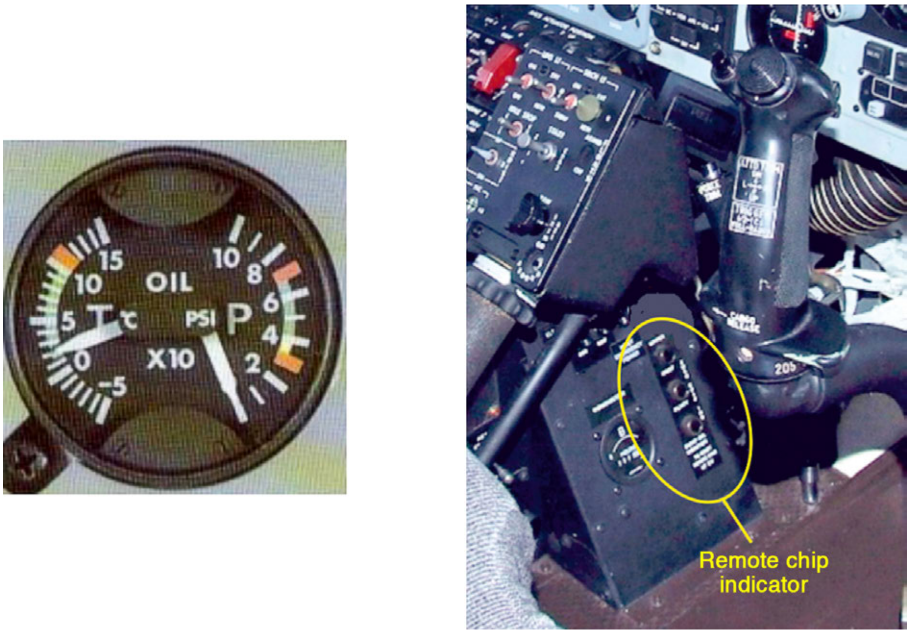

Figure 8. Instrument panel gauge and remote chip indicator in the cockpit

one below the main rotor mast bearing), a warning light (CHIP XMSN) on the caution panel and a remote chip indicator (Figures 7 and 8). The system is powered by 28V DC.

When a metallic chip contacts a detector, the circuit is bypassed to ground and a warning light (CHIP XMSN) is lit. The pilot can check the remote panel to see which detector was activated. The remote panel has the labels “UPPER MAST”, “PLNTY” and “SUMP”.

Figure 9 shows the caution panel. The XMSN OIL PRESS and XMSN OIL TEMP warnings are shown in red, and the CHIP XMSN caution is in yellow.

Figure 9. Caution panel

1.7. Meteorological information

The weather information at the time of the event and for the area of the accident was as follows:

- Variable light winds on the surface.
- Light winds aloft.
- Good visibility on the surface.
- Clouds: clear or few clouds.
- Temperature: between 12 and 22 °C.
- Relative humidity: around 54%.
- No precipitation or other significant phenomena.

1.8. Aids to navigation

Not applicable. The flight was being conducted under visual flight rules at the time of the event.

1.9. Communications

The crew were in constant contact with ATC in the area where the flight took place. The initial contact took place at 08:22:09 to report they had taken off, and the final contact at 09:13:39, when they signed off after reporting they would close out the flight plan through the ARO at the Granada Airport upon reaching their destination.

No emergency calls were recorded.

1.10. Aerodrome information

Not applicable.

1.11. Flight recorders

1.11.1. *Overview*

The aircraft was outfitted with two recorders, a flight data recorder and a cockpit voice recorder, located at the front of the fuselage, though they were not required for the ferry flight being carried out.

The flight recorders were as follows:

- Both were manufactured by L3 Communications Aviation Recorders.
- The data recorder was an F1000 model, P/N S800-2000-00 and S/N 00808 with solid-state memory. The unit complied with the stipulations in the TSO-C124 and EUROCAE[3] ED55 regulations.
- The cockpit voice recorder was an A100A model, P/N 93A100-83 and S/N 61600, with a tape recording unit. The CVR complied with the stipulations contained in the TSO-C84[4] regulation.

The recorders were located alongside each other in the interior of the burned wreckage of the fuselage. They had lost their orange color and their outer casings were deformed. The fire destroyed the locator beacons and caused the data connections to the recording medium to deteriorate.

It is estimated that some 27 minutes elapsed between the time of the event and when firefighting services reported to the site, and that a temperature of about 700° C[5] was reached, based on the extent of melting of the metals in the components that comprise the aircraft.

The recorders were taken to Italy's Agenzia Nazionale per la Sicurezza del Volo (ANSV) to recover their data.

1.11.2. *Information on the data recovery efforts*

The internal and external appearance of the flight data and cockpit voice recorders is as shown in Figure 10.

Similarly, the recording media were as shown in Figure 11.

In order to access the CSMU (Crash Survivable Memory Unit), it was necessary to cut the outer casing on both recorders.

In the case of the FDR, it was noted that the twelve screws that enclose the CSMU were loose. This underscores the high temperatures to which the units were subjected as a result of the fire.

[3] European Organization for Civil Aviation Equipment.

[4] Technical Standard Order TSO-C84 lists the minimum specifications that cockpit voice recorders must meet to ensure they are protected in the event of an accident.
The National Transportation Safety Board (NTSB) published a Safety Recommendation, reference A-92-45, urging the cancellation of this TSO after noting that data recorded by recorders based on this TSO's requirements were not sufficiently protected. This TSO was cancelled on 18 May 1996.

[5] The melting point of aluminum is 657 °C.

FDR CVR

Figure 10. Condition of the flight recorders after recovery

Figure 11. Condition of the recording media

Recovering the data from the flight data recorder required the involvement of the manufacturer, L3 Communications, which had to repair two pins on the connector, which was embedded in the insulating foam of the memory to which the data cable is connected as a result of the heat generated by the fire.

As for the CVR, once the CSMU was opened, the insulator on the recording medium was found burned by the fire. The magnetic tape that held the recordings had to be

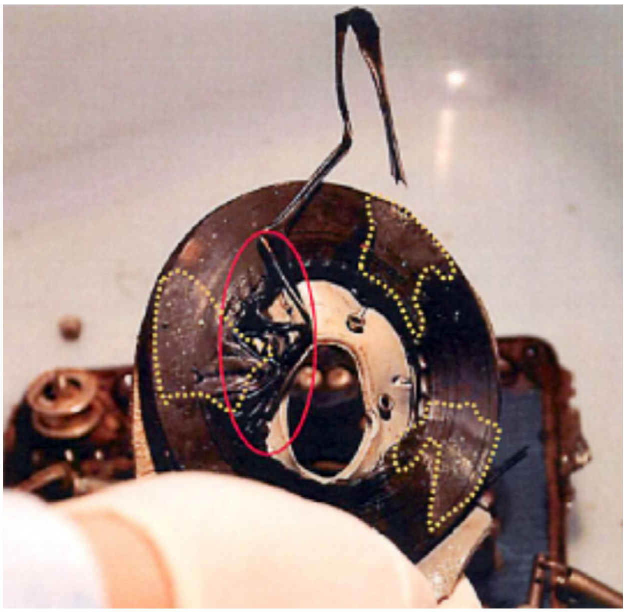

Figure 12. Condition of the magnetic tape

reconstructed (repair, assembly and cleaning) due to the temperatures reached inside the recorder (altering the length of the tape) and the heat transferred through the metallic components on the recording device (which radially damaged three sectors of the reel). This operation was unable to recover a segment equivalent to two seconds of the recording at the end of the recording. See Figure 12.

In the end, recordings containing 42 hours, 26 minutes and 12 seconds of FDR data and 24 minutes and 38 seconds of CVR data (including 7 seconds of silence at the end) were obtained.

1.11.3. *Information from the FDR*

While validating the data, it was noted that the *AIR SPEED*, *ALTITUDE RATE*, *OUTSIDE AIR TEMPERATURE, PRESSURE ALTITUDE* and *XMSN LOW OIL PRESSURE* had not been recorded[6].

A check of the two data recorders that had been installed on the aircraft and of the recorded contents identified a problem at the interface between the air data computer (ADC) and the flight data acquisition unit (FDAU) on aircraft EC-JRY. This malfunction was not identified earlier because the operator did not do operational checks or evaluations of the data recorded, nor was this required by the regulation.

As for the information recorded, it was verified that the flight lasted a total of 57 minutes and 47 seconds. The recordings revealed that the last radio communication involved the Granada control tower and took place 2 minutes and 43 seconds before the end of the recording.

Appendix 2 graphs the values of the most relevant flight parameters from this last communication until the end of the recording. The values for the final 65 seconds are shown in greater detail in Appendix 3.

[6] The loss of these data does not imply that the air data instrument or the main gearbox oil pressure readings were lost in the cockpit.

1.11.4. *Information from the CVR*

Of the four channels available, a 24 minute and 31 second recording was obtained from channel 2 (CH 2) that was clear enough to understand the conversations held in the cockpit. The contents of these conversations are presented below in two different segments.

The first segment, lasting 14 minutes 30 seconds, is for the final part of the instrument flight made with callsign FMA01. The context of the conversations shows that it was a flight in which the aircraft's captain was advising the instrument maneuver being executed by the first officer. The segment ends when the aircraft was cleared to make a "low approach" to runway 09 at the Granada Airport. The communications with ATC at the airport were verified to have been made by the pilot flying (first officer).

The second segment starts after flying over runway 09 at the airport and activating the visual flight plan with callsign FMA02. As had happened during the first plan, the captain was guiding the first officer through the navigation and making comments pointing out towns and points on the ground beneath them.

Below is a transcript of the most significant dialogue to the investigation after the visual flight plan was activated. The recording does not indicate the presence of an emergency or dangerous situation in the cockpit.[7]

CVR CH 2 (mm:ss)	Pilot flying	Captain
15:25	 OK. He said he'd be at 5,000[7] ft. I don't see him.	Let's go on this heading then, ok. At 120 kt, for example, go. We won't go up any further.
15:40	Puerto Lobo is around here, isn't? OK.	Yes, a bit further that way. Let's continue, ok? Let's stay on this heading we're on, ok?
16:05		Let's go to 120 kt.
16:16	We have to save fuel if it's going to last two hours.	
16:35	 Granada town.	We're passing over Granada. To the right will be the Alhambra.
16:53	I used to come here a lot with the health worker, to the hospital.	

[7] This value refers to the information from the Granada TWR about traffic in the vicinity.

CVR CH 2 (mm:ss)	Pilot flying	Captain
17:07	Climbing to 500 ft.	No, we'll stay at this altitude, right there is where we're going to pass.
17:18	I don't have enough torque to go at 120. OK.	We're ok like this.
17:28	Through that small hole at the end, right?	Yes, that way, we're going ok.
18:19		You see? We went from instrument flight to visual flight, we're flying lower here. I don't know if we're going (garbled)... down there. Start paying attention to the ground and stop looking at the instruments in here.
18:36	I was at the base there.	Puerto Lobo is there to the left, that drop-off there.
18:47	There was a pond here where I picked up water for a fire around here, but I don't see it now.	
20:03	We came to eat fried fish here.	¿At El Pilas?
21:31	Acknowledged with Granada TWR that they will close out the Flight Plan by phone when they reach Almería.	
21:50	When I get to (garbled).	
21:56		... (garbled) anticipate, don't (garbled) OK.
22:01	*Conversation between the flight crew concerning closing out Flight Plan FMA02*[8].	
22:48	Very well.	
22:56	Squeeze in through that hole, right?	
22:59		Yes, that way... (garbled).
23:01	Ah, here to the left or where?	... Garbled... I... (garbled).
23:11	I'm getting allergies again. I think it's more a cold than allergies now.	Good catch, no? Important.
23:14		Especially instrument flight. OK. Especially what they ask for and... (garbled) do everything well, is that clear?... (garbled).
24:10	(Garbled)... Another airplane... (garbled).	

[8] As it is irrelevant to the investigation, only the time of its activation is noted.

CVR CH 2 (mm:ss)	Pilot flying	Captain
24:20	(Garbled)... OK.	
24:28	NOISE	VOICE UNRECOGNIZABLE... C'mon... (garbled).
24:31	NOISE END RECORDING	

1.11.5. *Synchronization*

The sequence of events was synchronized using the ATC communications, the CVR recording and the radio activations recorded on the FDR. The synchronization time was established using the penultimate communication between the Granada TWR and the crew. This event occurred at 11:13:36, which corresponds to the 21 minute and 50 second mark on the CVR[9].

