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pour la sécurité de l'aviation civile

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REPORT
INCIDENT

Vertical flight path excursion during ILS approach with autopilot engaged

Airplane	Bombardier Canadair CL-600 2B 19 (CRJ700) registered F-GRZK
Date and time	Tuesday 19 January 2010 at about 08 h 00[1]
Operator	Brit Air
Site of accident	AD Paris Charles de Gaulle (95)
Type of flight	Public transport of passengers, scheduled flight
Flight crew	Captain (PF); Co-pilot (PNF)
Consequences and damage	None

[1] Except where otherwise indicated, times in this report are expressed in UTC.

HISTORY OF FLIGHT

Note: throughout this section and unless otherwise indicated, height is noted as AGL. Altitude values are those of the corrected recorded QNH parameter and are noted as AMSL.

LVP procedures were in force at Paris – Charles de Gaulle. Established on runway 08R[2] ILS on a CAT III A precision approach[3], the crew noticed that from 1,700 ft AMSL radio-altimeter 1 was working intermittently. The crew performed a missed approach at around 800 ft AMSL after detecting an APCH WARN message displayed on the head-up guidance system (HGS) and on the PFD. The origin of this message was a greater deviation to the permissible limits between the heights measured by both of the aeroplane's radio altimeters.

[2] Topographic altitude of runway 08R threshold: 336 ft.

[3] Precision instrument approach followed by a landing with a DH of less than 100 ft and an RVR equal or greater than 200 m.

A second CAT III A approach was performed on runway 08R. At around 1,700 ft AMSL, radio altimeter 1 was operating intermittently again. At 1,000 ft AMSL, a MASTER CAUTION warning message, accompanied by the EFIS COMP MON message at EICAS[4] and the APCH WARN message on the HGS were triggered for a few seconds for the same reasons as during the first approach. The crew performed a missed approach about fifteen seconds later, at an altitude of about 800 ft AMSL. The EFIS COMP MON and APCH WARN warning messages were triggered again.

[4] Engine Indication and Crew Alerting System.

The RVR was sufficient to perform a CAT I[5] precision approach on runway 08R. Using the cloud ceiling noted during the two previous approaches, the crew told the controller that they wished to make a CAT I approach and that in the event of another missed approach, they would divert to Lille airport. At around 1,700 ft AMSL, radio altimeter 1 was working intermittently again. The AP was connected. From 700 ft AMSL, that is 160 ft above DA and up to 340 ft AMSL radio altimeter 1 was not supplying height data. During this period, the aircraft's pitch attitude started to fluctuate. At the altitude corresponding to DA, it was slightly positive (0.3 degrees nose up) then it increased to 1.3 degrees nose up before decreasing rapidly to an attitude of about 7 degrees nose down at 100 ft AGL. The G/S deviation was then one point below the ILS glide path. The PF disconnected the AP as soon as he noted the decrease in attitude, at 120 ft AGL. He altered the glide path and, in sight of the approach lights, continued on to land without further difficulty on runway 08R.

[5] RVR required is 50 metres and DH is 200 ft.

ADDITIONAL INFORMATION

Meteorological information

Between the first CAT III A approach and landing, the following meteorological conditions were observed:

- the height of the cloud base remained less than 100 ft (runway 08R);
- the RVR on runway 08 R was between 500 and 1,000 metres.

The crew of the four aeroplanes that landed before the crew of the F-GRZK reported on the tower frequency having seen the approach lights at heights from between 70 and 200 ft.

Radio altimeters

General points

The CRJ700 is fitted with two radio altimetry systems calibrated to provide height data. Each system was made up of a radio altimeter (SHF[6] transmitter-receiver calculator) and two antennae (one for transmitting and the other for receiving). Each radio altimeter sent height data to equipment such as the EFIS, GPWS and the automatic flight control system (AFCS). The height on radio altimeter 1 was displayed on the Captain's PFD and that on radio altimeter 2 displayed on the co-pilot's.

[6]Super High Frequency between 4.2 and 4.3 GHz.

The radio altimetry system height measurement relies on measuring the time between the transmission of a signal to the ground and the aeroplane receiving the reflected signal. The height of the aeroplane is thus directly based on the signal return time. When this time is greater than a reference time, the aeroplane is considered by the onboard systems as being at an unspecified height greater than 2,500 ft.

