SERIOUS INCIDENT

Aircraft Type and Registration:	MD 900, G-LNDN	
No & Type of Engines:	2 Pratt & Whitney Canada PW207E turboshaft engines	
Year of Manufacture:	2008 (Serial no: 900-00125)	
Date & Time (UTC):	25 July 2021 at 2014 hrs	
Location:	In flight between Royal London Hospital and RAF Northolt, Greater London	
Type of Flight:	Commercial Air Transport	
Persons on Board:	Crew - 2	Passengers - 2
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Water damage to Symbol Generator and right Electronic Engine Controller	
Commander's Licence:	Airline Transport Pilot's Licence (Helicopters)	
Commander's Age:	58 years	
Commander's Flying Experience:	12,360 hours (of which 2,090 were on type) Last 90 days - 35 hours Last 28 days - 10 Hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a flight from the Royal London Hospital (RLH) to RAF Northolt, G-LNDN suffered a series of seemingly unconnected electrical system faults. The first faults related to the stability augmentation system (SAS) and the commander's flight instrument displays but did not materially affect the conduct of the flight. Later, when approximately 4 nm from their destination, the pilots were alerted to electronic engine control (EEC) system fault indications for both engines. A '*critical*' fault on the right engine required the pilots to manually control its throttle but the fault on the left engine was non-critical and the engine operated as expected in the NORMAL (automatic) control mode. The pilots were able to complete an uneventful approach and landing at RAF Northolt.

The electrical failures were the result of water ingress from the right engine bay onto electronic components located in the rear fuselage area.

Background

G-LNDN was an air ambulance helicopter hangared at RAF Northolt but routinely forward deployed to the RLH during operational hours, typically from 0800 hrs (local time) until sunset. The helicopter was operated in the multi-crew commercial air transport role and, for the incident flight, the co-pilot was initially Pilot Flying (PF).

History of the flight

Having deployed on routine tasking during the morning, G-LNDN returned to the RLH helipad shortly after 1300 hrs. During the afternoon there was no further tasking for the helicopter, so it remained on the helipad until the incident flight which departed for RAF Northolt shortly after sunset. Between 1300 hrs and 1700 hrs the helipad was subject to significant heavy showers and thunderstorms and, given its forward deployed location, it was not possible to shelter the helicopter during this period (Figure 1). The helipad's automated weather station recorded peak rainfall rates of 175 mm/hr and more than 50 mm total rainfall in the period 1300-2000 hrs (Figure 2), and the wind during this time was between 4 and 10 kt.

Figure 1

G-LNDN on the helipad at RLH during heavy rainfall

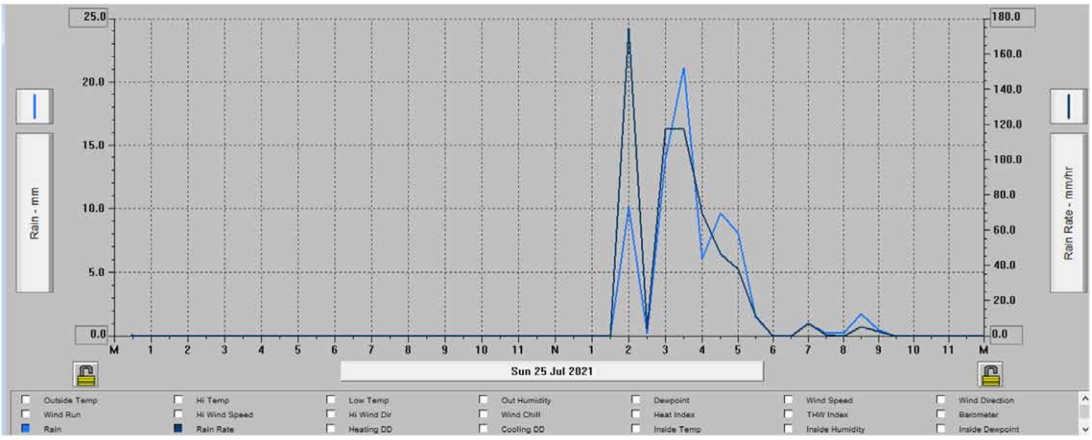

Figure 2

Rainfall chart for 25 July at RLH (times displayed are UTC+1)

At 2000 hrs the flight crew boarded the helicopter, along with two passengers, for the short flight to RAF Northolt. The start procedure was uneventful, but, having passed its built-in-test programme, the SAS would not engage prior to takeoff. Flight dispatch was conducted in accordance with the operator's minimum equipment list (MEL) which allowed day VFR flight with the SAS disengaged. The helicopter's planned flight profile would see it landing at RAF Northolt before nightfall.

After lift-off at 2014 hrs, the helicopter flew south to intercept the H4 London helicopter route above the River Thames, westwards towards Battersea. From Battersea the flight followed the H10 helicopter route to RAF Northolt (Figure 3).

