# Airbus A320-231, G-OOAB, 18 April 1998 at 2200 hrs

**AAIB Bulletin No: 8/2000 Ref: EW/ C98/4/4 Category: 1.1**

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| **Aircraft Type and Registration:** | Airbus A320-231, G-OOAB |
| **No & Type of Engines:** | 2 V2500-A1 turbofan engines |
| **Year of Manufacture:** | 1992 |
| **Date & Time (UTC):** | 18 April 1998 at 2200 hrs |
| **Location:** | Tel Aviv Airport, Israel |
| **Type of Flight:** | Public Transport |
| **Persons on Board:** | Crew - 11 - Passengers - 178 |
| **Injuries:** | Crew - None - Passengers - None |
| **Nature of Damage:** | None |
| **Commander's Licence:** | Air Transport Pilot's Licence |
| **Commander's Age:** | 33 years |
| **Commander's Flying Experience:** | 6,300 hours (of which 4,500 were on type) |
| | Last 90 days - 135 hours |
| | Last 28 days - 45 hours |
| **Information Source:** | AAIB Field Investigation |

**History of the flight**

The aircraft departed Gatwick on the afternoon of 18 April for a return flight to Tel Aviv. The outbound flight was entirely uneventful with no defects or significant abnormalities reported. On completion of the turnround the aircraft was loaded to 75.4 tonnes and the critical speeds for a configuration 1+ F (flap) take off were established as $V_1$ 155 kt, $V_R$ 163 kt and $V_2$ 163 kt. (The auxiliary power unit and both engine compressor air bleeds were OFF for take off).

After waiting at the holding point for some 10 minutes before being cleared to depart, the commander taxied the aircraft into position on the runway and commenced the take off from a standing start in calm wind conditions. The take off proceeded normally until at about 150 kt when the commander's Primary Flying Display (PFD) and Navigation Display (ND) suddenly went blank. Shortly afterwards both the upper and lower Electronic Centralised Aircraft Monitor (ECAM) displays also went blank, but the first officer's PFD and ND displayed normally. The commander and the first officer individually decided to continue the take off and neither called STOP. However, within three seconds the Master Warning lights illuminated and the continuous repetitive chime activated. At that point both pilots called 'STOP' and the commander selected full reverse thrust on both engines, which activated MAX autobrake and deployed the ground spoilers. He looked down at the autobrake selector button and confirmed that the DECEL light was illuminated, indicating that MAX autobrake was being applied. During the deceleration the first officer looked down at the ECAM and thought he saw, for a brief instant, a 'T.O. CONFIG' warning in red.

Meanwhile in the passenger cabin the main lights had been dimmed for the take off. The senior flight attendant had noticed that just before the braking had began, the cabin lights had extinguished and the emergency lights illuminated.

The commander allowed the autobrake system to bring the aircraft to a stop and it came to rest on the runway centreline, some 600 metres from the end of the runway. As the aircraft stopped, both pilots noticed it being overtaken by a pall of smoke, or dust. The commander applied the parking brake and at about that time he became aware that the cathode ray tube (CRT) displays had recovered to normal operation and the chime had ceased. There were no red (eg fire) warnings on the ECAM, but there were a large number of amber warnings including Slat and Flap Computer No 1 and System Data Aquisition Concentrator (SDAC) No 1. Turning his attention to the landing gear wheelbrakes, the commander noted that they were very hot (about 900°C) and so, having seen the smoke, he asked ATC to dispatch the Airport Fire Service (AFS) as soon as possible. He then summoned the senior flight attendant to the flight deck and briefed her on the situation, requesting her to standby for a possible evacuation.

The AFS arrived quickly, but there was no discrete frequency on which the commander could talk directly to the fire chief. (ATC were talking to the fire service in Hebrew on a dedicated ground vehicle frequency). All messages between the flight deck and the AFS had to be relayed through the Tower controller, who was also translating between English and Hebrew. ATC were expecting the arrival of a VIP flight and wanted the aircraft to clear the runway as soon as possible. However the commander was concerned that the hot brakes might seize and so, having had the landing gear inspected by the AFS, he decided to taxi slowly off the runway. Once clear of the runway he stopped the aircraft on the taxiway, but as the aircraft stopped the main landing gear tyres began to deflate as the wheel thermal safety plugs melted. The auxiliary power unit (APU) was started and at this time there was a strong smell of burning rubber in the cabin and on the flight deck.

