Update - 18-DEC-2009

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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.**

Keywords for today:

TRANSPONDER TEST

AWARENESS

SAFETY

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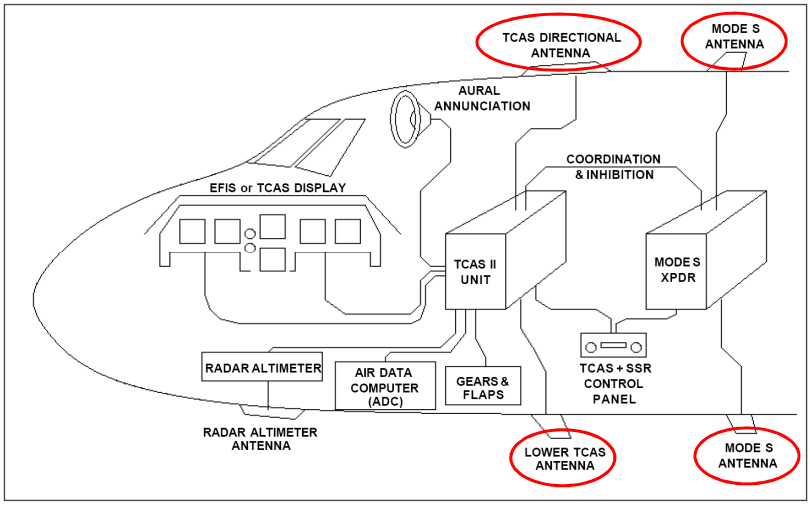
Aircraft Environment



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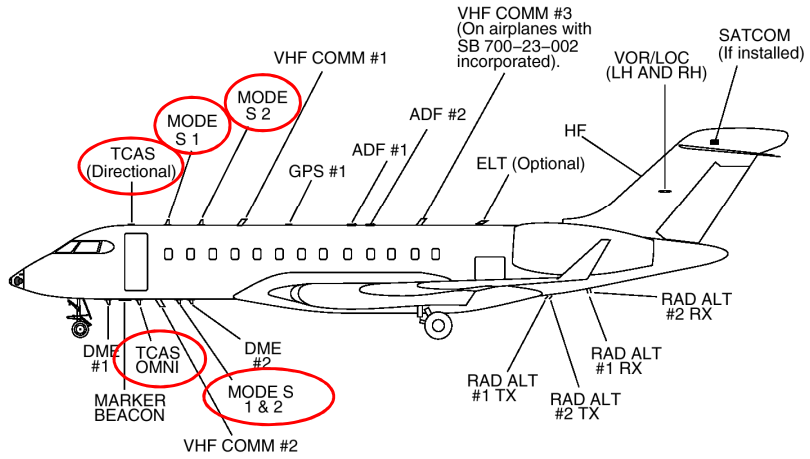
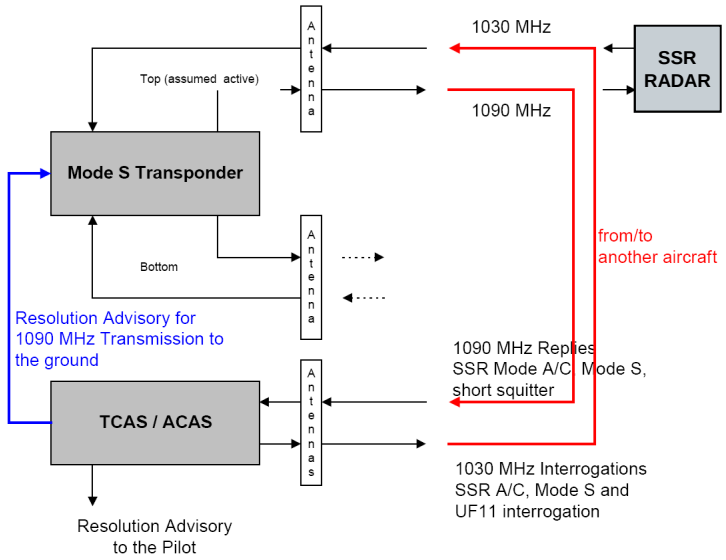
Aircraft Environment

ANTENNA LOCATION SCHEMATIC



Aircraft Environment



Transponder Power Off/On and Standby Status

	ICAO	MOPS	ARINC
Power OFF	Nothing stated	Nothing stated	- No power supplied - Inactive - No transmission
Standby	Nothing stated	Nothing stated	- Power supplied - No RF transmission - Active with bus activity and limited BITE
Power ON	Nothing stated	Nothing stated	- Power supplied - Active and transmit - Normal operation

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Mode of operation of ATC transponders

Mode	Operation
Off	None
Stand-by	No RF transmission. TCAS and transponder are in the warm up cycle.
On	The transponder replies on interrogations (see chapter 4)
Altitude reporting off	The transponder replies without altitude information. TCAS is in the standby mode.
Xpdr	Transponder on and TCAS is in the warm up cycle
TA only	The transponder is on. The TCAS is on but only the Traffic Advisory function of the TCAS is operational.
TA/RA	The transponder is on and all Traffic Advisory and Resolution Advisory functions of TCAS are operational

Check modes of operation on your aircraft!

