SERIOUS INCIDENT

Aircraft Type and Registration:	AgustaWestland AW139, G-CHCV
No & Type of Engines:	2 Pratt & Whitney Canada PT6C-67C turboshaft engines
Year of Manufacture:	2007
Date & Time (UTC):	23 December 2008 at 1405 hrs
Location:	The North Sea, 65 nm north-east of North Denes Heliport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 8
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilots Licence (Helicopters)
Commander's Age:	45 years
Commander's Flying Experience:	7,311 hours (of which 833 hours were on type) Last 90 days - 113 hours Last 28 days - 43 hours
Information Source:	AAIB Field Investigation

Synopsis

Whilst on a flight from North Denes Heliport to a North Sea drilling platform, the aircraft's crew alerting system displayed a VNE MISCOMPARE message. This was followed by the loss of No 2 engine indications and other aircraft system parameters. The No 1 engine parameters indicated normal operation and the crew elected to return to North Denes Heliport. Whilst still in cloud, the crew received indications that there was a fire in the baggage compartment at the rear of the aircraft. The commander then lost all altitude, airspeed and vertical speed information from his Primary Flight Display. Once below cloud, another company helicopter flew alongside G-CHCV and confirmed that there was no evidence of fire and a safe landing ensued.

The spurious warnings and the loss of indications were found to be due to corrosion in an avionic module. The corrosion had occurred due to the module cabinet being cooled by unfiltered, non-conditioned air drawn from intakes on the fuselage underside. The situation was exacerbated by the helicopter being operated in a maritime environment.

One Safety Recommendation is made.

History of the flight

The crew of G-CHCV were on their first flight of the day and were tasked to carry eight passengers from North Denes Heliport to the Noble Julie Robertson drilling

platform 88 nm to the north north-east. The en route and destination weather was forecast to be wind from 240° at 8 kt, visibility 6 km, overcast cloud at 1,200 ft and temperature 9°C.

G-CHCV took off at 1332 hrs and climbed to 2,000 ft on the regional QNH of 1030 mb where it was in IMC. The aircraft commander was PF in the right seat and the crew were in contact with Anglia Radar. The flight was uneventful until about 23 nm from the destination, when the crew recalled receiving a Crew Alert System (CAS) amber VNE MISCOMPARE message. This message is displayed when there is a difference in V_{NE}[1], as calculated by each of the two Modular Avionics Units (MAUs).

Immediately afterwards, the CAS displayed an ENG ANALOG FAILURE caution message, indicating the failure of an analogue engine parameter sensor. At the same time, information relating to No 2 engine systems was lost on the power plant page of the multi-function display (MFD). The crew reported losing indications of No 2 engine power index (a single scale composite display that provides the pilot with an indication of engine performance), inter-turbine temperature (ITT), oil temperatures and pressures and free turbine rotor rpm. In addition, they lost indications of the No 2 hydraulic system, the No 2 fuel quantity and the No 2 radio altimeter. There was also a caution message indicating failure of the No 2 pitot system.

There was no indication of a failure of the No 2 DC generator and the torque indication on the No 1 engine was indicating 50%. The crew assessed that these indications were consistent with both engines operating normally. They also concluded that the warnings and cautions displayed on the CAS were consistent with

failure of the No 2 MAU except there was no 2 MAU message displayed on either Primary Flight Display (PFD).

At 1401 hrs, the crew decided to return to North Denes and, after coordination with Anglia Radar, they turned right on track for the heliport and began a descent to 1,500 ft. During the descent, the CAS generated a BAG FIRE warning, with its associated aural warning, indicating a fire in the baggage compartment. There was no red light on the fire control panel, no smell of burning and no smoke visible inside the cabin. The crew were unable to check for smoke outside as they were flying in cloud and the PNF declared a Mayday. During the transmission, information from the No 2 Air Data System (ADS) disappeared from the aircraft commander's PFD and he lost indications of barometric altitude, vertical speed and airspeed. The PNF switched No 1 ADS information to the right PFD, which restored these parameters to the commander's display but meant that both PFDs were using the same source for information.

The crew decided to descend to VMC below cloud, expecting to have to descend to about 1,200 ft amsl. In the event, they descended to below 200 ft amsl, to be in sight of the surface, and found the visibility to be 2,000 m. They assessed that the sea state was suitable for ditching and briefed for such an event, in case it proved necessary. During the transit back to North Denes the crew were unable to couple the flight director to the autopilot. About 10 nm before reaching the heliport, indications of the No1 free power turbine rpm ($N_f 1$) and main rotor rpm (N_r) disappeared momentarily from both PFDs but there was no associated loss of power.

Just before reaching North Denes, a company helicopter flew alongside and confirmed that there was no smoke coming from G-CHCV's baggage compartment. At

Footnote

[1] V_{NE} the calculated helicopter never exceed speed.

1448 hrs, the aircraft landed without further incident. After landing, the passengers were evacuated, the aircraft was shut down and the emergency services inspected the baggage compartment to confirm that there was no fire.

Helicopter description

There are two basic variants of the AW 139: the 'short nose', which includes G-CHCV, and the later 'long nose', which include SAR aircraft. Approximately 170 short nose and 30 long nose aircraft are in service (as at February 2009), with the latter being the current production version.

The helicopter is equipped with the Honeywell Primus EPIC integrated avionic system, which was developed for fixed wing aircraft and currently equips types that include the Gulfstream IV and V, the Dassault Falcon X and Embraer 170/190 series aircraft. The AW139 is the first helicopter application for the system, with the type entering service during 2003. The EPIC system comprises two MAUs, each consisting of a cabinet that contains the functional modules, and each MAU has a main and auxiliary power supply. Should a MAU fail, multiple CAS cautions will be generated that could degrade the operational capability of the helicopter.