The commander asked for a further inspection of the landing gear by the AFS and he made an announcement to the passengers to reassure them concerning the large number of emergency vehicles which had surrounded the aircraft. At this point the Tower controller told the commander that the No 1 engine was on fire and that he should shut down both engines. This came as a surprise to the commander since both engines were already shut down and he had been assured that there was no fire. The Tower controller then said "no fire no fire". The commander then opened his DV window to check, just as the AFS began to discharge foam at the aircraft. He gesticulated to them to stop discharging since he did not want foam to be discharged onto the hot brakes. The AFS complied with his request and later wheel chocks were provided. The commander stood down the cabin crew from their standby positions at the exit doors and the passengers then left the cabin using steps provided and were returned to the Terminal in coaches. There were no injuries.

**Second related occurrence**

On 4 May this aircraft was descending towards Belfast when the commander's PFD, ND and both ECAM screens went blank intermittently. The commander also observed a 'GEN 1' fault indicated on the ECAM and so he selected No 1 generator to OFF. All of these displays then recovered to normal operation and the commander completed the flight using electrical power from the No 2 generator alone.

**Aircraft systems**

The Airbus A320 has electronic instruments comprising six cathode ray tube (CRT) displays on the instrument panel. Two CRTs provide each pilot with a PFD and a ND. The two remaining CRTs, positioned in the centre of the instrument panel, display data from the ECAM. The ECAM monitors most of the aircraft's systems and alerts the flight crew to any abnormal or hazardous conditions. The upper CRT normally displays the engine primary indications, fuel quantity and the position of the flaps and slats. Abnormalities and system failures detected by the ECAM are also displayed in text on the upper CRT when they occur; if there are multiple failures they are listed in priority order. The lower ECAM display may be switched automatically or manually to any one of 12 'pages', each giving a synoptic display of a particular system

There are three Display Management Computers (DMCs) which drive the six CRTs. No 1 DMC drives the left side PFD, ND and the ECAM upper display whilst No 2 DMC drives the right side PFD, ND and the ECAM lower display. The No 3 DMC is in standby mode until manually switched to replace either of the other two DMCs. Two identical Flight Warning Computers (FWCs) acquire data for the generation of alerts. They acquire data directly from the aircraft's sensors to generate red warnings, and from two identical System Data Acquisition Concentrators (SDACs) for amber cautions.

Most of the electronic systems interface with the Centralised Fault Display System (CFDS), the main component of which is the Centralised Fault Data Interface Unit (CFDIU). Faults are classified according to priority, with those requiring immediate action by the crew being displayed on the ECAM. Others requiring deferrable maintenance action are displayed on the ECAM as status messages. These are stored in the CFDIU, but can be accessed from the Multipurpose Control Display Units on the flight deck pedestal, and are presented in the form of Post Flight or Last Leg Reports. In addition, fault messages are stored which can be accessed by maintenance personnel.

**Electrical power system**

The A320 has a substantially conventional electrical system in that during normal flight conditions an integrated drive generator (IDG) on each engine provides a 115 volt, 400 Hz output supply to the main alternating current (AC) buses; No 1 IDG supplying AC bus 1 and No 2 IDG supplying AC bus 2. The direct current (DC) buses 1 and 2 are powered by a transformer rectifier unit (TRU) from each of the AC buses. Each generator has a line contactor, which is controlled by a Generator Control Unit (GCU). The latter monitors the generator's output parameters, such as voltage and frequency, and in the event of a fault the GCU disconnects the affected generator by opening the line contactor. This is followed by the closing of the bus tie contactors, which connect the remaining generator to the affected bus, thus restoring its power. The time delay before bus transfer is effected is dependent on the nature of the fault. For example, an underfrequency condition would result in a delay of 3 to 5 seconds, with only 100 milliseconds (ms) being allowed for an IDG underspeed. The generator power distribution is reasonably symmetrical in that the No 1 system supplies the commander's instrument displays and the upper ECAM screen, with the first officer's instruments and the lower ECAM screen supplied by the No 2 system. However the Essential AC and DC buses are normally powered from the No 1 system.