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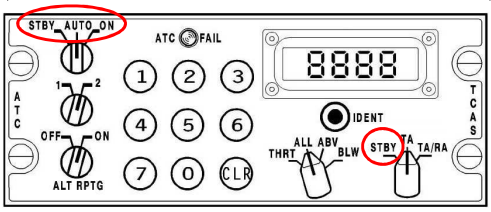
Check differences between "AUTO" and "ON" modes on your aircraft!
Do not mix up "STBY" modes from XPDR and ACAS!



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"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 – different cases: check on your a/c!)
- Transponder "behaviour" is dependent of the declared status:
  - Transmission of periodic squitters
  - Replies to interrogations

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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)

Type of Interrogations	ICAO Amendment 77	EUROCAE Mops ED73A	ARINC 718A
MODE A/C	*Recommendation:* Should be Inhibited	May be inhibited	Refer to ICAO
Mode A/C/S All Call (P1,P3, P4L)	Shall always be Inhibited	Shall always be inhibited	Refer to ICAO
Mode S only all call (UF 11)	Shall always be Inhibited	Shall always be inhibited	Refer to ICAO
Mode S (Roll Call UF= 0,4,5,16,20,21,24)	Shall not be possible to inhibit	Shall not be possible to inhibit	Refer to ICAO
Acquisition Squitter (Short Squitter)	shall be inhibited if surface type of extended squitter is transmitted	Shall not be possible to inhibit	Refer to ICAO
Extended Squitter (Long Squitter)	shall not be possible to inhibit	Shall not be possible to inhibit	Refer to ICAO

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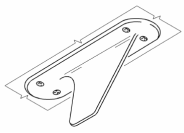
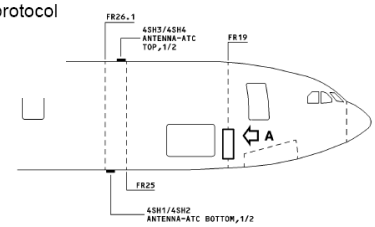
Transponder antenna selection

	ICAO		MOPS		ARINC	
Aircraft on the Ground	Inter-rogation	Squitter	Inter-rogation	Squitter	Inter-rogation	Squitter
Transponder + antenna diversity	**Diversity**	**SAS or Top**	**Div**	**SAS or Top**	**Diversity**	**Top**
Transponder with single antenna	**Bottom**	**Bottom**	**Bottom**	**Bottom**	**Bottom**	**Bottom**
ES/NT device	**Diversity**	**Top**	***TBD***	***TBD***	***TBD***	***TBD***

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





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"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.

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Use of Mode A/C/S Radar at EBBR

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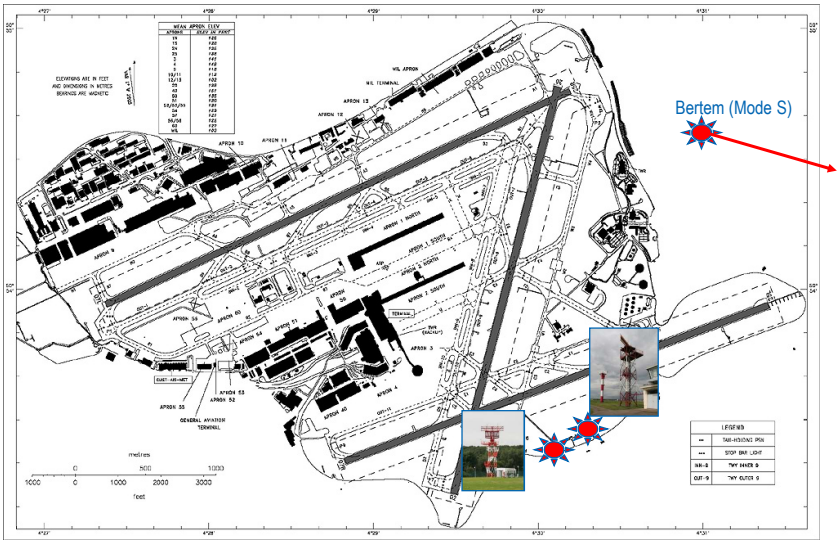
Use of Mode A/C/S Radar at EBBR



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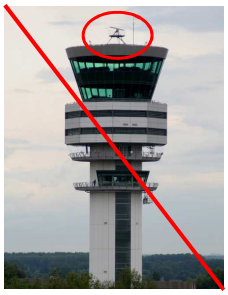
Use of Mode A/C/S Radar at EBBR

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

"MSSR"
Secondary
(Mode A/C)



"NOVA"
Primary
("Ground Radar")

CURRENT SITUATION
(= subject to changes!)

