INCIDENT

Aircraft Type and Registration:	Airbus A321-231, G-EUXL
No & Type of Engines:	2 International Aero Engine V2533-A5 turbofan engines
Year of Manufacture:	2007 (Serial no: 3254)
Date & Time (UTC):	20 December 2011 at 1542 hrs
Location:	Near London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 7 Passengers - 116
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	44
Commander's Flying Experience:	8,570 hours (of which 3,445 were on type) Last 90 days - 68 hours Last 28 days - 18 hours
Information Source:	AAIB Field Investigation

Synopsis

During the climb out from Heathrow Airport, both pilots experienced symptoms of dizziness and light-headedness. The pilots donned their oxygen masks and returned to Heathrow, where the aircraft landed without further incident.

No fault was found with the aircraft and no-one else on the aircraft experienced adverse symptoms. The incident uncovered a previously unknown fault with the cockpit voice recorder.

One Safety Recommendation is made.

History of the flight

The aircraft was on a scheduled flight from London Heathrow to Glasgow. The pilots were on their first sector of the day and were well rested; neither had flown the day before. The pilots met 15 minutes before check-in and, after going through security, each of them purchased a snack meal from a food outlet. They chose different meals but did not eat them prior to the incident.

Pre-flight preparation was routine and there were no aircraft or operational issues. Start up and taxi out were normal and the aircraft took off at 1520 hrs from Runway 27R. The commander stated that, on passing approximately FL120, she started feeling light-headed and slightly dizzy. The point at which she first experienced these symptoms coincided with her looking

down at the centre console to change a radio frequency, while the aircraft was rolling out of a 25° angle of bank (AOB) turn and the pitch attitude was increasing by 4°. The dizziness did not abate and, at FL210, she asked the co-pilot if she felt well. The co-pilot initially told the commander that she felt "OK", but shortly afterwards said she was feeling light-headed. Both pilots immediately donned their oxygen masks and the co-pilot levelled the aircraft.

The crew decided to return to Heathrow, declared an emergency and informed ATC of their intentions. The co-pilot asked which runway they could expect and was told Runway 27L. At an altitude of approximately 10,000 ft the crew were asked if they could accept Runway 27R for landing, to which they agreed. The crew requested a longer than normal straight-in approach and the aircraft landed safely at 1616 hrs.

After vacating the runway, the pilots removed their oxygen masks and, because some light-headiness returned, donned them again. Subsequently, as they approached their allocated parking stand they again removed the masks, this time with no ill effects.

Throughout the incident, there was no indication of an aircraft malfunction. The pressurisation system appeared to operate normally and the maximum cabin altitude indicated during the flight was 3,200 ft. Both pilots reported that they were not aware of any abnormal smells, smoke or fumes on the flight deck and none of the cabin crew or passengers experienced any ill effects.

Shortly after the aircraft arrived on stand, the Airport Fire and Rescue Service (AFRS) boarded the aircraft and examined the cockpit for smoke or fumes. None were detected. The pilots were examined by paramedics but neither showed any abnormal symptoms.

Medical aspects

The commander stated that she started to feel better shortly after fitting the mask but only felt fully recovered at an altitude of approximately 7,000 ft, in the descent. She also stated that she had recently suffered from a cold, although she felt fit to fly and had not taken any medication in the 48 hours prior to the flight. The co-pilot stated that she felt better approximately 5 seconds after donning her oxygen mask. She also stated later that this was the first time she could recall experiencing these symptoms in her 12-year career with the operator.

The following day the company flight operations department consulted a company doctor by telephone. The doctor informed the department that, as the pilots were no longer experiencing any symptoms or after effects, there was no need for them to be examined further. Both pilots have subsequently flown without a recurrence of these symptoms.

The investigation considered the following possible medical causes of the in-flight dizziness experienced by the pilots.

Alternobaric vertigo

This condition is caused by a difference between the left and right ear in the pressure felt across the tympanic membrane (or ear drum). An inability to equalise pressure across each ear drum at the same time, even to a mild extent, can lead to alternobaric vertigo. This effect can be aggravated by head movement as this may displace any residual nasal and Eustachian tube mucous. Alternobaric vertigo can also lead to mild disorientation.

Oculogyric disorientation

This condition occurs when the organs of balance within the ears become acclimatised to a prolonged turn and

therefore appear to signal that the turn has stopped, even though it is actually continuing. Once there is an actual cessation of the turn this causes further signals to be produced leading to a further sensation of a turn even when it has stopped. If this is combined with a concurrent head movement, the pilot may experience unexpected and significant sensation of motion. This can manifest itself as vertigo and a sense of nausea, with rapid breathing and resulting light-headedness.

Hyperventilation (increase in breathing rate)

The combination of mild disorientation and a sudden onset of alternobaric vertigo would easily lead to a period of hyperventilation. Hyperventilation can also be brought on by stress or anxiety. Hyperventilation can lower the partial pressure of carbon dioxide in the blood (hypocapnia) and this can induce a sensation of light-headedness.

