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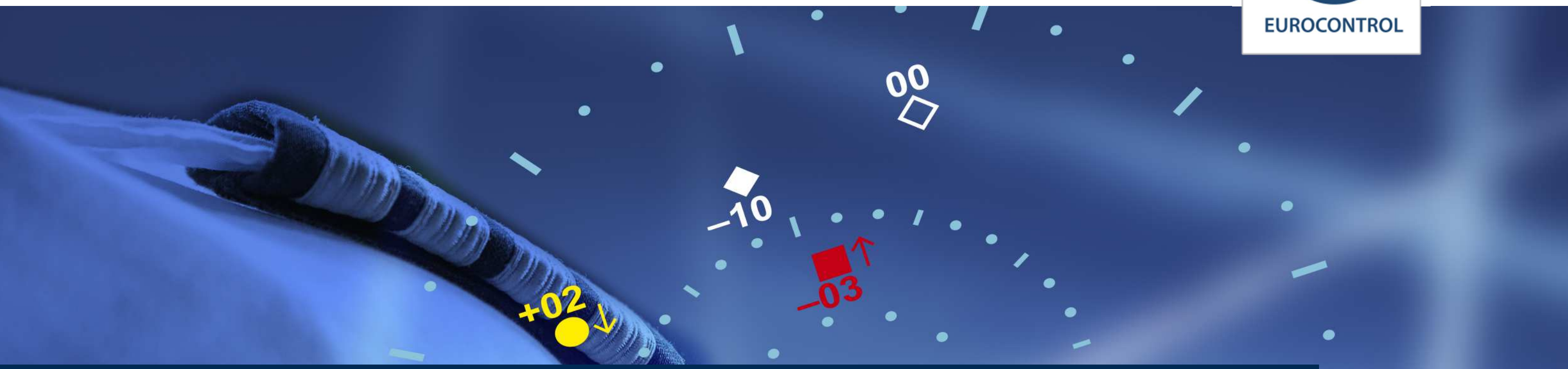

ACAS II Bulletin

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Equipment matters

WELCOME

In this issue of ACAS Bulletin we describe events in which the prime causes were technical anomalies, either associated with TCAS, transponder, or altimeters.

TCAS, to deliver its collision avoidance protection, depends on aircraft's transponder and altitude inputs – if either is lost the operation of TCAS will be compromised. As with any technical system, TCAS may sometimes fail or perform outside its design when presented with exceptional or unanticipated conditions.

Using cases, varying from the loss of transponder, to self-tracking RA, to false altitude input, we will learn how the system failures affected TCAS operations and how pilots and controllers reacted in the circumstances.

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Event 1 – Loss of transponder

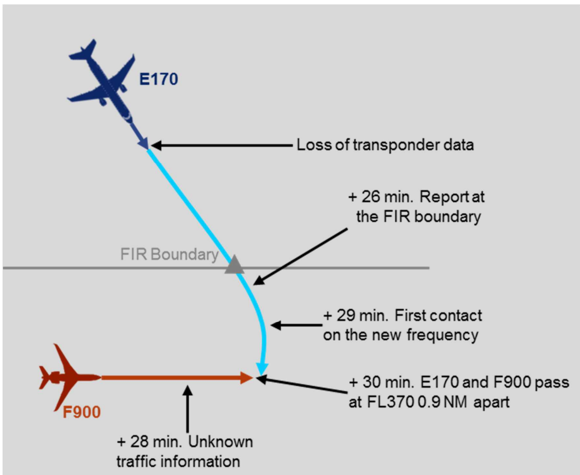
A southbound Embraer 170 is cruising at FL370. At some point the E170 transponder drops off-line but this goes unnoticed by the crew. Consequently, the aircraft is not shown on the ATC radar screen and that escapes the controller's attention.

Soon after, there is a shift change at the ATC centre and the new controller who takes over assumes that the E170 has already left the sector. Therefore, he does not take any action to establish radio contact with the aircraft.

The E170 reaches the FIR boundary 26 minutes after the loss of the transponder and shortly after crossing it the crew makes a position report. The controller gives the pilot a frequency change instruction but does not attempt to radar identify the aircraft.

At the same time, in the adjacent FIR a Dassault Falcon 900 business jet is also level at FL370 heading east. The controller observes the E170 as a primary target (i.e. without altitude or identifying squawk code) passing the FIR boundary and issues traffic information to the F900 crew about the unknown traffic.

Half a minute later, the E170 crew makes a call on the new frequency. The controller is not aware of the incoming traffic to his sector and in prolonged radio exchanges the controller attempts to verify the callsign, position, flight level, etc.