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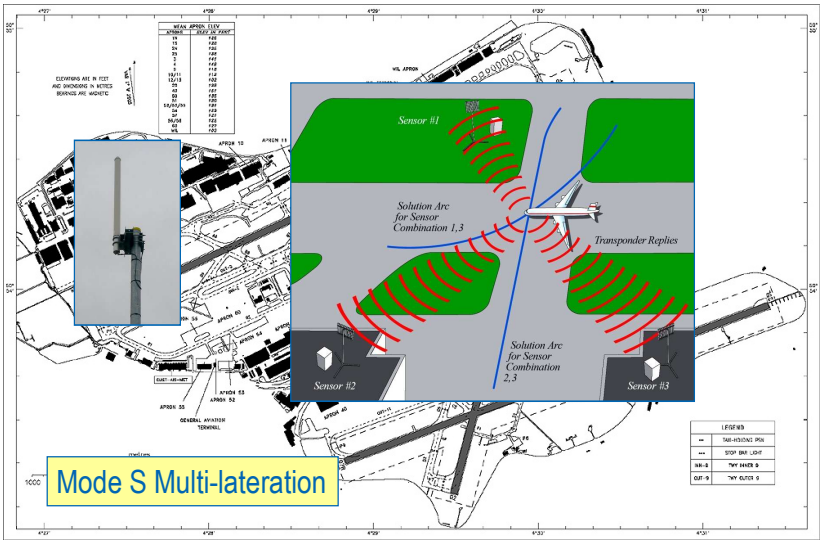
Use of Mode A/C/S Radar at EBBR



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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 STBY, 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 **2000** should be selected.

[Ref. AIP]

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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

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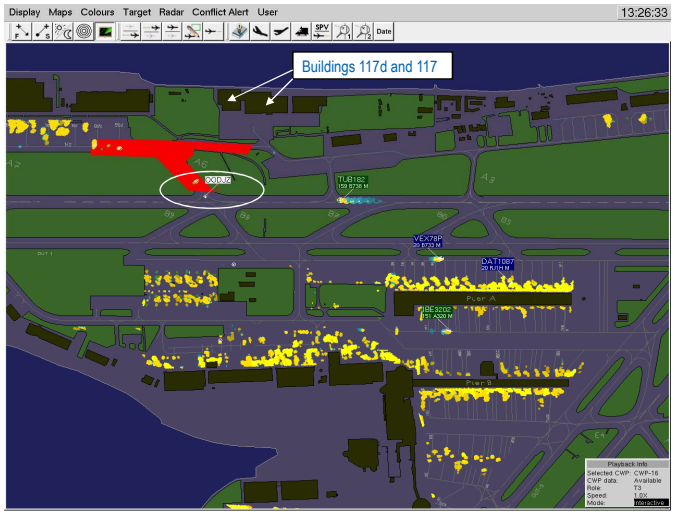
Functional test of transponder installations

- 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)*

Example of "nuisance" (1)



Example of "nuisance" (2)

Occurrence report from Eurocontrol Maastricht (MUAC):

OPS-00000061040 occurred on 13-OCT-07 16:47:57 in sector Brussels.
Reported by: DE BACKERE Kurt
Supervisor: DE BACKERE Kurt

Remarks:
OCCURRENCES: Others transponder check at EBBR

Detailed Description:
1645
A6303 upto FL300 for approx 30 minutes

pls forward this message to Danny Leenders and JM Leboutte

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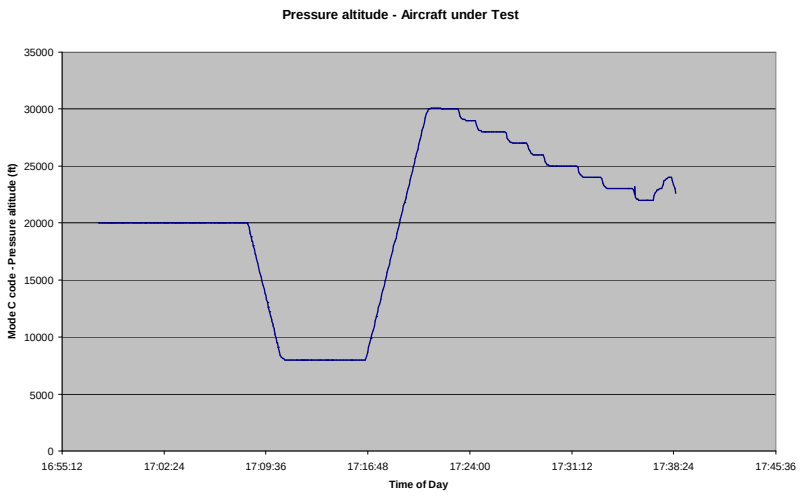
Example of "nuisance" (2)



