EPIC OPS-CAL meeting

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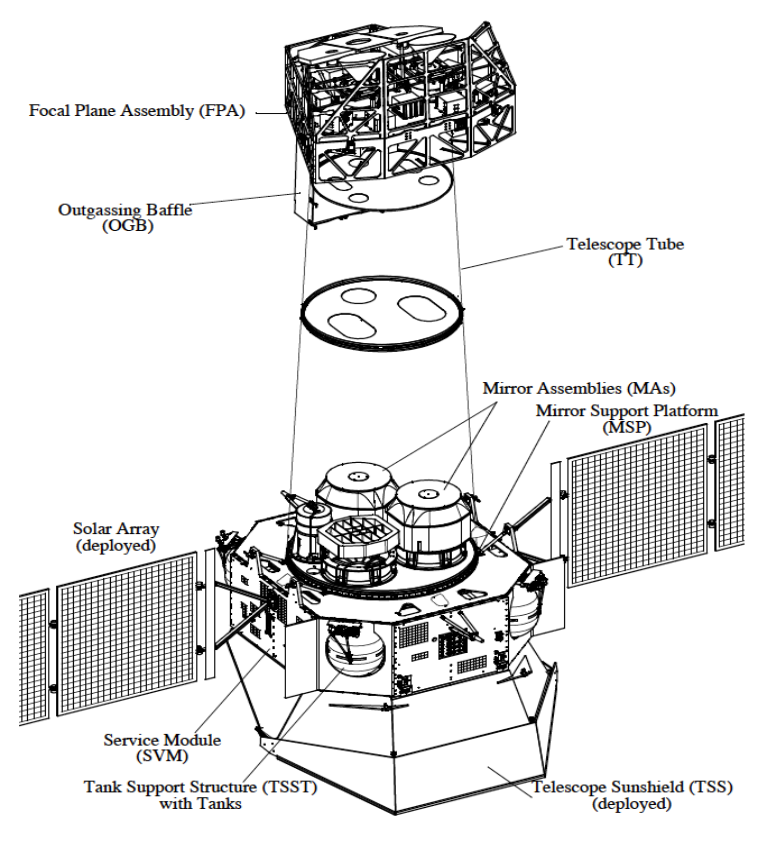
June 2024

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

spacecraft sub systems are all healthy



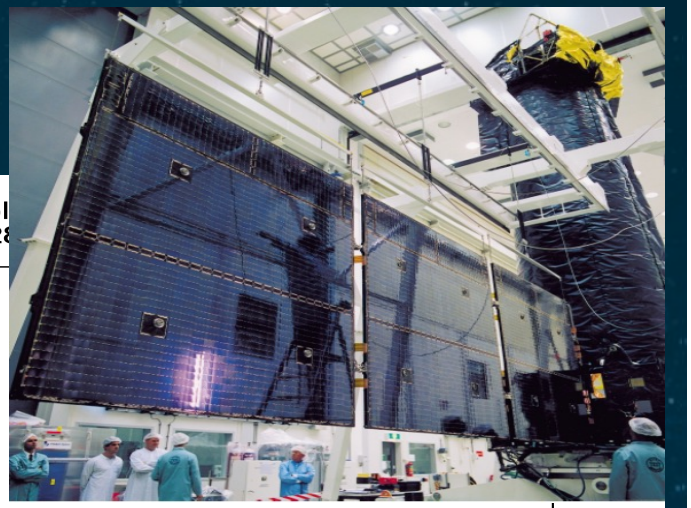
- weight: 3.8 t, length: 10 m
- **Attitude and Orbit Control System (AOCS)**
  4 Reaction wheels, 4 IMUs (gyros), 2 star trackers, + …
  Redundant reaction control system using hydrazine thrusters
- **Power + Thermal**: 2 solar panels with 16 metre span, 2 batteries, various active heaters
- **On Board Data Handling (OBDH)**
- **Radio Frequency system (RF)**: 2 Low Gain antennae plus redundant transponders
- Payload: 3 Wolter telescopes with 58 mirrors each, 3 cameras 2 gratings, active temperature control of mirrors and instruments

Money	Funded until	End 2026/2029
Fuel	remaining Use per year Mileage	**~32 Kg** < 2.5 kg/year 2034+
Thruster pulses	Remaining use per year Mileage	0 (200000 qualified) <4 100 2022 (B-system with full redundancy available, industry recommends to stay on A)
Solar array power	Maximum required Current margin	**~ 1350 W** **~ 400 W**
Battery	According to industry	15+ y
Gyros/(IMUs)	Usage	< 36 %
Reaction wheels	Usage	< 65 %
Optocouplers	Mileage	~ 2028 +
RF switches **Transponder switches**	Usage	Stuck at one position Back up not used instead transponders are switched TX A LCL switches <2415 TX B LCL switches <2389 (Qualified to 25000)