Company procedures

The company procedures define incapacitation as:

> *'the inability to function effectively as a Crew Member, it does not necessarily involve loss of consciousness.'*

The company Pilot Incapacitation Drill states:

> *'If a pilot appears to be in any way incapacitated for no obvious reason, the flight Crew should don oxygen masks without delay.'*

The co-pilot had discussed the Pilot Incapacitation Drill in a recent flight simulator training session.

The company operations manual requires any crew member who becomes incapacitated in flight to consult a company doctor as soon as possible after landing.

Cabin air supply

During normal operation, bleed air is taken from the engine compressors and passed through an air conditioning system to provide a supply of temperature controlled fresh air to the passenger cabin and cockpit. The air supply can also be provided by the auxiliary power unit (APU) or a ground source via an external connection if required. (See Figure 1.)

Each engine supplies a separate air conditioning pack and the output of conditioned air from both of these packs is fed into a single mixer unit before being distributed to one of the three cabin zones (cockpit, forward cabin and rear cabin). The air temperature for each zone is controlled independently by mixing hot unconditioned air into the conditioned air supply to that zone. This unconditioned air supply is a combined single supply of hot air that is taken from the inlet for each pack.

Examination of the aircraft

The aircraft was inspected by the operator's maintenance personnel under the supervision of the AAIB. There had been no engine oil or hydraulic fluid uplifts immediately prior to the flight and the aircraft had not been de-iced. An initial visual inspection of the aircraft was carried out and the cockpit area was inspected; no anomalies were noted. Analysis of the recorded flight data showed that the bleed air, air conditioning and pressurisation system appeared to be working normally throughout the flight.

An extensive ground run test was then carried out, with the bleed air and air conditioning systems configured in various combinations and temperature selections. These systems operated normally and nothing unusual was observed. No adverse affects were felt by any of the personnel in the cockpit during these tests. The aircraft