Description of the avionic system

1. Basic architecture

The Primus EPIC system architecture is the same for both the long and short nose airframes. However, in the long nose aircraft the MAU cabinets are located in the nose compartment, whereas in the short nose version they are installed either side of the baggage compartment aft of the cabin. Unlike all but one of the fixed wing installations, non-conditioned air is used for cooling the MAU cabinets. The MAU's function is to integrate the systems and sub-systems that supply the aircraft with navigation, communication, autoflight, indicating, recording and maintenance capabilities. Operation is via cockpit controls, sensors, displays and integrated computers.

At the heart of the system are the two MAUs; a generic block diagram of the system is shown in Figure 1. Each MAU consists of a cabinet equipped with Line Replaceable Modules (LRMs) which, for the AW139, may be different for each MAU, although most are duplicated. The module content can also vary between individual airframes: for example, MAU 1 contains a video module on Search and Rescue (SAR) aircraft, which are also flown by G-CHCV's operator. This processes the output from airframe-mounted video cameras. Communication and data processing within each MAU is managed by the Network Interface Controller/Processor (NIC/PROC), which also transmits and receives data from other systems on the aircraft on Aircraft Standard Communication Buses (ASCB) and Local Area Networks (LAN). A software function within the NIC/PROC monitors the aircraft systems and provides warnings, cautions and advisories through the CAS display.

Data from all airframe sensors are not wired directly to each MAU but wired separately to ensure segregation and to allow the MAUs to compare between duplicate sensors. Each MAU has visibility of data acquired by the other as, once acquired by the respective MAU, it is digitised and transmitted on the databuses. A majority of these parameters is acquired in the MAU Custom Input/ Output module (CSIO).

Engine parameters are acquired by the MAUs from the Electronic Engine Controllers (EECs). Each EEC collects data from sensors installed on its respective engine and digitises it. This data is then transmitted to both MAUs so that in the event of a MAU failure
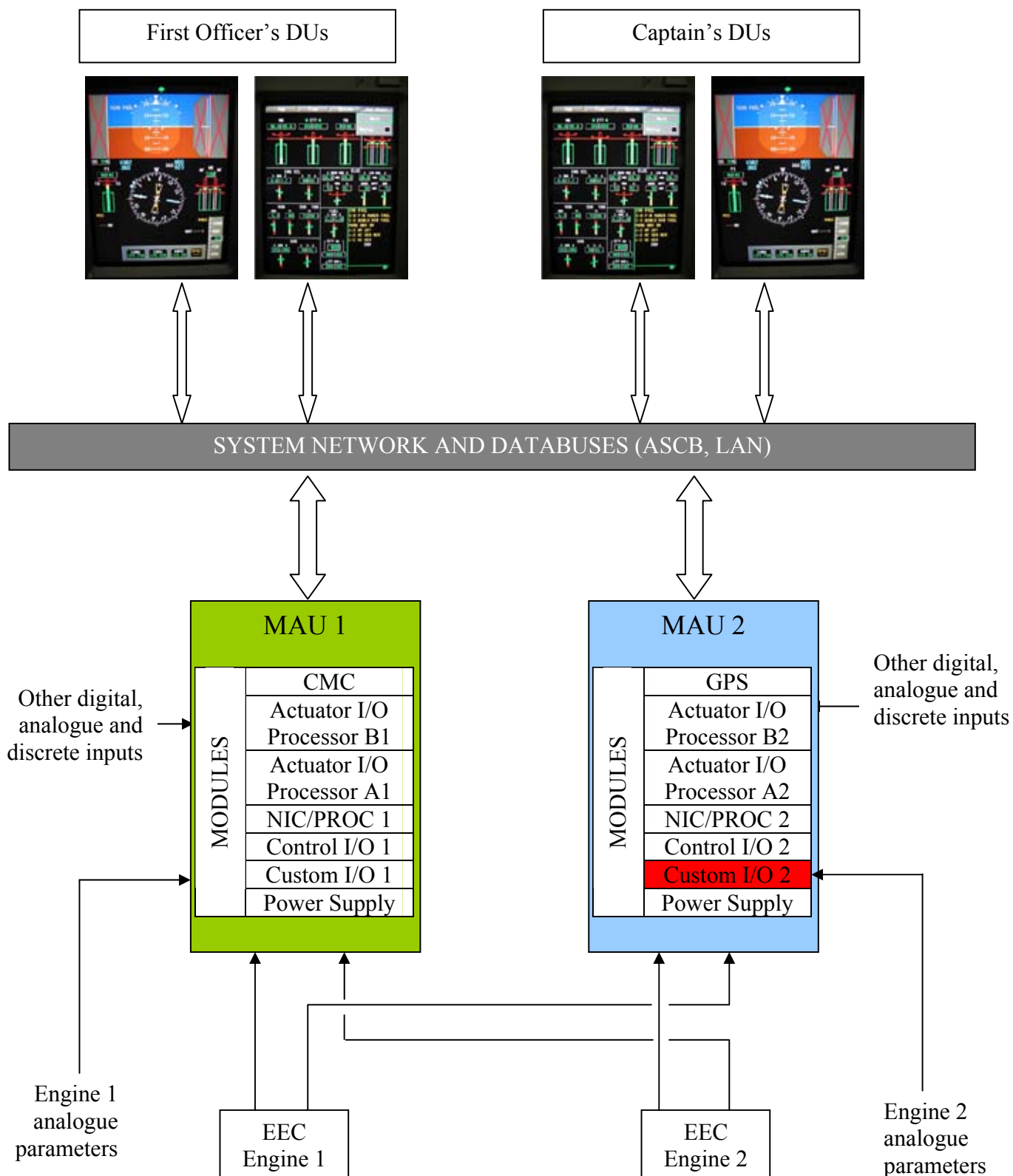
Figure 1

AW139 MAU installation

(caused, for example, by a power supply problem or a self-diagnosed shut-down), the data from both engines remains available. Data received from the EECs is referred to as 'digital' engine data. For redundancy purposes, some sensors are wired directly from the engine sensors to each MAU, bypassing the EECs. These parameters are referred to as 'analogue' engine parameters as they are acquired by the MAUs directly from the sensor. No 1 engine analogue parameters are only connected to MAU 1 and No 2 engine to MAU 2. The MAUs digitise the analogue parameters and transmit them on the ASCB. In the event of loss of any analogue engine parameters, an ENG ANALOGUE FAILURE message is displayed on the CAS.

