XMM recoveries in 2008

and

the new operations strategy re. antennae switching

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XMM-Newton Deputy Spacecraft Operations Manager

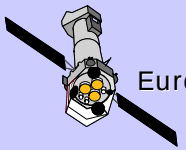
with Inputs from the MOC Flight Control Team

European Space Agency (ESA)
European Space Operations Centre (ESOC)

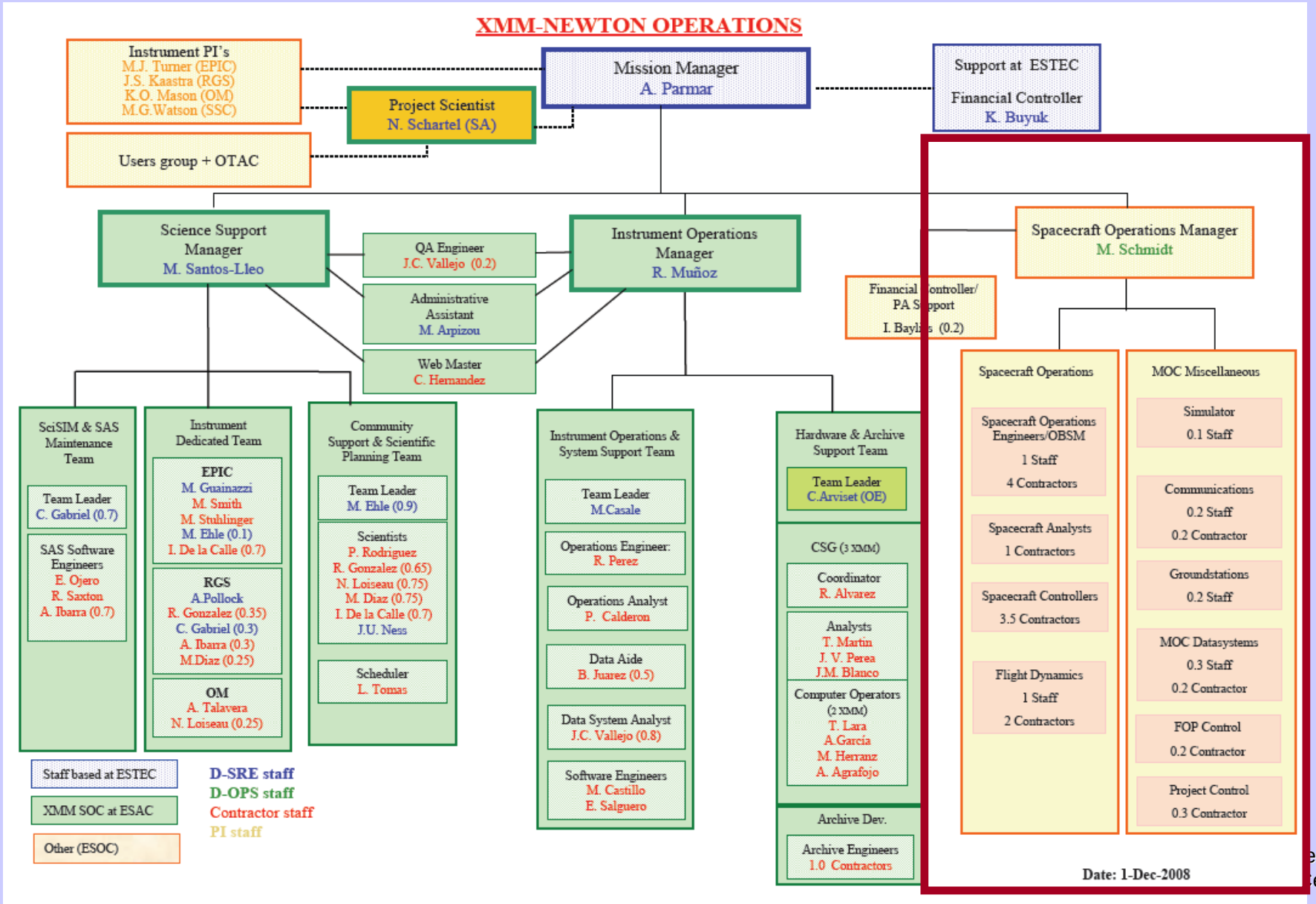
March 2009

menu

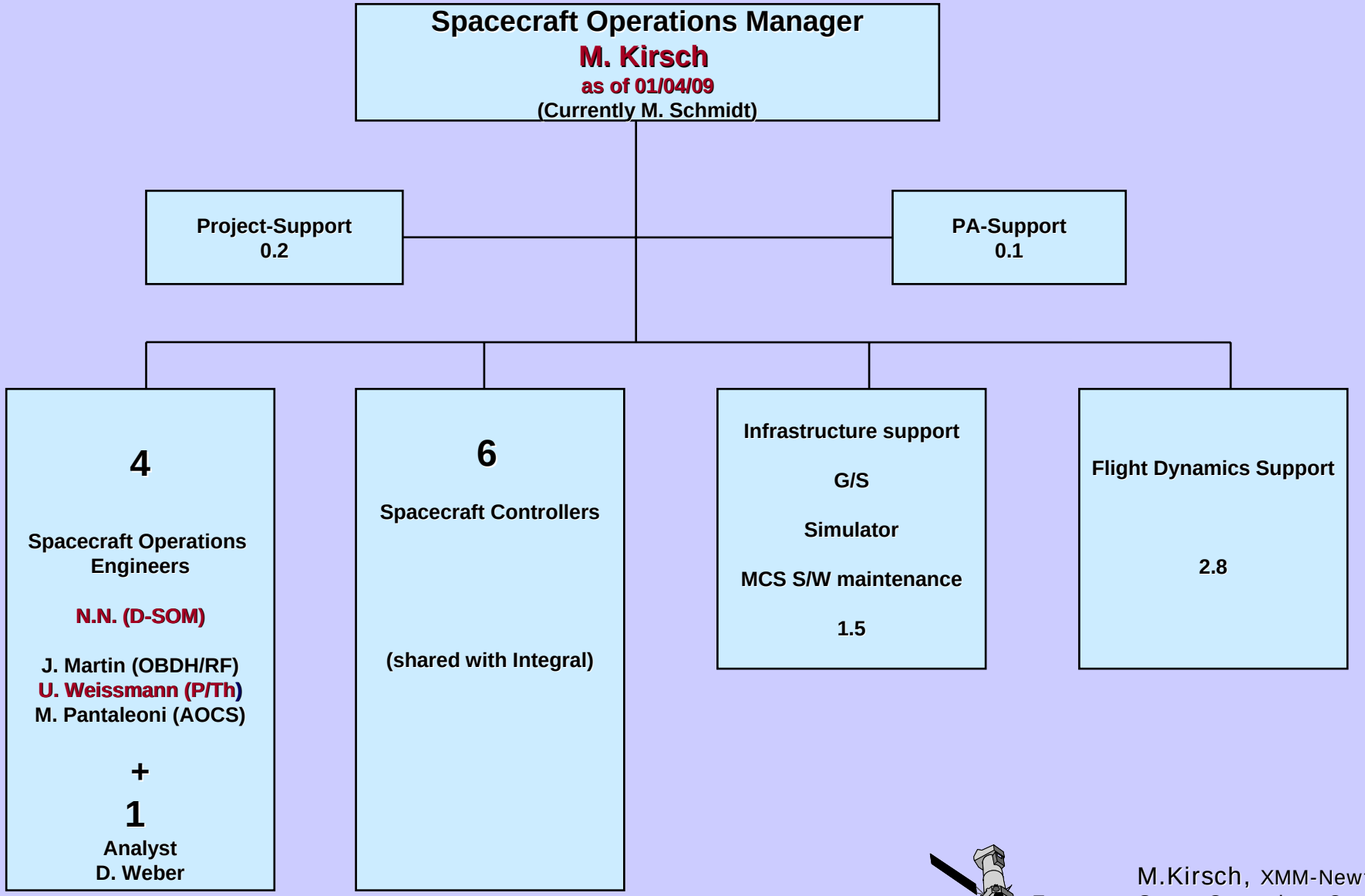
- XMM-MOC changes
- ESAM
- R/F switch anomaly