Less than 2 minutes after getting the traffic information about the unknown traffic, the F900 crew reports passing another aircraft in close proximity. They are surprised that they could not see the other aircraft on their TCAS traffic display.

A minute later, the controller instructs the E170 to check their transponder. Subsequently, the transponder information is displayed on the ATC radar screen – 31 minutes after the loss of transponder occurred.

The investigation of this incident established that the E170 and F900 passed each other at the same flight level with a horizontal separation of 0.9 NM. As the E170 transponder was not working no TCAS alerts were generated on any of the aircraft.

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Conclusions: This incident bears a striking resemblance to the 2006 midair collision over Brazil (see the text box underneath) and demonstrates the dependency of TCAS on an operational transponder. If a transponder is lost, the aircraft TCAS is automatically placed into standby and does not offer protection against other aircraft. Moreover, an aircraft with a non-operational transponder is invisible to TCAS on other aircraft as well as to ATC secondary radars. Therefore, pilots must systematically monitor the operational status of the transponder.

Some ATC ground systems will produce an alert if a secondary radar target (i.e. based on the transponder signal) is unexpectedly lost. If such functionality is not available, controllers should constantly monitor traffic in their sector. The disappearance of secondary radar target is an indication of transponder failure, another technical problem or an in-flight emergency.

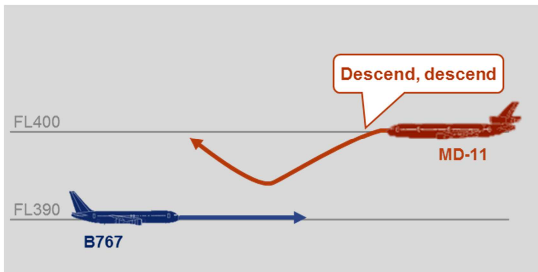
Learning points:

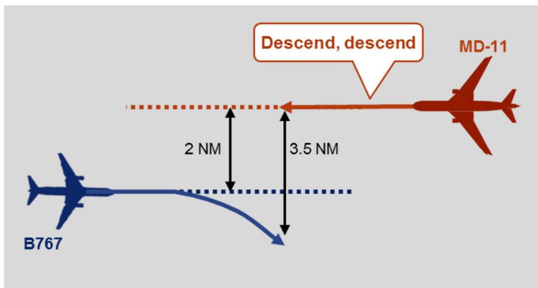
- TCAS II does not detect aircraft without an operational transponder. These aircraft will not be shown on the TCAS traffic display and there will be no alerts against such aircraft.
- If a transponder is switched off or fails, aircraft's own TCAS II will be placed into standby and the aircraft will not be detected by ATC secondary radars.
- During flight pilots should monitor whether the transponder operates correctly.
- Controllers should promptly bring to the pilot's attention a loss of secondary radar target.

2006 Brazil midair collision

On 29 September 2006 a collision between a Boeing 737-800 and Embraer Legacy occurred in Brazil. Both aircraft were TCAS II equipped. Following several problems related to ATC and communications, both aircraft were maintaining the same flight level (FL370), while ATC expected the Legacy to be at FL360 or FL380. Additionally, the Embraer crew was not aware that the transponder was no longer operating, consequently making the Embraer undetectable to the B737 TCAS. As the transponder did not work, Embraer's TCAS was automatically placed into standby, so the Embraer's crew could not receive TCAS alerts against the B737. The aircraft were flying in opposite directions at the same altitude and collided. The B737 crashed killing 154 people on board, while the Embraer managed to land.

Event 2: RA due to self-tracking





A westbound McDonnell Douglas 11 is cruising at FL400 while a Boeing 767 is level at FL390 in the opposite direction. The tracks are offset by some 2 NM. When the aircraft are approximately 15 NM head-on the MD-11 gets a Descend RA and the crew responds to the RA.

The air traffic controller is busy talking to other aircraft in the sector; however, he observes that the altitude of the MD-11 starts to change. As soon as another aircraft stops reading back its clearance, the controller instructs the B767 to turn to increase the horizontal spacing with the MD-11 which is now passing FL396. As soon as the B767 confirms the turn instruction, the controller calls the MD-11 asking for the reason they are descending. On the second call the MD-11 crew tells the controller they were descending because of an RA, reaching FL395 and now climbing back to FL400 as the RA is over.

A few seconds later, the aircraft pass each other with horizontal spacing of 3.5 NM and 600 feet vertically. The B767 pilot reports seeing the MD-11 and getting a TA. In the ensuing radio exchanges, the MD-11 crew informs the controller that they suddenly got a Descend RA and responded accordingly. Their traffic display showed another aircraft in close proximity at the same altitude.

An investigation of this event determined that the RA generated for the MD-11 was caused by self-tracking (see the text box on the next page).