Engine parameters are usually displayed on the MFD, with the system always defaulting (on power up) to the digital source. Logic within the Display Units (DUs) will always attempt to select valid engine parameters from the ASCBs. In the event of a fault with the digital data, the display can be 'forced' into analogue mode by using the cursor control device (CCD) on the cockpit pedestal to select a drop-down menu from the Powerplant system and selecting 'analog' from the options.

2. Module description

The modular design of the MAU provides flexibility in installation of the Primus EPIC system. Customisation of each airframe specific application is made possible by adding or removing the appropriate modules. In addition to the NIC/PROC, the MAU cabinets in G-CHCV also contained the following modules which were of relevance to the investigation:

- Central Maintenance Computer (CMC) Module. This contains the CMC function and the data loading function. It collects active

faults from member systems, conducts Built in Test (BIT) routines and compiles a Fault History Database (FHDB).

- Control Input/Output (CIO) module. This supplies an interface for external input/output data on the ASCB and other data buses. It also supplies an interface for the system display controllers, the multifunction cockpit display units and CCD devices and additionally contains audio warning circuitry for the crew alerting system.

- Custom Input/Output (CSIO) modules (one in each MAU cabinet). This module performs a similar function to the CIO, with more databus transmitter/receivers. There are also a number of additional aircraft-specific inputs, including analogue discretes and 28V dc. An example would be the bag fire sensor, which is processed in each CSIO module in MAU 1 and MAU 2, CSIO1 and CSIO2, respectively.

MAU installation

In order to meet the MAU installation requirements for the short nose aircraft, the helicopter manufacturer provided ducting that directed cooling air from two scoops on the underside of the rear fuselage. The ducts were asymmetrically disposed, such that the outlet of one of them was immediately underneath the MAU 2 cabinet. No outside air is used for cooling in the long nose MAU installation.

Honeywell specified the MAU installation requirements in an Installation Bulletin which details items such as dimensional, cooling and environmental requirements. Part of this bulletin highlights that, when installed in the airframe, the MAU must be protected against exposure to water.
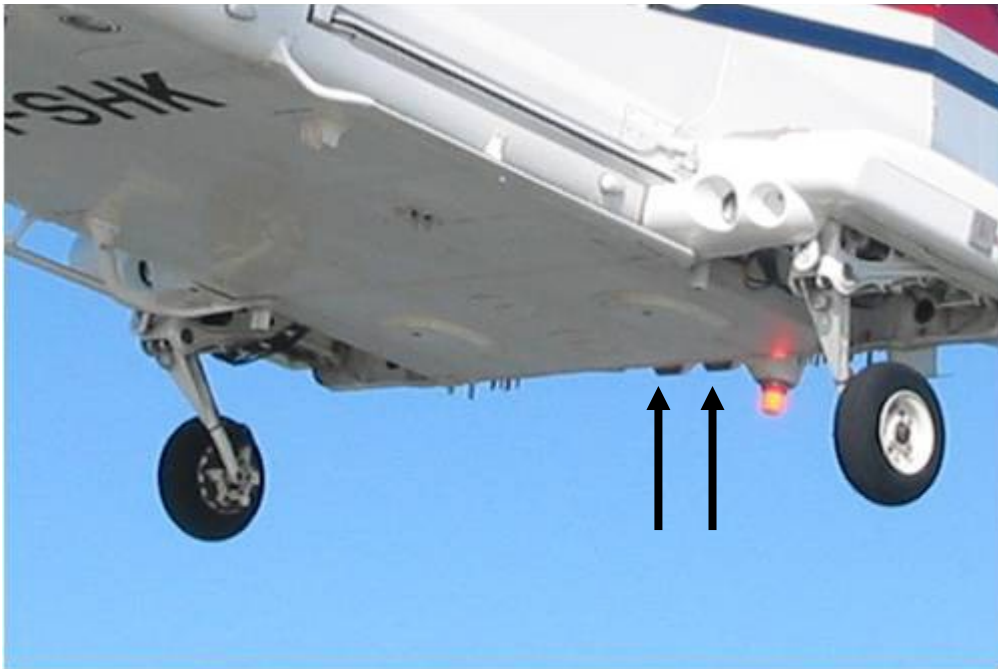
Figure 2

AW139 MAU Cooling Duct Intake Scoops

MAU hardware qualification

The environmental requirements for the MAU were agreed between Honeywell, AgustaWestland and the certification authorities during system development. These environmental requirements reference an RTCA document DO160D, '*Environmental Conditions and Test Procedures for Airborne Equipment*', which defines a series of minimum standard environmental test conditions and applicable test procedures. Standards within DO160D are commonly adopted by airframe manufacturers and recognised by airworthiness authorities.

Amongst the tests agreed were those for *'humidity and water proofness'* (sic), for which the MAU was found to be compliant. DO160D calls for the humidity test to be performed in a controlled test chamber but without requirements for the equipment under test to be operational. Compliance is achieved by removing the equipment from the test chamber after exposure and

applying power within one hour. A further 15 minutes is then allowed to warm up the equipment before determining whether or not susceptibility exists. For the water proofness tests, the manufacturer confirmed that the MAU was powered and suffered no failures when the environmental testing was performed.