XMM-Newton

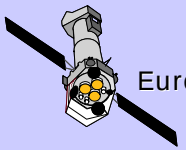

XMM-NEWTON OPERATIONS
Instrument PI's
M.J. Turner (EPIC)
J.S. Kaastra (RGS)
K.O. Mason (OM)
M.G.Watson (SSC)
Users group + OTAC
Project Scientist
N. Schartel (SA)
Mission Manager
A. Parmar
Support at ESTEC
Financial Controller
K. Buyuk
Science Support Manager
M. Santos-Lleo
QA Engineer
J.C. Vallejo (0.2)
Administrative Assistant
M. Arpizou
Web Master
C. Hernandez
Instrument Operations Manager
R. Muñoz
Spacecraft Operations Manager
M. Schmidt
Financial Controller/ PA Support
I. Bayliss (0.2)
SciSIM & SAS Maintenance Team
Team Leader
C. Gabriel (0.7)
SAS Software Engineers
E. Ojero
R. Saxton
A. Ibarra (0.7)
Instrument Dedicated Team
EPIC
M. Guainazzi
M. Smith
M. Stuhlinger
M. Ehle (0.1)
I. De la Calle (0.7)
RGS
A.Pollock
R. Gonzalez (0.35)
C. Gabriel (0.3)
A. Ibarra (0.3)
M.Diaz (0.25)
OM
A. Talavera
N. Loiseau (0.25)
Community Support & Scientific Planning Team
Team Leader
M. Ehle (0.9)
Scientists
P. Rodriguez
R. Gonzalez (0.65)
N. Loiseau (0.75)
M. Diaz (0.75)
I. De la Calle (0.7)
J.U. Ness
Scheduler
L. Tomas
Instrument Operations & System Support Team
Team Leader
M.Casale
Operations Engineer:
R. Perez
Operations Analyst
P. Calderon
Data Aide
B. Juarez (0.5)
Data System Analyst
J.C. Vallejo (0.8)
Software Engineers
M. Castillo
E. Salguero
Hardware & Archive Support Team
Team Leader
C.Arviset (OE)
CSG (3 XMM)
Coordinator
R. Alvarez
Analysts
T. Martin
J. V. Perea
J.M. Blanco
Computer Operators (2 XMM)
T. Lara
A.García
M. Herranz
A. Agrafojo
Archive Dev.
Archive Engineers
1.0 Contractors
Spacecraft Operations
Spacecraft Operations Engineers/OBSM
1 Staff
4 Contractors
Spacecraft Analysts
1 Contractors
Spacecraft Controllers
3.5 Contractors
Flight Dynamics
1 Staff
2 Contractors
MOC Miscellaneous
Simulator
0.1 Staff
Communications
0.2 Staff
0.2 Contractor
Groundstations
0.2 Staff
MOC Datasystems
0.3 Staff
0.2 Contractor
FOP Control
0.2 Contractor
Project Control
0.3 Contractor
Date: 1-Dec-2008
Staff based at ESTEC
XMM SOC at ESAC
Other (ESOC)
D-SRE staff
D-OPS staff
Contractor staff
PI staff

XMM-MOC

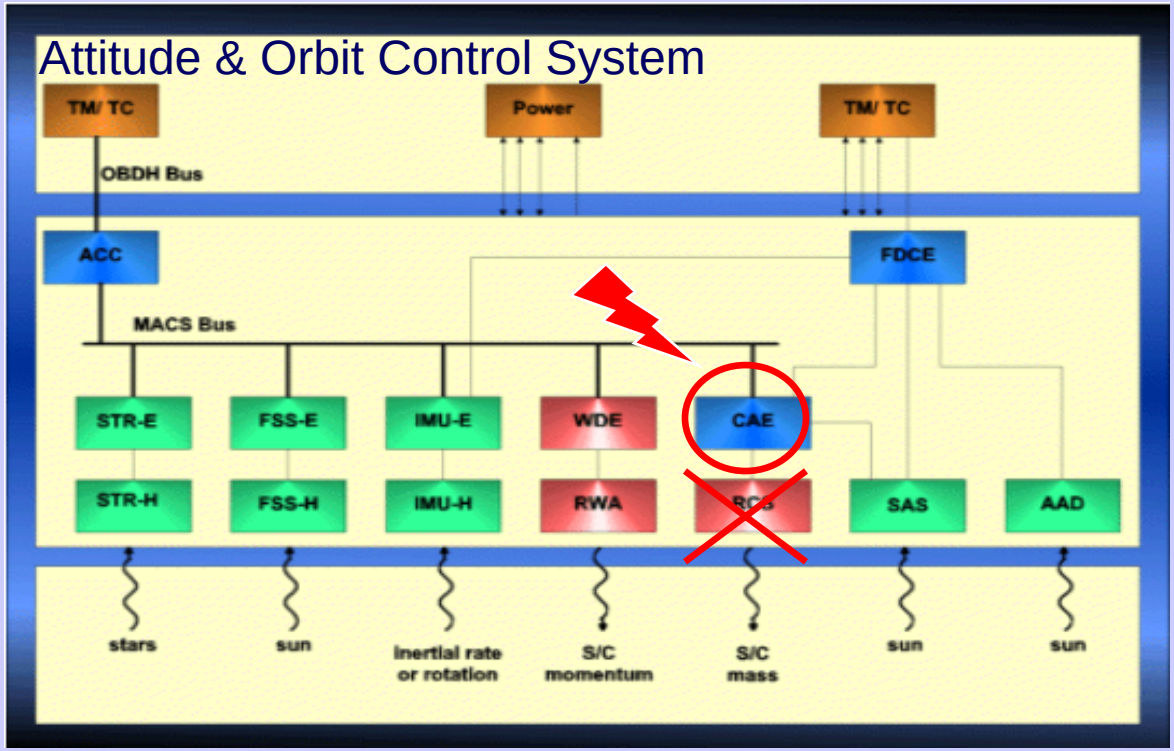

Spacecraft Operations Manager
M. Kirsch
as of 01/04/09
(Currently M. Schmidt)
Project-Support
0.2
PA-Support
0.1
4
Spacecraft Operations Engineers
N.N. (D-SOM)
J. Martin (OBDH/RF)
U. Weissmann (P/Th)
M. Pantaleoni (AOCS)
+
1
Analyst
D. Weber
6
Spacecraft Controllers
(shared with Integral)
Infrastructure support
G/S
Simulator
MCS S/W maintenance
1.5
Flight Dynamics Support
2.8

