TCAS RAs generated due to transponder testing on the ground
Additional information – 3 July 2008

In the Safety Warning Message “TCAS RAs generated due to transponder testing on the ground” published on 27 February 2008, EUROCONTROL cautioned about the instances in which TCAS RAs were generated as a result of transponders tests on the ground (see the full text of the Safety Warning Message underneath).

The issue remains a safety risk. Therefore, aircraft operators, regulators, and ANSPs are urged to continue to observe the recommendations of the Safety Warning Message and raise the awareness of the relevant personnel.

One of the examples of a successful awareness campaign was a workshop organized by Belgocontrol (Belgian ANSP), during which the issue, its consequences, and potential mitigations were discussed. The informative presentation from this workshop (attached underneath) was made available by Belgocontrol for potential use by other organizations in their training and awareness campaigns. Please note that several issues described in the presentation are applicable to the Belgian airspace and Belgian national regulations and, consequently, any material developed based on this presentation must take into account your local environment and regulations.

EUROCONTROL
Mode S and ACAS Programme
Email: acas@eurocontrol.int
Safety Warning Message

- **Safety Subject:** TCAS RAs generated due to transponder testing on the ground
- **Origin:** European airline, European ANSP
- **Date:** 27/02/2008
- **Distribution:** Aviation Safety Professionals

BACKGROUND INFORMATION

- TCAS II interrogates, within its range, all Mode S and Mode A/C SSR transponders squawking altitude. That includes ground-based transponders operated for testing or maintenance.
- If these transponders respond with an altitude report close to that of aircraft flying in the vicinity, their TCAS II Traffic Display will show a ‘ghost’ target and, more seriously, could generate TAs/RAs against such targets.
- Recently, events have been reported in which RAs were generated by transponders that were being tested on the ground.
- These unnecessary RAs were disruptive to the flight crew and air traffic control.

EUROCONTROL MODE S & ACAS PROGRAMME ADVICE

- TAs/RAs due to transponder testing on the ground are disruptive and potentially hazardous and must be prevented.
- To avoid these TAs/RAs special caution and appropriate procedures are required during transponder testing and maintenance.
- In order to prevent the transmission of a virtual altitude which could then be mistakenly used by airborne systems, the followings steps are recommended:
  - Use effective screening or absorption devices on the antennas or physically connect the ramp test set to the antenna system.
  - Where possible, perform the testing inside a hanger to take advantage of any shielding properties it may provide.
  - Manually set the altitude to a high value (e.g. over 60,000 feet) or unrealistically low (e.g. negative 2000).
  - Select the transponder(s) to ‘OFF’ or ‘Standby’ when testing is complete.
- The simulation of TCAS operations must not be carried out by the radiation from an antenna located on, or remotely based from a workshop.

ADDITIONAL INFORMATION AND ADVICE

- ICAO Annex 10, vol. IV
- JAA TGL 8 - Certification Considerations for the Airborne Collision Avoidance System: ACAS
- JAA TGL 13 - Certification of Mode S Transponder Systems for Elementary Surveillance
- EUROCAE WG49 guidance for ground test and maintenance
YOUR SUPPORT IS REQUIRED

- Note the subject and investigate the relevance for your operational environment.
- **National Regulators**: develop national guidance for transponder testing on the ground to prevent the interference with TCAS II operations.
- **Maintenance/test facilities**: ensure that steps are taken along the recommendations in this Safety Warning Message and any national requirements when transponders are tested on the ground.
- **ANSPs/airlines**: report occurrences of RAs generated by transponder testing on the ground to national regulatory authorities.

SHARE WITH US YOUR SAFETY KNOWLEDGE

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February 2008.

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ATC Transponder and ACAS Ground Testing

Paul HOPFF – Attaché DGO/ATS
Steenokkerzeel, November 29th, 2007

Agenda

- Introduction
- Mode S transponder & ACAS basics.
- Radar Environment – Brussels Airport.
- ATC use of transponder replies.
- Transponder « Nuisance »

- Transponder /ACAS Testing precautions.