The individual modules that are installed in each MAU were not required to be tested separately. Honeywell applied a spray-on conformal coating during manufacture which conferred a degree of water resistance. Whilst it is possible to provide a higher level of protection, for example by dipping the circuit boards into a container of the same liquid, it results in them being more difficult to repair during service.

Honeywell noted that no contamination-induced incidents had been reported in other Primus EPIC installations.

Baggage compartment fire detection

The baggage area is monitored by a smoke detector which is connected to both MAUs and the fire warning panel. If a baggage fire warning is detected, the crew should be alerted by a red light on the fire warning panel, a BAG FIRE CAS message and audio warning. The CAS warning will be displayed if either MAU detects a trigger from the smoke detector, but all audio warnings are generated by MAU 2. Figure 3 shows the system schematic diagram.

Recorded information

The aircraft was fitted with a Multi Purpose Flight Recorder (MPFR) which combined the functions of both flight data and cockpit voice recording. The MPFR was downloaded by the operator and provided to the AAIB for analysis. The MAU also contained a Fault History Database (FHDB) which logged detected failures for maintenance purposes. Due to late notification of the event, the voice recording was overwritten.

Data recorded by the MPFR is supplied by MAU 2, which transmits the same data as shown on the commander's displays. It indicated that G-CHCV was in cruise at a radio height of 2,100 ft, on a magnetic heading of 022°M and an indicated airspeed (IAS) of 145 kt. At 1358:48 hrs, the outside air temperature (OAT) parameter began increasing from 7°C and, over a 30-second period, reached 26°C, before failing (characterised by a drop to 0°C (see Figure 4). No 2 engine oil temperature, the tail rotor gearbox (TGB) and intermediate gearbox (IGB) oil temperatures and No 2 hydraulic system temperature also exhibited this characteristic rise, followed by failure. For clarity, Figure 4 only shows the OAT and No 2 engine oil temperature.

At the same time as the loss of these temperature parameters, data was lost from one of the two radio altimeters, No 2 engine ITT and, 20 seconds later, the No 2 engine power index. The loss of No 2 ITT caused the ENG ANALOGUE FAILURE warning and, five seconds later, the VNE MISCOMPARE warning was recorded.

V_{NE} is calculated as a function of pressure altitude and temperature. When there is a failure in the OAT probe, the V_{NE} computation is based on the current pressure altitude and the largest temperature value in a V_{NE} 'lookup' table. A VNE MISCOMPARE CAS warning is
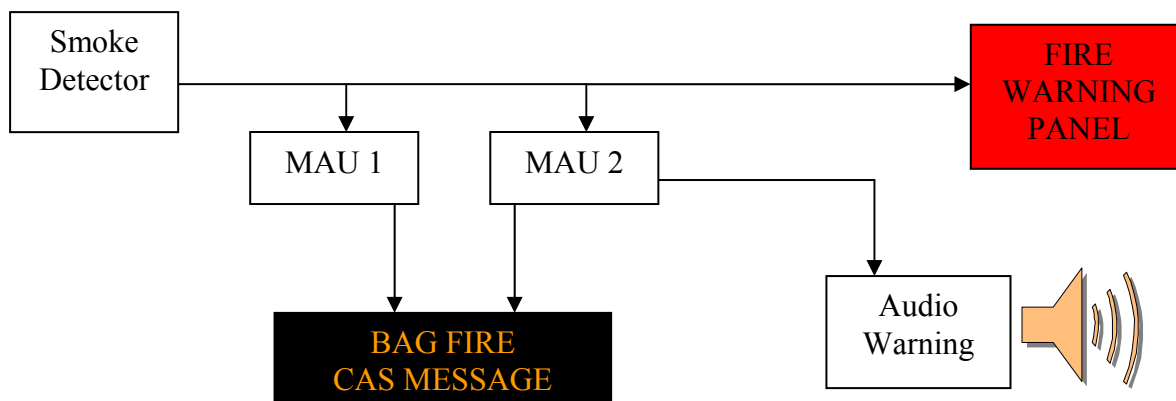