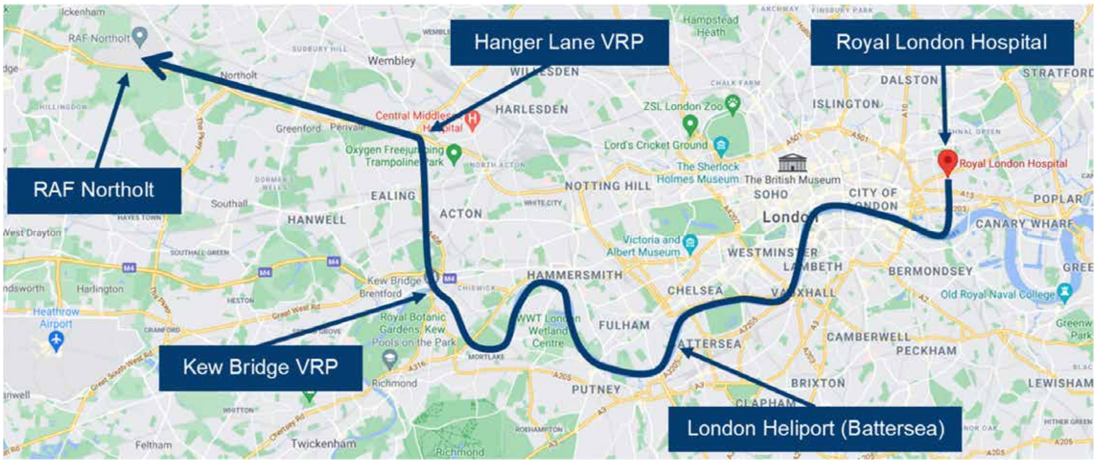

Figure 3

Overview of G-LNDN's planned route from RLH to RAF Northolt
(Map data ©2021 Google)

Shortly after passing the London Heliport at Battersea the commander's electronic horizontal situation indicator (EHSI) display (Figure 4) blanked. Then, as the helicopter approached the northerly turn at Kew Bridge Visual Reporting Point (VRP), the commander's electronic attitude display indicator (EADI) also began to fail, intermittently blanking and showing spurious caution messages. The co-pilot's electro-mechanical flight instruments were unaffected, and the flight continued northbound from Kew. Shortly after they turned westbound at the Hanger Lane VRP, the pilots were alerted to EEC system fault indications for both engines. Accompanied by an audio tone, a red FAIL warning indication on the helicopter's Integrated Instrument Display System (IIDS) (Figures 4 and 10) was displayed for the right engine's EEC (right EEC) and a yellow, non-critical failure, caution illuminated for the left engine's EEC (left EEC).

With just over three miles to go to RAF Northolt, the flight crew elected to continue to their destination as planned but the commander took control and the co-pilot assumed the role of Pilot Monitoring (PM). As part of their fault diagnosis the pilots noted that there was a torque (TQ) split between the two engines; the left engine was indicating approximately 47% TQ and the right engine was showing between 83 and 87% TQ. This was an abnormal indication because, with both throttles in the NORMAL detent, as they were, engine TQ's would normally be kept matched automatically by the EECs[1]. The pilots found that with its

Footnote

[1] See Aircraft information.

throttle in the NORMAL detent the right engine's TQ was fixed, but it could be successfully controlled with the right engine throttle rotated into the MANUAL range[2].

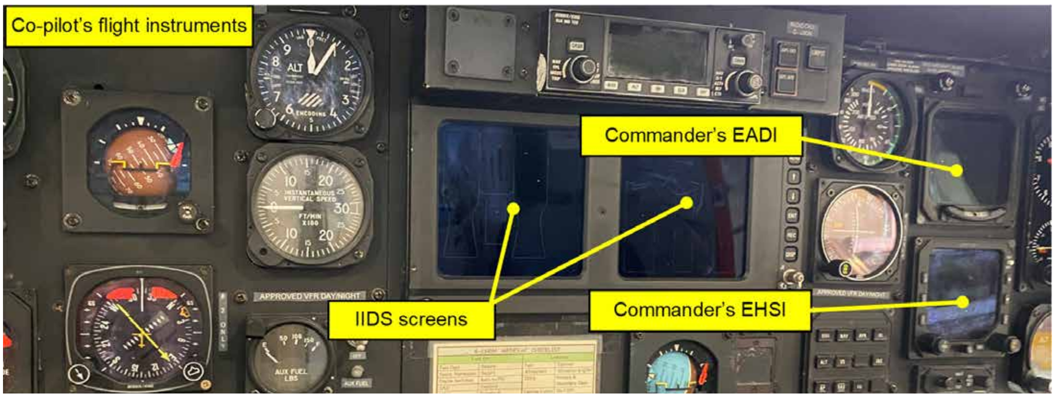

Figure 4
G-LNDN's cockpit instrument displays

The commander continued into the overhead of RAF Northolt to conduct fault diagnosis and to establish what level of automated engine control was available to him. After completing the two permitted reset attempts on each EEC, the faults remained. While it had a non-critical fault indication, the left EEC appeared to be controlling the left engine normally, so its throttle was left in NORMAL (automatic control mode) for landing. The commander then flew a slow, shallow approach to Runway 07, exercising manual control of the right engine's throttle. After a successful approach to a low hover at the runway midpoint, the commander was able to hover-taxi the helicopter to the apron where it touched down at 2046 hrs. The left engine was shut down using its rotary selector on the engine control panel (Figure 5), but, with its failed EEC, a manual shutdown procedure was required for the right engine.