At this synchronization point, the FDR was 2 minutes and 46 seconds before the end of the recording, while the CVR time was 5 seconds slower prior to the end of its associated recording.

Similarly, there was a 30-second deviation when comparing the times between the synchronization point and a nearby point at the start of the CVR recording.

1.12. Wreckage and impact information

The aircraft was on course 060. The wreckage was found scattered on the north side of a hill at an elevation of 1,250 m and an approximate gradient of 21%. The debris field indicated that before falling to the ground, the aircraft had flown over the area where it was found.

The first debris field was found at the top of the hill. There, blue and white paint chips, red bits of fluted plastic, clear flat glass and rivets from the outer skin were found. All were identified to have come from the lower part of the fuselage, from the anti-collision light and from the landing light, see Figure 13.

Located at this point and along the previous heading and perpendicularly to the left was part of the upper engine cowling, which was suspended atop a tree. Fifty meters further away in the same direction there was a fragment from a tail rotor blade.

[9] The complete text of the message is "When I get to base, OK?, obtained from the voice recording taped by ATC.

Figure 13. First debris found

In the same position as before but on the ground was where the front of the aircraft impacted. A rearview mirror, the front tip of the left landing skid and the base or support that held the battery were found there. One of the crew's seats was found on the rock that was supporting the landing skids, the crossbeams of which had been crushed. At the base of the rock was evidence of a strong impact that had caused part of it to break off.

Downhill from the rock, spread out over a 15-m distance, were the left side fuselage doors, molten aluminum material and finally the engines, main rotor and crew compartment, heavily damaged by the fire. The two flight recorders were located inside.

The four main rotor blades were in one piece and remained attached to the rotor head. They were bent at the middle and had no apparent damage at their leading edges. The

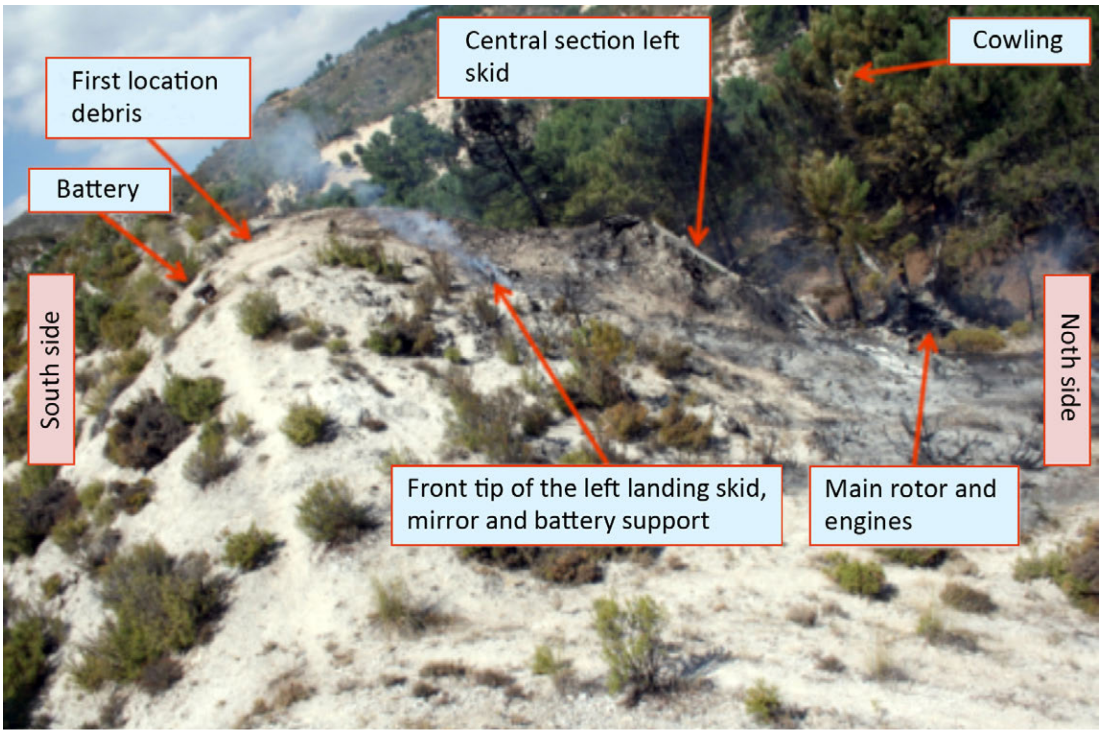

Figure 14. Locations of debris

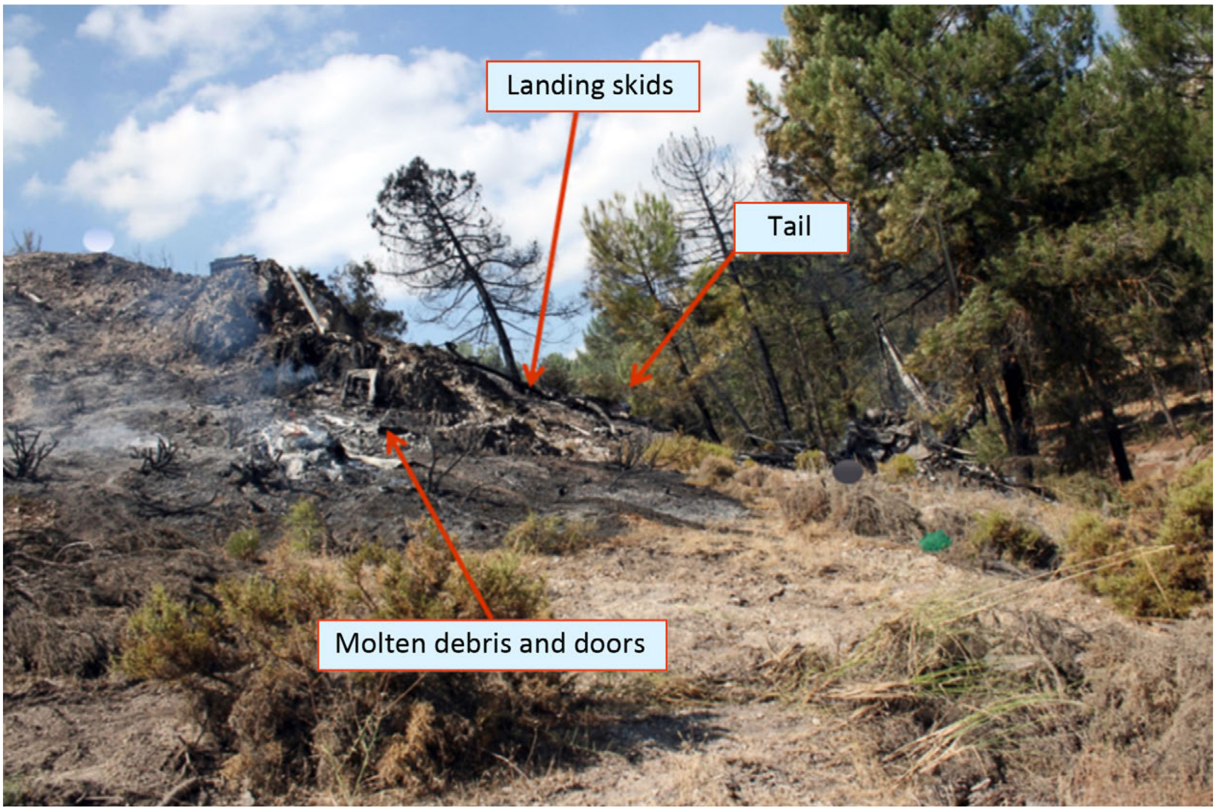

Figure 15. Debris field on the hillside

collective and cyclic control mechanisms were broken. The engine accessory box and the combined gearbox were destroyed. The cowling segment mentioned earlier was found at the top of a tree that was next to these fragments.

Figure 16. Impact of the tail

The tail of the helicopter had detached from the fuselage and was along the same line as the landing gear, the battery and the rock. The fracture area was molten and the driveshaft broken at several points. At the rear, in the area below the 42° box, was a strong impact mark and bits of embedded wood. The tail skid had detached, along with the tail rotor, and appeared to have broken off where it attached to the structure.

From the 42° gear box, the vertical stabilizer had pivoted and curved backwards. It was bent along the trailing edge. The two tail rotor blades also had several crease marks caused by the impact with the ground, and one of them had lost a segment of its tip some 20 cm long that, as noted earlier, was found separately from the main wreckage.

Finally, the battery was at the top of the hill, in line with the landing gear and the tail, just to the right of the location where the first debris were found at the top of the hill.

1.13. Medical and pathological information

The injuries sustained by the flight crew and described in the autopsies show that they were consistent with an impact with strong vertical and horizontal components. Similarly, the scope of the injuries due to the fire was different in each occupant.

No signs were found that the crew were cognitively impaired as a result of drug use.

1.14. Fire

The aircraft caught fire after it impacted the ground. Judging by the debris field and the molten material, the fire started when the aircraft impacted the ground, specifically, against the rock mentioned earlier.

The smoke alerted the firefighting services in the region, who responded with aerial and land resources. Their efforts were prolonged so as to protect the wooded area that surrounded the crash site.

The fire affected the entire aircraft except for the battery. The forest fire that broke out following the impact surrounded the debris field.

1.15. Survival aspects

The injuries produced by the impact forces were not survivable.

The fuselage was heavily damaged by the impact against the rock. The back side of one of the crew seats detached. The above circumstances, along with the motion of the wreckage down the hill, caused the crewmembers to be ejected from the fuselage.

1.16. Tests and research

1.16.1. *Flight path taken by the aircraft*

The flight path taken by the aircraft during the first segment, which ended at the Granada Airport, was recorded by ATC. It shows a linear trajectory between the waypoints defined by ATC and at the required altitudes.

The second segment was reconstructed using the data from the fleet tracking system and ended in the vicinity of the crash site. The last position recorded by the system was 37°14'43.01" N 003°22'45.21" W. Since the wreckage was located at coordinates 37°15'40.16" N 003°21'39.23" W, there is a straight-line gap of about 2,370 m between these two positions.

The reason for this gap is the loss of coverage in the GSM network used to transmit the data since in the area in question, of the three closest telephony antennas, one was beyond range and the signals from the other two were blocked by surrounding mountains.

Figure 17 shows the aircraft's flight path toward the municipality of Tocón de Quéntar, based on the data captured by the GPS fleet tracking system during the visual segment of the flight.

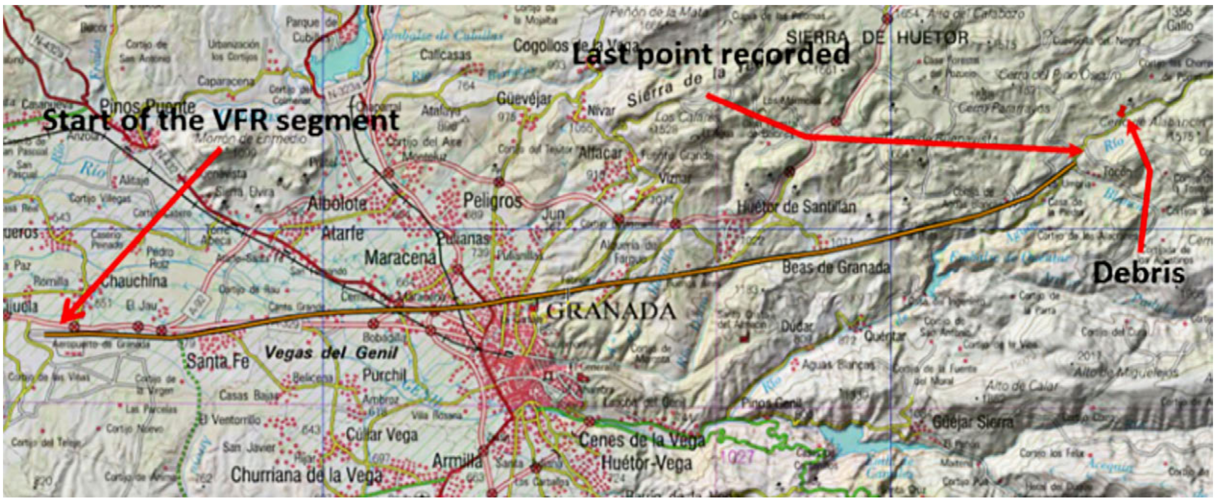

Figure 17. Flight path taken after flying over the Granada Airport

The table below shows the final datapoints recorded by the GPS.