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A controller's view

Example experienced at Maastricht UAC

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Source : Eurocontrol Maastricht (MUAC)

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One day of traffic

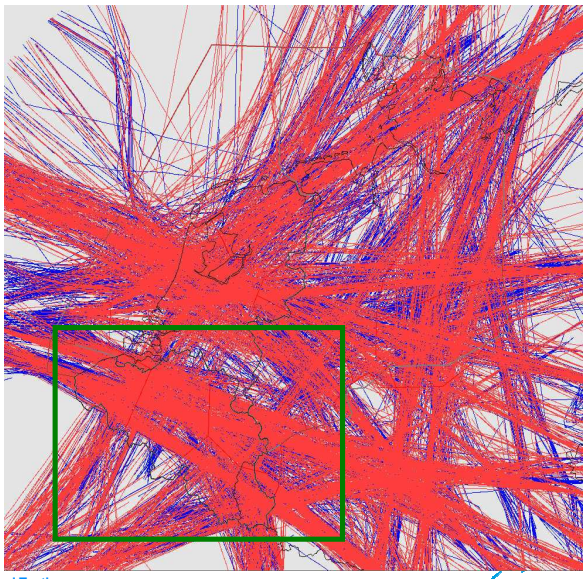
DATE: 30 June 2006

NUMBER OF TRACKS: 4,806

ONLY CORRELATED TRACKS

blue lines: traffic FL 240-340

red lines: traffic FL 340 and above



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Source : Eurocontrol Maastricht (MUAC)

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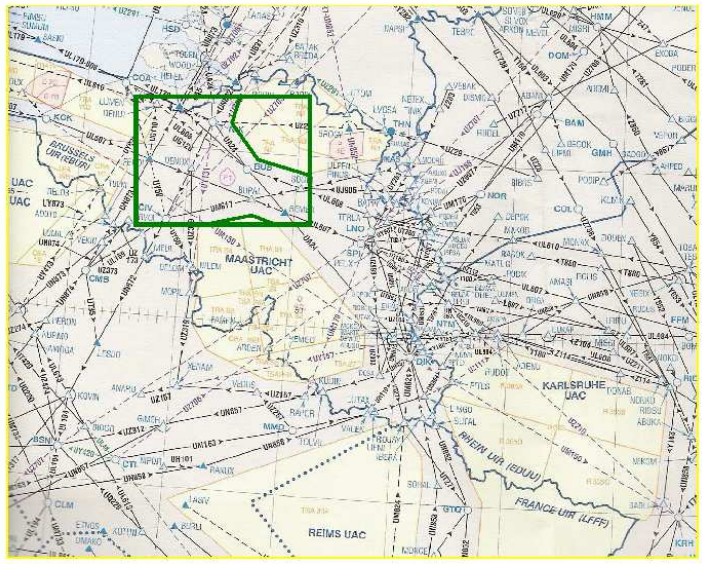
Radar Screen Shots



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Source : Eurocontrol Maastricht (MUAC)