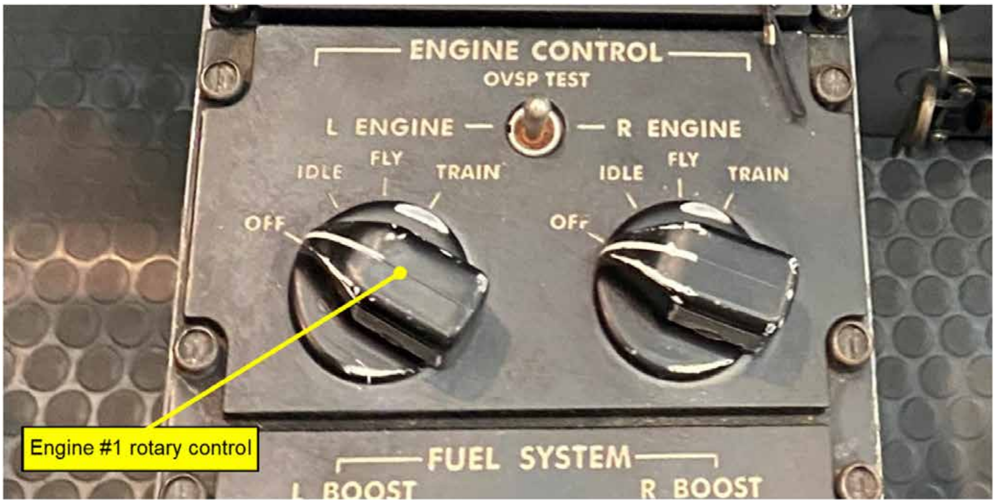

Figure 5
Engine control panel

Footnote

2 Although the associated MAN caution was not illuminated.

EEC malfunction procedure

Worldwide there are no simulators for the MD 900, therefore all practical emergency training is carried out on the helicopter. Training for EEC malfunctions was carried out on a regular basis and the crew felt adequately prepared for the emergency that faced them on the incident flight. Notwithstanding their preparedness for this event, the flight crew were confounded by the fault indications presented to them. From their interpretation of the Rotorcraft Flight Manual (RFM), it was not readily apparent that the non-critical fault presented for the left EEC was related to the critical fault of the right EEC. The pilots reported being further confounded in their fault diagnosis by the lack of a MAN indication on the IIDS when the right twist grip was rotated out of NORMAL.

Recorded information

The aircraft's flightpath from RLH to RAF Northolt was recorded by ground-based radar and a GPS-navigation software application[3] installed on a portable tablet computer used by the pilots. Ground-based recordings of radio communications between the pilots and ATC was also available for the flight. The helipad at RLH was monitored by CCTV, with recorded footage available for the period that the helicopter was on the helipad. The helicopter was not, and was not required to be, fitted with an accident-protected flight data recorder, image recorder or cockpit voice recorder.

The helicopter's IIDS was interrogated on the aircraft and subsequently downloaded. A fault message (Figure 6) relating to a loss of digital communications between the left and right EECs was recorded at 2028:49 hrs UTC (2128:49 hrs local time is displayed on the IIDS), which correlated with the pilots' account of when they had been alerted to the EEC system faults. Further information on this fault is included in the aircraft information section.

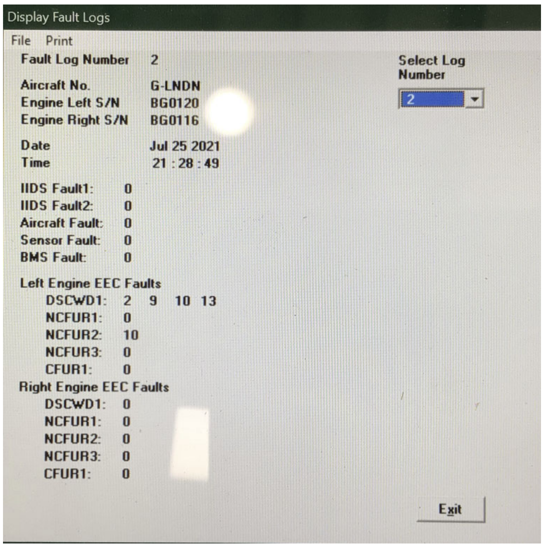

Figure 6

IIDS recorded fault message

Footnote

3 ACANS manufactured by Airbox systems.

Aircraft information

The MD900 is a light utility helicopter powered by two Pratt and Whitney turboshaft engines. The helicopter has a five-bladed main rotor and utilises a 'NOTAR' system which provides anti torque stability and directional yaw control without the use of a tail rotor.

G-LNDN is an MD 902 Explorer variant equipped with two PW207E engines. The engines are mounted behind the main gearbox on the 'upper deck' which forms the cabin roof (Figure 7), with the EECs and igniter boxes for each engine mounted in avionics racking within the rear baggage compartment. This racking is below the left and right engine compartments.