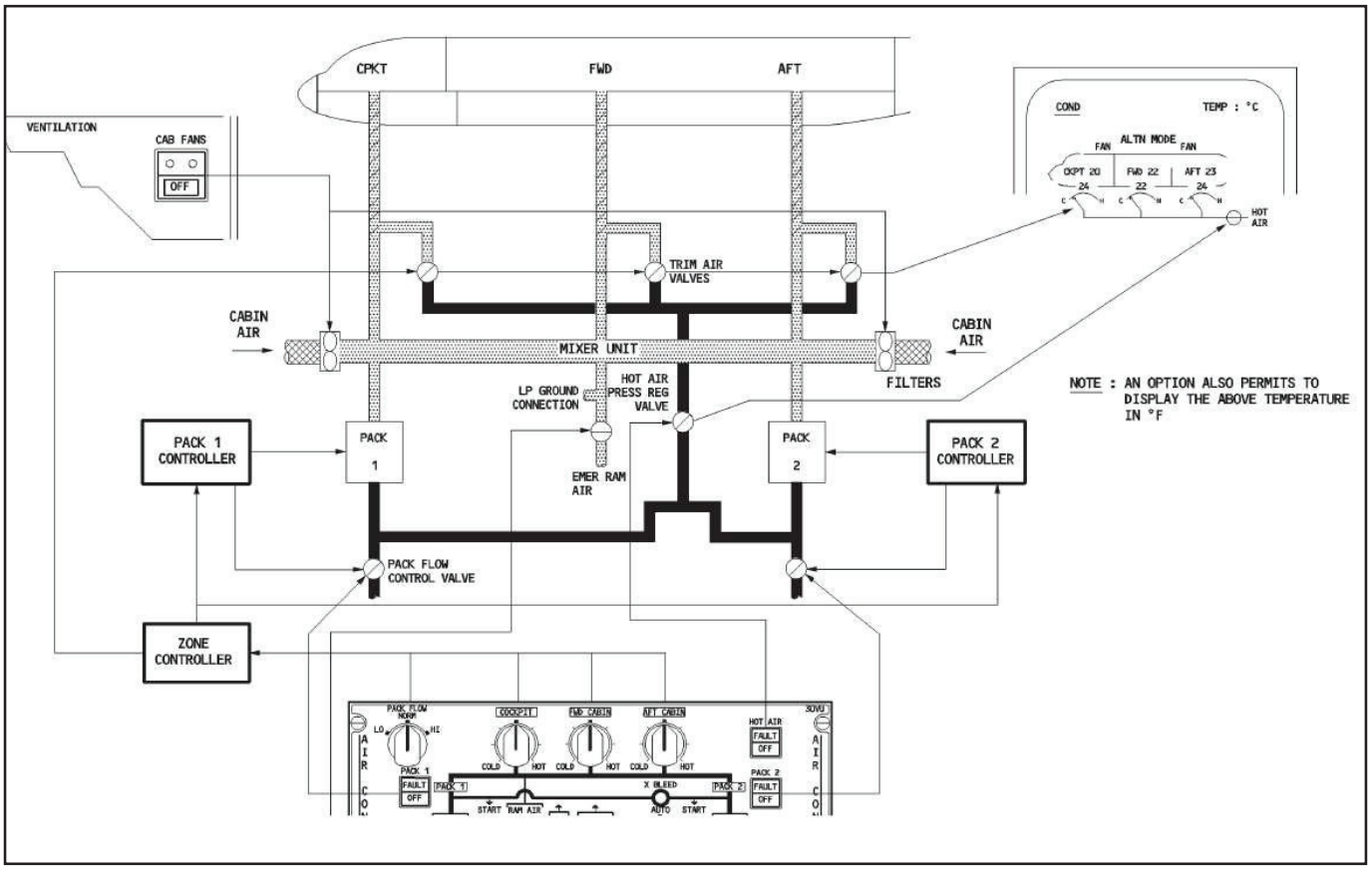

Figure 1

Schematic diagram of air conditioning system

bleed air and air conditioning systems, including the inside of ducting, were then thoroughly inspected. No anomalies or evidence of contamination were found. The aircraft subsequently flew without any reports of similar incidents.

Flight recorders

The aircraft was equipped with a 25-hour duration Flight Data Recorder (FDR), a Digital AIDS Recorder (DAR) and a 120-minute Cockpit Voice Recorder (CVR) that recorded audio to a solid state memory. FDR and DAR data was available for the entire flight. Also, the CVR provided a combined record of the commander's, co-pilot's and PA (Passenger Address) communications during the flight. However, due to a fault within the CVR, the Cockpit Area Microphone (CAM) recording was not available. The fault is discussed in detail in the following section titled CVR Fault.

The FDR and DAR data was analysed and no defect with the aircraft's environmental control system was identified. Figure 2 contains a plot of salient parameters commencing shortly before the flight crew felt unwell.

CVR Fault

CVR Description

The CVR[1] recorded a total of five audio channels to solid state memory. The CAM and a combination of the commander's, co-pilot's and PA/third crew member's

Footnote

[1] Honeywell manufactured Solid State CVR, part number 980-6022-001, serial number CVR120-08990.