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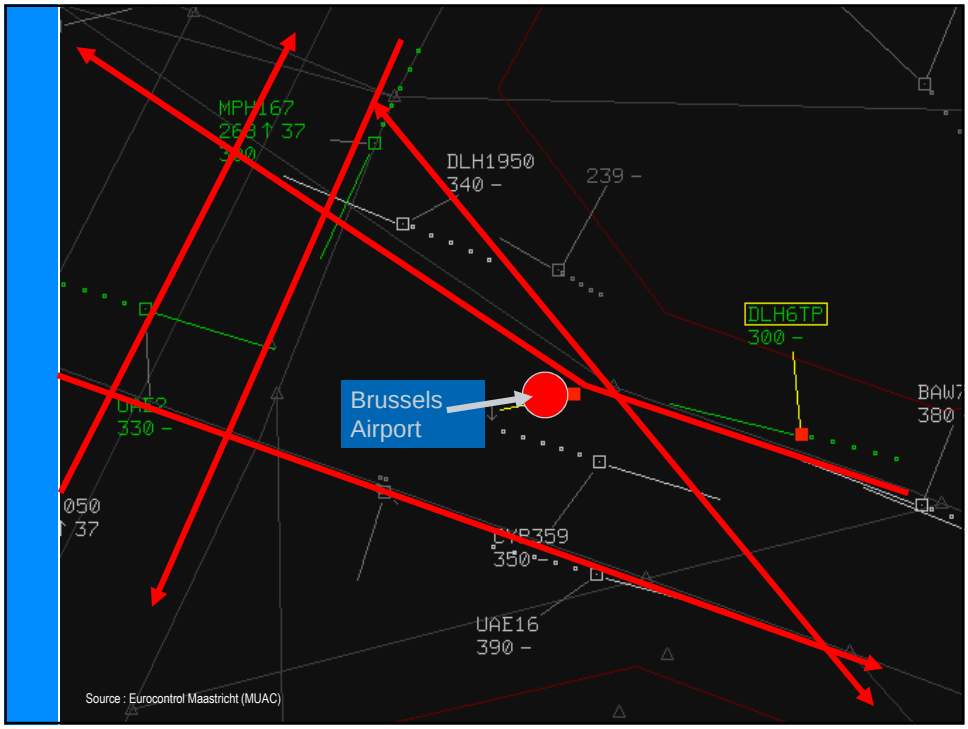