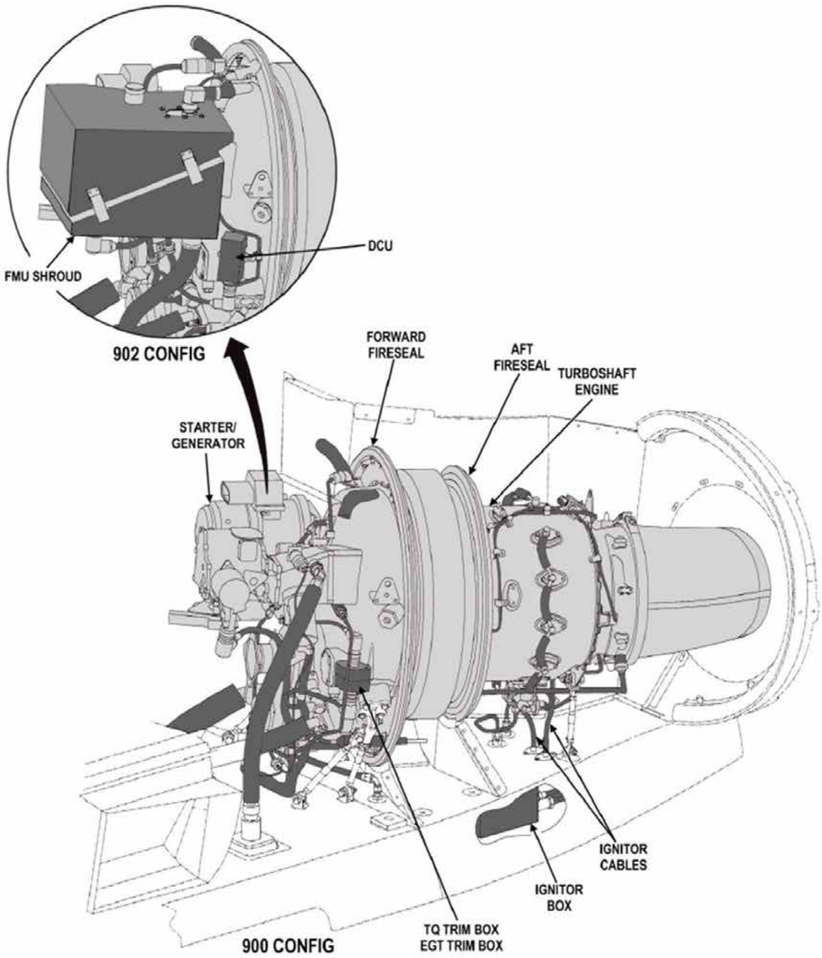

Figure 7

MD 900 left engine installation (reproduced with permission)

Each engine bay is partitioned by two firewalls. The engine's accessory gearbox and accessories, including the Fuel Metering Unit (FMU) and Data Collection Unit (DCU) are forward of the front firewall, and the engine turbomachinery to the rear of the aft firewall. The engine inlet plenum is located between the firewalls. The forward engine bay is accessed by lifting the forward access door, secured by quick access latches and can be opened without tooling. The inlet plenum cover houses the engine intake filter. The rear engine compartment is accessed by removing the rear engine cowling. The inlet plenum panel and the engine cowl are secured by screw fastenings and are only accessed during maintenance. The engine cowling has two mesh covered cut-outs, which allow airflow around the engine compartment (Figure 8). The floor of each compartment and the intake plenum has a series of drain holes to allow fluid that may enter the bay to flow out of it. The compartment to the rear of the aft fire wall is serviced by two drain holes. This compartment also has a series of thermal blankets covering the floor to protect the deck from overheating (Figure 9). These are secured in place using hook and loop fastenings. The thermal blankets lie over the drain holes, but do not obstruct them.

