## SERIOUS INCIDENT

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| **Aircraft Type and Registration:** | Boeing 747-436, G-BNLN |
| **No & Type of Engines:** | 4 Rolls-Royce RB211-524G2-T-19 turbofan engines |
| **Year of Manufacture:** | 1990 |
| **Date & Time (UTC):** | 9 June 2019 at 1559 hrs |
| **Location:** | In flight from London Heathrow Airport to Phoenix International Airport, USA |
| **Type of Flight:** | Commercial Air Transport (Passenger) |
| **Persons on Board:** | Crew - 18 Passengers - 320 |
| **Injuries:** | Crew - None Passengers - None |
| **Nature of Damage:** | None |
| **Commander's Licence:** | Airline Transport Pilot's Licence |
| **Commander's Age:** | 57 years |
| **Commander's Flying Experience:** | 23,465 hours (of which 2,537 were on type)<br>Last 90 days - 211 hours<br>Last 28 days - 77 hours |
| **Information Source:** | AAIB Field Investigation |

### Synopsis

On reaching top of climb the aircraft experienced unreliable airspeed indications resulting in overspeed warnings and activation of the stall warning system. In recovering, the crew carried out the unreliable airspeed procedure but also carried out the stall warning procedure, which was not required.

The problem was believed to have been caused by a fault with the right Air Data Computer (ADC), although this could not be replicated.

As a result of this incident, the aircraft manufacturer is providing additional information as part of their published unreliable airspeed procedure. The aircraft operator is also reviewing its maintenance procedures due to the accidental erasure of fault codes on the right ADC as part of the post-incident inspection process.

### History of the flight

The aircraft was on a scheduled flight from London to Phoenix, USA, with the commander and co-pilot being line-checked by a training captain, who occupied the jump seat. The aircraft took off at 1428 hrs with the co-pilot acting as pilot flying (PF). It had just reached the top of climb at FL330, with the right autopilot and autothrottle engaged, when the Master Warning activated. The crew reported that a line appeared through the Vertical Navigation (VNAV) path on the Flight Mode Annunciator (FMA) and that the Engine Indication and Crew Alerting System (EICAS) indicated a red overspeed warning, ALT disagree, IAS disagree, Rudder Ratio Single, Airspeed Low and Altitude Alert. The crew also reported feeling ear discomfort from a change in cabin air pressure.

The co-pilot recognised the airspeed had become unreliable, notifying the other two pilots before carrying out the recall drill. In doing so, he noted that the autothrottle had reduced thrust to 1.2 EPR before it was disengaged. He set a pitch of 4° nose-up and thrust of 80% N1, as required by the drill.

The crew declared a PAN with ATC and were cleared to remain on their current heading with a block altitude cleared for them to operate within. The commander and training captain then referred to the "Unreliable Airspeed Table" in the Quick Reference Handbook (QRH) from which they determined the required pitch attitude under the prevailing conditions was 3.5° nose-up and the required thrust setting was 87.5% N1.

While the datums were being agreed, and with the aircraft maintaining a pitch attitude of 4° nose-up and engine power setting of 80% N1, the stick shakers activated. The crew briefly discussed whether to maintain the 'Airspeed Unreliable' datums or carry out the stall recovery manoeuvre. They agreed that the stall recovery would be appropriate, and this was carried out by the co-pilot. He decreased the pitch attitude to 1° nose-down, at which point the stall warning ceased, which the crew considered confirmed their belief that the stall warning was genuine. He then slowly increased the pitch and engine power to the datums required in the QRH, however, as he did so the stall warning reoccurred, so the co-pilot reduced pitch again until the warning ceased. As the airspeed increased, the co-pilot gradually increased pitch, however the stick shaker activated once again, causing him to reduce the pitch angle until it stopped activating. He repeated this process several times until the QRH datums were finally attained and there were no further stick shaker activations.

The aircraft had lost about 2,800 ft during these manoeuvres. With the aircraft now stable, the crew completed the rest of the 'Airspeed Unreliable' checklist with the air data source being changed from the right to the centre Air Data Computer (ADC). This allowed the autopilot and autothrust to be re-engaged. The crew also contacted the operator's maintenance office by radio which was able to confirm, via the aircraft health monitoring system, that the right ADC had failed.