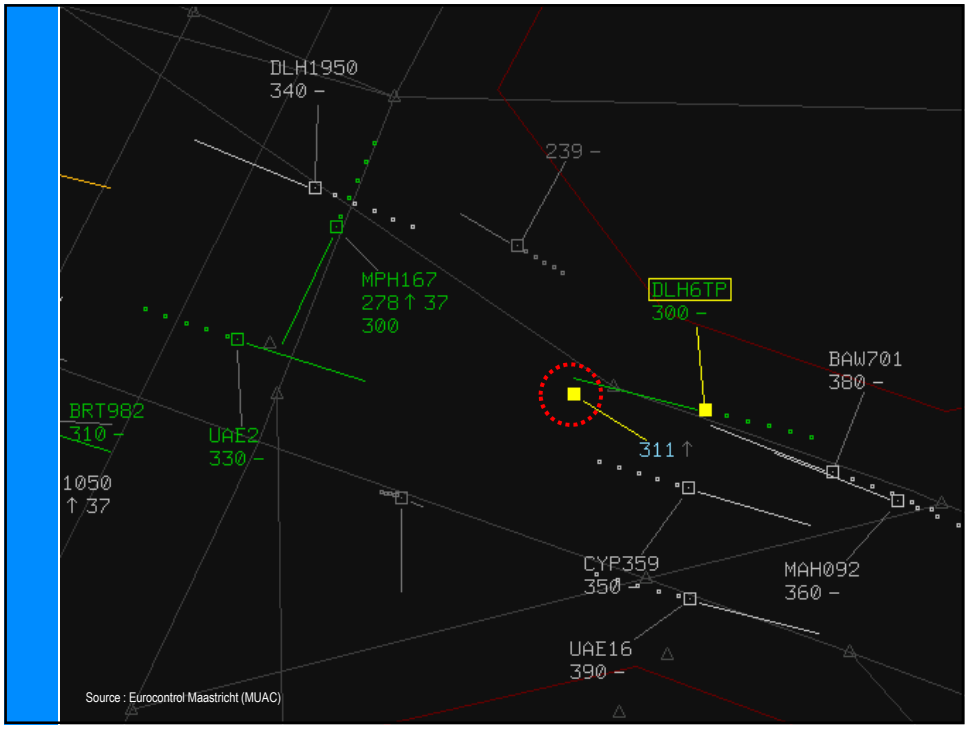
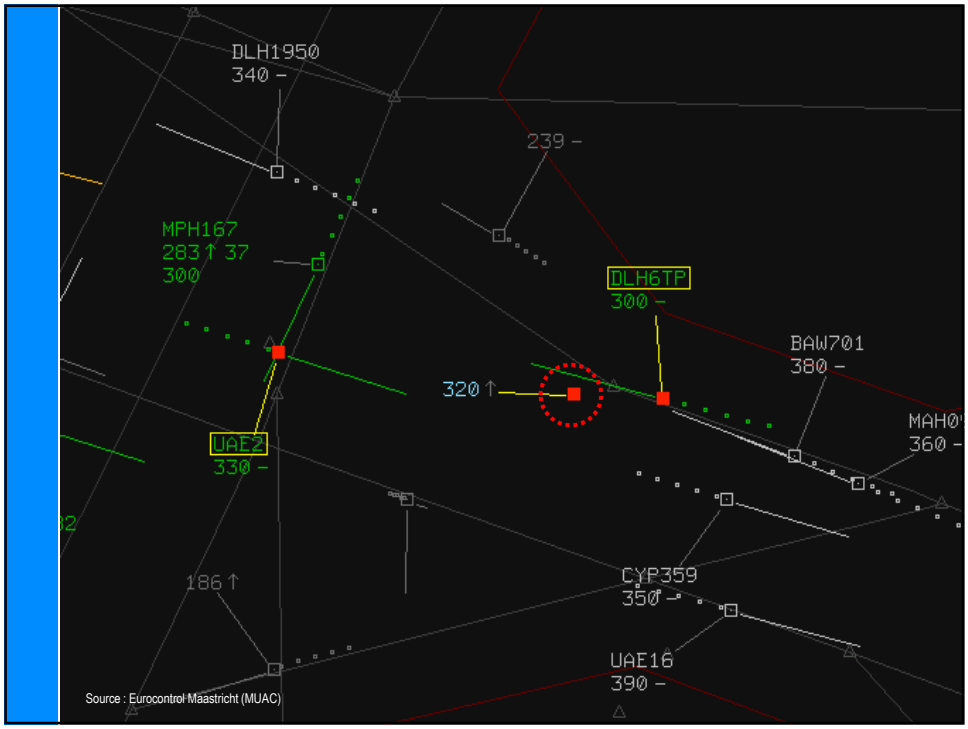
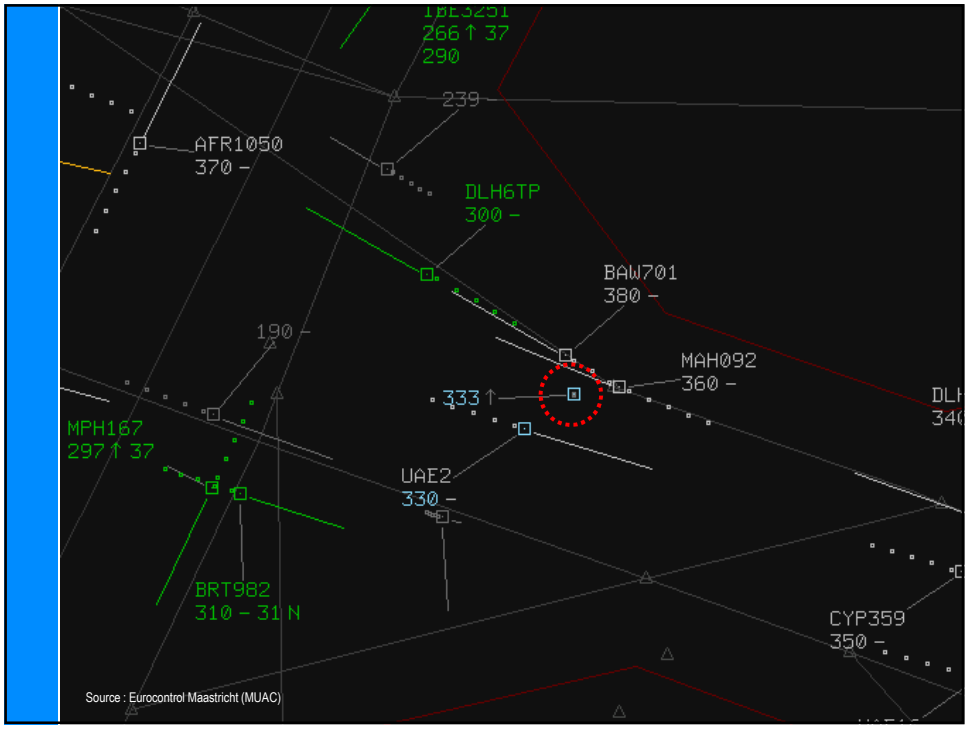