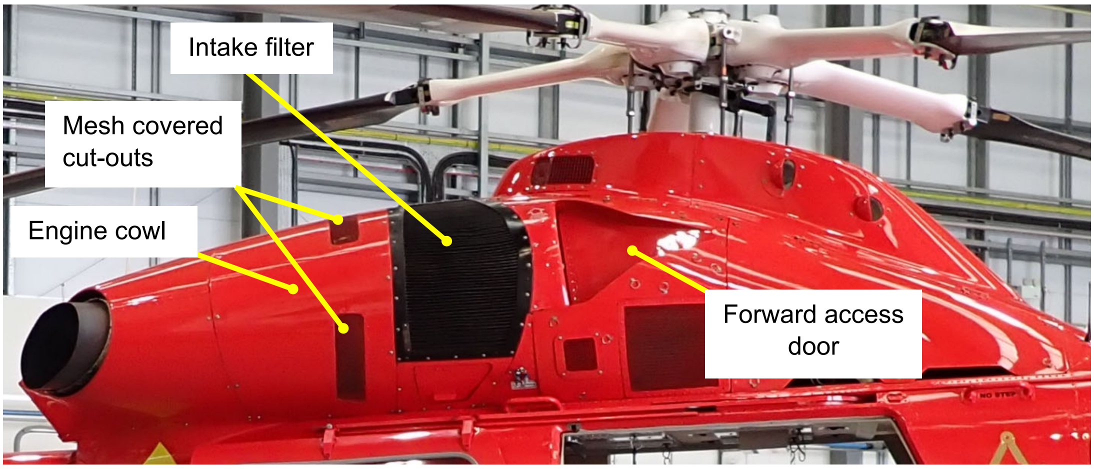

Figure 8

Right engine access doors and cowling

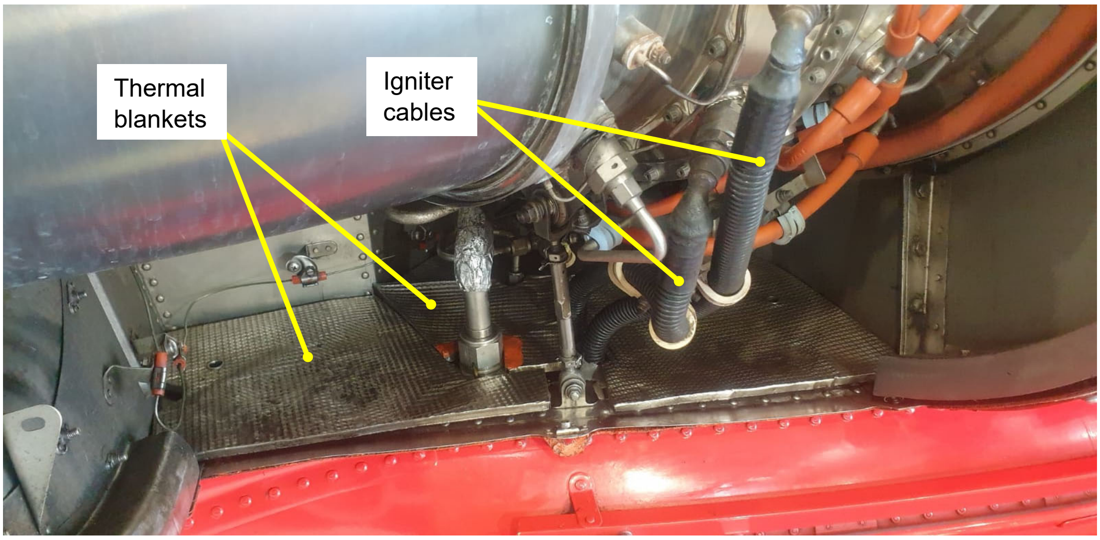

Figure 9

Rear engine compartment (right engine)

The igniter cables that connect the igniter box output to the engine igniters pass through the deck floor. The cables are encased within metal braided hoses which, in turn, are routed through a flexible sheath between the deck and the engine. The Rotorcraft Maintenance Manual (RMM) instructs the following when installing them:

> *'(7). Connect ignitor cables.*
>
> *(a). Route ignitor cables (11) though top of deck ….*
>
> *(f). Apply sealing compound (C215) to ignitor cable flanges and screws using fillet surface sealing and mechanical fastener sealing methods …*
>
> *(g). Apply sealing compound (C215) to ignitor sheath at top and bottom'*

Control of the engines is accomplished by a Full Authority Digital Electronic Control (FADEC) system. Each engine is controlled by a single channel EEC which uses incoming signals from engine and airframe transducers and converts them into a demand signal which is sent to the FMU to regulate the fuel flow to the engine. Each EEC communicates with the opposite engine's EEC through an ARINC[4] databus to torque match the engines. Each EEC is connected to a DCU which, in addition to storing engine performance settings, logs engine usage, status changes, events and faults.

The IIDS uses two liquid crystal colour display panels to provide engine and helicopter system information to the pilots, and they are mounted in the centre of the instrument panel (Figure 10). In addition to engine speeds, exhaust gas temperature and engine torques, the system displays cautions and warnings. It has a memory unit which stores fault information that can be downloaded to an external computer. Generated alphanumeric fault codes can also be displayed on the right display panel.

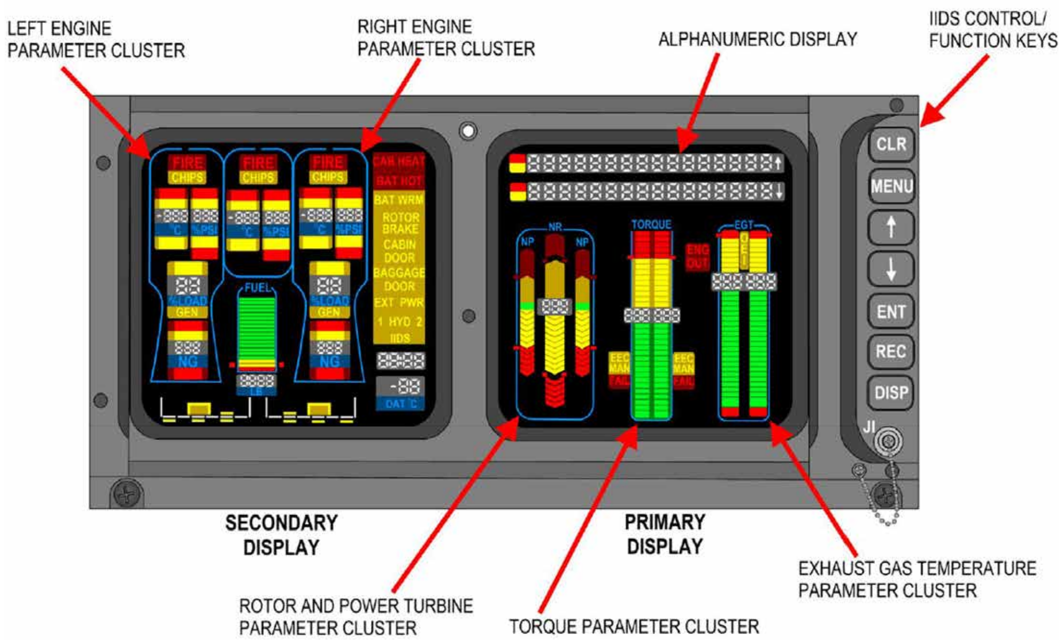

Figure 10

MD 902 [Integrated Instrument Display System] IIDS

Footnote

4 Aeronautical Radio Inc (ARINC) is an organisation responsible for aeronautical radio and communication standards.

If an EEC becomes inoperative the stepper motor in the affected engine's FMU is fixed at its last controlled setting. The engine can then be controlled using a manual back up system where a throttle twist grip on the collective can be manipulated to modulate the engine power. In this case the red EEC FAIL caption for the relevant engine will illuminate on the primary display. If an engine twist grip is taken out of NORMAL, the yellow MAN caption should illuminate; however, it may not if the EEC is unable to transmit digital data to the IIDS. If a non-critical EEC fault occurs the yellow EEC caption will be illuminated.