menu

- XMM-MOC changes
- ESAM
- R/F switch anomaly



Events leading to ESAM #6



CAE: Control and Actuation Electronics
RCS: Reaction Control System

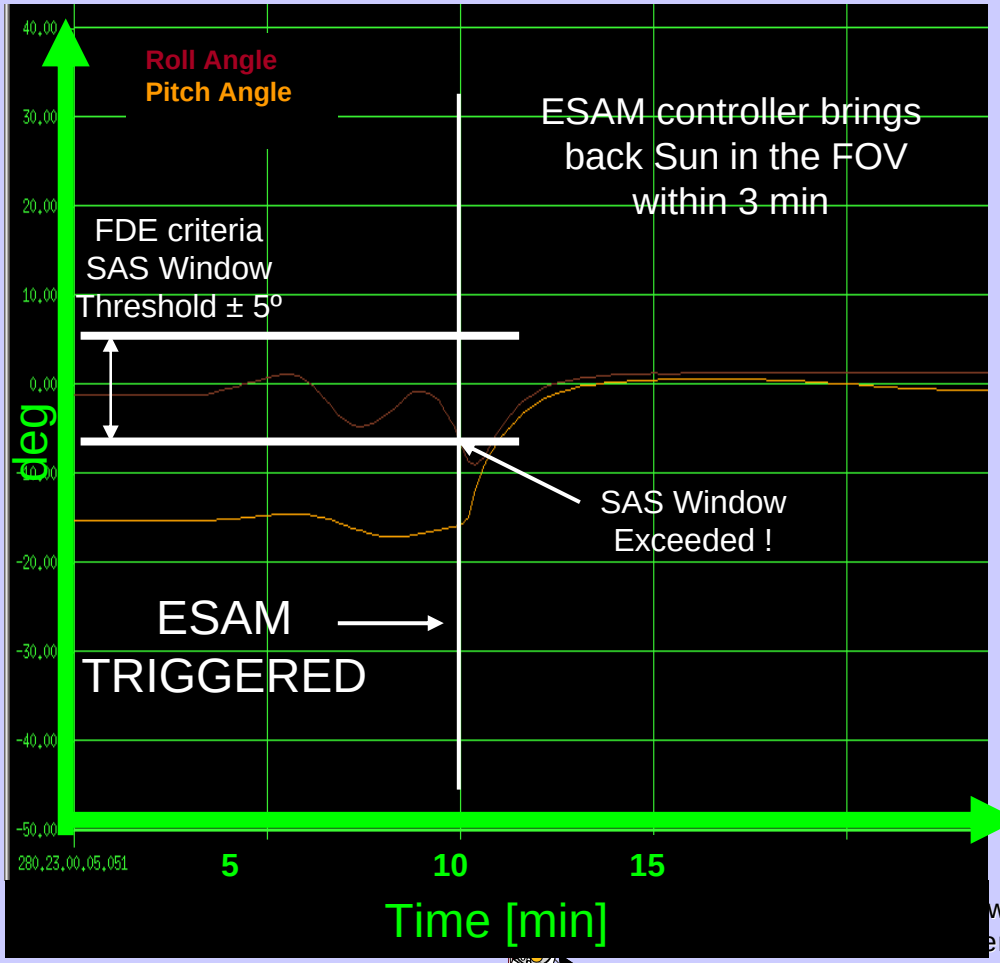
- **EVENT: LCL Trip-off CAE-A** (which drives the RCS).
- **ACTION:** CAE-A unit switched on but the Unit Configuration WORD B in the ACC was not re-initialized.
- EFFECT: ACC could not talk to the CAE-A → the RCS was not driven.

→ **In the following Reaction Wheel Bias the thrusters didn't fire** and the S/C entered in ESAM.

- **2008-10-05 09:49:25 (279):** OOL P1104 (LCL STA CAE-A) OOL
- 2008-10-05 09:49:33 (279): OOL A5010(MACS ERRORS) OOL
- 2008-10-05 10:12:25 (279): CRP_AOC_4019(Unexpected LCL switch on or off in the primary branch) executed step5 TC P3041(LCL CAE A ON) sent
- 2008-10-05 10:20:26 (279): SCC reset as per step 3 of CRP_AOC_4025(ACC anomalies and errors) → MACS errors still present but not anymore evident in OOL

ESAM #6: entry

- wheels try to compensate the lack of thruster firing
- Roll angle hits -5 deg threshold in SAS window → ESAM



ESAM #6 recovery

- ESAM entry **2008-10-06 at 23:10:07**
- Recovery into IPS after RCS-A/CAE-A failure (CRP_AOC_1528)
- RWB tested with CAE-B / RCS-B → all nominal - B branch healthy
- Slew to perigee attitude with RCS-B → S/C able to manoeuvre and put to safe attitude
- Test of CAE to health status of CAE-A
  Ad hoc procedure, tested on the Simulator, was used to swap from CAE-B to CAE-A.
- RWB with RCS-A → CAE-A was declared healthy
- Back to nominal operations with RCS-A.
- **S/C on target on DOY 283, 2008-10-09 at 12:18:00**

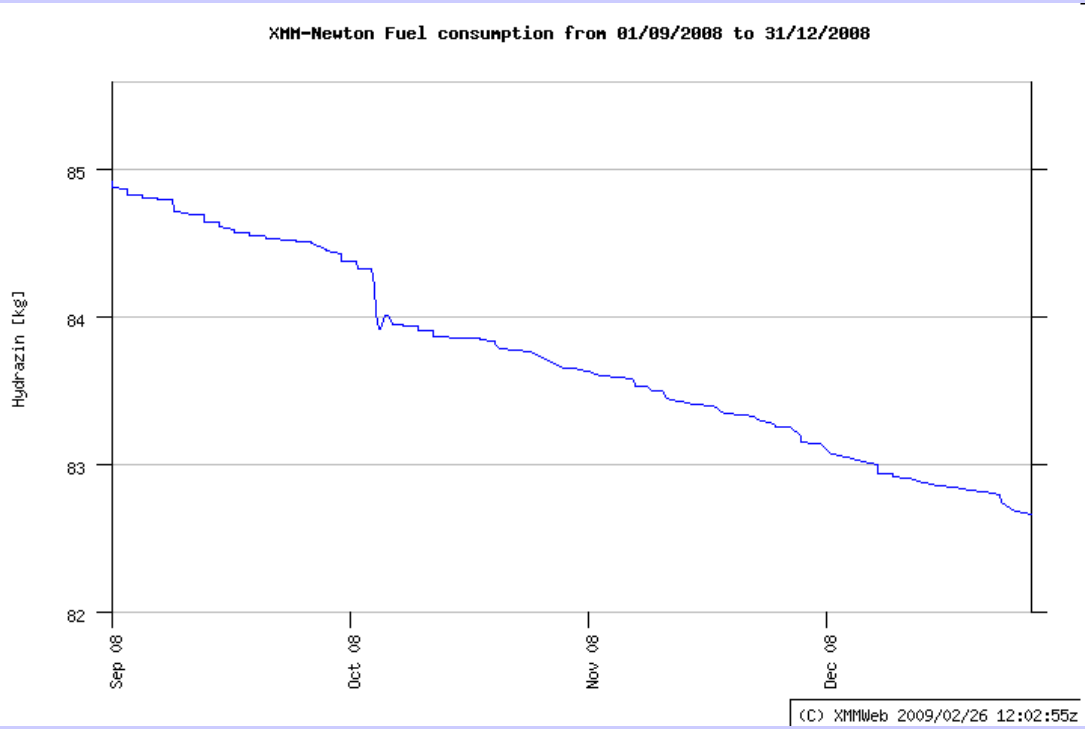
2 days 13 h

ESAM #6 follow up

- Fuel:
  - Consumption for ESAM: 320g
  - Consumption per month: 500g
  - Remaining Fuel after ESAM: 84 kg

  → Fuel margin until 2019

  (reserving fuel for 2 ESAM/year)

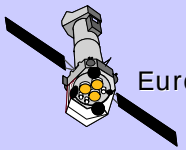


- LCL trip procedure corrected (CRP_AOC_4019)
- ESAM and main AOCS contingency procedures review and test with simulator ongoing
- Start mini simulation campaigns in 2009:

  → consolidate/maintain the engineering know-how for platform and instruments

menu

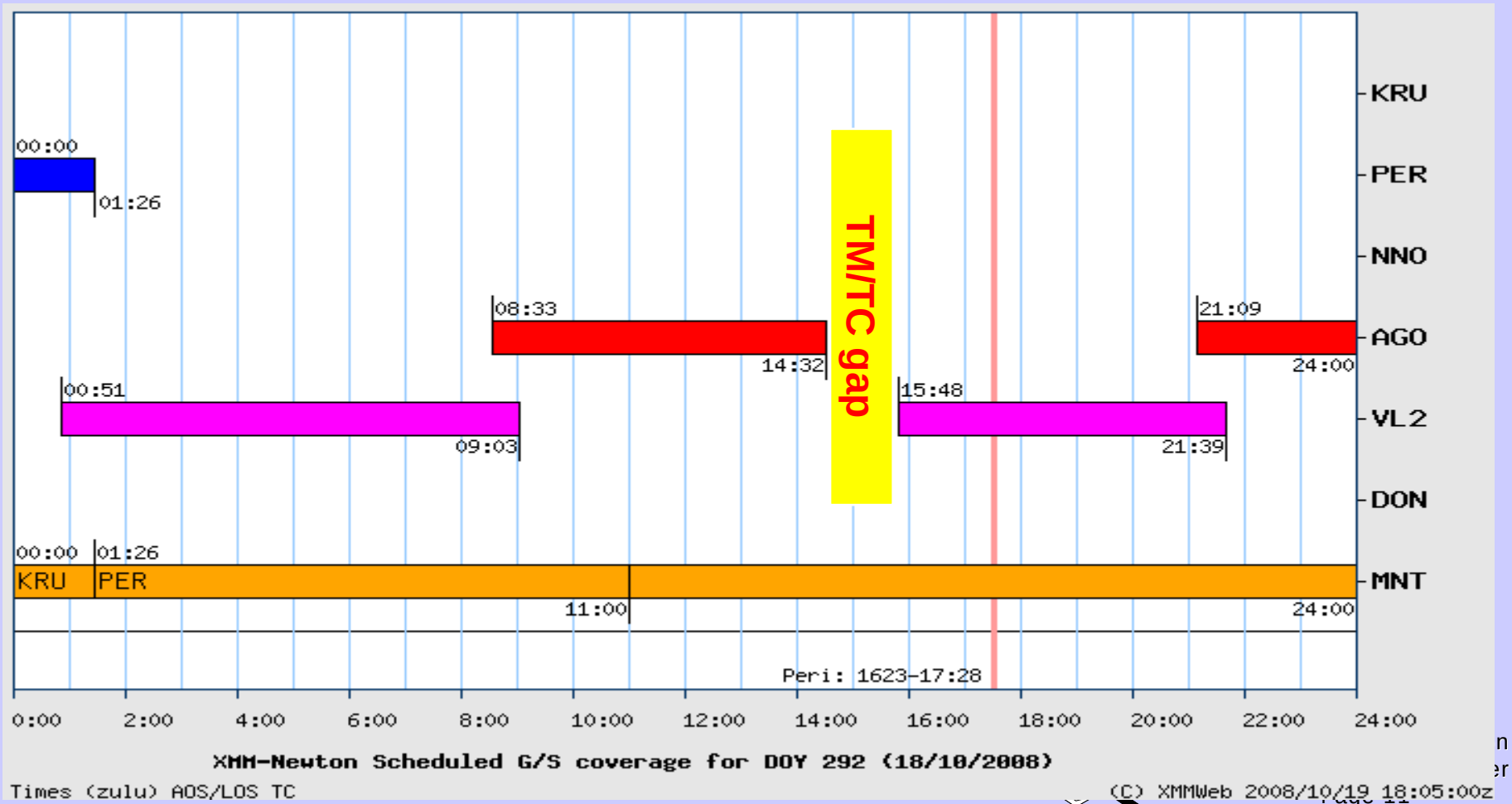
- ESAM
- R/F switch anomaly
  - Recovery
  - failure analysis and operations strategy



Failure Occurrence 18/10/2008

Sequence of Events

- 14.19: LOS Santiago
- 15.27: Time Tag Command RFDU SWA POS X
- 15.37: Expected AOS Villafranca → no signal



Spacecraft situation

- Configuration
  - Nominal platform configuration
  - Attitude safe for a long time
  - Wheel speeds safe for a few days
  - Payload configuration in a safe state

- Operational Constraints
  - Wheel Speed limit violation predicted 19/10
    - Autonomous Momentum Dumps
    - Orbit effected → commanding into the blind more difficult
  - Sun Aspect Angle violation predicted 24/10
    - ESAM entry
    - Orbit effected → commanding into the blind more difficult

Failure Assessment on 18 Oct

- **Ground station** failure excluded
  - No failure identified at Villafranca
  - Santiago also did not find the signal despite of search pattern

no

- Error in **orbit predicts** excluded
  - New orbit determined and data consistent based on last known status before LOS

no

- **Time tag command failure** excluded
  - Excluded after sending relevant commands several times into the blind
  - CDMU failure not considered as this would not explain why there was no signal

no

- **Transmitter switch-off by SEU** excluded
  - First considered as a likely failure but then discarded as commanding into the blind did not have the desired effect

no

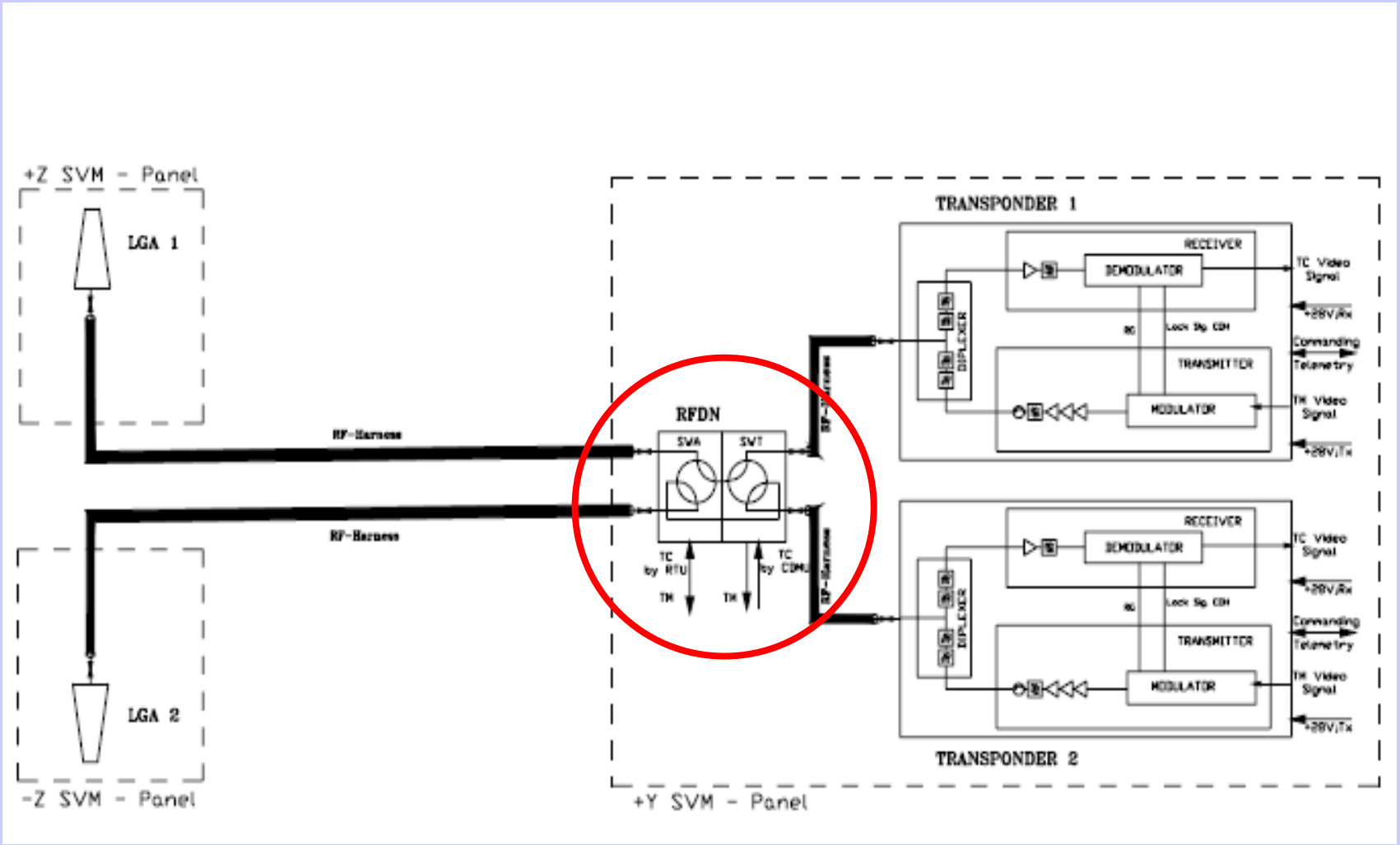
- **Failure of Transmitter** excluded
  - When switching the 2nd transmitter into the blind and still no signal though there should be visibility