Figure 3

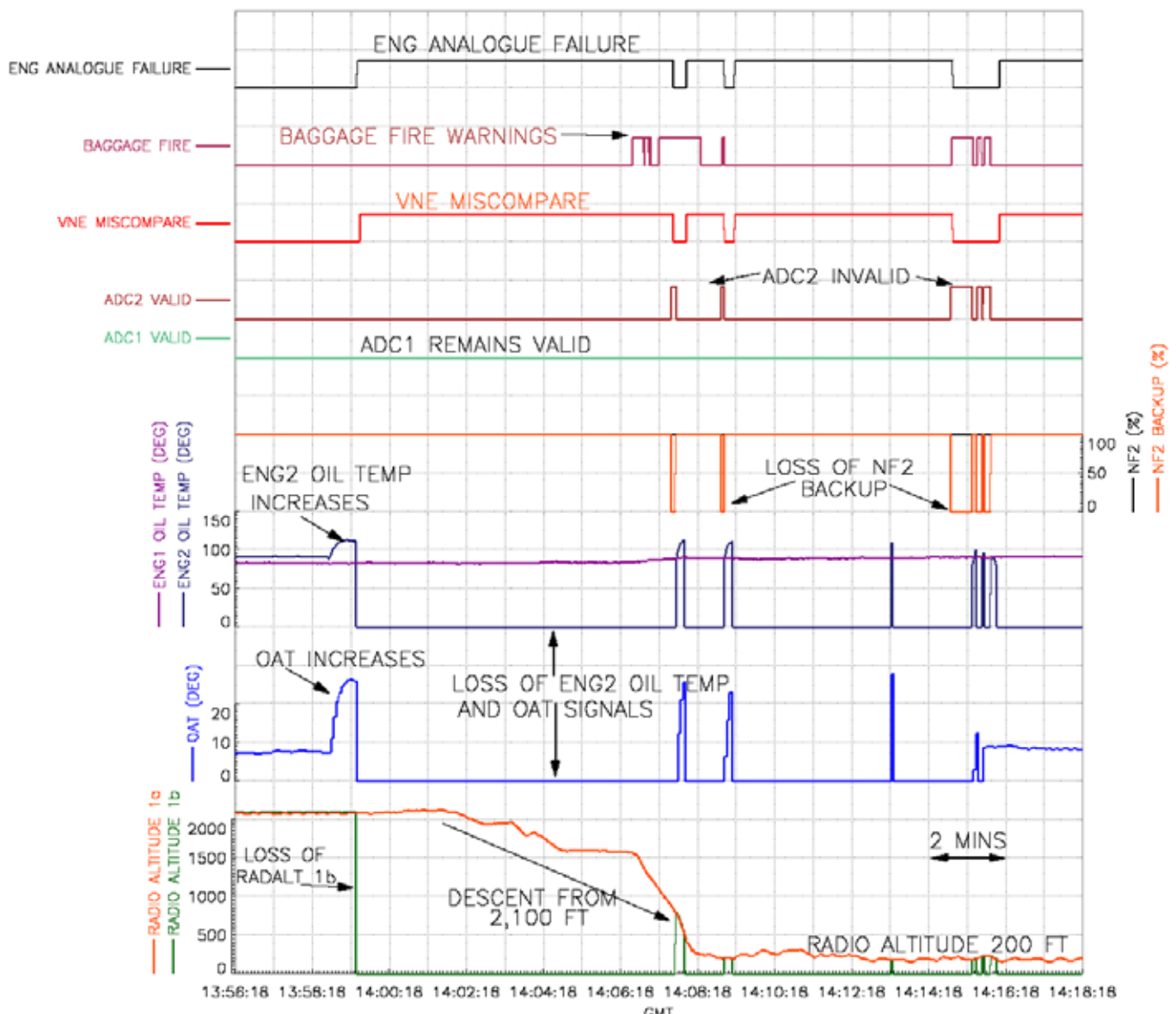The baggage compartment fire detection system schematic

Figure 4

G-CHCV MPFR recorded parameters

generated when the V_{NE} calculated by MAU 1 differs from that calculated by MAU 2.

At 1401 hrs, G-CHCV turned back towards North Denes and began a descent from 2,100 ft to 1,600 ft. Just over five minutes later, the first baggage fire warning was recorded. The descent then continued, with G-CHCV levelling off at a radio altitude of approximately 200 ft and an IAS of 110 kt. During this descent, the recorded data shows loss of further engine analogue parameters and the failure of No 2 ADC (Air Data Computer No 2). This loss of data appeared to be reversible, with some data apparently recovering but then failing again (Figure 4).

Also recorded were more ENG ANALOGUE FAILURE and VNE MISCOMPARE messages and a total of 25 separate baggage fire warnings. No loss of digital engine

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parameters was recorded and it was not possible to ascertain whether the digital or analogue engine parameters had been selected for display on the MFD. There is a flight recorder parameter which should indicate this but, after investigation it was found not to be working. The manufacturer has confirmed that this will be rectified in the next MAU software standard.

An analysis of the CSIO2 module FHDB from 14 December 2008 up to the incident flight did not reveal any other VNE MISCOMPARE, ENG ANALOGUE FAILURE or baggage fire warnings. Recorded analogue data from MAU1 revealed that at 1433:32 hrs, there was a momentary loss of No 1 engine N_g and N_f and the analogue N_r calculated by MAU 1. This loss of data lasted for between one and seven seconds and could not be explained by the manufacturer. All other failed parameters and spurious warnings were attributed to data generated by the MAU 2 CSIO card.

Similar incidents to AgustaWestland AW139 helicopters

During the investigation of the incident to G-CHCV, the AAIB became aware of three similar incidents:

1. An aircraft was transiting at 3,000 ft in IMC when a BAG FIRE message appeared on the CAS. There was no red light on the fire control panel. About 10 to 15 seconds later a list of cautions appeared, including an amber 2 MAU indication on the PFD. The crew began a descent during which the baggage fire indication disappeared. The crew declared a PAN and carried out the actions in the emergency checklist, following which the aircraft landed without further incident. No evidence of fire was found during the subsequent inspection.

2. An aircraft had been left out overnight during which there had been torrential rain. During the flight, whilst in IMC, the FDR FAIL and CVR FAIL CAS messages appeared followed shortly afterwards by ENG ANALOGUE FAIL and VNE MISCOMPARE. The warnings disappeared after a short time but later the BAG FIRE message appeared for approximately 10 seconds although there were no signs of fire or smoke. Later in the flight, the SERVO 2 message illuminated and, later still, a number of messages appeared including: NOSE DOOR; ENG ANALOGUE FAIL; VNE MISCOMPARE; 1 FUEL LOW; HOOK ARM; FLOAT ARM. While dealing with these indications, the crew noticed that the aircraft had descended from 8,000 to 4,700 ft. The autopilot was engaged but none of the flight director modes that had been selected were annunciated on the PFD. While climbing, following this uncommanded descent, the CAS displayed 1 ENG OUT followed by 2 ENG OUT. Other indications confirmed the engines were still functioning. The crew saw the ground through some breaks in the cloud and were able to descend and make a visual approach to a nearby airport. A number of CAS messages remained on the MFD until after landing.