The helicopter was fitted with an Electronic Flight Instrument System (EFIS) comprising an EHSI and an EADI, both mounted in the commander's side of the instrument panel. A Symbol Generator, mounted in the rear baggage compartment, interfaces with the helicopter's navigation sensors to compute and send the information that is displayed on the instruments, it also outputs data required by other systems onboard the helicopter.

MD900 aircraft operated under Instrument Flight Rules are equipped with an Automatic Flight Control System (AFCS), which incorporates a SAS.

G-LNDN had been operated as an air ambulance since August 2015, and prior to this it had been operating in the Middle East. Since operating in the UK, the left engine had been removed once, but the right engine had not been removed. The certificate of airworthiness and airworthiness review certificate for the helicopter were in date and valid.

Aircraft examination

The helicopter was moved into a hangar after the incident and the AAIB assessed it the following day.

There was no external damage to the helicopter. Internally, the fuselage lining around the rear baggage compartment was damp and water was observed dripping from its seams. Once the lining had been removed areas of the inner surface of the fuselage were damp. Water could also be seen pooling in a floor recess which secured a crew seat stay.

The Symbol Generator was found to have streaking along its outer casing and a bead of water was noticed on its locking mechanism. When it was removed the underside of the unit was wet (Figure 11). The Symbol Generator was returned to its manufacturer for assessment.

The right EEC, which is positioned inboard of the Symbol Generator, showed evidence of having been in contact with water. The unit is mounted horizontally in the helicopter and accessed by removing the rear mounts and then lowering it, hinging around the forward mounts. As the unit was lowered, water was seen dripping from the ambient pressure tapping on the rear of the unit (Figure 12). Water was also found accumulated within the JI connector when it was disconnected.

Figure 11

Underside of Symbol Generator when removed from G-LNDN

Figure 12

Right engine EEC showing water dripping from ambient pressure tapping

An attempt was made to download the event logs stored on both EECs' DCUs whilst they were installed in the aircraft. The left engine's fault codes identified an '*ARINC communication fault'* which indicates a loss of communication with the opposite EEC. Following the fault, the event codes stored indicated that the crew made transitions from NORMAL into

MANUAL and back to NORMAL during the remainder of the flight. The first transition was approximately 30 seconds after the initial fault; left engine control then remained in NORMAL until approximately seven minutes after the fault, when it was cycled to MANUAL and back to NORMAL twice in 12 seconds. Throughout this time the ARINC fault remained.

The right EEC would not power up and therefore the DCU could not be interrogated to download any event logs. The right EEC and the DCU were removed from the aircraft and returned to the engine manufacturer for investigation.

The right engine cowling was removed allowing access to the engine bay. With the thermal blankets removed it was possible to see that the rear bay drain hole was partially blocked with debris; the forward drain was clear (Figure 13). Both drains were functionally tested and showed that they could both pass fluid to the overboard drain outlets.

Figure 13

Rear and forward drain holes in right rear engine bay

The amount of sealant around the right engine igniter cables as they passed through the deck was minimal. The outer sheaths between the deck and the engine could be moved away from the deck with little force (Figure 14). A liquid solvent degreaser was sprayed on the area where the igniter cable passed through the deck. A stream of solvent was immediately observed flowing into the rear baggage compartment from around the igniter cables. This fluid flowed directly onto the right EEC. A similar assessment of the left engine igniter cables was carried out. This found that the sealant was well applied around the igniter leads and no leaks were observed when solvent was sprayed at the interface. As the right engine had not been removed whilst it had been in operation in the UK, the sealant around the igniter leads is likely to have been applied when it was being operated by its previous operator.

Interrogation of the AFCS found that the cause of the SAS fault was an ‘analogue to digital bit stuck’, that could not be attributed to a particular issue. When powered up after the incident, the SAS functioned normally.

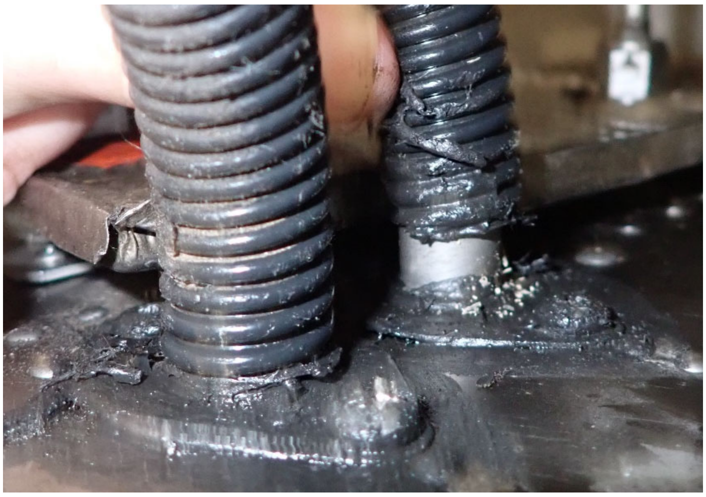

Figure 14

Right engine igniter cable sheath easily moved away from deck

Assessment of removed units at their respective manufacturers

Assessment of the Symbol Generator by its manufacturer found that although the unit turned on, there was electrical 'noise' on the display output. Detailed assessment of the power supply and circuit boards identified some corrosion on the Display Processor-HSI board which was likely to have been caused by exposure to water.