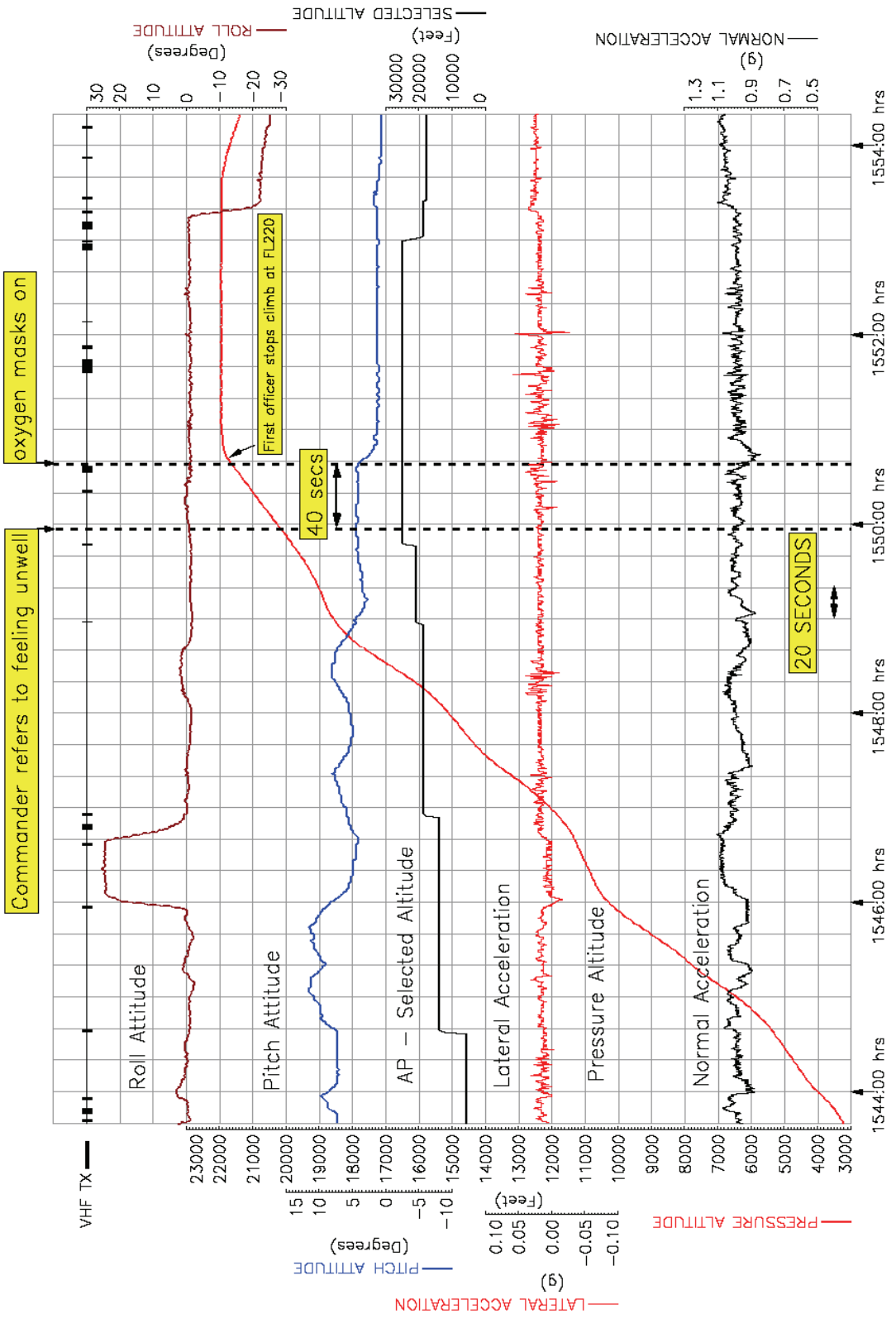

Figure 2

Aircraft attitude and vibration levels

communications are recorded to two 120-minute duration channels, and the most recent 30 minutes of the commander's, co-pilot's and PA/third crew member's communications to three separate channels (see Figure 3).

The CVR manufacturer refers to the CAM channel as the wide band (WB) channel, the combination of the commander's, co-pilot's and PA/third crew member's communications as mixed band (MB) and the three 30-minute channels as narrow band (NB). These terms are referenced for brevity where required.

The initial recording process consists of the analogue-to-digital conversion of the four audio signals. The commander's, co-pilot's and PA/third crew member's communications channels are also combined at this stage to generate the MB channel. The digital data for each of the five channels is then passed to a single integrated circuit (IC), referred to as the 'data packer[2]'. This component is central to the correct operation of the recorder. Under software control, the Data Packer component collects and packs the digital data into packets prior to it being written to the solid state memory. The data packer IC also forms part of the unit's Built-In Test (BIT) function.

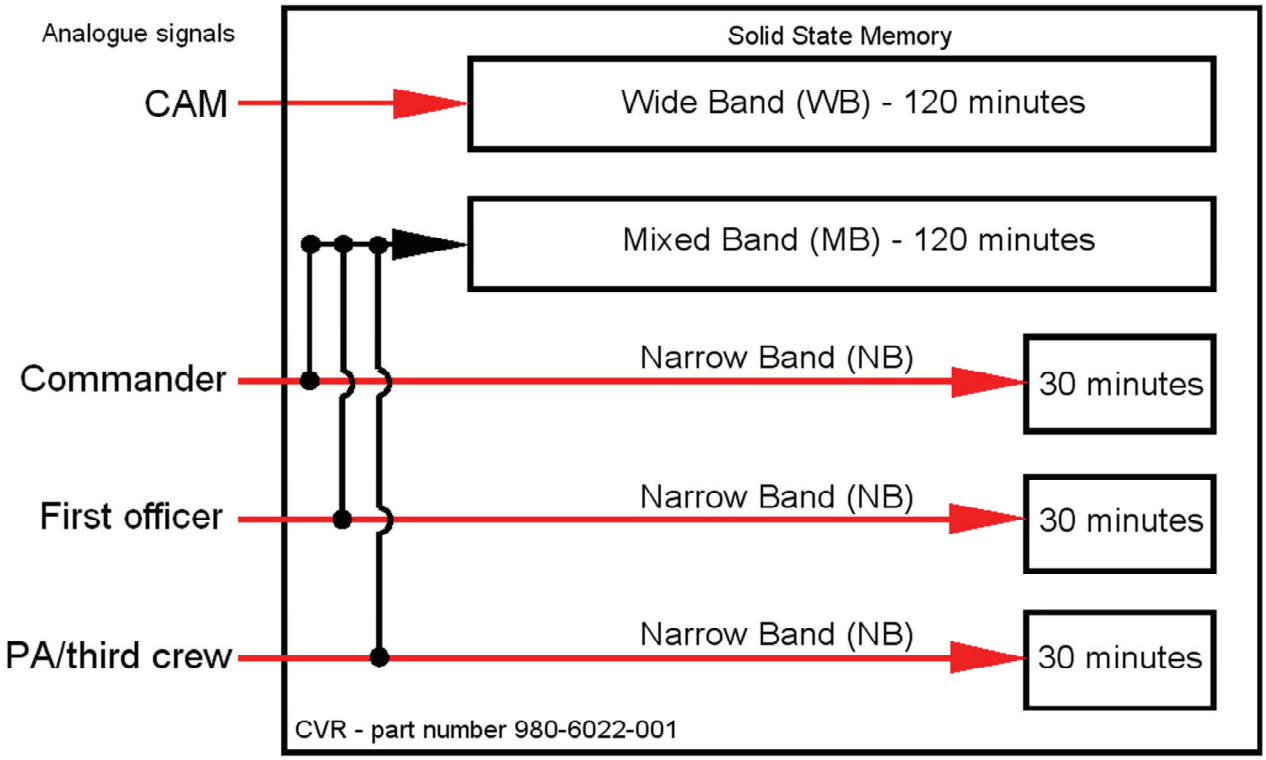

Figure 3

CVR channel architecture

Footnote

[2] Honeywell part number 718-1239-007. It is designated as component U21 and is installed on the system controller circuit card assembly (CCA), part number PN 722-4159-025. The component is a field-programmable gate array (FPGA) manufactured by Actel, with part number A1020B. A FPGA is an integrated circuit designed to be configured by the customer or designer after manufacturing. The component is widely used across industry.