no

- **Failure of R/F Switch**
  - Considered possible
    - Linked to the last planned satellite operation
    - Considered as possible failure for INTEGRAL

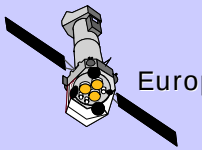
possible

RF Switch


+Z SVM - Panel
LGA 1
RF-Harness
RF-Harness
LGA 2
-Z SVM - Panel
RFDN
SWA
SWT
TC by RTU
TC by CDMU
TM
TM
RF-Harness
RF-Harness
+Y SVM - Panel
TRANSPONDER 1
RECEIVER
DEMODULATOR
TC Video Signal
+28V/Rx
DIPLEXER
Lock Sig CDH
TRANSMITTER
MODULATOR
Commanding Telemetry
TM Video Signal
+28V/Tx
TRANSPONDER 2
RECEIVER
DEMODULATOR
TC Video Signal
+28V/Rx
DIPLEXER
Lock Sig CDH
TRANSMITTER
MODULATOR
Commanding Telemetry
TM Video Signal
+28V/Tx

Additional Measures on 19 & 20 Oct

- Repetition of standard contingency procedures, commanding into the blind
  - Commanding switch position
  - Transmitter 1 and 2 commanded on
- Different sweep procedures applied to get either Receiver 1 or 2 or both Receivers in lock
- Different Virtual Channels (VC0 and VC63, i.e. different command chains)

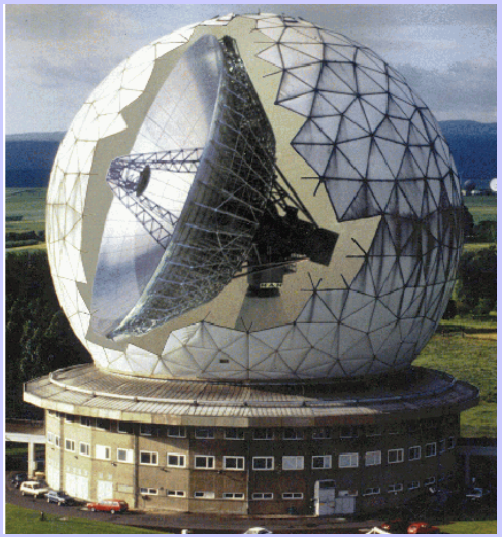


Optical detection

- October 20th: amateur astronomers at Starkenburg observatory imaged track of XMM-Newton. Observations were also performed by two other telescopes, German radar and US Space Command → No catastrophic event such as an explosion, thruster malfunction, or collision with space debris or a meteorite.

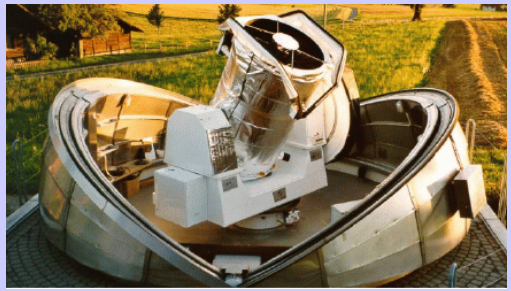
- Satellite on predicted path
- No visible debris
- No indication of light fluctuation caused by S/C spin

Radar and optical follow up

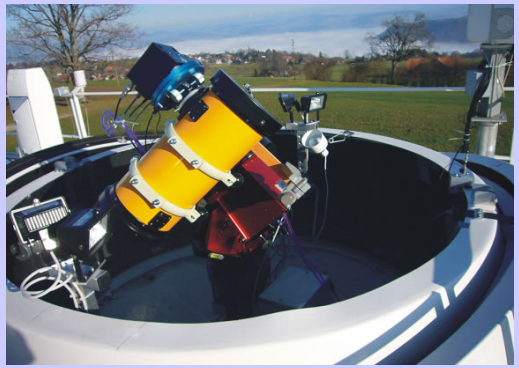


- **TIRA** (Tracking and Imaging Radar) at Wachtberg, Germany (lat: 50.62° North, 7.13° East)
- Monostatic L–band tracking radar and high resolution Ku–band imaging radar supported by one 34 m parabolic antenna
- This was the very first occasion for FGAN to track an object in more than 8000km range. XMM was at 22,000km (perigee) when FGAN started tracking

- ESA **Space Debris Telescope** in Tenerife
  1 m aperture, 0.7º field of view, Ritchey-Chrétien focus, 2,401 m altitude, 28.2º North, 16.3º West
- CCD: 4096 x 4096 Pixel; ~ 2s integration time, ~ 19s read-out time
- Limiting magnitude: 19 – 21 mag (object of ~ 15 cm size in GEO); 120º of the GEO-ring are visible

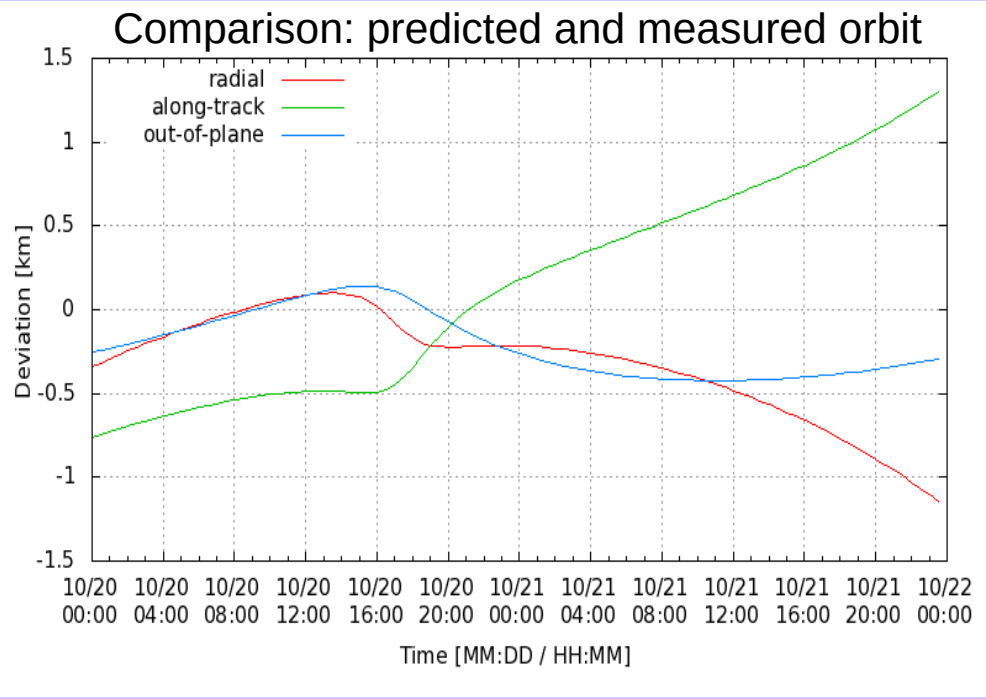


- **Zimmerwald telescopes** (CH)
- Owned and operated by the Astronomical Institute, University of Berne,
  950 m altitude at 46.9° North, 7.5° East