- Visit to Tower EBBR
Keywords for today:

TRANSPONDER TEST
AWARENESS
SAFETY

Aircraft Environment
ATC Transponder and ACAS Ground Testing

Transponder Power Off/On and Standby Status

<table>
<thead>
<tr>
<th>Mode</th>
<th>ICAO</th>
<th>MOPS</th>
<th>ARINC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power OFF</td>
<td>Nothing</td>
<td>Nothing</td>
<td>- No power supplied</td>
</tr>
<tr>
<td></td>
<td>stated</td>
<td>stated</td>
<td>- Inactive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- No transmission</td>
</tr>
<tr>
<td>Standby</td>
<td>Nothing</td>
<td>Nothing</td>
<td>- Power supplied</td>
</tr>
<tr>
<td></td>
<td>stated</td>
<td>stated</td>
<td>- No RF transmission</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Active with bus activity and limited BITE</td>
</tr>
<tr>
<td>Power ON</td>
<td>Nothing</td>
<td>Nothing</td>
<td>- Power supplied</td>
</tr>
<tr>
<td></td>
<td>stated</td>
<td>stated</td>
<td>- Active and transmit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Normal operation</td>
</tr>
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</table>

Mode of operation of ATC transponders

<table>
<thead>
<tr>
<th>Mode</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td>None</td>
</tr>
<tr>
<td>Stand-by</td>
<td>No RF transmission, TCAS and transponder are in the warm up cycle</td>
</tr>
<tr>
<td>On</td>
<td>The transponder replies on interrogations (see chapter 4)</td>
</tr>
<tr>
<td>Altitude reporting off</td>
<td>The transponder replies without altitude information.</td>
</tr>
<tr>
<td>Xpdr</td>
<td>Transponder on and TCAS is in the warm up cycle</td>
</tr>
<tr>
<td>TA only</td>
<td>The transponder is on. The TCAS is on but only the Traffic Advisory function of the TCAS is operational</td>
</tr>
<tr>
<td>TA/RA</td>
<td>The transponder is on and all Traffic Advisory and Resolution Advisory functions of TCAS are operational</td>
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Check modes of operation on your aircraft!
ATC Transponder and ACAS Ground Testing

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Check modes of operation on your aircraft!

“Airborne” vs “on-Ground” Status

- A (Mode S) transponder is either
  - Declared “on-the-ground”; OR
  - Declared “airborne”
- Declaration of the status is either
  - Automatic (i.e. landing gear squat switch); OR
  - Manual (pilot action)
- Transponder “behaviour” is dependent of the declared status:
  - Transmission of periodic squitters
  - Replies to interrogations
**Transponder transmissions on ground (1)**

- When the Mode S transponder is switched on and not in the stand-by mode and in the “on-the-ground” status, only all call transmissions are inhibited.
- Squitter messages will continue to be transmitted to be used by other systems like multi-lateration systems.
- Mode S transponders shall always reply to selective interrogations (24 bits Mode S address) e.g. to acquire the aircraft call sign or Mode 3A.)

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**Transponder transmissions on ground (2)**

<table>
<thead>
<tr>
<th>Type of Interrogations</th>
<th>ICAO Amendment 77</th>
<th>EUROCAE Maps ED73A</th>
<th>ARINC 718A</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODE A/C</td>
<td>Recommendation: Should be Inhibited</td>
<td>May be inhibited</td>
<td>Refer to ICAO</td>
</tr>
<tr>
<td>Mode A/C/S All Call (P1,P3, P4L)</td>
<td>Shall always be Inhibited</td>
<td>Shall always be inhibited</td>
<td>Refer to ICAO</td>
</tr>
<tr>
<td>Mode S only all call (UF 11)</td>
<td>Shall always be Inhibited</td>
<td>Shall always be inhibited</td>
<td>Refer to ICAO</td>
</tr>
<tr>
<td>Mode 5 (Roll Call UF= 0.4,5,16,20,21,24)</td>
<td>Shall not be possible to inhibit</td>
<td>Shall not be possible to inhibit</td>
<td>Refer to ICAO</td>
</tr>
<tr>
<td>Acquisition Squitter (Short Squitter)</td>
<td>shall be inhibited if surface type of extended squitter is transmitted</td>
<td>Shall not be possible to inhibit</td>
<td>Refer to ICAO</td>
</tr>
<tr>
<td>Extended Squitter (Long Squitter)</td>
<td>shall not be possible to inhibit</td>
<td>Shall not be possible to inhibit</td>
<td>Refer to ICAO</td>
</tr>
</tbody>
</table>
ATC Transponder and ACAS Ground Testing