## Flight data recorder analysis

The operator's replay contractor supplied raw (binary) Digital Flight Data Recorder (DFDR) data of the Tel Aviv incident to the AAIB. No cockpit voice recording was available, as the period covering the incident had been overwritten. The data was reduced to engineering units and the information used to assist in the reconstruction of the time history of the aborted take off.

The DFDR recording included a time history of the status of AC bus 2, DC bus 1, DC bus 2, the DMCs, the FWCs, the SDACs and take off configuration. The status of AC bus 1 was not recorded. However, since the electrical power for the DFDR is provided by AC bus 1, the availability of AC bus 1 could be inferred from the correct operation of the DFDR.

Figure 1 shows the time history of relevant recorded DFDR parameters during the attempted take off. In order to assist an understanding of the DFDR time history an arbitrary time (T) of zero seconds is ascribed to the time when the power levers (as represented by thrust lever angle, TLA) were moved forward at the beginning of the take-off roll.

As the aircraft accelerated along the runway, nose down elevator gradually decreased in response to inputs provided by sidestick 1, indicating that P1 (the commander) was the handling pilot. At T+33 seconds, as the aircraft accelerated through 143 kt, the synchronisation of the recorded data was lost for a period of about 1.5 seconds. The most plausible reason for this loss of synchronisation was due to a temporary loss of electrical power to the DFDR, consistent with a malfunction of AC bus 1.

After synchronisation was re-established, the aircraft was still accelerating. At T+36 seconds, as the aircraft speed reached 150 kt the thrust levers were retarded, reverse thrust was selected, the spoilers deployed and the aircraft began to decelerate. The 'engines' ECAM page remained selected. The DFDR showed that maximum autobrake had been selected before the take-off roll and the deceleration (average - 0.4g) confirmed that maximum autobrake was used.

At T+37 seconds the ECAM page changed to 'wheels', and at T + 37.5 seconds a Master Warning was recorded for a period of 1 second. The source of the Master Warning could not be determined from the time histories of the other recorded parameters.

The DFDR recorded no change in status of the electrical supplies, the DMCs, the SDACs or the FWCs before or after the throttle levers were retarded. It is important to note that this status data was obtained from the appropriate aircraft data bus, and as a consequence the status of the flight deck displays was transparent to the DFDR time history. Furthermore it is possible that data sampling rates and transport delays in the data aquisition and recording functions permitted some short duration (possible spurious) faults to be unseen by the DFDR.

## Subsequent investigations

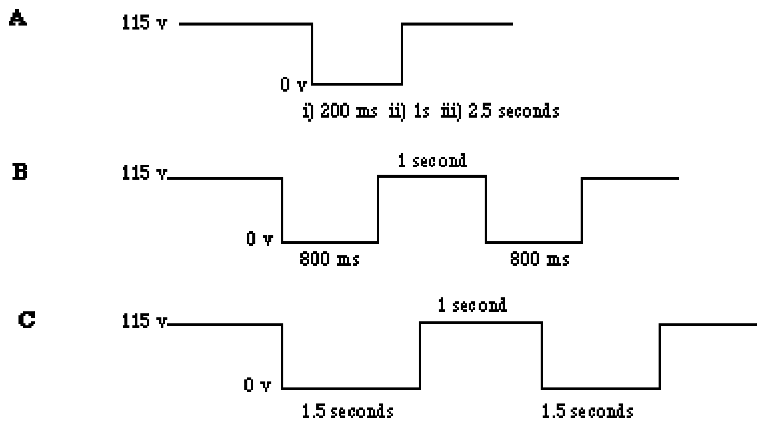
Following the Tel Aviv incident, the power generation system had been checked but no associated faults had been found. However, as a precaution the No 1 generator line contactor and the No 1 and No 2 GCUs had been changed. Since the GCUs were equipped with non-volatile memory, they were interrogated for fault records. No faults were recorded on the No 2 GCU memory, but the No 1 GCU memory had recorded a repetitive code which related to a disconnected wire in the IDG low oil pressure switch. This was consistent with a related maintenance message which was found to have been recorded by the CFDS.