Assessment of the right EEC and its DCU found that, even after drying, the EEC would not power up. The DCU download did not show any information about the EEC failure but did record engine control being moved into manual. There were no further events logged on the DCU. It was considered most likely that exposure to water caused a short circuit on the power board causing the EEC to fail permanently.

Personnel

The commander had been flying MD 900 series helicopters for more than 15 years. The co-pilot had flown more than 14,200 hours on fixed-wing aircraft and helicopters and was in his second summer season as a contract pilot for the operator. He had previously been a helicopter pilot with the National Police Air Service but had not flown the MD 902 type before starting with G-LNDN's operator.

Weighing his greater experience on type, the commander elected to take over as PF shortly after the EEC malfunctions manifested themselves. He later reflected that, in doing so he increased his own workload unnecessarily, especially given the limited flight instrumentation available on his side of the cockpit and the co-pilot's experience level. While it did not detract from a successful outcome, he thought that, if faced with a similar situation in the future he would still take control for landing but would consider remaining as PM until fault diagnosis and approach preparation had been completed.

Other information

The operator's operating procedures define the provisions for mooring the helicopter during high winds and storm conditions. They stipulate:

> *'0.1.8 Rotor Tie-Downs and Helicopter Mooring*
>
> *During periods when very high winds are forecast, extra care must be taken. It may be necessary to anchor (picket) the aircraft itself to the ground. The aircraft rotor must be tied down in winds in excess of 35 knots to prevent possible damage to the rotor flexbeams.*
>
> *In winds greater than 40 knots or in severe storm conditions, the helicopter shall be secured in a suitable hangar. If a hangar is not available and the only option available is to leave the helicopter in the open, the helicopter shall be moored in accordance with the procedures described in the RFM Section 8 Page 8-9.'*

The RFM section 8-3 (pages 4 to 9) provides guidance for parking and storing a helicopter. The section describes the tiedowns and covers available to the operator to protect the helicopter '*from inclement weather conditions and other outside environmental factors that could cause FOD damage while the helicopter is parked, moored, or while in storage.*' and highlights in a note that *'The decision to use protective covers and tiedowns is determined by the prevailing weather conditions, length of storage/parking, and location.'* This section includes a description of covers for the engine area and upper deck (Figure 15). There was no guidance within either the operator's operations procedures or the RFM to protect the aircraft during heavy rain specifically.

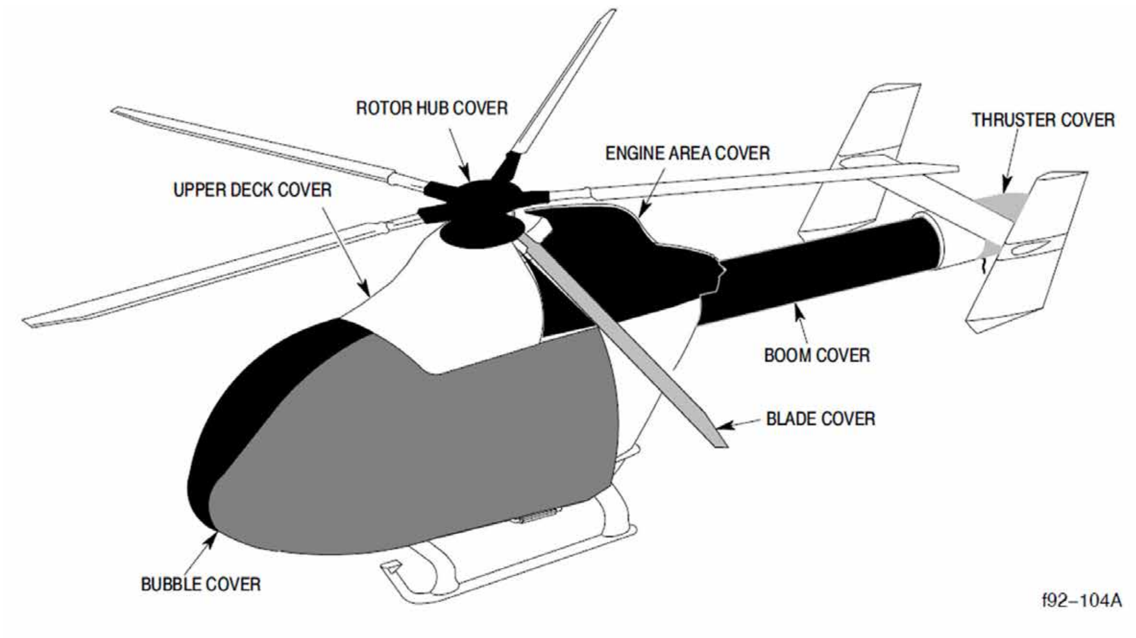

Figure 15

Covers available for the MD 900 series of helicopters

Analysis

The EHSI and EADI both failed during the flight because of a Symbol Generator malfunction. The right EEC FAIL warning indication on the IIDS was a result of the failure of the right EEC. This resulted in the MAN caption not illuminating when the pilot moved the right engine throttle out of NORMAL, because the IIDS only displays the EEC MAN indication when the EEC is transmitting digital data. The left EEC non-critical caution was due to an ARINC communication fault as the left EEC was unable to communicate with the right EEC for torque matching purposes. The left engine's EEC otherwise functioned correctly. Both the right EEC and Symbol Generator were mounted in the aft baggage compartment directly beneath the right engine and showed evidence of having been exposed to water.