GPS (Local time)	Longitude (degress)	Latitude (degress)	Altitude (m)	Speed (km/h)	Heading (degress)
11:12	–3.47936	37.21648	1,410	212	81
11:12	–3.45993	37.22002	1,506	205	71
11:13	–3.43943	37.22419	1,589	218	77
11:13	–3.4173	37.22826	1,580	229	77
11:14	–3.39695	37.23456	1,570	224	55
11:14	–3.37916	37.24532	1,545	233	51

Figure 18 shows the flight profile and the height above the ground.

The 2,370-m segment that would continue in the above figures took place over the terrain shown in Figure 14, which includes the location of the wreckage.

The reconstruction of the final seconds of the flight based on the FDR data show that the aircraft was on heading 60° and that, at one point, it descended toward the ground

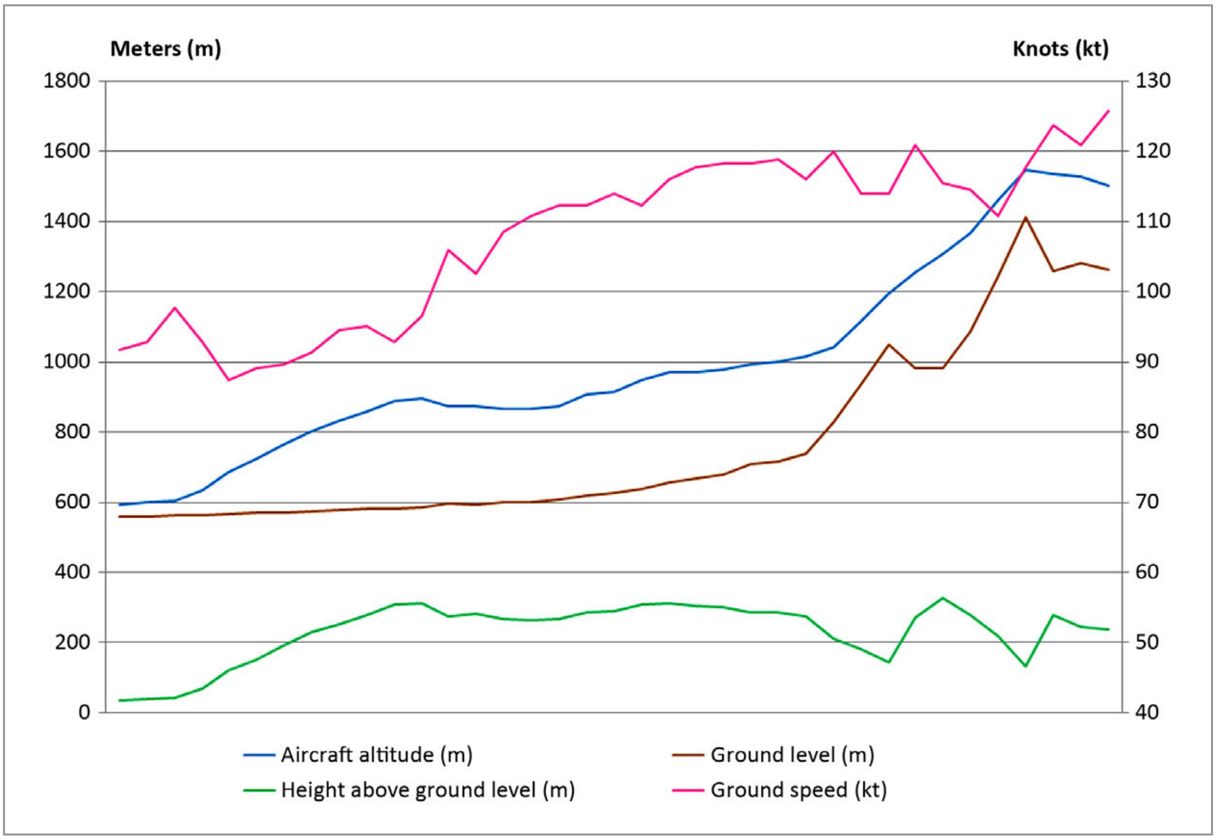

Figure 18. Flight profile

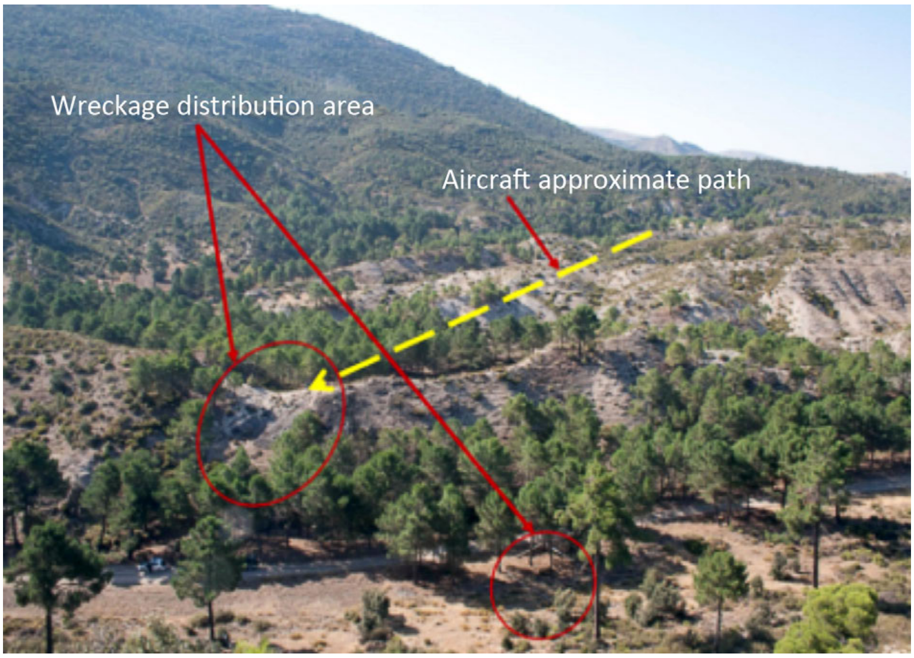

Figure 19. Area overflown by the aircraft and location of the wreckage

until it impacted it. The aircraft then pitched up and banked to the left, making a 106° turn to that side. In the final two seconds it made an almost instantaneous 187° turn. The total duration since the sudden drop in torque was 24 seconds.

1.16.2. *Analysis of the debris of the collective control system*

They were partially recovered from the wreckage of the transmission and control systems that comprise the aircraft's collective system, shown in figure 5. The components in the system were destroyed by the impact and the fire. The only identifiable parts were the two collective sticks, the tubes connecting the two sticks and the collective lever. Figure 20 shows the condition of this lever, labelled with the number "1" in figure 2.

Figure 20. Collective lever

A metallographic study of the two fracture points on the lever showed that the alloy in both had been partially melted by the heat. As a result, the micro-relief of the surface could not be used to identify the fracture process.

1.16.3. *Analysis of the engines*

The engines had been severely damaged by the fire and by the impact against the ground. The accessory box and the combined gearbox were destroyed.

Pratt & Whitney Canada reviewed the engine parameters recorded on the FDR and inspected the engines. Neither one revealed any sign of anything out of the ordinary prior to the impact with the ground. It can thus be concluded that the engines were operating normally.

1.16.4. *Spectrum analysis of the sounds recorded by the CVR*

So as to identify any potential malfunction in any of the aircraft's systems, its performance was analyzed depending on the system that failed, i.e. the cyclic, collective, driveshaft, fuel governor, etc.

The various analyses carried out that involved the pilot's control inputs showed an inconsistency in terms of the aircraft's response in the second prior to impact. To further analyze this issue, the CIAIAC asked the French Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) to aid in analyzing the spectrum of the CVR sound spectrum, and in particular the final seconds of the recording.

The analysis was unable to monitor the exact operating conditions of the engines due to how the sound had been altered by the heat to which the CVR tape had been subjected. As for the other spectra analyzed, there are no indications of any gradual or sudden damage to the tail rotor or to the main rotor blades.

The analysis did detect, however, an unusual acoustic signal coming from the main gearbox and that could be related to the operation of the epicyclic gears. Appendix 4 contains a graph showing a modulation of the frequency for the lower planetary gear, followed by another graph that details the last minute recorded and shows a boost in the frequency for the lower planetary gear. This is associated with an increase in the main rotor RPMs.

1.16.5. *Inspection of the main gearbox*

So as to verify the findings of the sound spectrum analysis, the aircraft's MGB (P/N 412-040-004-109 and S/N A108) was disassembled and inspected.

Externally it was heavily damaged from the impacts it had received, the heat of the fire and corrosion. The only original components remaining were the top part after the conical pinion on the driveshaft, which was exposed, along with the gear to the input pinion, see Figure 5.1 in Appendix 5. The external lubrication tubes and the electrical wiring were all consumed in the fire.

Overall, the inside of the MGB showed signs of having been subjected to high temperatures and corrosion. The four gears on the lower planetary gear were bent, their teeth worn and bent in the direction of rotation of the gear, the bearing cages and the steel bearings were detached and bent and/or crushed inside the MGB. The crown on which the gears rotate was practically intact.

The damage to the sun gear was similar to that on the planetary gear, with its teeth plastically deformed all around the perimeter.

The chip detector located under the lower planetary gear was seized in its housing and there were metal particles at one end.

The upper planetary gear, consisting of eight gears, only exhibited damage to some of its bearing.

All of the damage observed was consistent with the main gearbox having been operating without lubricating oil.

Appendix 5 shows the external and internal condition of the main gearbox.

1.16.6. *Verification test*

1.16.6.1. Discussion

In an effort to compare the indications found during the inspection of the MGB, arrangements were made with AgustaWestland to bench test a MGB in perfect working order to:

- Determine the response to a failure of the lower planetary gear.
- Simulate the loss of oil failure mode.
- Check the operation of the chip detector and the crew's response to the warning in these conditions.

The first scenario showed that 50 h of operation with a defect in the bearing of a gear in the lower planetary gear did not yield any signs of wear and the gearbox continued working properly. In other words, continuing to operate with a failure in a bearing does not have an immediate effect on the gearbox.

In the second test, once the parameters had stabilized, the oil was drained (run-dry test) and, in conditions equivalent to those of the event, the MGB ran for 16 minutes until the test was stopped as the unit's safety limits were approached.

During the test it was noted that the oil pressure reading immediately fell below the warning value (30 psi) and the warning light turned on in the control panel. Parallel with this the oil temperature reading started a constant decrease, while the gearbox's external temperature rose. Vibration values remained normal.

After 8 minutes the planetary chip detector warning light turned on, indicating the moment when this gear started to degrade. In the meantime, the temperature in the outer casing surrounding the planetary gears continued to increase.

Two minutes before the test was stopped, the noise level rose and there was smoke and signs of overheating in the outer casing surrounding the planetary gear. The amount of energy absorbed by the gearbox to maintain its rotational rate continued to increase as the transmission's resistance to rotation rose.

Once the gearbox was unloaded, the temperature outside the box reached values of around 310 °C.

1.16.6.2. Result and conclusions

At the end of the test the gearbox showed signs of overheating, particularly in the area where the planetary gears are located.

Inside, debris was confirmed to have adhered to the planetary chip detector, which caused the chip detector to be activated.

The gears on the lower planetary gear were discolored to varying degrees due to their temperatures. One of the gears in particular showed damage to the bearing races, with signs of abrasion and tilting about the axis.

It is reasonable to assume that had the run-dry test been continued, a large amount of heat would have been generated, deforming every component, especially the lower planetary gear.

The findings of the test are summarized below:

- A fault in the bearing cage of one of the gears does not cause damage that leads to the immediate degradation of the main gearbox.
- The first component damaged from running without oil is the lower planetary gear which, due to its operating conditions, is the component that works under the least favorable load and speed conditions.