The No 1 IDG was therefore changed following the second incident and the removed unit was sent for strip examination to the manufacturer. Strip examination found that the oil pressure switch wires had sheared off at the soldered joints to the associated connector, which confirmed the faults logged by the No 1 GCU memory and the CFDS. This established the existence of an IDG oil pressure indication problem, but this was not considered by the manufacturer to have been related to the loss of electrical power. The strip examination also revealed that the governor adjustment mechanism was worn and badly damaged, and the IDG output frequency could not be adjusted above 395 Hz. The nature of the damage was indicative of abuse during maintenance, although it was not established where or how this had occurred. The IDG manufacturer also considered that the fact that the frequency could not be adjusted to 400 Hz could not have been related to the loss of power, since the as-found value was well above the threshold of 363 Hz which would cause the GCU to disconnect the IDG. No other faults were found during the strip examination of the No 1 IDG.

The investigation was hindered by the fact that no Post Flight Report (PFR) from the Tel Aviv incident was available. However the first officer's recollection of a possible 'T. O. CONFIG' warning would not have been recorded, since it was not a failure condition requiring maintenance action. The PFR from the second incident noted an 'ELEC GEN 1 FAULT' and a 'SDAC 1 FAULT'. These would have occurred after the commander switched off the No 1 generator.

**Engineering simulator tests**

It was decided to conduct a series of tests on the A 320 engineering simulator ('Iron Bird') at Airbus Toulouse, during which the No 1 generator power was interrupted for a known period after simulation of the aircraft accelerating to approximately 150 kt. After a delay of some 4 seconds the simulated take off was aborted. The simulator was equipped with the same computer hardware and software as installed on production aircraft. Electrical power was supplied from two IDGs driven by electric motors. The following electrical power output interrupt profiles were used with output power loss achieved by cutting the current to the excitation coils.




The 200 ms power interrupt resulted in the commander's instrument displays and the upper ECAM screen blanking out for approximately 0.5 seconds. The 1 second power cut caused the same screens to blank for 5 to 6 seconds, and the 2.5 second power cut caused an 8.5 second blanking time. It was noted that after the screens had blanked out, the display on the upper ECAM screen was immediately transferred to the lower screen. There was no audio warning at any time during these tests, although cases A(ii) and A(iii) resulted in ECAM amber messages 'AUTOTHROTTLE OFF' following recovery of the screens. In the case of the A(iii) interrupt profile there was also an 'FWC 1' amber ECAM message. Post 'flight' reports were available from the tests which recorded the ECAM warning messages, however these did not necessarily reflect those seen on the ECAM screen during the simulations. For example, no messages were recorded for A(iii), whereas with the A(ii) interrupt profile the PFR recorded a 'SDAC 1 FAULT' which had not been seen on the ECAM screen during the test. It was noted that during the first test some of those witnessing the test thought that they had seen four displays go blank, while others saw only three.

The results of tests B and C were similar, with blank screen times of 8.5 and 10 seconds respectively, and no recovery during the 1 second power restoration. Once again, there were no audio warnings. No amber warnings were seen on the ECAM screen during test B, although a 'SDAC 1 FAULT' was recorded on the PFR. In test C, amber 'AUTOTHROTTLE OFF' and 'FWC 1' ECAM warnings occurred, but no associated PFR ECAM records. In addition, the No 1 Flight Guidance Management Computer (FGMC) was lost for a time.

The next test was similar to test A, but with the power being cut by disconnecting the three phase supply upstream of the line contactor, and with an interrupt time of 2.8 seconds. The screens blanked for approximately 9 seconds and there was a single audio chime as the simulation modelled the aircraft decelerating through 80 kt. The No 1 FGMC was again lost.

Finally, the test was repeated with the bus tie contactor locked out, so that there was a permanent loss of AC 1. There was no audio warning on this occasion, but there were about 6 amber ECAM warnings, all relating to the electrical system.

**Discussion**

The investigation into the two incidents failed to identify positively the cause of the electrical power interruptions. Two faults were identified on the No 1 IDG, ie the sheared off oil pressure switch wires and the jammed governor adjuster. The IDG manufacturer considered that these defects could not have accounted for the loss of electrical power, however the aircraft experienced no further related problems after the No 1 IDG was changed. This indicated that the problem probably occurred due to an intermittent and unidentified defect associated with the No 1 IDG.