Transponder antenna selection

<table>
<thead>
<tr>
<th></th>
<th>ICAO</th>
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<th>ARINC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft on the Ground</td>
<td>Interrogation</td>
<td>Squitter</td>
<td>Interrogation</td>
</tr>
<tr>
<td>Transponder + antenna diversity</td>
<td>Diversity</td>
<td>SAS or Top</td>
<td>Div</td>
</tr>
<tr>
<td>Transponder with single antenna</td>
<td>Bottom</td>
<td>Bottom</td>
<td>Bottom</td>
</tr>
<tr>
<td>ES/NT device</td>
<td>Diversity</td>
<td>Top</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Diversity = replies following the antenna diversity protocol
Bottom = Bottom antenna
Top = Top antenna
SAS = Squitter Antenna Selection

“Antenna diversity protocol”?

- ICAO Annex 10 - Volume IV – Chapter 3:
  - 3.1.2.10.4.3 Antenna selection. Mode S transponders equipped for diversity operation shall have the capability to evaluate a pulse sequence simultaneously received on both antenna channels to determine individually for each channel if the P1 pulse and the P2 pulse of a Mode S interrogation preamble meet the requirements for a Mode S interrogation as defined in 3.1.2.1 and if the P1 pulse and the P3 pulse of a Mode A, Mode C or intermode interrogation meet the requirements for Mode A and Mode C interrogations as defined in 3.1.1.
  - … the antenna at which the signal strength is greater shall be selected for the reception of the remainder (if any) of the interrogation and for the transmission of the reply.

- ARINC 718A:
  - squitter transmissions should occur alternately out the top/bottom antennas when the aircraft is airborne, and out the top antenna only, when the aircraft is on-the-ground.
ATC Transponder and ACAS Ground Testing

Use of Mode A/C/S Radar at EBBR

Use of Mode A/C/S Radar at EBBR
Use of Mode A/C/S Radar at EBBR

"ASR9"
Primary + Secondary
(Mode A/C)

"MSSR"
Secondary
(Mode A/C)

“NOVA”
Primary
("Ground Radar")

CURRENT SITUATION
(= subject to changes!)

Use of Mode A/C/S Radar at EBBR

Mode S Multi-lateration
Operation of transponders on ground - EBBR

- Aircraft operators intending to use EBBR shall ensure that the Mode S transponders are able to operate when the aircraft is on the ground.

- Pilots shall:
  - Select XPNDR or the equivalent according to specified installation, AUTO mode if available, not OFF or STDBY, and assigned Mode A code:
    - From the request for push back or taxi whichever is earlier.
    - After landing, continuously until the aircraft is fully parked on stand.
    - Whenever the aircraft is capable of reporting aircraft identification (i.e. call sign used in flight), the aircraft’s identification should also be entered from the request for push back or taxi whichever is earlier (through the FMS or the Transponder Control Panel). Air crew must use the ICAO defined format for entry of the aircraft identification, as specified in item 7 of the ATC FPL (e.g. DAT123, VEX6380,...).

- To ensure that the performance of systems based on SSR frequencies (including airborne TCAS units and SSR radars) is not compromised, TCAS should not be selected before receiving clearance to line up. It should then be deselected after vacating the runway.

- For aircraft taxiing without flight plan, Mode A code 1000 should be selected.