- The speed at which the damage propagates is closely related to the speed and load applied to the individual components.
- In the AB-412 aircraft and without lubricating oil, the MGB can, depending on its existing condition, on the operating regime and on its configuration, last between 10 and 20 minutes before it fails.
- The process inside the MGB during a loss of oil generates and moves a sufficient amount of chips to activate the chip detector located below the lower planetary gear and activate the crew alert.

1.16.7. *Background*

The information provided by Bell Helicopter concerning findings with similar characteristics stem from two events, a dry bearing on an aircraft on the ground and a run-dry test on a similar gearbox.

The results of both events are similar and resemble those obtained for the accident of aircraft EC-JRY. Figures 21 and 22 show the damage to the lower planetary gear in both cases.

Figure 21. Condition of the lower planetary gear in the first case

Figure 22. Condition of the lower planetary gear in the second case

1.16.8. *Information from the aircraft's previous pilot*

The pilot who flew the aircraft before the accident flight stated that during his walkaround inspection, the oil level in the two sight glasses near the cabin pylon was adequate.

The chip detectors were also armed.

1.17. Organizational and management information

Not applicable.

1.18. Additional information

As noted earlier, the cockpit voice recorder was in poor condition due to the circumstances to which it was subjected during the accident. As a result, the process to recover its information was very complex and partly unsuccessful.

This L3 Communications A100A CVR with a tape recording medium was certified as per the specifications contained in regulation TSO-C84, which listed the minimum requirements that cockpit voice recorders had to comply with.

This TSO was cancelled on 18 May 1995 and replaced by TSO-C124a. The cancellation also affected TSO-51a on flight data recorders, which was replaced by TSO-C123a.

This cancellation took place because the NTSB informed that the information contained in seven recorders could not be recovered due to a post-impact fire in six accidents. These events underscored the concern over the inadequacy of the standards in place at the time.

As a result, new TSOs were published that require a temperature and fire resistance equal to the previous ones, but that also include a series of better defined tests and checks that ensure that recorders can withstand an 1100° C temperature for 30 minutes, as specified in the requirements.

The cockpit voice recorder in this accident had been certified under TSO-C84 and had been severely damaged by the fire, resulting in part of the information not being retrievable. The flight data recorder, which had been subjected to the same temperatures for the same length of time, was also damaged but the condition of its CSMU (Crash Survivable Memory Unit) was such that the flight data were able to be recovered.

This accident underscores the correctness of the decision to cancel TSO-51a and TSO-C84 and to replace them with TSO-C123a and TSO-C124a, since in the same fire conditions after an impact, the states of the two recorders evidenced the need to change the requirements they had to meet in order to pass a fire exposure test.

1.19. Useful or effective investigation techniques

Not applicable.

2. ANALYSIS

2.1. General

The operator of an Agusta AB-412 aircraft, registration EC-JRY, had planned to make a ferry flight from its base in Palma de Río (Cordoba) to Alhama de Almería (Almería), where the aircraft would join the firefighting unit located in that town.

The crew planned the flight over two segments and created two different flight plans. The first plan (callsign FMA01) would follow instrument flight rules and was activated after taking off from the departure airport. It ended with a flyover of runway 09 at the Granada Airport. The second plan (callsign FMA02) was activated next and was to have finished in Alhama de Almería. It would be flown under visual flight rules.

The operation was carried out with a crew of two pilots, both qualified to fly this type of aircraft. The pilot in command was also TRI(H) rated on that aircraft, and his duties at the company included responsibility for type instruction. Both pilots had been working together continuously since at least 2009, as a result of which they had flown together on many occasions.

The investigation determined the positions in the cockpit of each pilot, concluding that the captain was in the LH seat and the first officer in the RH seat. This arrangement is interpreted to mean that the first officer was acting as the pilot flying during the flight, perhaps because he was close to doing his instrument rating (IR(H)) check, and this flight provided the perfect setting to practice the check, with the captain advising the first officer during the flight.

Similarly, the contents of the CVR revealed that the captain continued training the first officer during the second segment of the flight, that the route was known to both and that the emergency or alert situation was not contained on the recording.

The evidence does not show which pilot was flying once the emergency occurred.

There was also a passenger on the flight accompanying the two pilots.

2.2. Reconstruction of the flight path taken during the second segment of the flight

So as to analyze the flight path and profile followed by the aircraft in the second segment of the flight, the investigators resorted to the information provided by the fleet tracking system and by the CVR recording.

Figure 18 in section 1.16.1 shows the altitude difference between the aircraft and the elevation of the terrain, thus yielding the height above the ground which was, on average, some 200 m (656 ft), which is considered reasonable for the visual flight that was being performed.

Two additional circumstances identified are that 1) while flying over the hills with the highest elevations, the aircraft adjusted to the terrain and kept a sufficient margin of safety, and 2) when the fleet tracking GPS signal was lost, the aircraft's altitude was 1,545 m (terrain elevation 1,266 m), while the altitude of the crash site was 1,250 m. There was thus a margin of altitude of 300 m until the impact site. Since there is no geographic feature that requires a climb maneuver, the aircraft is believed to have been far enough above the ground to carry out a safe maneuver.

As for the route taken, the CVR records how the crew identified various places along their path. It is thus reasonable to think that the first officer knew the area they were flying in, and thus the mountainous nature of the terrain.

The route taken between the point where the data from the fleet tracking system was lost until the site of the wreckage was reconstructed by relating the aircraft's heading based on the FDR data and the relief of the terrain. This allowed investigators to determine that starting from the altitude of the last known point (1545 m), the aircraft had to cross road GR-3201, leaving the hillside shown in Figure 23 to the right, as its

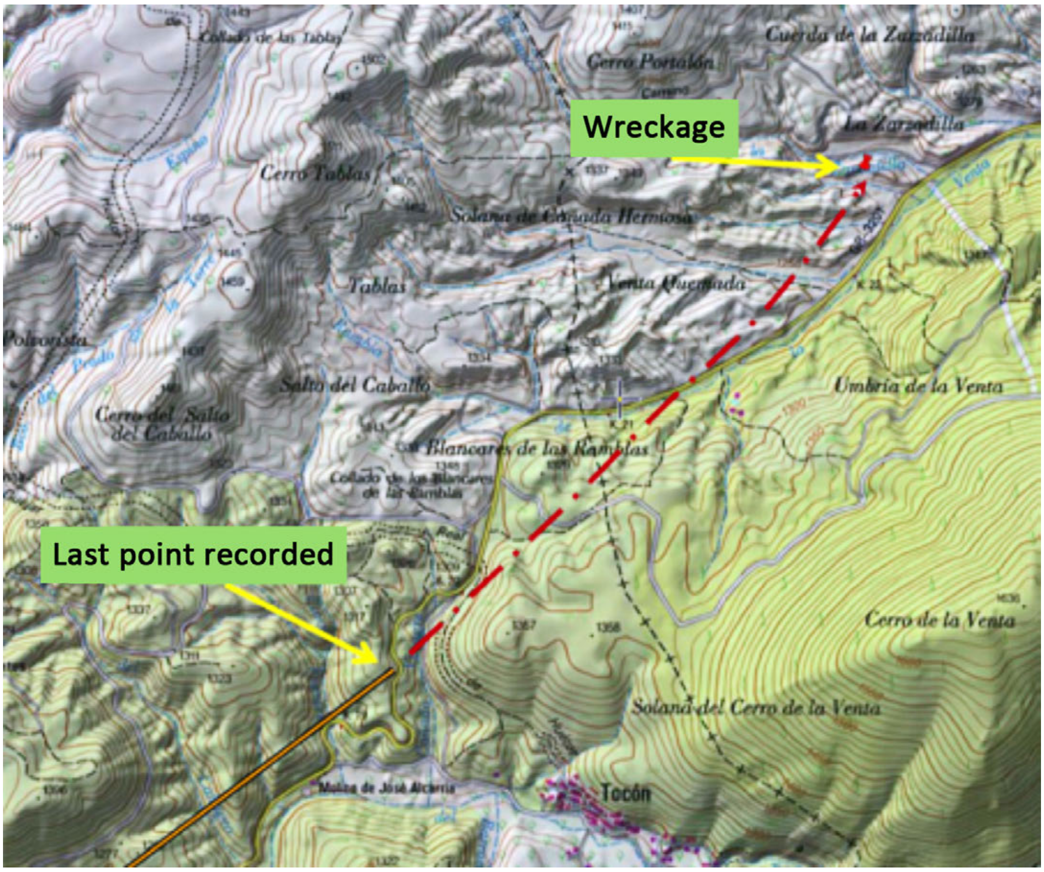

Figure 23. Reconstruction of the flight path

elevation was considerably higher than the preceding elevation. A panoramic view of the ground they would have had to fly over is shown in Figure 19.

As for the speed they could have maintained on this 2,370-m long segment, it is believed to have been 120 kt, this being the speed mentioned in the CVR[10] and recorded by the fleet tracking system. Moreover, there were no elevation changes in the terrain that would have required the pilot to change the flight parameters, as evidenced by the absence of any inputs to the collective and cyclic controls during the last 40 seconds before the pilot reacted to the emergency.

2.3. Investigation

The aircraft wreckage was severely damaged by the force of the impact and by the fire that broke out immediately afterwards. The CIAIAC's investigation considered different hypotheses resulting from a mechanical failure and/or the crew's actions. These included evaluating the failure of the collective lever, though no conclusions could be drawn due to the effect of the fire on the lever.

Similarly, the heat affected the magnetic tape that serves as a recording medium in the CVR, causing its length to be altered and degrading the quality of the recording. The information obtained nevertheless revealed important aspects pertaining to the operation.

As for the FDR, the parameters it recorded involving the aircraft's speed and altitude and the main gearbox oil pressure warning could not be validated due to a faulty connection between the ADC and the FDAU.

Finally, the investigation believes that the recording was missing at least the final 24 seconds of the flight since at no point do its contents reveal conversations involving the alerts the crew must have received as a result of the failure of the main gearbox.

2.3.1. *Interpretation of the final 24 seconds recorded by the FDR*

The segment analyzed in this point concerns the aircraft's final minute of flight, this being the most significant to the event. At the start of this segment, the pilot flying was holding the collective and longitudinal cyclic positions constant, making small changes with the lateral cyclic and the pedals that resulted in minor heading changes.

[10] It was not possible to calculate the speed from the FDR data.

At 24 seconds from the end (time 152728 in the table in Appendix 3), the recording shows a sudden drop in torque from 43% to 6%. Over the following second (time 152729) the following events occurred:

- Lowering of the collective and zeroing the cyclic,
- Pitch attitude climbs from 0° to 8°,
- Right-pedal correction,
- Movement of the cyclic to the right,
- Main rotor overspeed,
- "MASTER CAUTION" activation after exceeding the 104.5% limit and reaching a value of 130%.

This is interpreted as the aircraft initiating a descent, with the immediate and intuitive response of the pilot flying being to lower the collective and level the cyclic. This is a logical reaction to start an auto-rotation maneuver. The pilot flying must also have noticed that the torque readings on both engines were the same (the needles were not separated) and that they were descending quickly.

This would have been immediately followed by a check for a possible engine failure, though the crew would have noticed that the engines were running and that gas generator RPMs[11] (N1) were normal. In the meantime, the rotor RPMs (Nr) increased, activating the MASTER CAUTION, and remained above 100%[12], similar to N2.

In his initial assessment, the pilot flying would have been surprised by the failure of the collective to respond to his inputs and would have tried to find a place to land.

After the first 8 seconds, the aircraft continued descending. The heading was changing a constant 2-3 degrees left every second (until time 152735) and the aircraft had a 9° nose-up angle until it touched the ground for the first time, at which point the anti-collision and landing lights broke and paint chipped off the fuselage.

Then, from time 152735 on, the aircraft began a sharp turn to the left even though the pilot was moving the cyclic to the right while applying right pedal in an effort to correct the left yaw and bank angle that was developing. Likewise, to correct the nose up attitude, the cyclic was being pushed down.

In the next to last second (time 152750), the pilot's control inputs were at their highest values. During the final two seconds the aircraft was making a 41° turn to the left while banking sharply to that side, completing what had been a 247° turn since it first impacted the ground.

[11] The FDR was not set up to provide this information.

[12] The FDR recorded that the Nr RPMs were constant until the end, on the order of 106% after the failure. This is because the device that measures these RPMs is in the chain of transmission and its drag was not affected by the failure of the planetary gear.