The CVR's BIT function operates in one of three modes whenever the unit is electrically powered. The modes are Power-on, Background and Push-to-test. The Power-on mode is entered as soon as electrical power is supplied to the unit. Once the Power-on tests have been completed, the unit will enter the record mode and the BIT will enter the Background mode, which runs continuously unless the Push-to-test mode is activated or electrical power is removed. The Push-to-test mode may be activated by its selection on the CVR control panel, which is located on the flight deck. In the Push-to-test mode the unit performs additional tests over and above those conducted during the Power-on and Background modes. These include the use of a digital test pattern which is generated within the data packer IC. The data packer IC is permanently generating the test pattern, but it is intended that it should never be written to the solid state memory during normal recording operation. It is controlled by a multiplexer circuit within the data packer IC. When the Push-to-test mode is entered, the unit stops recording and switches the test pattern through the multiplexer circuit so that it is output from the data packer IC to the unit's recording circuitry, which is then tested by the BIT for the presence of the test pattern. The same multiplexer circuit switches the WB, MB and NB channels when they are to be recorded.

When the unit is recording, the BIT Background mode does not check for the presence of the test pattern being written to the solid state memory. The manufacturer advised that when the unit was in the record mode, it was not possible for the BIT Background mode to check for the test pattern as there is insufficient processing capacity.

If a fault is detected by the BIT, the unit's front mounted Built In Test Equipment (BITE) light will be illuminated, a failure message will be sent to the aircraft's central maintenance computer and a record written to a BIT history file, which is stored within the unit's solid state memory. When the unit's electrical power is cycled, the BITE light will be extinguished until a fault is detected again.

If no fault is detected during the Push-to-test, a tone will be generated and a status signal momentarily latched, which may be used to provide a visual indication in the cockpit. On G-EUXL, the tone is heard through the overhead speakers with no visual confirmation being provided. The CVR was not connected to the aircraft's central maintenance computer.

In addition to the Push-to-test, the unit provides a monitor function which loops back the incoming audio so that the serviceability of each of the channels may be established by speaking into each microphone and ensuring that the speech can be heard through a headset connected to the monitor connector. On G-EUXL, the monitor connector for the headset is located in the cockpit. The audio provided to the monitor does not pass through the data packer IC.

The unit also stores markers to the solid state memory whenever the unit enters the Power-on mode and when a Push-to-test has been activated.

Unit History

The CVR was manufactured in December 2006 and fitted to G-EUXL in September 2007. It had not been fitted to another aircraft and had remained installed until its removal following the incident. The operator had no history of a fault with the unit.

Erroneous audio recording and BIT history

The recovery of audio from G-EUXL's CVR required two processes. The first was to download the digital

information stored in the solid state memory; this was successfully completed. The second process extracted the five audio channels and converted them to an industry-standard audio file. It was during this process that the manufacturer's software tool, Playback 32[3], indicated an error. Analysis of the audio files identified that although the WB channel was of the correct duration, it was found to contain only 12 minutes (seven towards the beginning and five at the end) of normal audio from the CAM. The remaining audio consisted of an erroneous 'pulsing' sound. Further, several minutes at the beginning of the MB also contained an erroneous pulsing sound and the three NB files were of only five minutes duration.

From information provided by the manufacturer, the AAIB developed its own software tool which generated 30-minute records for each of the NB channels. The PA/third crew member's channel was found to contain 30 minutes of normal audio, other than at the beginning, where there was a very short duration erroneous pulsing sound. For the commander's and co-pilot's NB channels, only the most recent five minutes contained normal audio. The beginning of these channels also contained a very short duration erroneous pulsing sound, which was followed by 25 minutes of erroneously recorded silence. Figure 4 depicts the erroneous recordings on each channel.