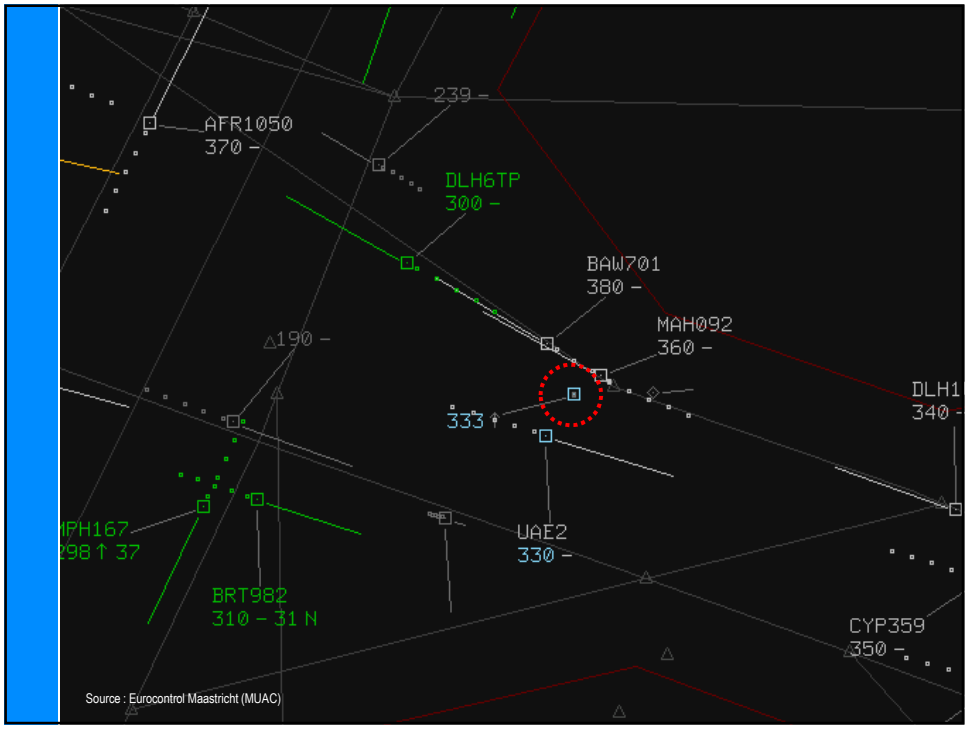
ATC Transponder and ACAS Ground Testing

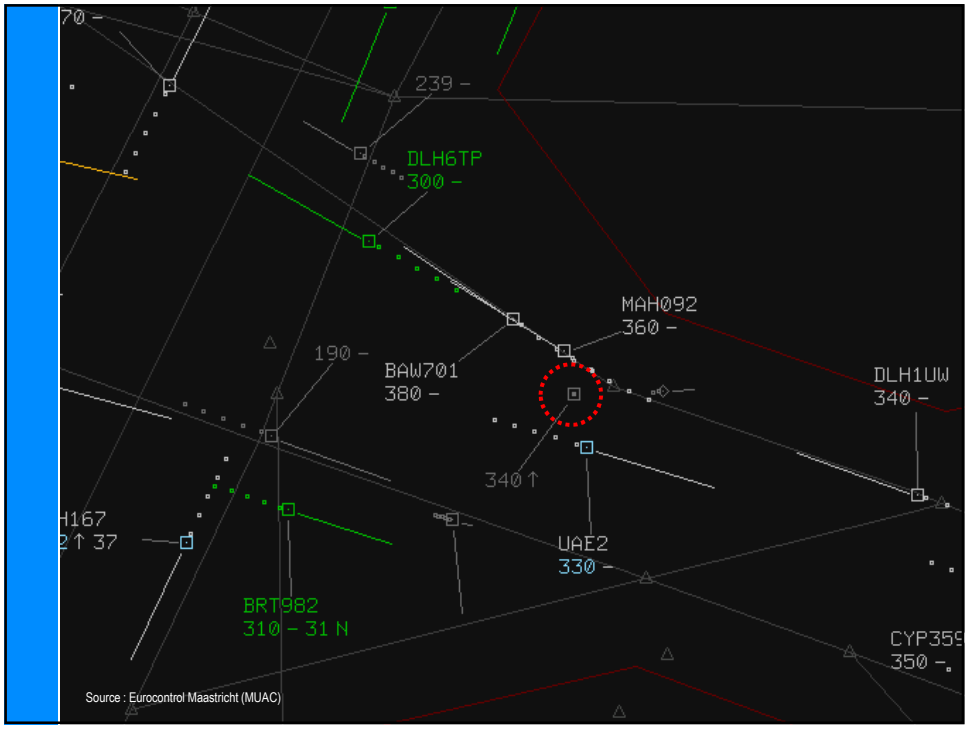




ATC Transponder and ACAS Ground Testing







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

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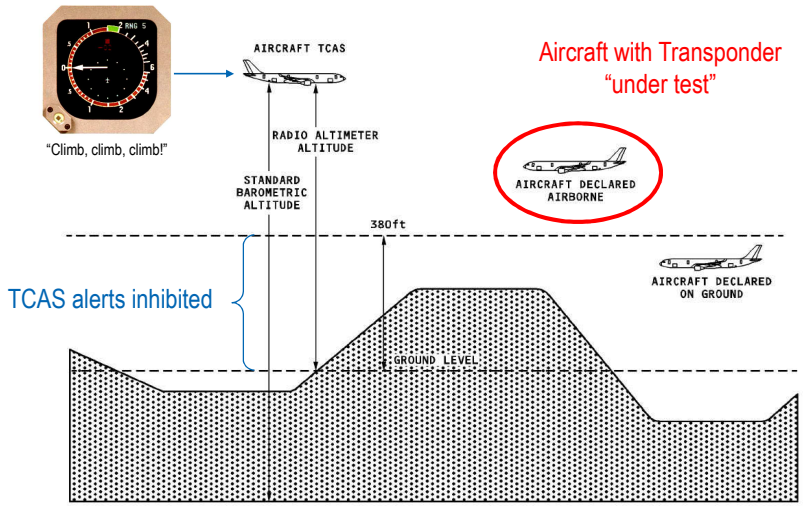
Interactions with TCAS



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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!

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Agenda

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

- **Transponder /ACAS Testing precautions**

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 !!!