G-LNDN had been parked on the helipad at the RLH at the time of heavy rainfall. During this time rainwater entered the right engine bay through the mesh covered cut outs in the engine cowling. The rainwater had then flushed debris in the engine bay toward the rear drain hole, which then partially blocked. Either because of the partial blockage of the drain hole, or through sheer volume of water overwhelming the drains in the engine bay, it started to fill. As the water level reached the igniter lead through-holes, water was able to pass into the rear baggage compartment because inadequate sealing round the igniter leads, which had been applied whilst it was operated by its previous owner, did not prevent water ingress.

The right engine had not been removed from the helicopter since it had been acquired from its previous operator. Without the intervention of an engine removal there would have been no need to remove the igniter leads and re-apply the sealing compound around the base of the igniter lead sheaths. As the engine bay cowling is only removed during maintenance inspection, pilots cannot assess the condition of the components in the engine bay during pre-flight checks. This therefore relied on maintenance inspections to assess the condition and cleanliness of this area. The positioning of the thermal blankets on the floor of the engine bay would have prevented the amount of sealant and the quality of its application from being easily assessed. It is also unlikely that the thermal blankets would have been removed during routine maintenance to expose this location. After the incident, the operator inspected the sealant around the igniters on the other MD 902 they operated and found it to be in good condition. The operator also instructed regular cleaning of the engine bays to remove debris and inspect the drain holes for contamination. It is good practice to maintain inspection and husbandry standards with all aircraft.

Had engine area or upper deck covers been used to protect the engine bays during the heavy rainfall, the pathway for the rainwater to enter the engine bay would have been blocked. The operator explored the feasibility of using engine cowl covers in addition to the tie downs and engine blanks already required, but this was considered detrimental to the operation of the helicopter when considering its three-minute launch target in its role as an air ambulance. The operator also identified risks of causing damage to the aircraft's antenna and creating possible foreign object debris (FOD) whilst removing the covers that protect the upper surfaces of the fuselage.

The commander reported that the failure of the SAS to engage after start was a rare occurrence on the MD 902 but the operator's MEL did permit day VFR flight with the SAS disengaged. The investigation found that the SAS fault was unrelated to the water ingress issue, and there were no other indications before liftoff to alert the pilots to the electrical failures that would later manifest themselves in flight.

While a distraction, the crew did not consider the commander's instrument display failures to be a significant problem because they were in day VFR flight conditions and the co-pilot's instruments were all indicating as normal. The subsequent EEC faults were less benign but did not pose an immediate risk to the helicopter. With both engines still developing sufficient power, the pilots were able to proceed to the RAF Northolt overhead where they could then fault diagnose and prepare for landing.

Had it been clearer to the pilots that the caution for the left EEC was due to its inability to communicate with the right EEC, the commander would not have taken the left engine out of the NORMAL setting to attempt an unecessary EEC reset. The lack of explicit explanation in the RFM of the potential for two separate EEC alerts relating to a single failure meant that a serviceable engine was temporarily put into manual throttle control mode when not required. While the pilots were able to diagnose that the left EEC was working satisfactorily, had that not been the case then a much more challenging double manual throttle approach would have been required. The manufacturer recognised that RFM guidance on EEC malfunctions could be more comprehensive and undertook to include additional information for pilots on EEC failure modes. The helicopter manufacturer proposed to re-write the *'EEC malfunctions'* section of the RFM to include the following text as a note:

> *'If a critical fault occurs on one EEC, a noncritical fault may occur on the other EEC. In this case, always address the critical fault first. If time permits, and it is safe to do so, the pilot may address the noncritical fault.'*

The commander considered that, with the additional knowledge and understanding of the faults that he obtained subsequent to the flight, he could have reduced his personal workload by staying as PM for longer.

Conclusion

During a period of heavy rain, water entered the right engine bay where it began to pool, possibly because of a partially blocked drain and possibly because of the sheer volume of water. Inadequate sealing of ignitor lead holes allowed water to enter the rear baggage compartment where the right EEC was located, causing it to fail. A resulting electronic communications failure with the left engine EEC caused a noncritical fault in that EEC.

The resulting events were handled effectively by the pilots, but a more comprehensive explanation of EEC system faults and reversionary modes in the RFM might have avoided any risk associated with unnecessary reset attempts on the left EEC.

Safety action

The following safety actions were taken.

> The operator inspected its other aircraft to ensure that the sealant around the igniter leads was applied correctly.
>
> The operator introduced additional maintenance procedures to ensure the engine bays remained clear of debris and the drains remained serviceable.

Published: 23 June 2022.