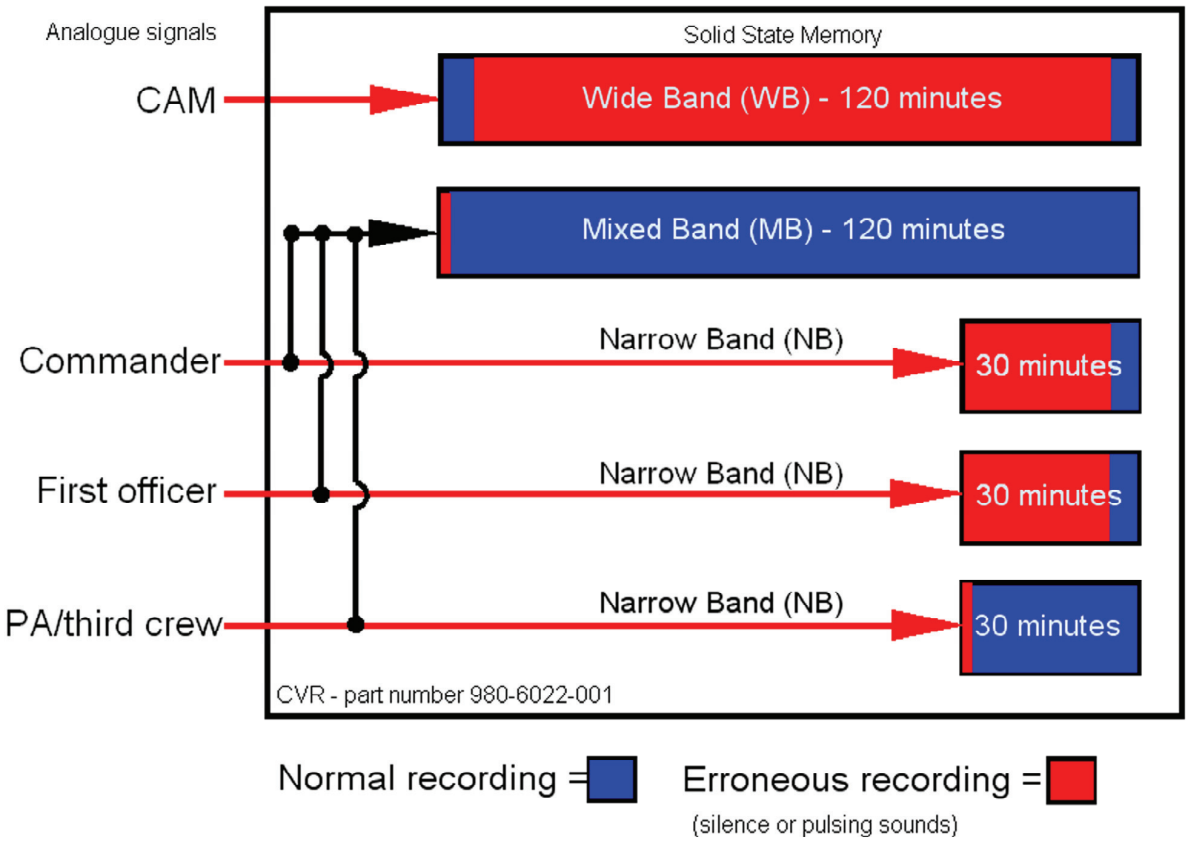

Figure 4

Erroneous recording

Footnote

[3] Honeywell manufactured software, part number 998-3414-509. This was the latest version released.

Analysis of the unit's BIT history by the manufacturer indicated that no fault had been detected during the period of the incident flight. The unit had operated for 17,286 hours and one fault had been detected. The fault occurred at 9,296 hours and related to the processing of the NB channels.

Through inspection of the Power-up and self-test markers, it was confirmed that the flight crew had carried out a Push-to-test on the unit shortly before the incident flight and that the unit's electrical power had been briefly cycled five minutes before the end of the recording as the aircraft's electrical power source automatically switched following engine shutdown. The electrical power cycle was found to coincide with the WB and NB (commander's and co-pilot's) channels returning to normal operation.

Testing by the manufacturer

The unit's lower cover was removed and the system controller circuit card assembly (CCA) was visually examined. No discrepancies were identified. The unit's record and Push-to-test functions were then tested using the Honeywell Automated Test System (HATS). No fault was found, having completed 3,548 test cycles over a period of about 12 hours; a unit would normally be subjected to one test cycle during a return to service test.

A test tone was then input to all four channels whilst the data packer IC was repeatedly heated and cooled. Shortly after commencing the test, multiple channels failed, with the recording of either no signal (silence) or the data packer IC test pattern. Cycling of the unit's electrical power or activation of the press-to-test was then found to return the unit to normal operation. The test was repeated a number of times and on each occasion at least one channel failed, with the channels affected and failure mode (silence or test pattern) varying randomly between each test. It was also noted that Playback32 generated normal length audio files, even though errors were present in the recording. The unit's BIT did not identify the failures.

Two further CVRs of an identical build standard were tested using these techniques but no faults were observed.

G-EUXL's CVR was then subjected to a thermal test, based on the one used during the manufacturing phase. The CVR was instrumented so that any erroneous recording could be identified. No fault was detected.

Inspection of the data packer IC and failure analysis

The data packer IC was removed from the CCA and inspected by a specialist company using a scanning electron microscope. Neither an external nor an internal inspection identified any defects.