2.3.2. *Scenarios considered*

The scenario presented in the previous section assumes that the sudden loss of torque was not caused by the engines stopping, since there was no "ENG OUT" warning. The subsequent study of the engines also failed to show any malfunction in their operation.

Similarly, the cockpit instruments must have shown no gap between the needles on the triple tachometer, and although the value of N1 is unknown, the engine power can be assumed to been driven to a low level by the power management systems, but above 53 ± 2%.

Based on the flight data recorded by the FDR, the governor that regulates the turbine power on both engines was determined to have been in the automatic operation position.

As concerns the absence of any response in the torque parameter to the pilot's inputs to the collective, the possibility was considered that a fault had occurred in one or more of the following systems or components: the assembly that transmits the motion of the collective lever, the pitch control on the main rotor blades, loss of material from said blades or the engine power management, which would have caused the main rotor to overspeed, triggering a MASTER CAUTION alert. In this regard, and in light of the N2 values for each engine, a simultaneous failure of both governors is unlikely since they are independent from one another; furthermore, the fuel control system must have remained operational since the N2 RPMs stabilized.

As for a failure somewhere in the pitch control system, the investigation was only able to recover the collective lever from the wreckage, though an analysis of this component did not reveal why it fractured since the fracture surface had been altered by the high temperatures to which it had been subjected.

2.3.3. *Analysis of the impact with the terrain*

The helicopter crashed into a rock on a hillside that it had flown over seconds earlier. The debris field shows that the impact involved the lower front part of the aircraft, which caused the battery to be ejected in the direction of motion and the front tip of the left skid and rearview mirror to fracture.

The energy from the vertical freefall was enough to detach the back of the LH seat and for its occupant to be thrown out when the aircraft flipped over on its left side.

The fuel onboard was spilled on the ground and instantly caught fire, as evidenced by the layer of molten aluminum found along the hillside.

The way the tail skid was bent reveals that this must have happened during the initial impact with the ground, when the aircraft was in a nose-up attitude. This also seriously affected one of the tail rotor blades, which was ejected. Figure 24 shows the condition of the tail rotor after the accident and its reconstructed state after the ejected blade was recovered.

Figure 24. Tail rotor debris

2.4. Failure of the main gearbox

The spectral analysis of the sound recorded by the CVR showed a change in the frequency generated by the lower planetary gear in the main gearbox as it rotated. So as to check its condition, the recovered MGB was inspected.

This revealed that the four gears on the lower planetary gear were bent and their teeth worn and bent in the direction of rotation. The sun gear exhibited similar damage. These findings were similar to those in the earlier incident reported by Bell Helicopter and to the tests carried out by both manufacturers (Bell and Agusta). This condition makes it impossible to transfer rotational torque to the main rotor.

The damage found is believed to be the result of operating the main gearbox without lubricating oil. This led to increased friction and thus increased temperature which, along with the loads that the assembly is subjected to, caused the failure of the components. The ensuing investigation into aspects such as the maintenance conducted and the checks of oil level carried out during the final walkaround checks did not allow for a determination of the process and circumstances that led to the loss of oil, and thus to determine the origin of this failure.

2.5. Absence of indications and/or warnings

The investigation was unable to confirm why the CVR contains no conversations involving the crew's reaction to the changes that must have taken place in the readings and to the activation of the lights on the caution panel resulting from the pressure and temperature changes in the MGB lubricating oil.

In this regard, the fact that the XMSN OIL PRESS parameter was not recorded is not interpreted as implying a fault in the caution panel or in the pressure gauge, since if such a fault had occurred, it would in all likelihood have been noticed during the engine start procedure. It is also not believed to indicate a failure of the oil pressure transducer during the flight, which would only have been noticeable through the pressure gauge.

The tests carried out show that the gearbox can continue operating for at least 15 minutes without lubrication. The loss of lubricant leads to a drop in the oil pressure reading while at the same time triggering the warning on the control panel when it drops below the lower limit. The temperature reading would then increase and the chip detector warning (CHIP XMSN) would be activated in the caution panel as material starts to detach. It is thus reasonable to assume that the cockpit voice recording would have reflected some kind of concern from the crew, especially given that there is a sufficient time gap for the crew to have been alerted.

While the magnetic tape was damaged by the heat and its length cut short by a few seconds, the segment of tape lost during the recovery efforts is not believed to be of sufficient length for the portion of tape that remained not to have contained some kind of warning to the crew. Therefore, the scenario present in the tape of the accident could indicate that the event took place suddenly at the last moment, with no signs of any malfunction, just as in the recording of the event there is no alert in the final seconds.

2.6. Analysis of the aircraft's performance with no torque in the main rotor

The fault affecting the lower planetary gear in the main gearbox caused the main rotor mast to be removed from the chain of transmission, see Figure 25. The remaining elements downstream, however, continued operating due to the rotation that the input pinion was receiving from the engines. This means that in this case, the tail rotor continued operating at the rate that was being driven by the engines.

The data show that instants before the torque was lost, the crew were not aware of the impending failure; therefore, when the emergency occurred, the aircraft was flying at a speed of approximately 120 kt at an altitude AGL of 200 m (656 ft). Immediately following the failure, the main rotor stopped receiving torque from the engines, while components like the vertical stabilizer and the tail rotor continued operating, as they were still being mechanically driven.

At the speed that the aircraft had at the time of the failure, the function of the vertical stabilizer is to offset the rotational momentum of the main rotor (the pedal input is

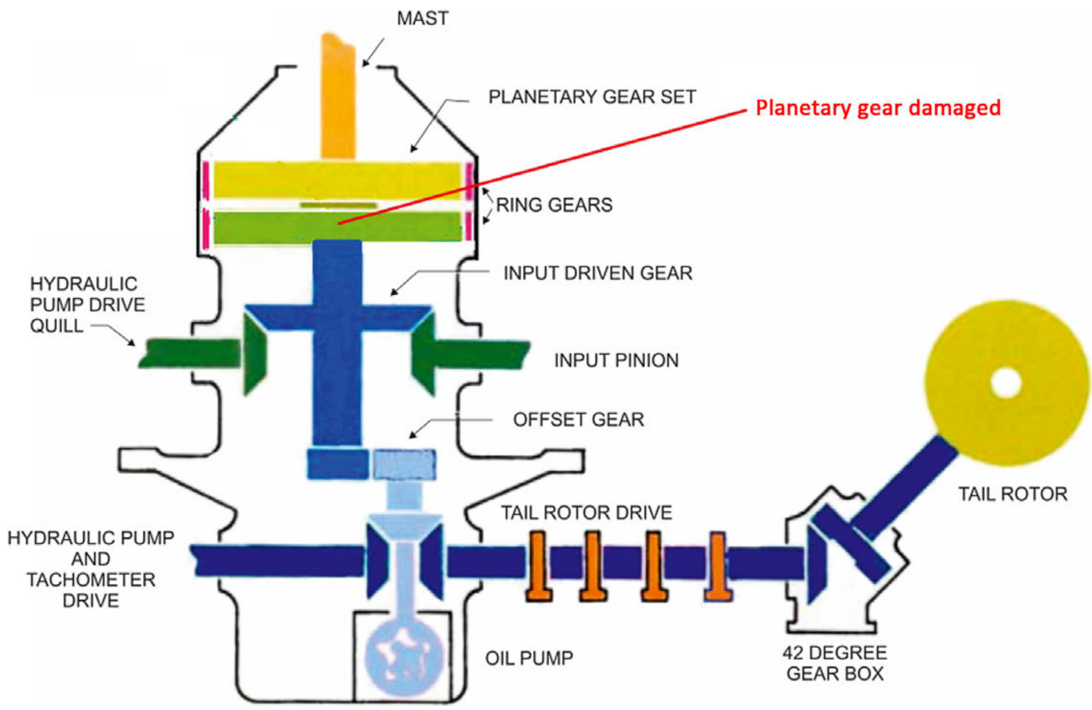

Figure 25. Area where the chain of transmission was interrupted

minimal). When the kinetic moment to be compensated disappears, a left yaw is immediately induced since there is still a force pushing the tail to the right. The pilot flying attempts to correct this yaw by applying right pedal.

The engines continue running and the control system for each allows the N2 RPMs to remain at about 100%. In the initial seconds, the tail rotor responds to the pedal inputs and the collective control is able to change the pitch of the main rotor blades, even if the lateral cyclic control losses effectiveness due to the considerable loss of lift from the main rotor.

As a result, the only way to maintain Nr RPMs is by losing height and/or translational velocity. The aerodynamics of the vertical stabilizer loses effectiveness as the speed approaches 55 kt, meaning that the input to the right pedal gradually becomes less important.

In this condition, the aircraft maneuvers close to the ground to reach suitable terrain, with the added difficulty of having the engines running but without the ability to match the rotations of the mechanical linkage between the main and tail rotors.

After about 8 seconds and with a high pitch angle, the initial impact with the ground took place, with the tail skid striking the top of a hill, affecting the rotor blades. The flight undoubtedly became more destabilized. The elevation change and the remaining energy in the main rotor kept the aircraft aloft.

The pilot's inputs with the pedal and right cyclic to correct the rotational momentum to the left had no effect due to the loss of effectiveness of the tail rotor and the low RPMs remaining in the main rotor. Finally, with the aircraft out of control, there was a sharp turn to the left, driving it to the ground.

As concerns the initial response of the pilot flying to the failure, learned instincts would indicate that he attempted to auto-rotate, but the assessment he must have made of the instrument readings must not have corresponded to the maneuvers he had learned.

A pilot's response to a failure on which he is trained, and which he has therefore learned, provides a certain degree of control and predictability of the aircraft's response. For the type of failure analyzed in this case, the pilot's actions do not correlate with the aircraft's expected response, making it unlikely to regain control of the aircraft.

3. CONCLUSION

3.1. Findings

1. The two crewmembers had valid licenses and were qualified for the flight. They also had valid medical certificates.
2. The aircraft had a valid certificate of airworthiness and the last maintenance tasks had been in conformance with the approved program.
3. Both pilots had flown together as a crew on several occasions.
4. The captain was a type rating instructor and was in the LH seat in the cockpit. The RH seat was occupied by the pilot flying.
5. The flight took place in two segments, the first under instrument flight rules and the second under visual flight rules.
6. The crew had previous references for and knowledge of the terrain they were flying over.
7. The internals of the cockpit voice and flight data recorders were affected by the heat of the fire.
8. The information recorded on the magnetic tape does not contain any kind of alarm from the crew or from the cockpit. The flight data recorder did not record some parameters, in particular those that indicate the aircraft's speed and altitude.
9. The voice recording confirms the captain's influence over the pilot flying.
10. The analysis of the reconstructed flight path indicates that the aircraft was at a reasonable altitude above the ground.
11. The main transmission failed during the flight, making it impossible to transfer torque to the main rotor.
12. The localized fault of the main transmission does not interrupt the transfer of power to the tail rotor.
13. The flight data recorder shows that the pilot flying started an unfinished auto-rotation maneuver in response to the emergency.
14. The analysis of the inputs to the controls shows that the aircraft could not be controlled.
15. It was not possible to determine who was the pilot flying during the emergency.
16. The training program does not teach the actions to take for the emergency that took place, and therefore the pilots have no training on this scenario.
17. The response by emergency services allowed the resulting fire to be controlled.
18. The fire started immediately after impact.
19. It is not known how or when the loss of lubricating oil in the transmission took place.

3.2. Causes/Contributing factors

The investigation revealed that the most probable cause of the accident was a failure of the lower planetary gear in the main gearbox that made it impossible to transmit torque to the main rotor, causing the aircraft to plummet to the ground.

This fault is thought to have resulted from a lack of lubricating system oil in the main gearbox. The condition of the aircraft wreckage, mainly as a result of the fire that engulfed it after the crash, made it impossible to determine the situation that caused the loss of oil.

4. SAFETY RECOMMENDATIONS

None.

APPENDICES

APPENDIX 1

EASA AD No: 2011-0247

EASA	AIRWORTHINESS DIRECTIVE
	AD No.: 2011-0247 **Date: 22 December 2011** Note: This Airworthiness Directive (AD) is issued by EASA, acting in accordance with Regulation (EC) No 216/2008 on behalf of the European Community, its Member States and of the European third countries that participate in the activities of EASA under Article 66 of that Regulation.