The crew and maintenance office both assured themselves that the aircraft was still able to comply with the Required Navigation Performance and Minimum Navigation Performance Specifications and, having done so, the flight continued to the destination with no further incidents.

## Aircraft information

Following the incident, the aircraft flew a further five sectors in accordance with an Acceptable Deferred Defect (ADD) before the technical problem was fully addressed. System redundancy enabled continued operation to take place without compromising safety after the right ADC had been isolated and the centre ADC activated to function in its place (in conjunction with restrictions on low visibility operation). A series of rectification actions was proposed, including leak and drain checks on the relevant pitot-static systems, and replacement of the right ADC. These actions were carried out at the conclusion of the five sectors following the event.

The aircraft then flew a further eight sectors, with no subsequent problems encountered. Following these sectors, the aircraft was grounded and permanently removed from service.

## Recorded information

The aircraft was equipped with a two-hour CVR, a 25-hour FDR and a Quick Access Recorder (QAR). The CVR and FDR recordings of the incident were not available as they had been overwritten, but data was available from the QAR.

Salient parameters included airspeed, Mach number and pressure altitude recorded from the left and right ADC. The QAR did not record the activation of the stall warning stick shakers when triggered by the right stall warning computer.

*Interpretation of QAR data*

The aircraft was configured with the autothrottle and right autopilot engaged, with the right ADC selected to provide data to the auto flight system.

Shortly after the aircraft reached the top of climb and levelled at FL330, data started to deviate between the left and right ADC (Point A, Figure 1). Over about 12 seconds, airspeed from the right ADC increased from 300 kt to 407 kt, whilst airspeed from the left ADC remained at 300 kt. In response to the increase in airspeed from the right ADC, the engine thrust was automatically reduced from 89% N1 (1.54 EPR) to 70% N1 (1.2 EPR) (Point B, Figure 1). Thus, whilst data from the right ADC indicated that the airspeed had increased and the aircraft had climbed, data from the left ADC showed that the aircraft's actual airspeed and altitude were gradually reducing due to the reduction in engine thrust.

The autothrottle and autopilot were then disconnected by the crew and the engine thrust manually increased from 70% to 80% N1 and the pitch set to approximately 4.5° nose-up (Points C, Figure 1). After a further 80 seconds, the airspeed from the left ADC stabilised at about 266 kt as the aircraft continued to gradually descend. During this period, airspeed and altitude from the right ADC had continued to deviate from the left ADC by as much as 122 kt and 500 ft.

The engine power was maintained at 80% and pitch at approximately 4.5° nose-up, but there were small variations in pitch consistent with hand flying the aircraft. After a further 90 seconds (Point D, Figure 1), there was a slight increase in pitch to just over 5° nose-up with a corresponding increase in angle of attack. The airspeed and Mach number were 266 kt / 0.73 Mach respectively from the left ADC and 340 kt / 0.92 Mach from the right ADC. At about this time (Point D, Figure 1) the stick shakers were activated by the right stall warning computer. When the flight crew carried out the stall recovery manoeuvre the pitch was reduced to about 0.5° nose-up and engine thrust increased to 87% N1 (1.5 EPR). The pitch was then gradually increased to 4° nose-up, during which the airspeed and altitude deviation between the left and right ADC reduced to approximately zero. The aircraft was subsequently levelled at FL293 where the air data source was changed and the autopilot and autothrottle re-engaged.