The CVR manufacturer stated that although the physical inspection had been inconclusive, its analysis of the data and test findings indicated that the multiplexer circuit within the data packer IC was intermittently failing. Further, it considered the failure to be an isolated case.

Operational test requirements and routine readouts

The operator advised that, for its fleet of 87 Airbus aircraft, the flight crew were required to test the CVR prior to each flight by selection of the Push-to-test button in the cockpit. Additionally, once every 180 days, an operational test of each of the channels was conducted by engineering personnel using the CVR monitor function (refer to *CVR Description*).

The model of CVR in G-EUXL does not require any routine maintenance and will, typically, remain fitted to an aircraft until it fails or is removed for readout. ICAO recommends that annual readouts of the CVR are conducted and the EASA highlighted this in Safety

Information Bulletin (SIB) 2009-28, which discussed the detection of dormant failures. Currently, there is no EU-OPS regulatory requirement for an annual readout of the CVR. National Aviation Authorities (NAA)'s may impose their own requirements and, in the case of the operator of G-EUXL, they were instructed to readout annually a sample of CVRs that used magnetic tape as the recording media. Although many of its aircraft were no longer equipped with a tape-based CVR, the operator had continued to conduct two readouts each year on its solid state memory CVR-equipped Airbus fleet.

The operator advised that its readout process typically consisted of listening to the 30-minute NB channels in full, and then sections of the 120-minute WB and MB channels. The operator had readout a total of 130 CVR's of the same type fitted to G-EUXL. Discussions with a UK-based avionic repair facility that specialises in CVR readouts indicated that they typically conducted 100 to 150 readouts on the same type of CVR each year. Their replay procedure was similar to the operator's, in that sufficient audio was reviewed to validate that each channel was functional but did not extend to reviewing the full duration of each channel. Both the operator and avionic facilities replay techniques were in accordance with the guidance contained within UK CAA Publication CAP 731, *Approval, Operational Serviceability and Readout of Flight Data Recorder Systems and Cockpit Voice Recorders.* Neither the operator nor avionic repair facility had observed a fault similar to that on G-EUXL's CVR.

Testing of the unit within an avionic repair facility is conducted in accordance with the manufacturer's Component Maintenance Manual (CMM), using approved test equipment. Testing is largely automated and includes a test of the unit's ability to write data to the solid state memory. There is no requirement or recommendation in the CMM to download the unit and evaluate the recorded audio for erroneous recording, as part of the fault finding, testing or recertification phase.

Previous occurrences of the fault

The design of the CCA and associated implementation of the data packer IC dates back to 1993 when the manufacturer introduced its first 30-minute duration solid state memory CVR. There are now approximately 25,000 units in service that are based on the same design.

The AAIB had replayed approximately 250 units and the manufacturer estimated that it had replayed about 1,000. Neither had observed a similar fault before. In addition to reviewing audio files aurally and visually, the manufacturer generated a software tool that it used to scan 79 readouts digitally for the presence of the test pattern. No faults were found with these units.

In an attempt to determine if a similar fault may have gone unreported to the manufacturer, and to gather information on the number of the units analysed in detail, the AAIB contacted several international accident investigation laboratories. The Australian Transportation Safety Board (ATSB), Bureau d'Enquetes et d'Analyses Pour la Securité de l'Aviation Civile (BEA) of France, National Transportation Safety Board (NTSB), Transportation Safety Board (TSB) of Canada and National Research Council (NRC) of Canada all provided information. None of the laboratories had observed a fault of the same type before.

Figures indicate that, since 1993, approximately 3,000 units have been replayed by a combination of the manufacturer, the AAIB and the other accident investigator authorities mentioned above. It is unlikely that all the units were of the 120-minute duration model, but had they been, this would equate to a total of 6,000 hours of audio being analysed. On G-EUXL, the annual operation of the CVR averaged 3,850 hours. Based on an annual industry average of 3,000 flight hours per aircraft (mix of long and short haul routes),

the operator's 198 aircraft, equipped with the same model of CVR, operate for a total of approximately 594,000 hours per year.

Analysis.

The commander of the aircraft experienced symptoms of dizziness during the climb and, when the symptoms did not abate, made the co-pilot aware. At this stage, the co-pilot was feeling well but, shortly afterwards, started to feel light-headed. Realising that they were both experiencing adverse symptoms without any obvious reason, and mindful of the possibility of incapacitation, the pilots immediately carried out the Pilot Incapacitation Drill as a precaution and donned their oxygen masks. Although the symptoms abated, the pilots took the precaution of continuing to wear the masks until after the aircraft had landed. Meanwhile, they were able to continue to operate the aircraft effectively and carried out a normal approach.

The commander's symptoms of light-headiness and dizziness started when she moved her head to look down at the centre console to change a radio frequency and this point coincided with a 25° AOB change and a 4° pitch attitude change. As a result, the commander may have suffered a disorientation episode caused by a combination of oculogyric disorientation and an alternobaric episode made more likely by the lingering effects of a cold. The resulting natural instinct to hyperventilation could lead to hypocapnia which may well have contributed to the feeling of light-headedness.