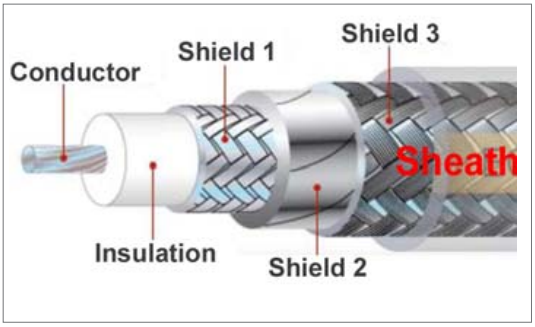
The radio altimeters and the antennae were not specific to a type of aeroplane. The length of the cables between the antennae and the calculator depend on each aeroplane type. It is determined in such a way that on touchdown, the height information is equal to 0 ft. Delay devices may be installed between the antennae and the calculator to limit cable length and weight, as well as their coiling.

The data sent to each PFD is compared constantly for specific parameters. As soon as a variation is detected, an amber light flashes for five seconds on the PFD then stays displayed for as long as the variation persists. An EFIS COMP MON warning message is also displayed on the EICAS. During a precision approach, comparison of heights and ILS variations is carried out continuously.

The CRJ700 does not have an autothrust or autothrottle system. Thus, any erroneous values coming from the radioaltimeter do not have any impact on the thrust system.

Cause of intermittent functioning of radio altimeter 1

Action by the Brit Air maintenance system based on a plan drawn up by Bombardier made it possible to identify the origin of the radio altimetry system 1 malfunction as being in the coaxial cable between the receiver aerial and radio altimeter 1.



A coaxial cable is made up of a core wrapped in insulation, then metallic shields an outer sheath

An examination of the coaxial cable carried out by the operator showed:

- a short circuit between the core and the shields the origin of which could not be determined;
- an insulation failure of the cable connector of the radio altimeter 1 receiver aerial due to the presence of oily fluid between the shield and the connector.

After this examination, the coaxial cable was replaced and destroyed. Subsequent tests confirmed the normal functioning of the radio altimetry system.

During the three approaches performed by the crew, the signal reflected by the ground was received intermittently by radio altimeter 1 due to damage in the reception system. Consequently, the radio altimeter was sending the information that the aeroplane was travelling above an altitude of 2,500 ft to the other calculators as soon as there was a short circuit in the coaxial cable.

Erroneous values from radio altimeters

Feedback from Brit Air and Bombardier

A number of ASRs were transmitted by Brit Air crews concerning erroneous values provided by one of the two radio altimeters on aeroplanes in the fleet. These reports did not have such serious consequences as those in this event but they were all the subject of corrective action on the aeroplanes and of notifications to Bombardier.

For its part, Bombardier received reports on behalf of numerous operators concerning the reliability of radio altimeter systems. The manufacturer found in particular that the coaxial cables deteriorated over time for the following main reasons:

- excessive curvature beyond the minimum curve radius, deteriorating the shields mainly at the interface between the connectors and cables;
- humidity (water, hydraulic or cleaning fluid, etc) in the cables and/or connectors;
- airframe vibrations;

- maintenance operations during which the coaxial cables were moved forcibly for accessibility.

Modifications were introduced to limit the penetration of humidity in the non-pressurised zones where specific coaxial cables were located.

Accident involving a Boeing 737-800 on approach to Amsterdam[7]

During descent for an ILS approach, radio altimeter 1 regularly provided a height of -8 ft, displayed on the Captain's PFD, which generated the "LANDING GEAR CONFIGURATION" warnings, as the landing gear was retracted. This erroneous height value was considered valid by the systems using this data, in particular the auto-throttle. The AP 2 was engaged and used the data from radio altimeter 2. On final approach, with the flaps in position 15 and the landing gear extended, radio altimeter 1 again supplied a height of -8 ft, which selected the auto-throttle to RETARD mode and the thrust levers to idle position. Established on the glide path, the speed decreased while the angle of attack increased without the crew noticing. At 460 ft AGL, the stick shaker activated. Some seconds later, the aeroplane stalled and struck the ground about 1.5 km short of the runway threshold.

In relation to erroneous values that could be supplied by the radio altimeters to the various aeroplane systems, the results of the safety investigation conducted by the Dutch investigation authority showed that:

- the technical documentation for pilots did not make it possible for them to understand the possible consequences of erroneous height values supplied by a radio altimeter on the on-board systems using this data;
- the problems associated with erroneous height values supplied by radio altimeters were known to Boeing and the FAA and were the subject of studies that were not able to determine with certainty the cause of these anomalies;
- non-systematic notification by crews and maintenance services of anomalies observed, on radio altimeters in particular, made it impossible to assess the associated risks.

In September 2010, the FAA proposed an airworthiness directive (AD) for the Boeing 737 family -600, -700, -700C, -800 and -900 models that required detecting and correcting in the aeroplanes' FCC possible erroneous values provided by the radio altimeters.

Boeing also published a flight operations technical bulletin[8] about the possible consequences of erroneous values provided by at least one of the three radio altimeters equipping Boeing 777's. This bulletin mentioned the importance of multi-crew cooperation in the event of detection of such a problem and required the crews to reduce the level of automation to ensure and maintain control of the aeroplane.