This AD is issued in accordance with EC 1702/2003, Part 21A.3B. In accordance with EC 2042/2003 Annex I, Part M.A.301, the continuing airworthiness of an aircraft shall be ensured by accomplishing any applicable ADs. Consequently, no person may operate an aircraft to which an AD applies, except in accordance with the requirements of that AD, unless otherwise specified by the Agency [EC 2042/2003 Annex I, Part M.A.303] or agreed with the Authority of the State of Registry [EC 216/2008, Article 14(4) exemption].

Type Approval Holder's Name :	**Type/Model designation(s) :**
Agusta S.p.A	AB412/AB412EP helicopters

TCDS Number:	ENAC Italy SO/A 375
Foreign AD:	Not applicable
Supersedure:	None

ATA 62	**Main Rotor – Collective Lever – Inspection / Replacement**
Manufacturer(s):	AgustaWestland S.p.A.
Applicability:	AB412 and AB412EP helicopters, all serial numbers.
Reason:	A case of a fractured collective lever Part Number (P/N) 412-010-408-101 occurred on a Bell 412. The results of the technical investigation, carried out by Bell Helicopter, revealed that the main probable cause of the fracture was fatigue due to residual stress induced during the manufacturing process. This condition, if not detected and corrected, could lead to further events of collective lever fracture resulting in reduced control of the helicopter. To address this condition, Bell Helicopter issued Alert Service Bulletin 412-11-148. Taking into account that the AgustaWestland AB412/AB412EP helicopters have the same component installed, manufactured either by AgustaWestland or Bell Helicopter, AgustaWestland issued Bollettino Tecnico (BT) 412-131 which provides instructions to inspect the collective lever, and to replace the lever, if a cracked part is found. For the reasons described above, this AD requires repetitive inspections of the collective lever P/N 412-010-408-101 and, if a crack is detected, replacement of the lever.
Effective Date:	05 January 2012

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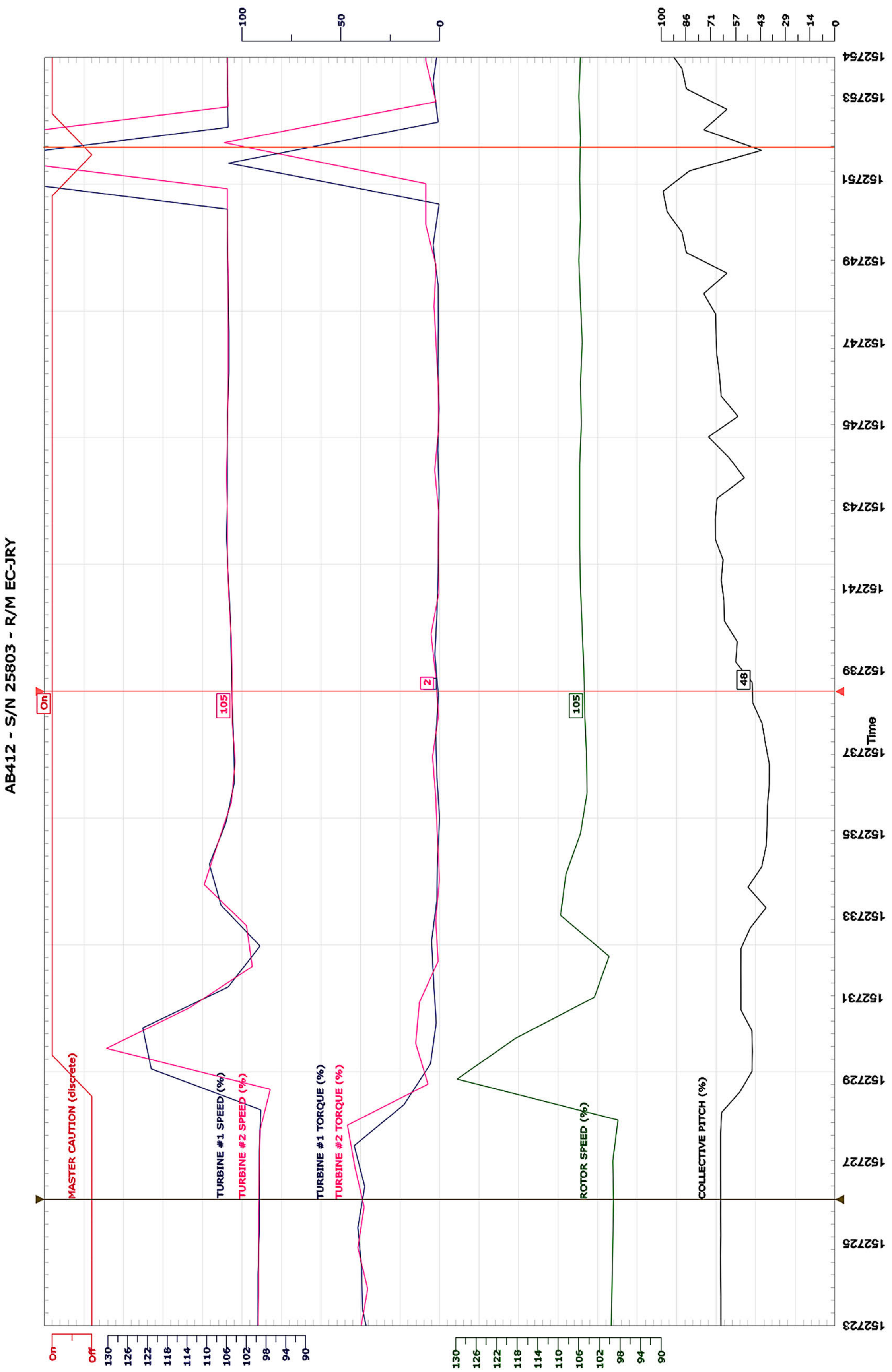
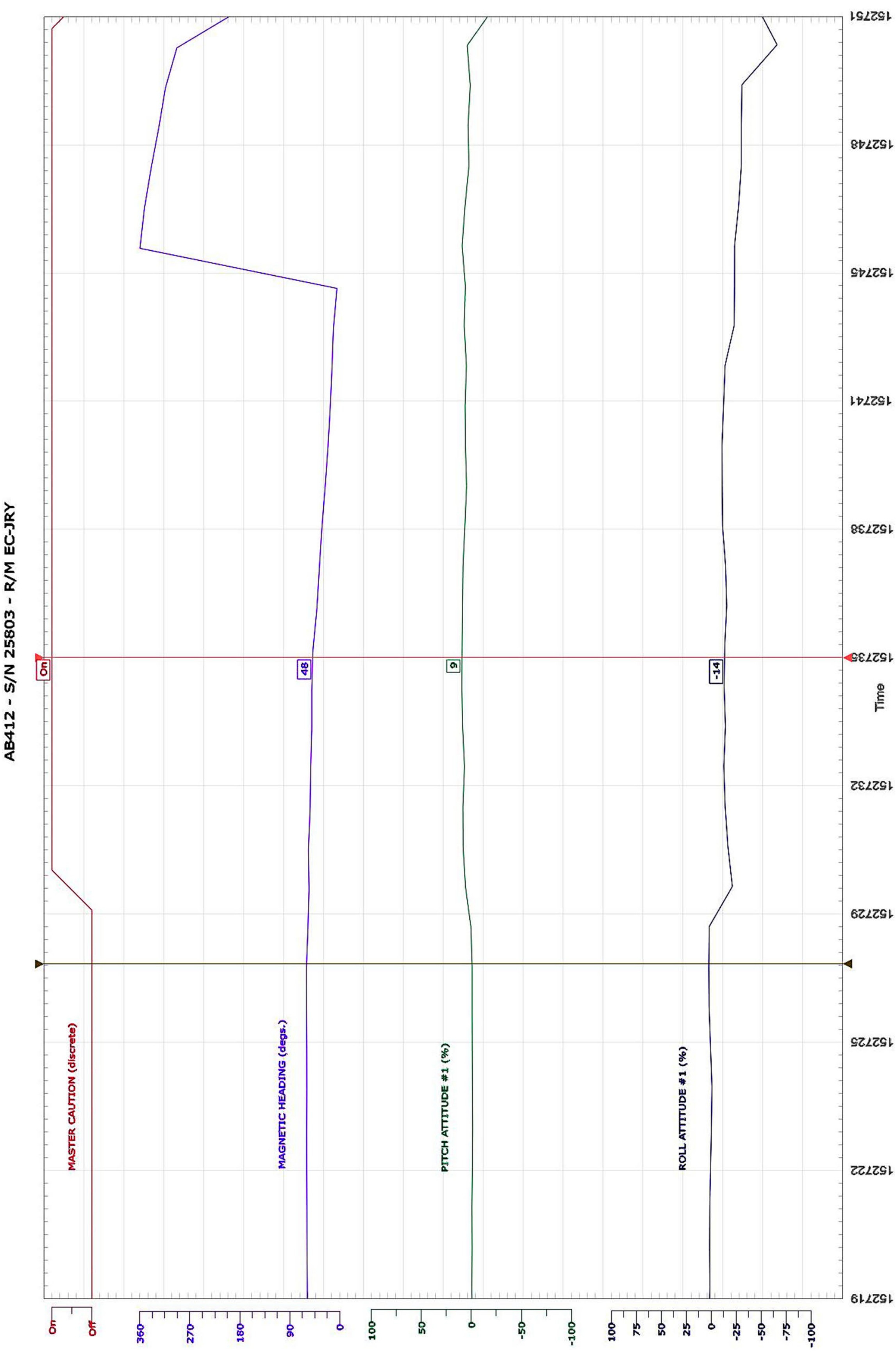
EASA AD No: 2011-0247

Required Action(s) and Compliance Time(s):	Required as indicated, unless accomplished previously: (1) Within 25 flight hours (FH) or 3 months, whichever occurs first after the effective date of this AD and, thereafter, at intervals not to exceed 100 FH, accomplish a visual inspection of the collective lever Part Number P/N 412-010-408-101 in accordance with the Accomplishment Instructions of the AgustaWestland BT 412-131. (2) If, during any inspection as required by paragraph (1) of this AD, a crack is suspected, before next flight, accomplish a Fluorescent Penetrant Inspection of the collective lever in accordance with the Accomplishment Instructions of the AgustaWestland BT 412-131. (2.1) If, during the inspection as required by paragraph (2) of this AD, a crack is detected, before next flight, replace the collective lever with a serviceable part. (2.2) If, during any inspection as required by paragraph (2) of this AD, no crack is detected, before next flight, accomplish the actions as detailed in paragraph 9 of the Accomplishment Instructions of AgustaWestland BT 412-131. (3) Replacement of the collective lever with a serviceable part, as required by paragraph (2.1) of this AD, or accomplishment of corrective actions as required by paragraph (2.2) of this AD, does not constitute terminating action for the repetitive inspection requirements of this AD.
Ref. Publications:	AgustaWestland BT 412-131 dated 21 November 2011. The use of later approved revisions of this document is acceptable for compliance with the requirements of this AD.
Remarks :	1. If requested and appropriately substantiated, EASA can approve Alternative Methods of Compliance for this AD. 2. This AD was posted on 28 November 2011 as PAD 11-128 for consultation until 20 December 2011. No comments were received during the consultation period. 3. Enquiries regarding this AD should be referred to the Safety Information Section, Executive Directorate, EASA. E-mail: ADs@easa.europa.eu . 4. For any question concerning the technical content of the requirements in this AD, please contact: AgustaWestland S.p.A. Customer Support Via del Gregge, 100 - 21015 Lonate Pozzolo (VA) – Italy Telephone + 39 0331-664873 ; Fax: + 39 0331-664680 E-mail: absereng@agustawestland.com.