The onset and clearance of the co-pilot's symptoms within approximately 25 seconds may have been a reflection of the potentially evolving situation of crew incapacitation at an early stage in the flight leading to mild hyperventilation. However, the symptoms she experienced were unique in her 12-year career with the operator.

The reason for the dizziness experienced by both pilots when they first removed their oxygen masks on the ground could not be positively determined but it is possible that it was caused by the effect of a sudden reduction in inspired oxygen concentration on cerebral oxygenation, blood flow and pressure.

Whilst the company operations manual requires any crew member who becomes incapacitated in flight to consult a company doctor as soon as possible after landing, the crew were still able to operate the aircraft as effective crewmembers and, by definition, were not incapacitated. However, the operator did consult a company doctor and was advised that they did not require any medical treatment. Both pilots returned to flying duties without a recurrence of the symptoms they had experienced.

No anomalies were found with the bleed air and air conditioning systems during the ground tests or inspections and there were no signs of contamination. The recorded data shows that all relevant systems appeared to be working normally throughout the flight.

CVR issues

It was demonstrated that the CVR's erroneous recording of both erroneous silence and a pulsing sound was a result of an intermittent failure of the data packer IC. The physical inspection of the IC was inconclusive, although analysis of the data and test findings by the manufacturer indicated that the multiplexer circuit within the IC was at fault.

It was shown that the CVR's BIT function was ineffective in identifying the fault, and the design of the audio monitor function is such that the erroneous audio would not be evident at the monitor output. Thus, neither the Push-to-test nor the operational test of the CVR on the

aircraft would have been able to identify the failure. The intermittent nature of the fault also meant that the unit was able to pass both the manufacturer's return to service test and a test used during the manufacturing phase. It is, therefore, possible that the fault had been present since the unit had been manufactured in 2006.

The initial indication of a fault occurred during the replay, when the manufacturer's software tool, Playback 32, generated shorter than expected NB audio files. However, during testing it was shown that shorter than expected audio files may not always be created by Playback 32 when a fault is present. Therefore, the only reliable method of determining if a fault of this type had occurred would be to conduct a thorough review of the audio file for each channel during readout.

The AAIB established that approximately 3,000 CVR's based on the same design as that of G-EUXL's had been analysed previously by a combination of accident investigation laboratories and the manufacturer. The operator had also obtained readouts from 130 units and the avionic repair facility from approximately 2,000 units. No similar faults had been observed during these readouts, although it must be noted that the operator and avionic repair facilities readout process did not check the full duration of each channel for errors, and so it remains a possibility that erroneous recordings may have gone undetected. It is reasonable to assume that other operators and companies offering a readout service would conduct readouts in a similar manner.

The manufacturer considered that the failure of the data packer IC was an isolated occurrence. This in part was supported by having no previous reports of a similar failure. The units that have been analysed in detail by accident investigators and the manufacturer represented about 12% of the total units manufactured. However, as the fault has been shown to be intermittent in nature, the significant measure to consider is the analysis of operational (recorded) hours since the units were introduced in 1993. The exact number of aircraft equipped cannot be determined easily, although if only 100 units had been fitted to aircraft since 1993, the operational hours would have reached nearly six million (based on an aircraft operating an average 3,000 flight hours per year); the estimated 6,000 hours analysed in detail by accident investigators and the manufacturer would reflect just 0.01% of this. Equally, if an annual readout was performed on every aircraft per year (which it is not), this would equate to a sample size of just 0.07 % for each aircraft (based on 3,000 flight hours) per year equipped with a 120-minute CVR.

Although this intermittent fault is likely to prove an isolated occurrence, it is possible that there are other CVRs with this fault currently in service and that the fault could remain undetected. It is considered that operators and approved CVR maintenance organisations should be made aware of the symptoms so that there is less chance that a CVR with such a fault is inadvertently released back to service. Therefore:

Safety Recommendation 2012-029

It is recommended that Honeywell Aerospace notify all relevant operators and repair organisations of the symptoms that may be observed when the data packer integrated circuit (Honeywell part number 718-1239-007), fitted to Cockpit Voice Recorder (CVR) part number 980-6022-001 and similar models, malfunctions. Honeywell should draw attention to the fact that such a malfunction may only be detectable by conducting a full readout of the CVR.

Conclusions

The symptoms experienced by the commander may have been the result of the after-effects of a

cold, combined with coincidental head and aircraft movement. The temporary symptoms experienced by the co-pilot may have been a reflection of the potentially evolving situation of an incapacitation at an early stage in the flight leading to possible mild hyperventilation. Their subsequent actions were taken in view of this perceived potential for incapacitation. No aircraft faults were discovered and no other aircraft occupants were affected by any symptoms. The crew did not require medical treatment and resumed flying duties without any recurrence of their earlier symptoms.

A previously unknown intermittent fault with the CVR was identified and this has resulted in a Safety Recommendation.