[7] Investigation report www.onderzoeksraad.nl/docs/rapporten/rapport_TA_ENG_web.pdf

[8] Flight Operations Technical Bulletin n°777-30 of 21 July 2010.

Airbus' Safety First review

The Safety First n°11 review published by Airbus in January 2011 also quoted in-service event notifications relating to problems with radio altimeters. An erroneous height value provided by a radio altimeter may be considered valid by the aeroplane systems and may thus have consequences on the aeroplane display screens, warning systems, flight directors (FD) and angle of attack protections. In particular, an erroneous value of -6 ft was observed in several events provoking the activation of FLARE mode by the autopilot and RETARD mode by the auto-thrust[9] as well as the inhibition of some aeroplane angle of attack protections.

[9]FLARE and THR IDLE displayed on the FMA.

The source of these erroneous indications may be internal or external to the radio altimeter system. It could be linked to:

- an ingestion of water in the transmitting and receiving aerial installation of the radio altimeters, which could affect the antennae and potentially the coaxial cables.
- a damaged installation of the cable connectors.
- a terrain with variations in reflectivity.

Following these event notifications, Airbus published:

- bulletins to operators[10] which describe the operational consequences and provide recommendations to follow in the event that radio altimeter errors are detected;
- new maintenance operations relating to radio altimeter antennae and coaxial cables.

[10]Operator Information Telex/ Flight Operations Telex and Red Operations Engineering Bulletins.

Airbus also required that the crews identify and notify any detection of erroneous radio altimeter indications. In order to better detect problems relating to errors provided by radio altimeters, improvements are underway both on radio altimeters and onboard systems.

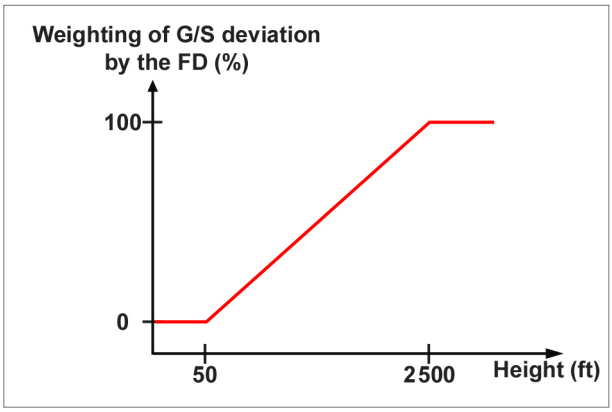
Guidance on an ILS glide path

Use of height in guidance laws on an ILS glide path

G/S variations (in relation to ILS glide path) indicated to the pilot are directly based on the angular deviation between the aeroplane and the oblique plane embodying the glide path.

For any given deviation, the distance from the aeroplane to the glide path decreases as the aeroplane gets closer to the runway threshold. The flight path correction to apply to return to the glide path consequently becomes less significant as the aeroplane flies closer to the runway threshold.

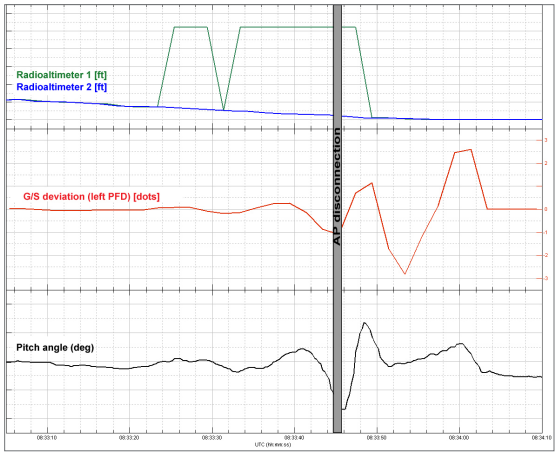
In order to adapt this correction to apply to return to the glide path, the FD instructions are weighted using height data supplied by the radio altimeter. This data enables the gain to be adapted, and thus the use of the G/S deviation in the FD guidance law on the glide path.



implified diagram of the use of the G/S deviation by the flight directors during guidance on the ILS glide path

Approaching DA during the last approach, the altitude data supplied by radio altimeter 1 to FD1 led the latter to consider that the aeroplane was at a height of more than 2,500 ft and thus apparently far from the runway threshold. To correct the glide path, the FD thus ordered over-corrections[11], leading to an opposing G/S variation, which was again over-corrected. The G/S variation and the attitude then began to fluctuate with increasing intensity.

[11]A G/S variation at a short distance from the threshold is corrected by an attitude adapted to this same variation at a greater distance.