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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…

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Test-sets

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Test-set Manual

AEROFLEX

OPERATION MANUAL
ATC-601-2

4.4.3 "Over the Air" Ground Test Procedure (UUT Aircraft Altitude Reporting System ≤ Airfield Altitude)

STEP	PROCEDURE
1.	Perform Setup#1 Menu procedure, refer to 1-2-4.3.1.
2.	Connect Test Set antenna to ATC-601-2 ANTENNA Connector. Position Test Set antenna facing UUT Antenna at Setup#1 Menu Range.
3.	Either shield with Antenna Shield (refer to Appendix C) or disconnect and terminate UUT Antenna not being tested. Deactivate other area transponders or position transponders at least three times the Setup#1 Menu Range from the Test Set antenna.
4.	Press AUTO TEST Key to enter Auto Test screen. (The ATC-601-2 shows the results of the last Auto Test on the DISPLAY.)
5.	Press RUN/STOP Key or ANTENNA PUSH 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 (UUT Aircraft Altitude Reporting System >Airfield Altitude ["Pumped Up"])

STEP	PROCEDURE
1.	Perform Setup#1 Menu procedure, refer to 1-2-4.3.1).
2.	Connect Test Set antenna to ATC-601-2 ANTENNA Connector.
3.	Shield UUT antenna being tested with Antenna Shield. Refer to Appendix C. Either shield with Antenna Shield or disconnect and terminate UUT Antenna not being tested. Deactivate other area transponders or position transponders >50 feet (15.24 meters) from the Test Set antenna.
	NOTE: The Antenna Shield causes failure indications for Diversity, MTL Difference and Power Tests. The Antenna Shield may cause failure indications for the Frequency test. Such indications may be disregarded. Frequency, Diversity, MTL Difference and Power tests are verified without the Antenna Shield.

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Test-set Manual

AEROFLEX

OPERATION MANUAL
IFR 6000

Procedure to Avoid False TCAS RA's on Overflying Aircraft or Altitude:

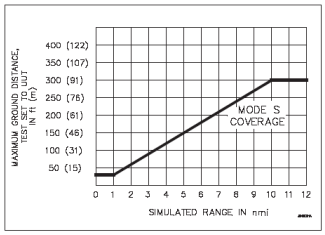
If the aircraft barometric system is at altitude, shield UUT Antenna being tested with Antenna Shield (Appendix J). Shield with another Antenna Shield or disconnect and terminate UUT Antenna(s) not being tested. Deactivate other area transponders or position transponder >50 ft (15.24 m) from the Directional Antenna. Position Directional Antenna ≤20 ft (6.1 m) from UUT Antenna being tested.

DME:

DME Antennas are bottom mounted on airframe. Verify which antenna(s) is DME Antenna(s) as the transponder lower antenna(s) look similar.

Position Directional Antenna in direct sight of UUT antenna, avoiding close obstructions (such as gantries, ladders and tool chests etc.), to minimize multipath reflections which cause random test failures. Usual distance from UUT antenna is approximately 10 to 20 feet.

NOTE: Directional Antenna should not be positioned closer than 6 feet, to ensure that the antenna far field is tested



Mode S Coverage
Within 12 nmi Simulated Range
Figure 107

Refer to 1-2-4, Figure 107. Due to high power density reduction in some TCAS interrogators, Mode S effective coverage distance may be dependent on the Test Set simulated range. For those units place Test Set according to 1-2-4, Figure 108. For simulated ranges within 1 nm, position test set within 30 ft (9.0 m) of UUT antenna.

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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)

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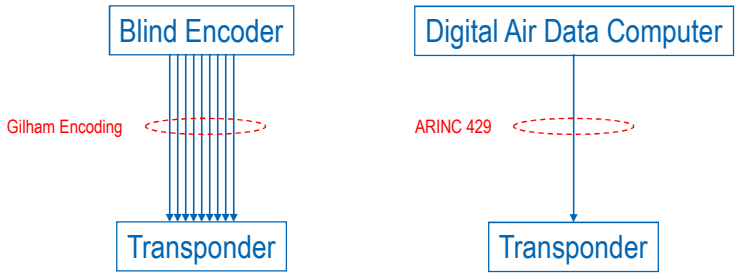
Aircraft systems architectures



- 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!

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Gilham coding – integrity check.

RANGE	PULSE POSITION									
(0 or 1 in a pulse position indicates absence or presence of a pulse, respectively)										
INCREMENTS (FEET)	D4	A1	A2	A4	B1	B2	B4	C1	C2	C4
-1000	0	0	0	0	0	0	0	0	1	0
-900	0	0	0	0	0	0	0	1	1	0
-700	0	0	0	0	0	0	1	1	0	0
-400	0	0	0	0	0	0	1	0	1	1
-200	0	0	0	0	0	1	1	0	0	1
800	0	0	0	0	1	1	0	0	0	1
2800	0	0	0	1	1	0	0	0	0	1
6800	0	0	1	1	0	0	0	0	0	1
14800	0	1	1	0	0	0	0	0	0	1
30800	1	1	0	0	0	0	0	0	0	1

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

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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.
- Belgocontrol requests to use Mode A code "**7776**" for transponder tests ("**2000**" as second code if 2 codes are required)!

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Questions?

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