3. An aircraft had made an approach to a hospital in poor weather and was climbing in IMC during a go-around from a missed approach. The pilot saw multiple CAS messages and noticed that the airspeed, altitude and radio altitude had disappeared from his PFD. He switched No 1 ADS information to his PFD, which restored the

lost parameters, declared a PAN and decided to fly another approach. While climbing to 2,500 ft, he switched guidance controllers and re-engaged the heading and altitude acquire modes, confirming that the correct annunciations appeared on the PFD. He began to programme the flight management system for a further approach when he was told by the crewman that the aircraft was approaching 3,000 ft. The pilot re-selected 2,500 ft and noticed that a rate of descent of 750 ft/min was being shown on the PFD. He began to review the CAS messages with the crewman and saw that failures were indicated in the following systems: electrical, fuel and hydraulic; flight management; weather radar; flight control unit and autopilot; GPS and other avionics and aid data. When he looked back at the PFD, the pilot saw that the aircraft was approaching 3,300 ft. He regained control and flew the approach but, once again, was unable to land due to the weather. He then undertook a manually flown diversion to a nearby airport where he landed successfully.

Initial investigation of the G-CHCV modules

As noted earlier, no evidence of a fire was found after the aircraft had landed. The aircraft was subsequently powered up electrically and the systems functioned normally, with no repeat of the multiple failure indications.

MAU 2 was removed from the aircraft, which allowed the associated wiring and connectors to be inspected for damage; no defects were found. The MAU 2 modules were then removed and visually inspected for water damage, overheating, or any other defect. The

fault history database (FHDB) generated by the Central Maintenance Computer (CMC) was downloaded and was found to contain a number of continuous failure entries. This, together with data from the MPFR, was reviewed by Honeywell, who advised removal of the NIC/PROC, power supply module and the CSIO card from MAU 2 and these were despatched to the manufacturer's facility. There, an examination, together with some initial tests, was conducted under the auspices of a local FAA official, who was appointed to look after the AAIB's interests.

The power supply module was found to be clean and functioned correctly on test. Similarly, no problems were found with the NIC/PROC module. However, inspection of the CSIO2 card revealed that it was contaminated with dirt and debris. In addition there was evidence of corrosion with what appeared to be copper oxide on the pins of some of the circuit card components. Figures 5a and 5b show photographs of the module and an example of the corrosion, the latter being from one of the Australian incident helicopters. It was then decided to conduct a series of tests on this module on Honeywell's MAU system test bench.

Tests on the CSIO2 circuit board

The presence of contamination and corrosion on the CSIO2 card strongly suggested that moisture had been present on the board during service and, thus, may have been responsible for the incident to G-CHCV, although no indications of water were apparent on the MAU modules after the event. However, during the investigations of the Australian incidents, water was found to be present in and around the MAU cabinets. Accordingly, it was decided to examine the behaviour of the CSIO2 card under damp conditions by subjecting it to a water spray during operation.

(Photo: Honeywell)

Figure 5a

A CSIO2 module

(Photo: Honeywell)

Figure 5b

Example of corrosion on another CSIO2 processor

Honeywell examined the CSIO2 module components with a view to establishing the input/output functions that were implicated in generating the invalid data that was responsible for the multiple CAS messages. Table 1 lists the signal inputs that were investigated.

The tests were conducted at a Honeywell facility in the presence of the AAIB and the helicopter manufacturer. The MAU system test bench was linked to an AW139 flight deck, which effectively functioned as a fixed base simulator. The system was loaded with the same application software standard which was installed on G-CHCV and the CSIO2 card was mounted on an extender board, which allowed it to be visible and accessible during test. The bench was then powered up so that any cockpit effects could be monitored. All the ASCB data generated during the tests was recorded and later analysed by Honeywell. This data represented everything that was available to the software responsible for such functions as the autopilot and cockpit displays.

The CSIO2 card operated normally, with no CAS messages. Thus it was considered that the contamination and corrosion had little or no effect when dry. The system was allowed to reach its working temperature, following which a short water spray, using deionised water, was applied to the area of the board that included, amongst other components, the central processing unit (CPU), which had the most corrosion. This resulted in a number of amber CAS messages, including VNE MISCOMPARE, although this subsequently disappeared. The OAT indication disappeared, followed by an ADS 2 failure message. This was accompanied by the loss of altitude, airspeed and vertical speed indications from the right hand cockpit display. These were replaced with

Signal Name	Signal Type
Analog ITT	Analog
No. 2 fuel pressure	Analog
Analog NG	Analog
Analog NF	Analog
Analog torque	Analog
Main Bus Voltage	Analog
Analog NR	Analog
Engine 2 oil pressure	Analog
Pitot 2 Fail	28V/Open Discrete In
Fuel quantity 1b	ARINC 429 Rx
No. 2 Hydraulic Oil Temp	Analog
Engine 2 oil temp	Analog
Fuel quantity 2b	ARINC 429 Rx
IGB temperature	Analog
Outside Air Temperature	Analog
Bag Fire Warning	28V/Open Discrete In
DC generator 2 amps	Analog
TGB temperature	Analog
Air Data Module	ARINC 429 Rx
Radar Altimeter	Analog

Table 1

red Xs, as occurred on the incident flight. In addition, some engine analogue indications failed, although the digital parameters remained.

After a few minutes the cockpit display indicated a slow decrease in altitude; there was no autopilot audio warning, although there was a chime. The observed effect was assumed to be the result of the loss of the No 2 ADS and appeared to mirror closely one of the Australian events. The problem was rectified by coupling the Flight Director to No 1 ADS.