Orbit Determination Results

- Although observation data only covered a period of 4 hours after perigee passage, it was sufficient to determine an accurate orbit
- Orbit determination was independent from any operational data
- Orbit determination accuracy was sufficient to clarify that the orbit was nominal (matched the predicted one within 1km RMS)



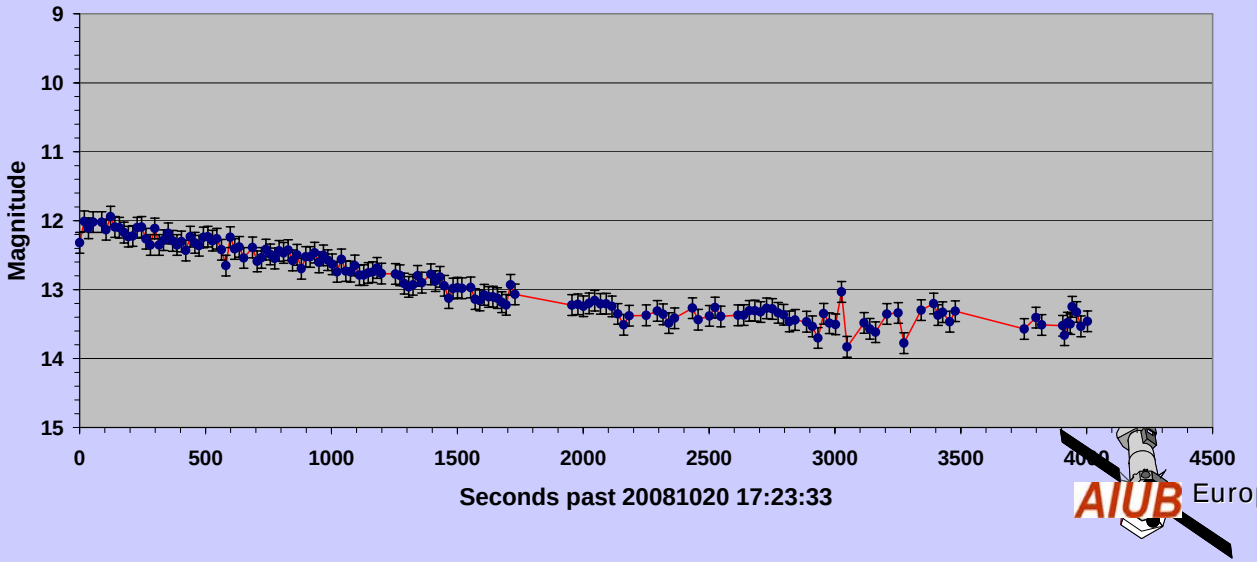
USED OBSERVATIONS	*A* [KM]	*E* [-]	*I* [DEG]	Ω [DEG]	*ω* [DEG]	*V* [DEG]
TIRA	66849.6 ±198.4	0.5825812 ±0.0011727	57.7900 ±0.0157	102.8368 ±0.0196	116.3677 ±0.0283	8.0323 ±0.0193
TIRA, ZIMSMART, ZIMLAT	66926.7 ±23.0	0.5830662 ±0.0001321	57.7797 ±0.0002	102.8258 ±0.0002	116.4064 ±0.0032	8.0096 ±0.0031
TIRA, ZIMSMART, ZIMLAT, ESASDT	66929.3 ±2.8	0.5830820 ±0.000015	57.7794 ±0.0001	102.8261 ±0.0001	116.4058 ±0.0009	8.0100 ±0.0009

Observation Data

- Despite of the enormous range, FGAN was able to generate 1.5 hours of tracking data
- Fusion of data from optical telescopes and radar was performed for the very first time in ESA

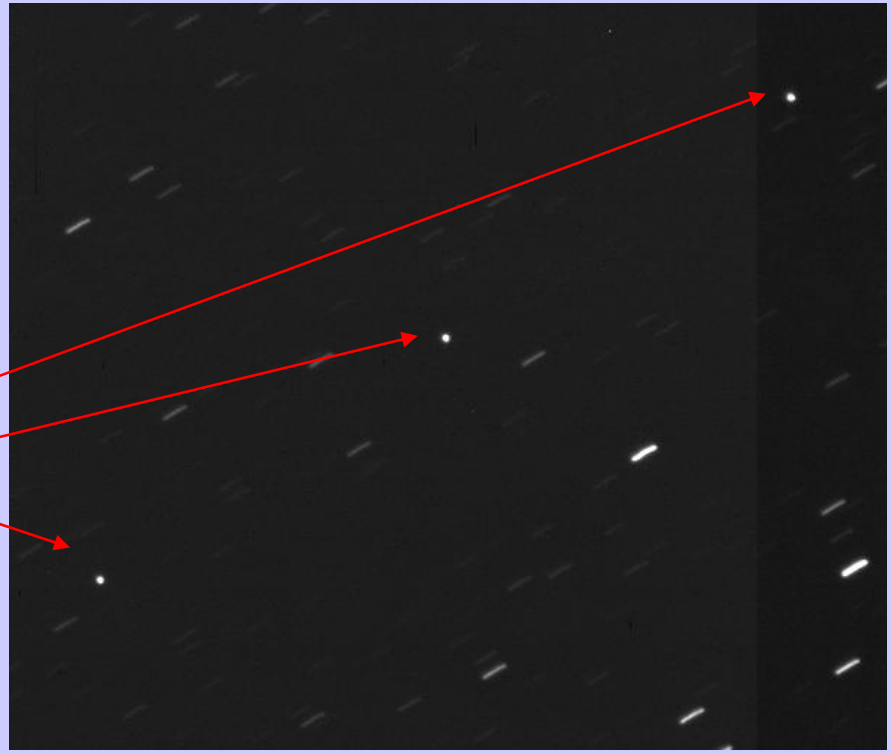
Sensor	Data Type	Arc [2008/10/20]
TIRA at FGAN	Range, azimuth, elevation	17:28:43 - 18:07:06
Zimmerwald telescopes	Right ascension, declination	17:23:33 - 18:30:15
ESASDT	Right ascension, declination	21:17:13 - 21:35:12

- While weather conditions on Tenerife allowed only 20 minutes of observation, the Zimmerwald telescopes were able to observe for about 1 hour
- High frequent magnitude variations were not observed revealing that the attitude was nominal



Optical data

- ESA Space Debris images re-confirmed that XMM was intact and no debris (> 10cm) was visible in its vicinity (150km)
- Astrometry is precise down to a level of a few arcsec
- Post-processing and determination of object states was done within 1 hour
- The telescope was tracking with XMM's angular velocity
- Three overlayed frames showing XMM as dots and stars as trails (2-second exposures)