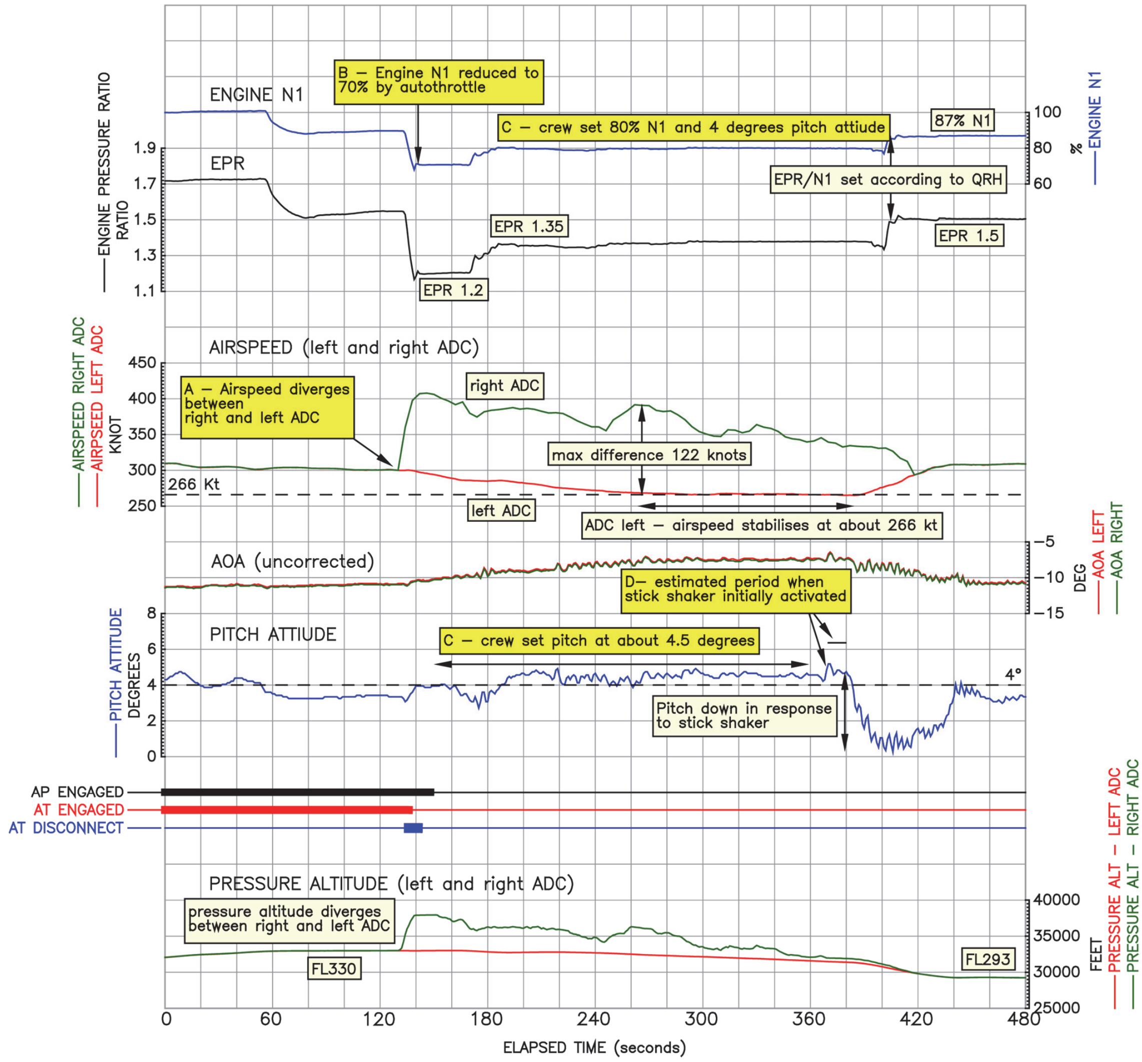


**Figure 1**

Discrepancy between the right and left ADC

## Right Air Data Computer inspection

The removed right ADC unit was forwarded to the operator's avionics overhaul base for inspection. Unfortunately, the non-volatile memory incorporating fault codes was mistakenly erased from the unit as the first action. The unit was then subjected to a series of checks which did not reveal any abnormalities. It was subsequently forwarded to the manufacturer where extensive functional tests were carried out. Despite prolonged operation and testing, the unit did not exhibit any incorrect functioning.

The data plate on the relevant ADC indicated that a number of modifications had been incorporated, one of which was not amongst those applicable to this unit type. It was further determined that a non-mandatory modification, applicable to this ADC type and devised to overcome a previously identified periodic malfunction, had not been incorporated.

Stall warning, in the form of stick shaker operation, requires inputs of vane angle and Mach number to compute proximity to the stall and to operate the stick shake when a predetermined threshold is passed. If the malfunction which the non-incorporated modification was designed to address occurred, it would have resulted in an incorrect Mach number being supplied to the stall warning system. This would then cause the stall warning system to operate erroneously at a safe airspeed (ie a speed corresponding with a safe angle of attack).

Assessment of the recorded data suggested that the malfunction may have occurred on the incident flight.