Precision Approaches

Precision approaches in LVP conditions

According to Brit Air's operations manual[12], in order to perform a precision approach in LVP conditions, the Captain must be PF.

[12]Operation manual part B.02.04 page 01.

CAT III precision approaches

During CAT III precision approaches, the Captain undertakes the approach in manual using HGS. When it is fitted, this system ensures the monitoring of various sensors, of its integrity and approach and landing performance. If an anomaly is detected above 500 ft AGL, an AIII message is displayed in yellow on the PFD and a NO AIII message is displayed on the head up display and on the HGS system control panel. Below 500 ft AGL, an APCH WARN warning message is displayed on the head up display. It is also displayed in red on the PFDs. When this message is displayed, if the external visual

references are not established, the Captain must carry out a missed approach.

Both CAT III approaches were carried out as missed approaches by the crew as allowed for in the operator's procedures, following the triggering of the APCH WARN messages.

CAT I precision approaches in LVP conditions

This type of approach must be performed where possible with the AP and FD engaged[13]. At DA, the PF can disconnect the AP or keep it on until a minimum height of 80 feet. The PNF responds by calling out "decision". If the external visual references are adequate to continue the approach, the PF calls out "contact" and continues the approach in manual handling. If the external visual references are not adequate the PF calls out "go around".

[13]Operation manual part B.02.03 page 35.

For the crew, even if the decision to carry out a CAT I approach before a diversion led to a raising of the DA, this decision would certainly permit release from the monitoring carried out by the HGS system on CAT III approach. The CAT I approach carried out was affected by the radio altimeter 1 problems, generating EFIS COMP MON warning messages to EICAS. But unlike a CAT III approach, the crew had the option of continuing the approach despite these warning messages, in compliance with procedures.

However, the crew was not aware of the FD using data from the radio altimeters during guidance on an ILS glide path and of the consequences of a radio altimeter problem on the FD instructions. The descent was continued with the AP connected up to a height of about 120 feet, that's to say 40 feet above the authorised limit for its use.

CONCLUSION AND RECOMMENDATIONS

During the event, the comparison of height values from the two radio altimeters displayed on their respective PFDs enabled the crew to detect the origin of the problem with radio altimeter 1. Both members of the crew were unaware of the consequences of the AP/FD using these erroneous values which, taking these altitudes as valid, tended to over-correct the flight path deviations in relation to the ILS glide path. Having kept the AP connected as long as possible, the PF, certainly surprised by the flight path deviation, had to react at very low altitude to correct the glide path.

Cable fragility in maintenance

It is possible, given the characteristics of the coaxial cables, the handling needed to connect these cables and the length of cable used (a roll between the antennae and the transmitter-receiver), that the excessive curvature of the cable led to a short circuit. The radio altimetry systems are made up of several distinct elements (radio altimeter, cables, antennae, etc) that can be changed and handled independently, leading to possible damage to other elements of the system. In this way, the aeroplane manufacturer's recommendations to the maintenance services on operations to be performed in the event of an anomaly detected in a radio altimetry system, as well as for the maintenance operations of these systems, would limit the number of events on related to erroneous altitude values.

Influence of erroneous height values

The various examples presented show the importance of the use of radio altimeter height values by onboard systems and the consequences of erroneous values on their operation. The provision of such values by radio altimeters is a generally recognised problem that concerns the increasingly complex onboard systems on all types of aircraft. The examples also show the manufacturers desire to limit the risks related to erroneous values from radio altimeters.

In most cases, crews detect radio altimeter malfunctions either by themselves by monitoring their PFD or by system warnings. However, crews are often made to react to undesirable events caused by the use of these erroneous values by the onboard systems, rather than deciding and acting pre-emptively. This could be explained by the lack of information provided to crews, in the documentation available to them, during their training and also by the in-flight warning systems. This does not make it possible for them to foresee the consequences of errors from radio altimeters.

The decisions then taken by crews may be inappropriate, especially on approach where the estimation in real time of the risk associated with these problems is not necessarily possible. Additional information on the use by the automatic height systems provided by the radio altimeters (crew documentation, procedures, training, practice etc.) would allow crews to better perceive a radio altimetry malfunction.

This is why the BEA recommends that EASA ensure that:

Recommendation FRAN-2012-008

- **Aircraft manufacturers examine and correct when possible the undesirable effects produced on onboard systems by erroneous altitude values provided by at least one radio altimeter.**

Recommendation FRAN-2012-009

- **Aircraft manufacturers modify aircraft operations manuals specifying the operation by onboard systems of data provided by radio altimeters as well as recommendations or procedures for crews to follow in the event that erroneous data is detected from at least one radio altimeter.**

Recommendation FRAN-2012-010

- **Aircraft manufacturers modify maintenance procedures that could have consequences on the radio altimetry system in order to take into account the risks of damage.**