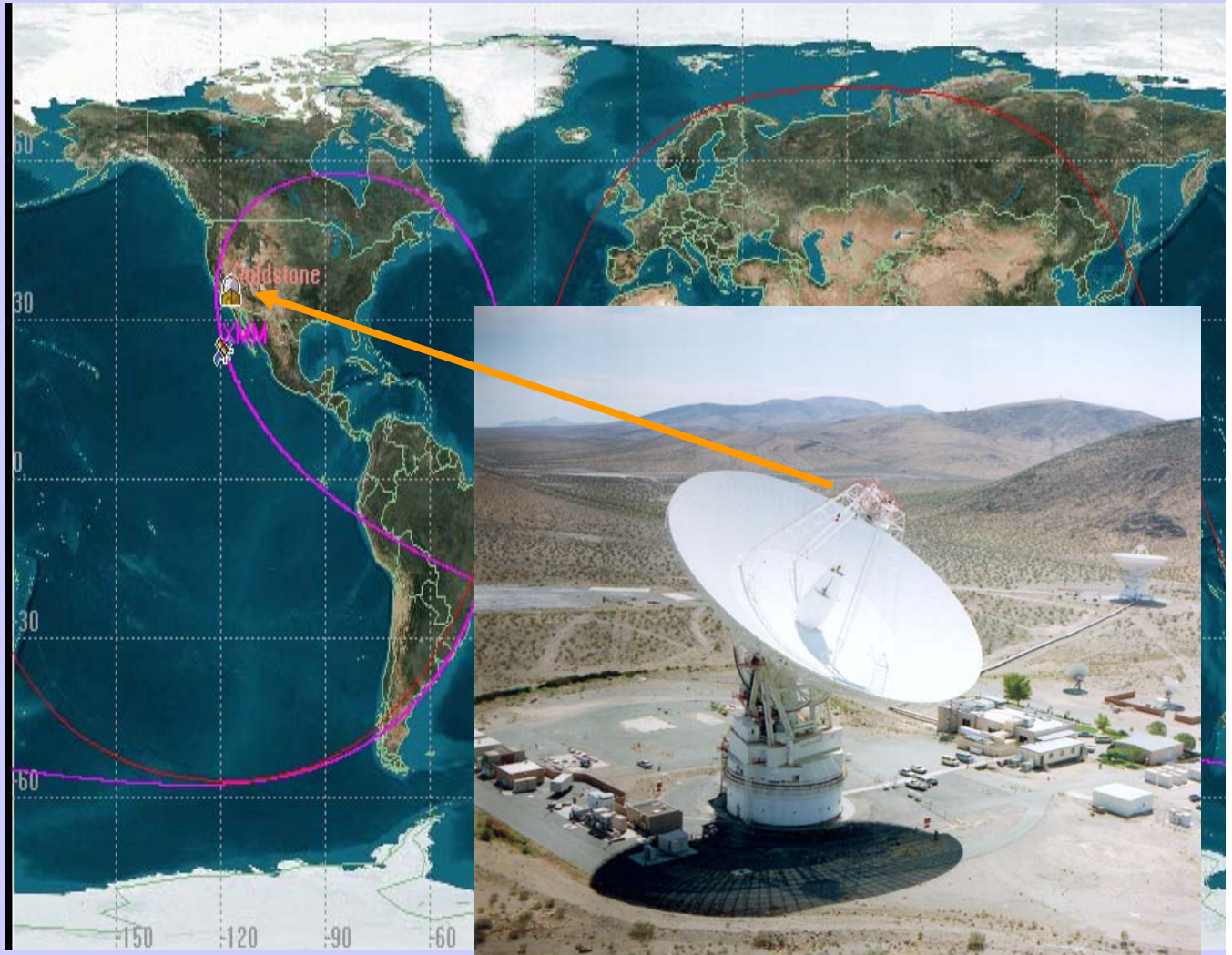
Radio Contact

- On 21 Oct a very weak signal was picked-up by ESA's 35-m antenna in New Norcia (West Australia) →Doppler information could be collected to confirm the orbit derived from the radar and optical tracking data
- Measurement of the signal attenuation (-55 db) indicating a failure of the switch → information concerning the required uplink power
- Commanding not possible via New Norcia, uplink power not sufficient
- Commanding not possible via Canberra, frequency not supported

35m ESA New Norcia

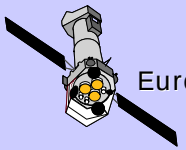
Final Recovery

- 22nd Oct: Configuration of Goldstone to be able to support XMM
- Validate procedures on simulator
- Uplink command to put RF switch into = position using high uplink power of Goldstone
- Check Satellite status
- Update Platform and Payload configuration to put satellite into a safe state



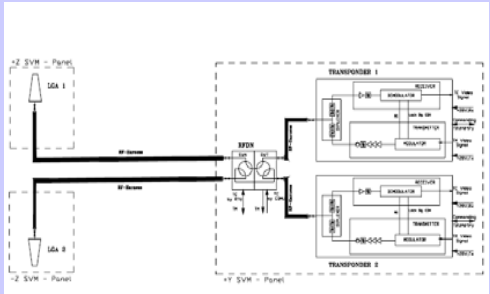
menu

- ESAM
- R/F switch anomaly
  - Recovery
  - failure analysis and operations strategy



RF switch failure

- For downlink hemispherical coverage the nominal operating transmitter will be interconnected to the earth pointing antenna by the Transfer Switches (RF switch).
- The Transfer Switches, that interconnect the transponders to the antennae, are of pulse latching type and operate in **break-before-make mode**.
- Each Transfer Switch will be capable of performing **minimum 50.000 switching cycles** and was tested to 10.000 hot switchings by INTEGRAL in October 1999 (same switch as XMM-Newton)
- Status Switch on 06-10-2008
  - **Total number of switchings: 3486**
  - Number of switchings left: 6514



- On 18 October, XMM-Newton failed to establish contact with the Villafranca 2 (Vil-2) ground station upon emerging from a nominal period of non-visibility between the Santiago ground station in Chile and Vil-2 in Spain.
- Reason: RF switch SW-A stuck in open position after Time-Tag command execution

Possible causes

1. application of simultaneous switch commands
   → not possible with s/c or ground design

2. extremely high vibration and shock levels
   → no more possible

3. Imperfect switch commands
   → never achieved during pre-launch ground testing (waiver issued)
   (however, imperfect pulse was demonstrated during ESOC Lab testing, switch stuck in neutral position at about 50% of the commands)

4. Mechanical problem
   - (switch cannot be moved at all) → no; switch was moved back to +z position
   - switch cannot be moved to one position (-z) because of broken contact → possible; needs testing (?)

5. Electrical problem
   - full or partial coil failure to move to –z position →possible; needs testing (?)
   - impact of SEU (Single Event Upset) caused imperfect pulse (?) →very low possibility
   - other component failures that could lead to degraded pulses → none identified

RF switch testing (ESOC Lab)

Objective:

1. Demonstrate whether it is possible to reproduce the suspected neutral position under a variety of failure conditions.

2. The EM RFDN switches with serial number 001 & 002 were removed from the XMM/Integral RF suitcase and being regarded as representative of the flight model switches and used for the test

Conclusions:

- Switch with serial number **001 can be put into neutral position** with reduced pulse duration with a suspected bias in one direction.

- Reducing the amplitude of the pulse appears to cause the switch not to operate at all.

- Losses through the switch are consistent with flight anomaly observed values

- Switch with serial number **002 cannot be made to fail**, but there appears a possible mechanical bias when switching with a reduced pulse by the clicking of the switch on one direction only until switchover

Recommendations

R 1:
Establish Operational Concept without the use of any RF switch

• use of only 1 transmitter

• use both transmitters permanently on or TX1 always on and TX2 on/off

• alternate operations of transmitters TX1 on/TX2 off and TX1off/TX2 on

R 2:
Use back-up RF switch

• switch can only be commanded with direct commands

• switch cannot be commanded by use of time-tag commands

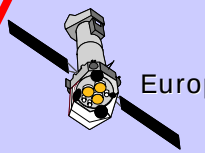
• therefore if switch gets stuck, safety time-tag commands to move switch back to previous position cannot be used

R 3: Test of RF-A switch

• most likely cause of anomaly is an imperfect pulse

•multiple time-tag commands to move switch would cover both cases

Management permission for a test of R2 and R3 is required.