Conclusions: The MD-11 crew reacted correctly responding to the RA. In real-time the pilot has no possibility to know if an RA is generated against a real threat or, as in this case, it is caused by a technical malfunction. However, the delayed RA report to ATC could have been a source of increased risk as it limited the time available to the controller to issue avoiding instructions to another aircraft.

The controller, quite correctly, took an action to provide a horizontal avoidance manoeuvre to the B767. In the case of close aircraft proximity and in the absence of an RA report, controllers should provide horizontal avoiding instructions as they will not interfere with the vertical RA manoeuvres and may help to reduce the risk of a collision. TCAS II is able to simultaneously process several intruders and provide an appropriate RA. In this case because of the increasing horizontal spacing no RAs were issued for the B767 – MD-11 conflict pair.

Learning points:

- The MD-11 crew reacted correctly responding to the RA.
- The RAs causing a deviation from ATC clearance should be reported to ATC as soon as possible.
- In the case of close aircraft proximity and in the absence of an RA report, controllers should provide horizontal avoiding instructions (rather than vertical) as the horizontal manoeuvres will not interfere with vertical RAs and may help to reduce the risk of a collision.
- Following a suspected self-tracking RA, the aircraft equipment should be checked by the operator's maintenance department.

What is a self-tracking RA?

In rare cases, an RA can be triggered as a result of self-tracking, i.e. when an aircraft tracks itself as an intruder. The pseudo-intruder is then seen at the same altitude and same position as own aircraft. TCAS II will not track Mode S intruders whose 24-bit aircraft address is the same as own aircraft and although an aircraft's suppression bus should prevent own transponder replying to Mode C interrogations, failures may occasionally occur.

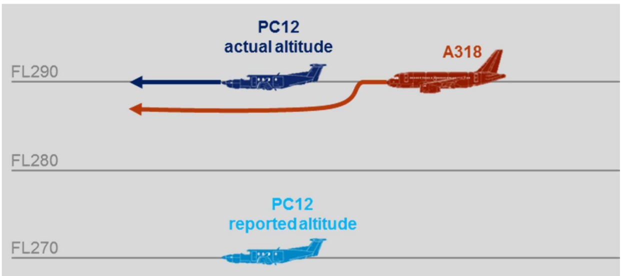
Self-tracking RAs may be operationally disruptive as the pilots would follow these RAs not knowing that they result from a failure and cause large deviations from ATC clearances.

Event 3: Incorrect altitude

A Pilatus 12 reports on frequency maintaining FL270. Four minutes later, the pilot notifies ATC that the left-hand side altimeter indicates FL270 while the right-hand side FL290. The pilot is not certain which altimeter is right. They have attempted to determine their altitude using their GPS but that was inconclusive.

The controller observes FL270 at his screen but this altitude is provided by the left-hand side altimeter. In the attempt to establish which altimeter is showing the correct altitude, the controller seeks information from a military radar operator. He says that he can also observe FL270. Therefore, an assumption is made that the aircraft is at FL270. Neither the pilots nor the controllers realise that in fact the right-hand side altimeter is correct and the PC12 is really maintaining FL290.

An Airbus 318 at FL290 is flying along the same airway as the PC12. It is 170 kt faster than the PC12. The A318 crew is busy with their arrival briefing when they feel that the aircraft starts to roll slowly like it is encountering wake turbulence. One of the pilots looks outside and can see the PC12 very close, slightly above and to the right. He disconnects the autopilot making a pitch down input to the left keeping a visual contact with the PC12. He also checks the TCAS traffic display for any traffic below but he can only see a target indicated 2000 feet below. At the time he does not realise that the target below was actually representing the PC12. The A318 descends approximately 200 feet before overtaking the PC12.



Conclusions: An avoiding action undertaken by the A318 pilot potentially prevented a midair collision. The crew estimated horizontal separation was 15-30 metres (50-100 feet) horizontally and 100 feet vertically.

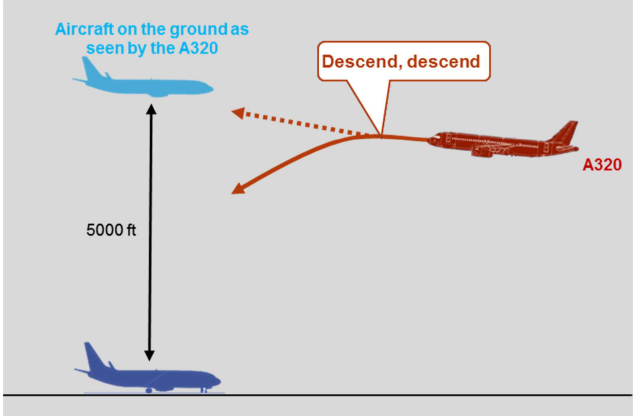
Both the PC12 crew and air traffic controllers made an incorrect assumption about the PC12's altitude. The altitude provided to "the outside world" (i.e. ground radars and TCAS) was coming from the faulty altimeter reporting 2000 feet below the real altitude. Air traffic controllers do not have equipment that allows them to resolve any doubts concerning an aircraft's altitude and the only source of information they have is Mode C information from an aircraft's transponder. While some military radars are capable of providing altitude information based solely on primary radar, the accuracy of such measurement is sufficient for military purposes but not for traffic separation.