A second water spray was then applied to the CSIO2 card, this time slightly away from the CPU, in the area of a bank of multiplexers. This produced no additional effects. A heat gun was used to dry the module, but none of the displayed faults unlatched. However, after MAU 2 was powered down and then restarted, all indications returned to normal.

Next, the spray was applied to the lower half of the CPU, with the remainder of the board masked off with a piece of card. This produced no cockpit effects, so the test was repeated with the complete CPU exposed, again with no effects. Two more sprays were applied close to the CPU, the second of which provoked three amber CAS messages and one red warning, MGB OIL TEMP. This represented the main gearbox over-temperature discrete, which was processed by the CSIO2 module. It was noted that the MGB temperature indication had remained within the green, ie normal, area of the indicating scale.

A reset operation was carried out in order to clear the CAS captions, followed by two additional spray applications. This produced the same captions as in the previous test, plus a drifting OAT 2 indication and the loss of some analogue indications. By this time the card was wet from the repeated spray applications, with the effects most probably becoming increasingly meaningless. However, it was decided to direct the final spray application in between the two circuit card assemblies that comprised the CSIO2 module. This resulted in three amber CAS captions, two of which subsequently disappeared. Then ENG 1 OUT, ENG 2 OUT messages appeared, together with the associated audio warning. There was also a momentary BAG FIRE warning. The module was then dried out but failed to reset, which suggested that permanent damage had occurred as a result of the repeated water applications. This was confirmed on a subsequent attempt to subject the module to an automated test, when the associated software failed to load.

An 'as new' CSI02 card was installed in the test bench MAU and a water spray applied to the general area of the CPU. After a few minutes the engine analogue data failed and an ADS2 message appeared, although all indications subsequently recovered to normal.

It was considered that the recovery of the replacement card, as it dried out, reflected the fact that the deionised water was of low conductivity, whereas, the contaminated components on the card from G-CHCV became conductive when wet, and remained so for considerably longer than with deionised water alone.

Finally, a fire detector sensor, which comprised a photoelectric device that operated on the light-scattering principle, was tested by spraying a water mist at it. This produced the appropriate warning when connected to a serviceable CSIO module.

Analysis of tests

After the tests, Honeywell conducted a detailed analysis of the extensive ACSB data, which was compared with the FHDB data from G-CHCV and the other incidents. The key findings are summarised as follows:

1. The tests reproduced the loss of engine analogue parameters, together with instances where digital engine parameter group data was recorded as *'invalid and stale'*. However, there was no effect on displays, as valid data continued to be supplied via MAU1. It was noteworthy that no similarly invalid digital engine parameter data was observed on the G-CHCV recording, although there was the loss of engine analogue parameters.

2. The data indicated that the CSIO2 module triggered the CAS BAG FIRE caption after water was sprayed between the two circuit boards of the module. Additional messages were generated simply as a result of water shorting out the 'Bag Fire 28V/Open Discrete' signal. However, it should be noted that the warning light on the Fire Control Panel is not connected to CSIO2 (or any other MAU module) and is only illuminated following activation of the bag fire sensor (see Figure 3).

3. The slow increase of the OAT 2 parameter seen in the G-CHCV MPFR data was also reflected in the ASCB data from the tests. One possible scenario was that failures in the analogue processors resulted in a loss of calibration, causing large changes in the calculated value. The software imposes a heavy filter on this value in order to damp out small fluctuations. Thus it would, in Honeywell's estimation, take around 30 seconds for the parameter to ramp up to a value where it became invalid, when the OAT display consists of a series of dashes. This represented a similar time period to the G-CHCV event, following which the signal was lost.

4. The OAT is used by the ADS, which in turn is used by the AFCS. If it determines that any differences between the ADS1 and ADS2 signals exceed monitoring thresholds, the AFCS declares that the ADS data is invalid. This results in the cancellation of Flight Director modes and the removal of the associated mode annunciations and guidance cues from the PFD. Other ADS signals monitored by the AFCS include Pressure Altitude, Altitude Rate and Calibrated Airspeed.

Finally, the investigation did not provide an explanation for the apparent loss of digital engine data reported by the crew of G-CHCV. During the tests, digital data remained available at all times, although the analogue failures were reproduced. Honeywell speculated that a graphical generation function software fault within the cockpit display units may have displayed the digital data as failed, when in fact it was valid. Alternatively, a similar software fault, either within the display units or the NIC/PROC, may have displayed analogue data despite digital data having been selected. However, Honeywell considered these scenarios to be unlikely in the light of a lack of other indications of hardware or software failures.

Examination of other MAU modules

In addition to the three incidents referred to earlier, other similar incidents came to light during the course of the investigation. Honeywell was also aware of a number of CSIO modules that their service centres had reported as displaying evidence of corrosion, although without associated incidents. Many of the modules were examined in Honeywell laboratories, which included energy dispersive X-ray analysis of the corrosion products. A high proportion was found to contain elements such as sodium and chlorine, which

was indicative of operation in maritime environments. Other contaminants were consistent with dust and dirt being blown into the MAU cabinet.

The investigation additionally found that CIO and power supply modules had been affected by corrosion, although there had been no resulting incidents. All the affected modules were located in MAU 2, with their location close to a cabinet vent which was, in turn, near to the cooling duct outlet.

Safety action

In April 2009 AgustaWestland issued a Service Bulletin, Bollettino Tecnico BT AW139-166, which applied to short nose configuration helicopters. The purpose of the BT was twofold. Firstly, the power supply, CIO and CSIO modules of *both* MAUs were to be inspected for evidence of corrosion. The BT contained guidance material on accept/reject criteria, in order to assist in this process. Secondly, the cooling air duct was modified so that the outlet was moved away from the lower surface of the MAU 2 cabinet.

This BT was applicable to 168 short nose AW139 helicopters and, at March 2010, had been completed on 137, not applied on one, with no information available on the remaining 30. Embodiment of this BT is not mandatory.