APPENDIX 2


AB412 - S/N 25803 - R/M EC-JRY
MASTER CAUTION (discrete)
TURBINE #1 SPEED (%)
TURBINE #2 SPEED (%)
TURBINE #1 TORQUE (%)
TURBINE #2 TORQUE (%)
ROTOR SPEED (%)
COLLECTIVE PITCH (%)
Time
On
Off
105
2
105
48


AB412 - S/N 25803 - R/M EC-JRY
MASTER CAUTION (discrete)
MAGNETIC HEADING (degs.)
PITCH ATTITUDE #1 (%)
ROLL ATTITUDE #1 (%)
On
Off
360
270
180
90
0
100
50
0
-50
-100
100
75
50
25
0
-25
-50
-75
-100
On
48
9
-14
Time
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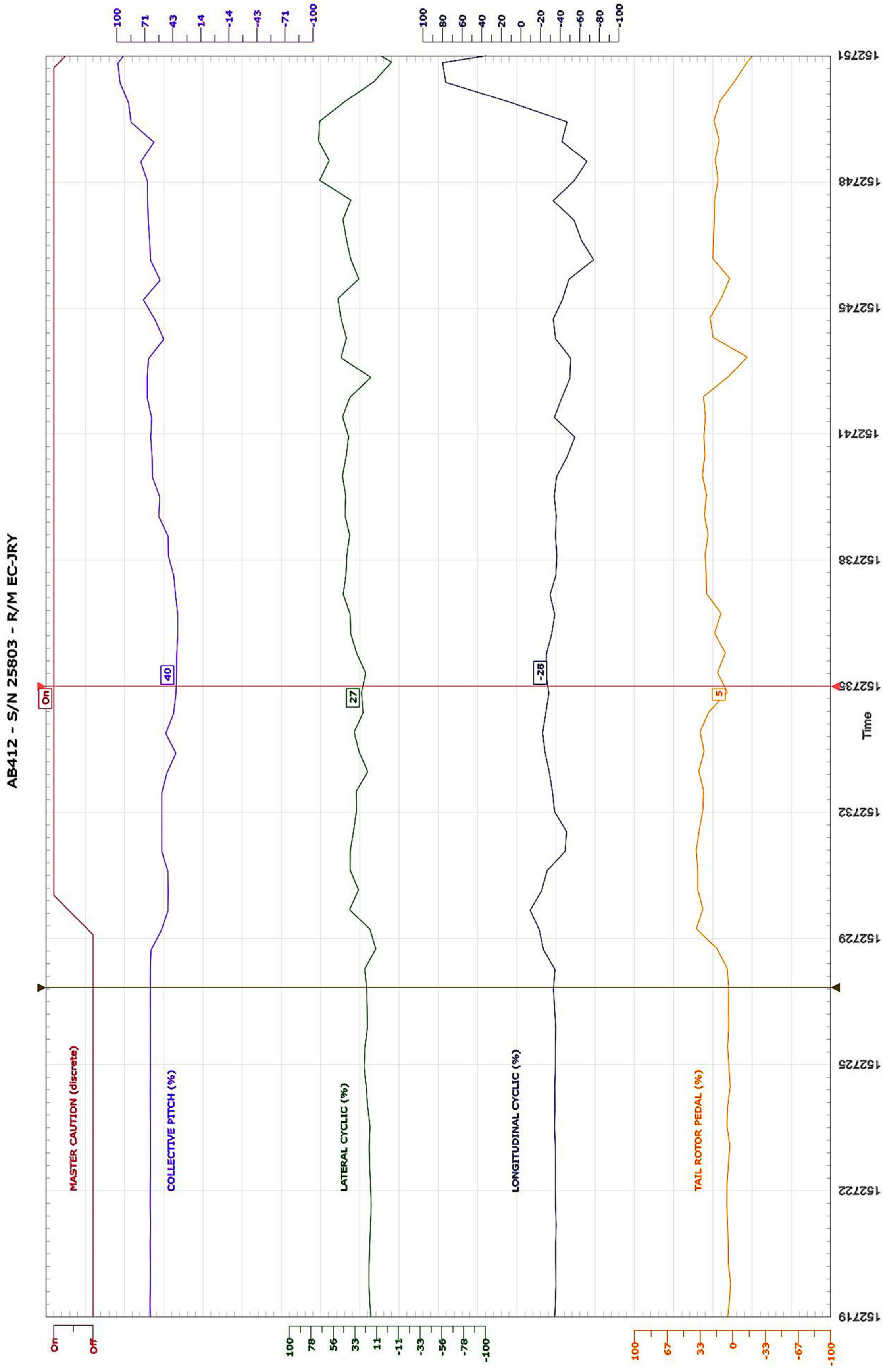
152745
152748
152751

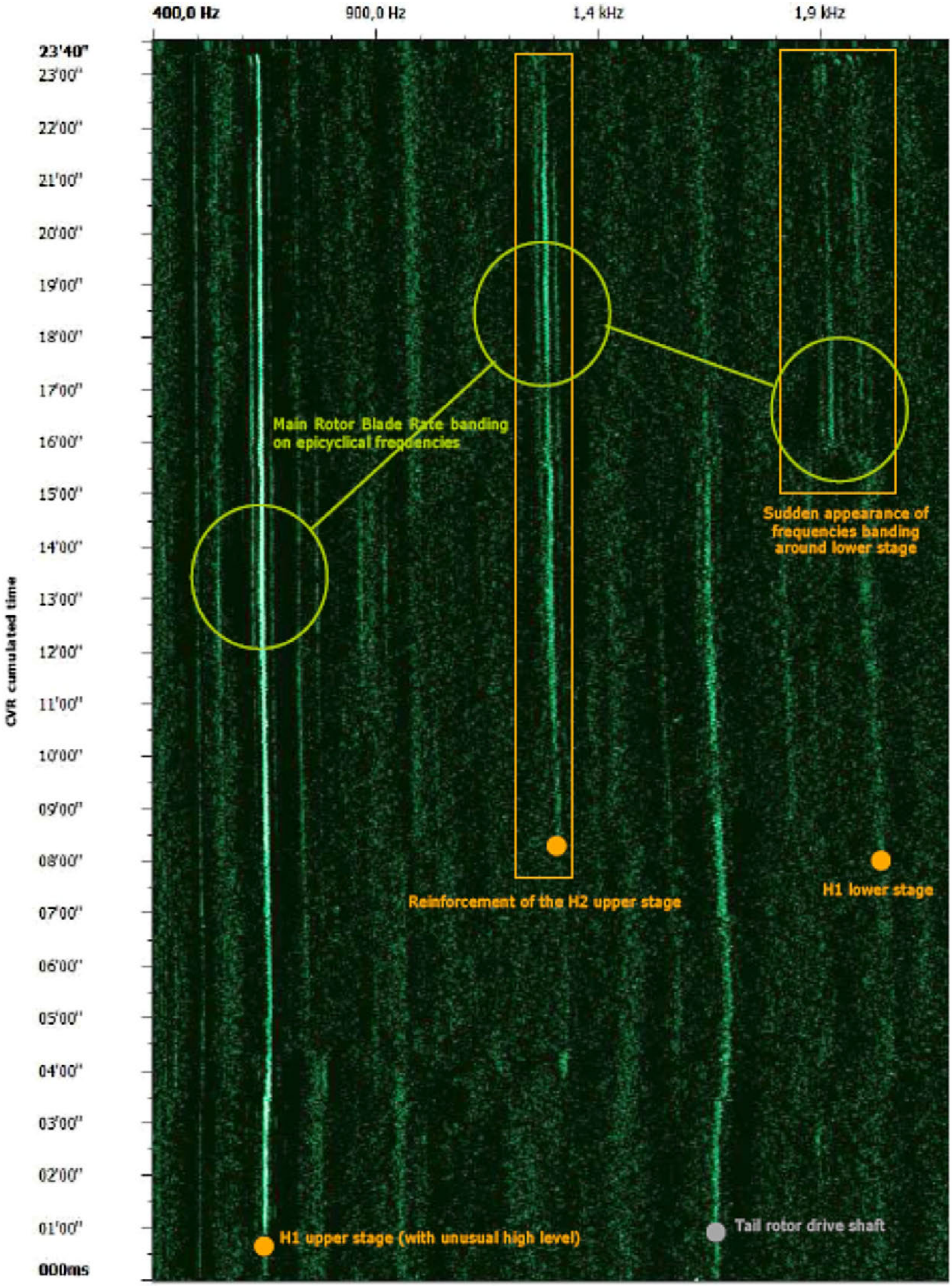

AB412 - S/N 25803 - R/M EC-JRY
MASTER CAUTION (discrete)
COLLECTIVE PITCH (%)
LATERAL CYCLIC (%)
LONGITUDINAL CYCLIC (%)
TAIL ROTOR PEDAL (%)
Time
152719
152722
152725
152729
152732
152735
152738
152741
152745
152748
152751
On
40
27
-28
5
On
Off
100
71
43
14
-14
-43
-71
-100
100
80
60
40
20
0
-20
-40
-60
-80
-100
100
78
56
33
11
-11
-33
-56
-78
-100
100
67
33
0
-33
-67
-100