Also, the use of GPS would not resolve the doubt as the GPS altitude is based on a geometric calculation whereas the altimeters compute barometric altitude.

Learning points:

- TCAS II and ATC systems use the altitude data provided by the aircraft's transponder. If the data fed to the transponder is incorrect, the error will be propagated. Consequently, air traffic controllers will not know the real barometric altitude of the aircraft and TCAS II alerts might not be generated correctly.
- ATC centres do not have equipment that allows them to determine aircraft's altitude other than transponder Mode C reports.
- If the aircraft altitude is unreliable, air traffic controllers should ensure that the aircraft is separated horizontally from other traffic in the area and should request the pilot stops altitude data transmission, if possible.

Event 4: Testing on the ground



An Airbus 320 has just departed and is climbing through 4000 feet when the crew receives a Descend RA. The crew respond to their RA by starting a descent at 1500 ft/min. and reports the RA to ATC. The controller informs the crew that there is no other traffic on his radar screen in their vicinity. Nonetheless, the crew – quite correctly – follows the RA. After a number of seconds the RA weakens to Level Off and then a Clear of Conflict message is posted.

Although the crew could see a conflicting traffic target on their traffic display, no aircraft could be acquired visually. Both, the crew and air traffic controller filed reports.

A subsequent investigation established that the RA was caused by transponder testing on the ground. The departure route took the A320 overhead another aerodrome, used as a maintenance base. There work was being conducted on an aircraft parked on the apron with the transponder active indicating an altitude of 5000 feet. As TCAS II interrogates all Mode S and Mode A/C SSR transponders reporting altitude within its range (including those on the ground operated for testing or maintenance), the TCAS II on the A320 detected a potential threat and issued the RA. The tested transponder was not visible on the ATC radar, as the test site was shielded from the ground radar by terrain.

Learning points:

- The A320 crew correctly responded to the RAs even though they could not see the intruder. In hindsight, the RA was not necessary but the crew could not have determined that in real time.
- Any unshielded transponder under maintenance or testing on the ground will be shown as a 'ghost' target on a TCAS traffic display and could also generate TAs/RAs, if the altitude of the airborne aircraft and the altitude set on the transponder on the ground are within the alerting range. That will result in an alert against a non-existent threat.
- TAs/RAs due to transponder testing on the ground are disruptive and potentially hazardous; therefore, must be prevented.

Avoiding unnecessary TCAS alerts due to transponder testing on the ground

- To prevent the transmission of a virtual altitude (which could then be mistakenly used by airborne systems) use effective screening or absorption devices on the antennas.
- Alternatively, perform the testing inside a hangar to take advantage of any shielding properties it may provide.
- Otherwise, manually set the altitude to a high value (e.g. over 60,000 feet) or unrealistically low (e.g. negative 2000 feet).
- Select the transponder to 'OFF' or standby when testing is complete.

Transponder altitude setting

- If the transponder on the ground is providing actual (i.e. ground) altitude data, the TCAS logic will deem this to be on the ground and will not generate an alert.
- If no altitude data is provided TCAS II will generate only a 'non-altitude reporting' TA, if the alert generation criteria are met.
- If an artificial altitude is used TCAS II will generate both a TA and/or an RA if the alert generation criteria are met.

EASA (European Aviation Safety Agency) AMC 20-13, § 14.1 on maintenance of transponders

Maintenance testing of altitude reporting transponders should be suitably screened to minimise the risk of nuisance traffic or collision resolution advisories in operating aircraft. When performing transponder testing which involves the use of the altitude changes, it is advisable to ensure the transponder is in 'standby' or 'off' whilst the air data system is set to the required altitude. The transponder should only be operated during the testing phase to minimise the risk of interference with other aircraft. Following completion of the testing, the transponder should be returned to 'standby' or 'off'. The air data system may then be returned to atmospheric pressure. Note: Before performing any transponder testing involving altitude changes the local Air Traffic Controller should be contacted and a 'safe test altitude(s)' agreed.

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