### Unreliable airspeed procedures

Boeing has developed a generic response to unreliable airspeed, the first step of which is to disconnect any related automation which may be reacting to the unreliable indications. This should be followed by setting memorised pitch attitude and thrust settings to stabilise the aircraft before refining these settings by reference to tabulated figures before determining which airspeed source is reliable. This will allow the aircraft to be appropriately re-configured and, where possible, automation to be re-selected.

This generic response has been used to develop the QRH drill for the 747-400 (Figure 2).

### Analysis

No evidence was found to account for the initiation of the event sequence, but the sequence of events was consistent with a known fault mode of the model of ADC which was fitted to the aircraft, for which a modification was available but had not been incorporated.

The malfunction of the right ADC was not identified despite extensive functional testing. It is likely that the false warnings had been generated erroneously as a result of an incorrect Mach number being supplied by the right ADC. This would then also have caused the stall warning system to operate erroneously at a safe airspeed.

The identification of the recorded faults within the right ADC unit during the flight was not possible as the fault codes had been deleted after the unit had been received into the operator's avionics workshop.

The QRH procedure applicable at the time of the incident noted that 'overspeed warnings and AIRSPEED LOW alerts may occur erroneously or simultaneously'. Stall warnings were not mentioned specifically as the aircraft manufacturer considered that crews would understand this was included. It is apparent this was not however the case with the crew involved who considered they must react to the stall warning when it occurred. The AIRSPEED LOW alert is a specific warning and the crew considered that as the stall warning was not mentioned separately in the procedural note, operation of the stick shaker should not be considered erroneous. This seemed to be confirmed to them when the stick shaker operation ceased when pitch was reduced, as they would expect after a genuine stall warning. This highlights the importance of clear, unambiguous information being readily available to crews at times of high workload when dealing with potentially critical incidents. It also reinforces the need for crews to understand the protection afforded by adopting the pitch and power settings provided as part of the procedure.

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**IAS DISAGREE**
**or**
**Airspeed Unreliable**

Condition: The airspeed or Mach indications are suspected to be unreliable. (Items which can indicate unreliable airspeed are listed in the Additional Information section.)

Objective: To identify a reliable airspeed indication, if possible, or to continue the flight using the Flight With Unreliable Airspeed table in the Performance Inflight chapter.

1 Autopilot disengage switch . . . . . . . . . . . . .Push

2 A/T ARM switch . . . . . . . . . . . . . . . . . . . . . OFF

3 F/D switches (both) . . . . . . . . . . . . . . . . . . OFF

4 Set the following gear up pitch attitude and thrust:

Flaps extended . . . . . . . . . . 10° and 90% N1

Flaps up . . . . . . . . . . . . . . . . 4° and 80% N1

**Note:** Incorrect aileron lockout and yaw damper motion may occur. Avoid abrupt control inputs.

5 The following are **reliable**:

Attitude

N1

Ground Speed

Radio Altimeter

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**Note:** Overspeed warning and AIRSPEED LOW alerts may occur erroneously or simultaneously.

The Flight Path Vector and Pitch Limit Indicator may be unreliable.

6 Refer to the Flight with Unreliable Airspeed table in the Performance Inflight chapter and set the pitch attitude and thrust setting for the current airplane configuration and phase of flight.

7 When in trim and stabilized, cross check the PFD and standby airspeed indicators. An airspeed indication that differs by more than 30 knots or .03 mach from the airspeed shown in the table should be considered **unreliable.**

*Author Note:* Two ADC airplanes

8 Choose one:

◆**Reliable** airspeed **can** be determined:

►►**Go to step 9**

◆**Reliable** airspeed **cannot** be determined:

►►**Go to step 10**

**Figure 2**

Boeing 747-400 Unreliable Airspeed QRH Procedure

**Safety Action**

The aircraft manufacturer is planning to update the QRH procedure to specifically include stall warnings as part of the note. This update is due to be included in the block revision to the B747-400 FCOM in April 2020. They are also considering similar action with other relevant types.

Since the event, the operator has taken steps to identify the process shortcomings that permitted the loss of the fault codes to occur following arrival of the ADC in their avionics workshop. As a result, procedural changes are being introduced aimed at preventing future loss of troubleshooting and fault data that can assist incident investigations.

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