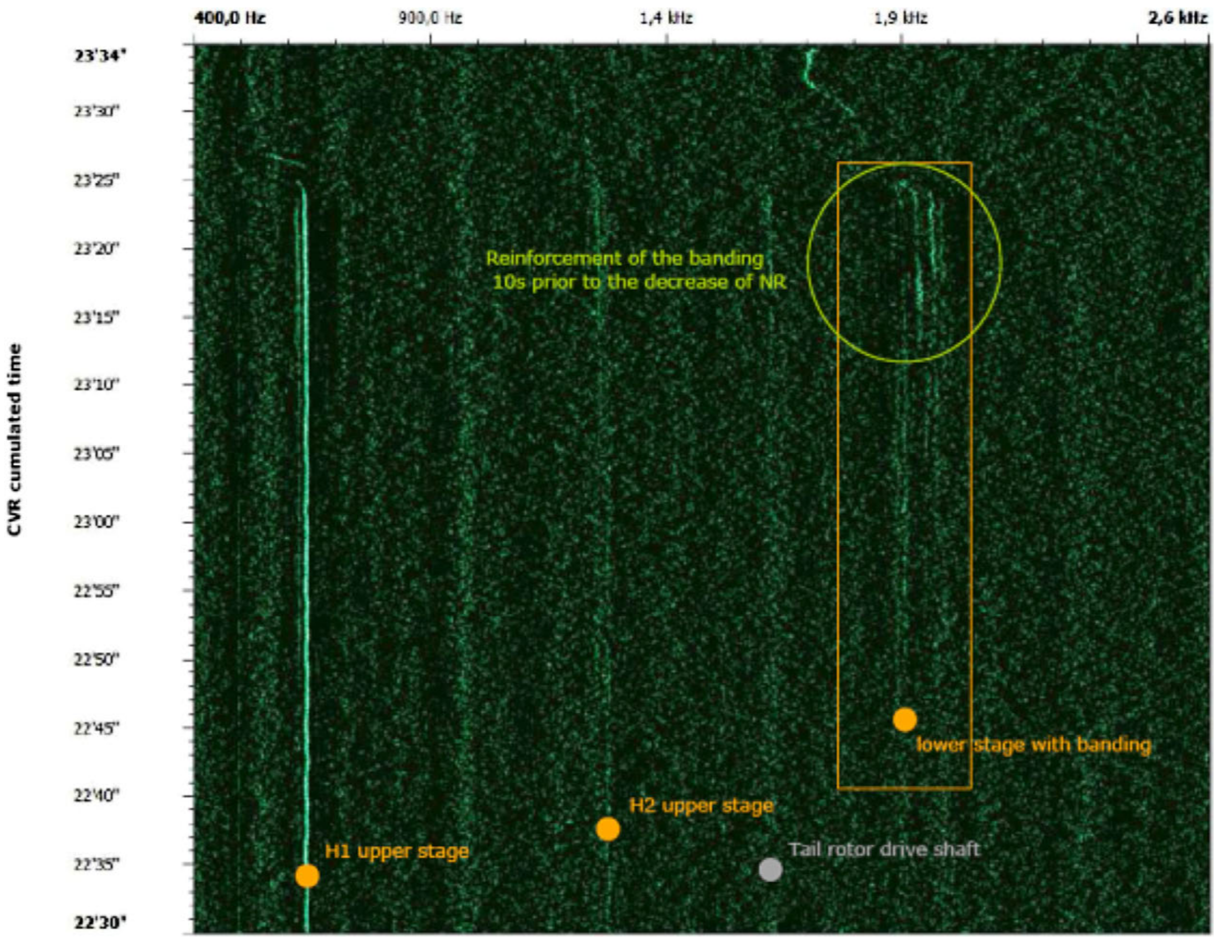
APPENDIX 3

Time	COLLECTIVE PITCH (%)		LONG. CYCLIC (%)		LATERAL CYCLIC (%)		PITCH ATT (Deg)		ROLL ATTITUDE (Deg)		PEDAL (%)		N2_1 (%)	N2_2 (%)	NR (%)	TQ_1 (%)	TQ_2 (%)	HEADING (Deg)	ENG_1 OUT	ENG_2 OUT	MASTER CAUTION
152687	66	66	-37	-38	9	11	-1	0	-1	-1	4	5	100	100	100	36	40	57	On	On	Off
152688	66	66	-37	-37	11	10	0	0	-1	-1	1	3	100	100	100	38	36	57	On	On	Off
152689	66	66	-38	-38	12	13	0	0	-1	-1	3	3	100	100	100	40	37	57	On	On	Off
152690	66	66	-36	-37	13	13	0	0	0	0	3	3	100	100	100	39	37	57	On	On	Off
152691	66	66	-38	-38	14	15	0	0	0	1	3	3	100	100	100	35	36	57	On	On	Off
152692	66	66	-38	-38	15	15	0	0	0	0	3	3	100	100	100	35	40	56	On	On	Off
152693	66	66	-38	-37	16	16	0	0	1	1	3	3	100	100	100	34	38	56	On	On	Off
152694	66	66	-38	-38	16	17	0	0	1	1	3	3	100	100	100	35	39	55	On	On	Off
152695	65	66	-39	-38	17	16	0	-1	1	1	3	3	100	100	100	35	37	56	On	On	Off
152696	66	66	-38	-38	16	17	0	0	1	1	3	3	100	100	100	35	37	56	On	On	Off
152697	66	66	-37	-38	18	16	0	-1	1	2	3	3	100	100	100	36	38	55	On	On	Off
152698	66	66	-36	-37	17	19	-1	0	1	1	3	3	100	100	100	35	38	55	On	On	Off
152699	66	66	-38	-36	18	15	-1	0	1	1	1	2	100	100	100	36	38	55	On	On	Off
152700	66	66	-36	-36	14	13	-1	0	1	0	2	3	100	100	100	35	39	56	On	On	Off
152701	66	66	-38	-37	15	14	0	0	0	0	3	1	100	100	100	39	37	55	On	On	Off
152702	66	66	-36	-37	14	16	-1	0	0	0	2	1	100	100	100	38	40	56	On	On	Off
152703	66	66	-38	-38	17	16	0	-1	0	1	1	1	100	100	100	38	41	56	On	On	Off
152704	66	65	-37	-38	15	15	-1	-1	1	1	3	2	100	100	100	39	39	56	On	On	Off
152705	66	66	-37	-34	15	13	-1	-1	0	0	2	1	100	100	100	40	39	56	On	On	Off
152706	66	66	-36	-36	14	16	0	-1	-1	-1	-2	-1	100	100	100	41	41	55	On	On	Off
152707	66	66	-36	-35	16	16	-1	-1	1	0	2	2	100	100	100	38	38	55	On	On	Off
152708	66	66	-36	-36	18	17	-1	-1	1	1	1	1	100	100	100	40	39	55	On	On	Off
152709	66	66	-36	-36	16	17	-1	-1	1	1	-1	1	100	100	100	40	38	55	On	On	Off
152710	66	66	-35	-34	17	16	-1	-1	1	1	3	-1	100	100	100	40	42	54	On	On	Off
152711	66	66	-35	-35	16	18	0	0	1	0	3	4	100	100	100	40	37	54	On	On	Off
152712	66	66	-35	-35	18	17	0	0	1	1	0	2	100	100	100	40	39	55	On	On	Off
152713	66	66	-35	-35	17	19	0	0	1	0	0	3	100	100	100	40	37	55	On	On	Off
152714	66	66	-36	-36	20	20	0	0	1	2	2	4	100	100	100	41	36	56	On	On	Off
152715	66	66	-36	-36	18	18	0	0	2	1	4	3	100	100	100	40	41	57	On	On	Off
152716	66	66	-36	-36	16	13	-1	0	1	1	4	2	100	100	100	35	39	58	On	On	Off
152717	66	65	-36	-36	19	18	0	0	1	2	4	2	100	100	100	37	43	58	On	On	Off

Time	COLLECTIVE PITCH (%)		LONG. CYCLIC (%)		LATERAL CYCLIC (%)		PITCH ATT (Deg)		ROLL ATTITUDE (Deg)		PEDAL (%)		N2_1 (%)	N2_2 (%)	NR (%)	TQ_1 (%)	TQ_2 (%)	HEADING (Deg)	ENG_1 OUT	ENG_2 OUT	MASTER CAUTION
152719	66	66	-35	-36	18	19	0	0	1	1	4	2	100	100	100	38	39	58	On	On	Off
152720	66	66	-36	-35	19	18	-1	-1	1	1	5	5	100	100	100	43	38	59	On	On	Off
152721	66	66	-36	-35	17	17	-1	-1	1	1	5	6	100	100	100	39	39	59	On	On	Off
152722	66	66	-35	-35	17	18	-1	-1	0	-1	6	5	100	100	100	35	40	59	On	On	Off
152723	66	66	-35	-34	19	18	-1	-1	0	-1	3	6	100	99	100	39	36	59	On	On	Off
152724	66	66	-35	-35	20	22	-1	-1	-1	0	5	3	100	99	100	40	41	59	On	On	Off
152725	66	66	-35	-35	24	23	-1	-1	1	1	4	5	99	99	99	41	38	59	On	On	Off
152726	66	66	-36	-34	20	21	-1	-1	2	2	4	4	99	99	99	38	43	60	On	On	Off
152727	66	66	-33	-35	21	23	-1	0	2	2	4	6	99	99	99	43	47	60	On	On	Off
152728	65	55	-23	-19	12	18	0	3	2	-8	16	37	99	97	98	18	6	57	On	On	Off
152729	48	47	-10	-21	39	30	6	8	-21	-19	30	36	121	130	130	5	12	55	On	On	On
152730	48	54	-27	-45	38	38	8	9	-17	-15	36	37	123	113	118	2	10	56	On	On	On
152731	54	54	-46	-34	35	32	9	8	-14	-14	34	31	106	101	103	3	1	53	On	On	On
152732	54	49	-32	-29	32	20	7	8	-13	-12	30	35	99	102	100	4	2	52	On	On	On
152733	40	50	-25	-22	29	34	9	9	-14	-15	29	33	107	110	110	1	0	50	On	On	On
152734	42	40	-25	-28	25	27	10	10	-13	-14	24	5	109	108	109	1	1	50	On	On	On
152735	39	39	-26	-26	22	31	9	9	-14	-15	16	8	106	105	106	0	2	48	On	On	On
152736	38	38	-31	-35	37	38	9	9	-16	-15	19	12	104	104	104	1	4	41	On	On	On
152737	40	42	-30	-36	45	42	8	8	-15	-13	27	27	105	105	105	2	1	37	On	On	On
152738	47	48	-37	-35	41	39	7	5	-12	-11	28	25	105	105	105	1	2	32	On	On	On
152739	57	56	-36	-34	43	43	5	5	-11	-11	29	27	105	105	105	2	4	26	On	On	On
152740	64	64	-36	-47	46	42	6	6	-11	-11	31	28	105	105	105	1	0	21	On	On	On
152741	65	64	-55	-34	40	46	6	5	-13	-14	29	28	106	106	106	1	1	17	On	On	On
152742	69	69	-42	-50	38	17	5	6	-14	-16	30	5	106	106	106	1	1	14	On	On	On
152743	68	52	-51	-35	47	42	7	7	-23	-23	-15	20	106	106	106	0	3	11	On	On	On
152744	61	73	-33	-42	47	51	6	8	-24	-23	23	12	106	106	106	1	1	5	On	On	On
152745	56	65	-49	-74	29	37	9	10	-24	-25	3	20	106	106	106	0	1	360	On	On	On
152746	66	68	-62	-54	42	45	6	4	-28	-29	20	19	105	106	106	1	2	352	On	On	On
152747	68	69	-33	-54	37	69	2	3	-30	-33	19	15	105	106	105	1	3	340	On	On	On
152748	75	62	-67	-42	59	70	3	2	-30	-31	18	14	106	106	106	1	2	326	On	On	On
152749	85	88	-47	11	69	43	1	2	-31	-40	19	13	106	106	106	3	7	314	On	On	On
152750	97	99	77	80	14	-4	4	-3	-66	-73	-2	-15	106	106	106	0	7	293	On	On	On
152751	84	42	-47	-51	30	24	-24	-13	-45	-45	-34	1	172	172	106	107	109	173	On	On	Off

APPENDIX 4


400,0 Hz
900,0 Hz
1,4 kHz
1,9 kHz
CVR cumulated time
23'40"
23'00"
22'00"
21'00"
20'00"
19'00"
18'00"
17'00"
16'00"
15'00"
14'00"
13'00"
12'00"
11'00"
10'00"
09'00"
08'00"
07'00"
06'00"
05'00"
04'00"
03'00"
02'00"
01'00"
000ms
Main Rotor Blade Rate banding on epicyclical frequencies
Sudden appearance of frequencies banding around lower stage
Reinforcement of the H2 upper stage
H1 lower stage
H1 upper stage (with unusual high level)
Tail rotor drive shaft


400,0 Hz
900,0 Hz
1,4 kHz
1,9 kHz
2,6 kHz
CVR cumulated time
23'34"
23'30"
23'25"
23'20"
23'15"
23'10"
23'05"
23'00"
22'55"
22'50"
22'45"
22'40"
22'35"
22'30"
Reinforcement of the banding
10s prior to the decrease of NR
lower stage with banding
H2 upper stage
H1 upper stage
Tail rotor drive shaft

APPENDIX 5

Figure 5.1. External condition of MGB

Figure 5.2. Lower planetary gear

Figure 5.3. Close-up of gears on lower planetary gear

Figure 5.4. Chip detector

Figure 5.5. Sun gear

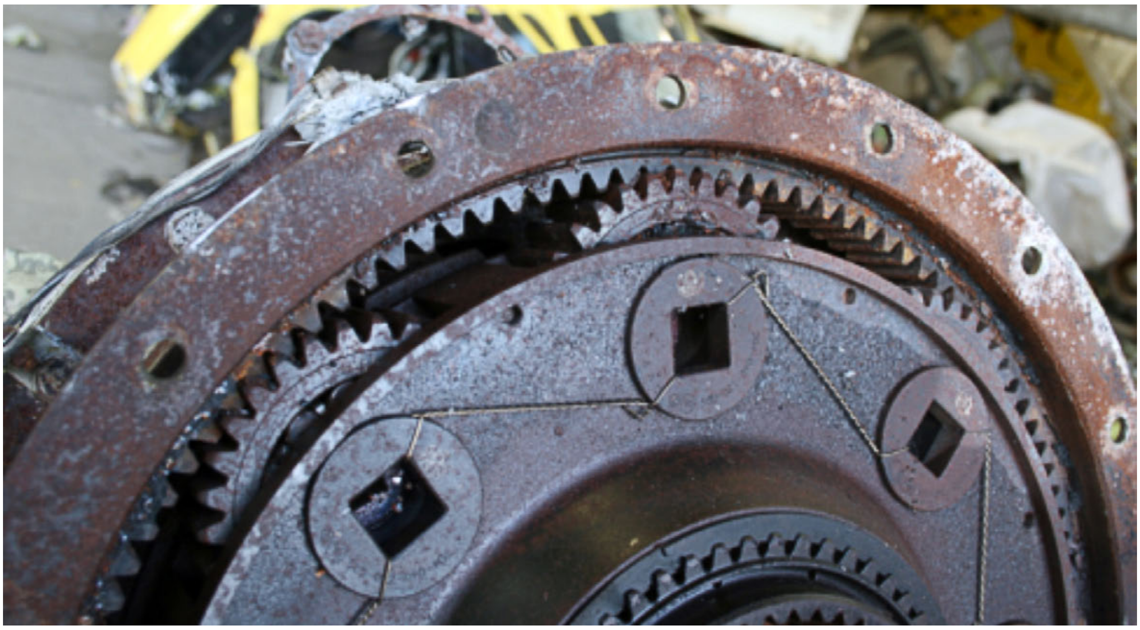


Figure 5.6. Upper planetary gear