The tests on the engineering simulator showed that the commander's PFD, ND and upper ECAM screens blanked out for a time which was considerably more than the duration of the power loss. Airbus indicated that this was due to the displays going through their normal power-up self-test procedure. The FDR data was unsynchronised for about 1.5 seconds in the Tel Aviv incident, which represented the maximum duration of the power cut. It is probable that the actual duration was about 1 second, which would have caused the screens to blank out for some 5-6 seconds, although the crew may have perceived this to be longer as they attempted to understand what was happening at a critical stage in the take off. It was not possible to determine whether the power loss had been a simple OFF-ON sequence (as in test A), or had involved a more complex profile (as in tests B and C). At no time during the tests did the lower ECAM screen blank out, and as both the screen and its associated DMC are supplied from AC bus 2, there was no reason why it should have been affected. Nevertheless, the crews reported that this had occurred in both incidents, and some of the personnel who witnessed the first test at Toulouse thought that they had seen four displays go blank.

The tests additionally illustrated the discrepancy that could exist between the messages displayed on the ECAM (after power was restored) and those logged on the PFR. The aircraft manufacturer indicated that a number of factors could have influenced the CFDS operation, the principal one being the fact that the CFDIU was supplied from AC bus 1, and would thus also have been affected by the power interruption. In addition, the individual units affected would have different fault confirmation times, with a fault message being sent only once to the CFDIU. Thus, if the latter had not returned to its operational state at the time that a fault message had been sent, fault registration would not have occurred.

It was considered likely that the Master Warning was related in some way to the electrical power interruption. Although the DFDR indicated that the throttles had been retarded 3 seconds after the start of the power interruption and 1.5 seconds before the Master Warning was recorded, it was apparent that the recording of data temporarily ceased for 1.5 seconds after the electrical power was lost. Consequently, the recovery of electrical power to the DFDR may have been accompanied by delays in the resumption of recording fidelity due to data sampling rates and associated transport delays.

It was noted that an 'FWC 1' amber ECAM message was observed during the 2.5 and 1.5 seconds power interrupt tests, but with no corresponding PFR ECAM records. In addition, the first officer in the Tel Aviv incident thought he had seen, for a brief instant during the deceleration, a 'T.O. CONFIG' warning in red on the lower ECAM. Since a configuration warning is one of those key warnings which is not inhibited from being displayed during take off between 80 kt and 1,500 feet agl, Airbus were asked if the loss of FWC 1 as a result of the power interrupt on take off could have generated the configuration warning, red Master Warning lights and continuous repetitive chimes. Airbus responded that both FWC 1 and FWC 2 'identically and permanently' monitor the aircraft, and that each FWC independently illuminates half of the Master Warning/Caution attention getters. One FWC assumes priority, and if it fails the other takes over. Both DMCs use FWC 1 by default and if FWC 1 fails, the DMCs 'reconfigure' to FWC 2 (after a certain configuration time). This explanation implied that the loss of FWC 1 should not have led to a configuration warning, Master Warning and repetitive chimes. Airbus could not explain why such warnings should have occurred.

However, the fact that an (unexplained) Master Warning was recorded by the DFDR when a Master Warning did not occur during the tests at Toulouse gives credence to the pilots' recollection of events. The DFDR indication that the Master Warning occurred after the commander had closed the thrust levers was, therefore, considered by the AAIB to have arisen from a combination of transport delays and loss of data synchronisation.

With the sudden disappearance of the commander's PFD and ND flight displays (and the apparent near simultaneous disappearance of both ECAM displays) the commander could have decided to abandon the take off. Nevertheless, he decided to continue the take off on the standby instruments before transferring control to the first officer, whose flight instruments continued to operate normally.

However, the aircraft was still below $V_1$ speed when, moments later, the Master Warning lights illuminated accompanied by the continuous repetitive chime. During take off in the A320 all minor warnings are suppressed after 80 kt until the aircraft climbs through 1,500 feet radio altitude. During that period only major warnings such as fire, engine failure, sidestick fault, double elevator fault or a configuration warning should activate the Master Warning. Consequently, a Master Warning during take off is one of very few events for which take off should be abandoned when the airspeed is between 80 kt and $V_1$. Therefore, the commander was fully justified in abandoning the take off.

Neither Airbus Industrie nor the AAIB were able to explain fully the sequence of events. However, there was no reported recurrence of such an event on this aircraft after the No 1 generator was changed following the second event on 4 May 1998.

The rejected take off and ensuing confusion on the part of ATC and the fire service, caused principally by language translation problems under stress, were well handled by the entire crew and by the commander in particular.