In the case of the BAG FIRE warnings, the absence of the red light on the fire warning panel indicated that it had not been triggered by the smoke detector. The investigation indicated that the warnings were generated by a spurious signal in CSIO2.

Shortly after this incident, the Flight Manual was amended so that the flight crew should only take action if all three indicators are present in the event of

a baggage fire warning, ie CAS message, red light on Fire Panel and audio warning.

Finally, as part of a product improvement update, Honeywell upgraded the Primus EPIC software to Phase 5 software in late 2009. This upgrade included correcting the problem of the MPFR not recording which engine parameters, analogue or digital, have been selected for display.

Analysis

1. Incident causes

The incidents involving G-CHCV and other helicopters occurred as a result of corrosion on the CSIO2 module installed in MAU 2. The corrosion had affected numerous pins on the components of the circuit board assemblies, which shorted out when they became conductive under the action of moisture, which in turn resulted in corrupted data being processed. In the case of G-CHCV, the resultant cascade of spurious warnings caused confusion on the flight deck as, in addition to the loss of ADS related information, the crew had difficulty in assessing the operational state of other aircraft systems. The BAG FIRE warning had a particular significance, as it raised the possibility of having to ditch, with the attendant risks to the aircraft and its occupants. Had the aircraft been equipped with the onboard video package, as installed in the SAR variant, the airframe mounted cameras could have been used to inspect for evidence of fire. Other incidents involved uncommanded descents, following disengagement of the autopilot and the potential risk to the aircraft with a busy, possibly distracted crew dealing with other CAS warnings. In all cases, upon reset on ground, the system recovered and the faults could not be reproduced during on-aircraft troubleshooting.

The nature of the occurrences, together with the detailed investigation conducted by Honeywell in support of the investigation, served to underline the complexity and high degree of integration of the Primus EPIC system. In particular, the level of integration resulted in an interdependency of the aircraft systems which rendered them vulnerable to what was, essentially, a common mode failure. This was abundantly illustrated by the fact that information from the engines, drive train, air data, fire detection and other systems is processed by the CSIO2 module; the redundancy conferred by multiple data paths is somewhat negated by this single point module.

The tests did not explain the apparent loss of digital engine data reported by the crew of G-CHCV; digital data remained available during the tests, although many of the analogue parameters had failed. The MPFR data from the incident similarly recorded no loss of digital data, although it was not possible to determine whether the digital or analogue displays had been selected. Honeywell investigated the possibility that a potential software failure could result in the cockpit display units and/or the NIC/PROC not displaying digital data or displaying it as having failed, despite there being valid engine data on the ASCB. However, there were no other indications of such failures, which would have been in addition to, and coincident with, the failures on the CSIO2 module. Despite the fact that the NIC/PROC was changed following the incident, it is considered that a failure of this nature was unlikely.

The cockpit displays would have defaulted to digital data when the helicopter was powered up. Changing to analogue data requires the use of a cursor control device and, hence, is unlikely to have been accomplished accidentally by one of the crew. A potential explanation is that the analogue display had been selected earlier in

the flight and subsequently was not reselected to digital. However, the crew did not recall having changed the engine data display during the flight.

2. MAU installation and validation

During the course of the investigation it became apparent that the issue of corrosion was widespread, although in many cases it had not progressed to the stage where it caused an incident. Whilst the corrosion had also affected other modules, the incidents invariably stemmed from the CSIO module in MAU 2. The source of the corrosion was attributed to moisture in unfiltered cooling air, which was drawn from a duct intake on the fuselage underside and discharged directly onto the MAU 2 cabinet, with the affected modules being located close to the cabinet vents.

The corrosion and the ensuing incidents are typical of development problems that can occur on new or, in this case, relatively new, aircraft types. This was the first helicopter application for the Primus EPIC, which differed from its previous, fixed-wing installations in that unfiltered, non-conditioned air was used for cooling. This, in combination with the helicopter's predominant operation at low altitudes in salt-laden air, generated the conditions that resulted in corrosion on the module components. With the benefit of hindsight, it might have been beneficial if the avionic and helicopter manufacturers had been aware of such a possibility and developed a temporary module inspection programme for the early years of service. Honeywell service stations were noting evidence of corrosion on modules returned for repair and had recently initiated an investigation.

As part of the certification process, the MAU had demonstrated compliance with the specified environmental standards; some confidence in the process has been demonstrated in that the incidents

discussed here have not occurred on any other Primus EPIC-equipped aircraft. With complex equipment it is difficult to predict, using failure mode/effect analyses, the full range of failure modes and their associated indications. Honeywell had anticipated the common mode failure of moisture ingress in the MAU cabinets and had addressed this by means of the requirements in the Installation Bulletin.

Environmental testing is unlikely to generate corrosion and its associated products. However moisture penetration may well produce the sort of problems likely to occur in service, a fact that was demonstrated during this investigation when a 'new' CSIO module was subjected to water spray tests.

Safety Recommendation

In the event of a common mode failure in part of an integrated avionic system, there can be potentially more serious consequences, relative to earlier generations of equipment, in terms of loss of essential parameter indications and spurious system warnings.

After extensive testing and investigation, it has been concluded that the Primus EPIC system MAU installed on the short nose version AW139 is susceptible to failures in the event of moisture ingress. Although measures have been introduced to remove a likely source of moisture, the modification to the ducted air supply to MAU 2 is not mandatory. As a result, the following Safety Recommendation is made:

Safety Recommendation 2010-077

It is recommended that the European Aviation Safety Agency mandate the embodiment of the AgustaWestland Bollettino Tecnico BT AW139-166 on all short nose versions of the AgustaWestland AW139.