[Ref. AIC 03-2005]

Use of Mode A/C/S Radar at EBBR

- Sensors to take into account:
  - ASR9 + MSSR (Mode A/C)
  - Bertem (Mode S)

- Users:
  - EBBR Tower
  - CANAC (Approach + ACC)
  - MUAC (Maastricht) – Reims ACC!
  - Overflying aircraft (TCAS)

Different altitude “slices”!

- Multi-lateration (Mode S)
  - Used by EBBR Tower for tracking on ground only
**ATC Transponder and ACAS Ground Testing**

**Functional test of transponder installations**

- **Test requirements in Belgium (BCAA):**
  - Yearly test of transponder installations i.a.w. Appendix F of FAR Part 43.
  - In addition: check Mode C information against pressure altitude as shown to the pilot.
    
    [Ref. CIR/EQUIP-04]

- **Test “requirements” for ATC:**
  - Avoid any nuisance during the test(s)!
  - No (Belgian) guidance publication.
  - **UK CAA: Leaflet 9-5 (contained in CAP562)**

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**Example of “nuisance” (1)**

![Example of “nuisance” (1)](image)
ATC Transponder and ACAS Ground Testing

Example of “nuisance” (2)

Occurrence report from Eurocontrol Maastricht (MUAC):

Example of “nuisance” (2)
ATC Transponder and ACAS Ground Testing

A controller’s view

Example experienced at Maastricht UAC

One day of traffic

DATE: 30 June 2006
NUMBER OF TRACKS: 4,806
ONLY CORRELATED TRACKS

blue lines: traffic FL 240-340
red lines: traffic FL 340 and above
ATC Transponder and ACAS Ground Testing

Radar Screen Shots

Source: Eurocontrol Maastricht (MUAC)
ATC Transponder and ACAS Ground Testing

Source: Eurocontrol Maastricht (MUAC)
ATC Transponder and ACAS Ground Testing
Interactions with TCAS

- A ground operated transponder may trigger a **nuisance advisory** on a TCAS equipped aircraft operating in the close vicinity.

- If the ground target is providing altitude data the TCAS logic should declare the aircraft to be on the ground and ought not to generate an advisory.

- If no altitude data is provided the TCAS will generate a TA if the threat criteria are met.
  - TA: Traffic Advisory

- If the ground is providing altitude data other than surface altitude, as may happen with a defective altitude encoder, or if a test pressure is being applied to the altitude encoder, the TCAS may generate both a TA and a RA if the threat criteria are met.
  - RA: Resolution Advisory
Interactions with TCAS

The ‘bottom’-line:

*Nuisance advisories may be caused to any TCAS equipped aircraft flying in the vicinity of transponders which are being tested.*

*This may also include aircraft passing overhead at medium or even high altitudes!*
ATC Transponder and ACAS Ground Testing

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- Visit to Tower EBBR

UK CAA Recommendations

- When not required ensure that transponders are selected to ‘OFF’ or ‘Standby’.
- For transponders under test, when equipped for altitude reporting, set the control unit to ‘Mode A/C’ and select Altitude Reporting ‘ON’.
- Where possible, carry out testing inside a hangar to take advantage of any shielding properties it may provide.
- Always use the antenna transmission absorption covers when these are provided with the test set.
- When testing mode C operation which require the altitude to be increased, radiate directly into the ramp test set via the prescribed attenuator.
- In between test parameters, select the transponder to the ‘Standby’ mode.
- The simulation of TCAS operation by the radiation from an antenna located on, or remotely based from a workshop, is not permitted.
UK CAA Recommendations

- Air Traffic Control Units may be advised when testing is to be carried out if it is considered that there is a possibility of nuisance advisories being caused by the activity due to its proximity to operational runways.

CAUTION

Even if ATC has been advised, it does not relieve you of the FULL RESPONSIBILITY for the proper conduct of the test !!!

EASA Recommendations

- 14 MAINTENANCE
- 14.1 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.