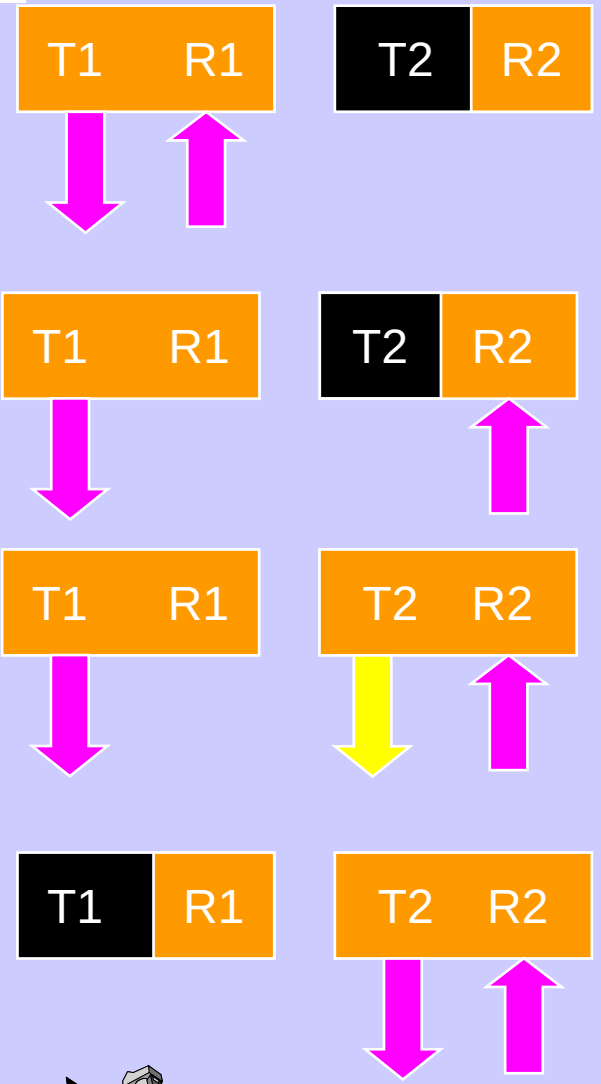


Operational concept: Alternate switching of transmitters

- **Provides Omni-directional coverage:**
  - **Lock uplink on receiver to be used**
  - **Switch on TX to be used**
  - **Switch off TX no further in use**

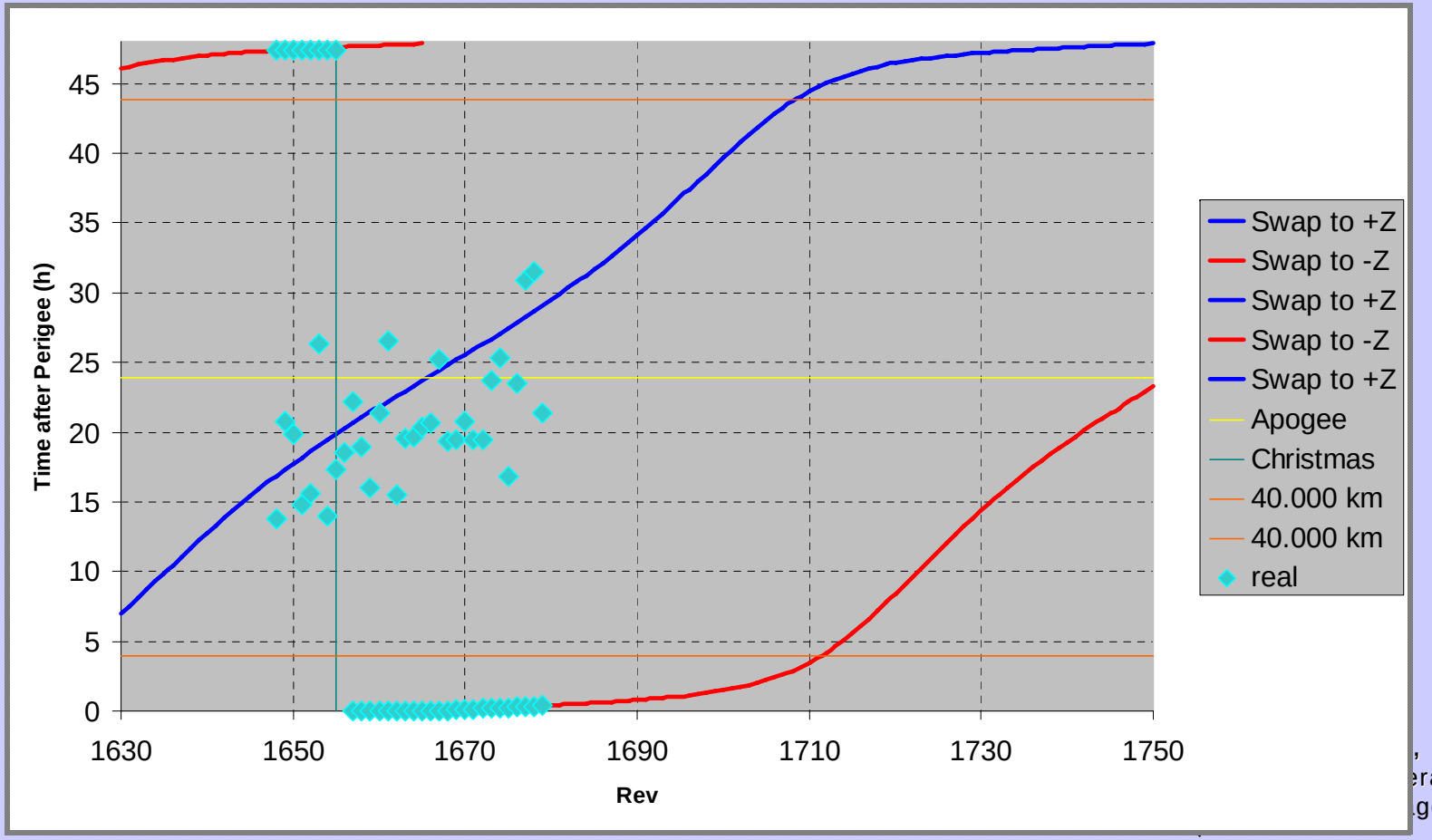
→ **almost no impact to the mission and easy to coordinate with mission planning and network activities**

→ **operational since beginning of December 2008**



Implementation

- FD generates PSF
- SOC modifies PSF by introducing antenna hand over windows
- SOC generates POS
- MOC generates EPOS and from EPOS automatically hand over command stacks
- Spacon loads command stacks for handover



Conclusion

- **Full mission can be conducted by using the option alternating the 2 transmitters.→ This option is in operation since beginning of December 2008**
  - **Resumption of science operations after the R/F anomaly took place in Rev-1631 (starting on 03/11/08) and full orbit operations (which allowed recovering the standard science efficiency) were resumed as of Rev-1649 (09/12/08).**
  - **After the definition of the new strategy for operations by the MOC, the SOC modified internal planning tools to include the new constraints. This has allowed fully utilising the available science window and operating with the efficiency achieved before the anomaly.**
- **Full mission can also be resumed by using the back-up switch.**
- **Also the option having 1 transmitter on all the time and switching on the other transmitter when needed is possible but less favourable since more complex. Only to be used as back-up.**
- **Should one of the two transmitters fail, the RF switch (prime or redundant) needs to be used again**