[Ref. EASA AMC 20-13]

Virtually impossible at EBBR...
ATC Transponder and ACAS Ground Testing

Test-sets

Antenna Shield (absorption cover)

Directional antenna

Test-set Manual

4.4.3 "Over the Air" Ground Test Procedure (IUT Aircraft Altitude Reporting System = Airfield Altitude)

1. Perform Setups Menu procedure, refer to 1-2-4.3.1.
2. Connect Test set antenna to ATC-901-2 ANTENNA Connector, Position Test set antenna facing IUT Antenna at Setup Menu Range.
3. Either shield with Antenna Shield center to Appendix O or disconnect and terminate IUT Antenna not being tested. Disconnect other area transponders or position transponders at least three times the Setup Menu Range from the Test Set antennas.
4. Press AUTO TEST Key to enter Auto Test screen. (The ATC-901-2 shows the results of the last Auto Test on the DISPLAY.)
5. Press RUN/STOP Key or ANTENNA PUBLISH BUTTON Switch if Flat Antenna is being used to run Auto Test. (TEST RUNNING and asterisks in bottom line of DISPLAY indicate test is running.)

4.4.4 "Over the Air" Simulated Altitude Test Procedure (IUT Aircraft Altitude Reporting System = Airfield Altitude ("Pumped Up")

1. Perform Setups Menu procedure, refer to 1-2-4.3.1.
2. Connect Test set antenna to ATC-901-2 ANTENNA Connector.
3. Shield IUT antenna being tested with Antenna Shield. Refer to Appendix O. Either shield with Antenna Shield or disconnect and terminate IUT Antenna not being tested. Disconnect other area transponders or position transponders at least three times the Setup Menu Range from the Test Set antenna.

NOTE: The Antenna Shield causes false indications for Diversity, NTL, Difference and Power Tests. The Antenna Shield may cause false indications for the Frequency Test. Such indications may be disregarded. Frequency, Diversity, NTL, Difference and Power tests are unlisted without the Antenna Shield.
ATC Transponder and ACAS Ground Testing

Test-set Manual

Need for tests at various altitudes?

- Tests with the aircraft “declared airborne” are most delicate.
  - Cannot we limit the number and duration of these tests?

- "Measure the automatic pressure altitude at the output of the installed ATC transponder when interrogated on Mode C at a sufficient number of test points to ensure that the altitude reporting equipment, altimeters, and ATC transponders perform their intended functions as installed in the aircraft. The difference between the automatic reporting output and the altitude displayed at the altimeter shall not exceed 125 feet.”
  [Ref. Appendix E to FAR Part 43 — Altimeter System Test and Inspection]

- How many ‘test points’?
  - Discussion
  - Dependent of aircraft system architecture!
    (i.e. Airbus A320: 1 test point)
Aircraft systems architectures

- Purpose of the test:
  - Verify proper operation of the sensor used for pressure altitude.
  - Verify connection between sensor and transponder.
  - Verify proper operation of transponder.
- Discuss matter with aircraft OEM and your airworthiness authority!

Gilham coding – integrity check.

<table>
<thead>
<tr>
<th>RANGE</th>
<th>PULSE POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INCREMENTS</td>
</tr>
<tr>
<td></td>
<td>(FEET)</td>
</tr>
<tr>
<td>-1000</td>
<td>0 0 0 0 0 0 0 0 0 1 0</td>
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<tr>
<td>-900</td>
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<tr>
<td>30800</td>
<td>1 1 0 0 0 0 0 0 0 1</td>
</tr>
</tbody>
</table>

Integrity of code lines is ensured through testing at these increments.
Conclusions

- **CAUTION** is required when performing Transponder and/or ACAS tests!
- All involved persons should be made aware of the potential risks for ATC and other aircraft!
- Tests are preferably to be conducted in a shielded environment (hangar with closed doors).
- If not possible, all precautions should be taken to avoid any interrogation of the aircraft under test by other aircraft or ATC radars!
- Follow instructions given in the test-set manual!
- Test sequence should be optimised in order to reduce test duration.

Questions?

Contact: Paul Hopff
paul_hopff@belgocontrol.be
ATC Transponder and ACAS Ground Testing