Status of S/C 2024: healthy

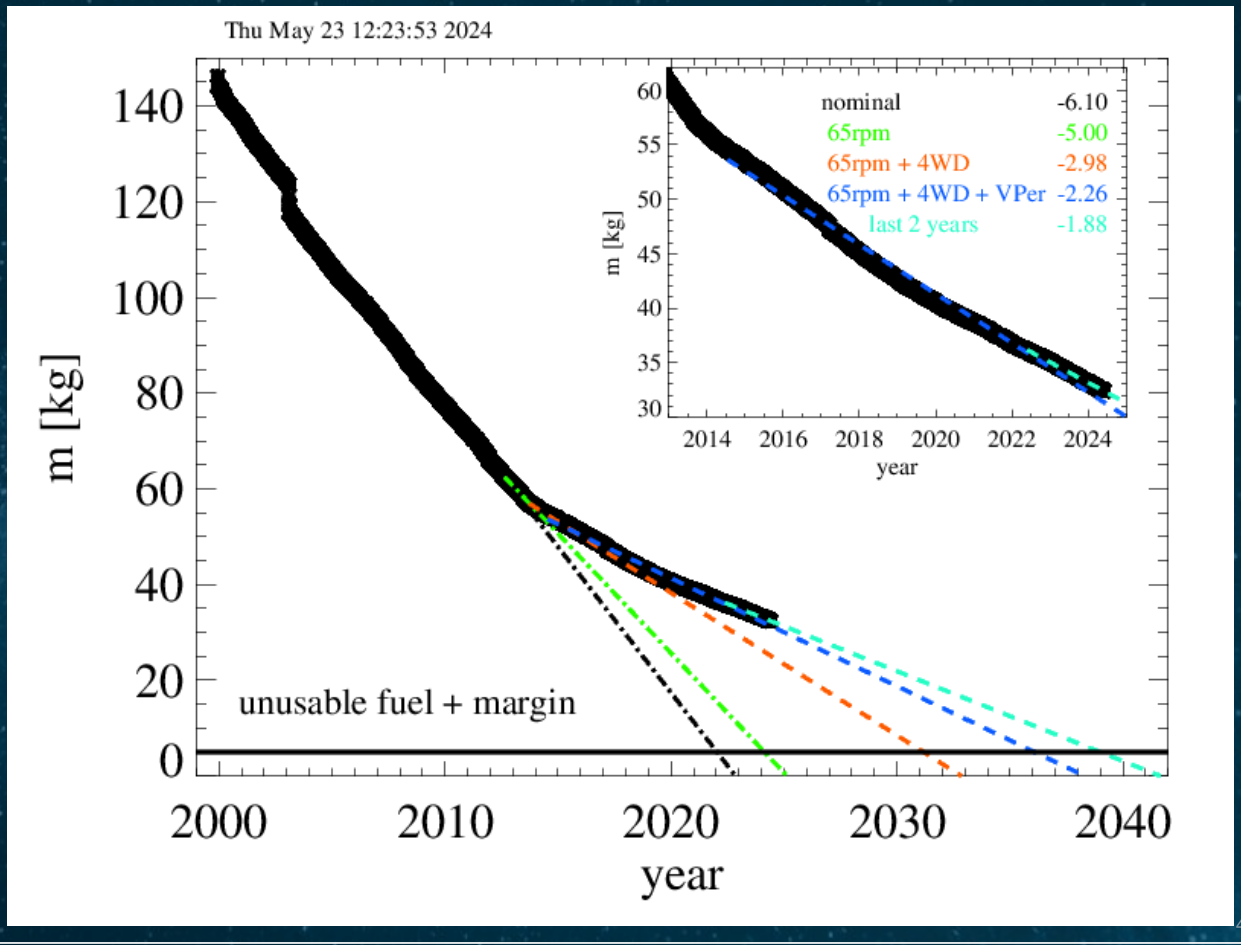
solar cell power has sufficient margin

- power generation capabilities are normal
- no sign of unexpected degradation visible



fuel estimates give life time > 2034+

- **Reaction wheels are the primary actuators** for attitude control. **Thrusters are only used for wheel unloading**.
- Changed in 2013 the onboard attitude control software to use **4 reaction wheels instead of 3** before (use the back up wheel)
  called 4 wheel drive **(4WD)**
- the degree of freedom that is introduced by this change, allows to **reduce the fuel consumption and to change wheel speeds without changing the S/C total momentum** (null space operation).
- **This reduced the fuel consumption by more than a factor of 2**
- **Note average fuel consumption**
  - since 2014.5: 2.3
  - since last year : 1.8



Review of all subsystems ongoing

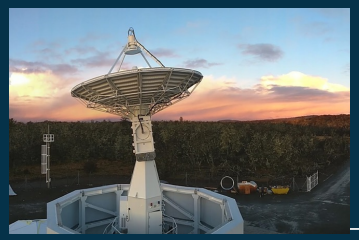
- Together with indusrtry we are reviewing all subsystems and life limiting items with the view to operate XMM towards the launch of Athena (now more late 30ies)
- Radiation dosis will be reevaluated with ESTEC experts to align model predictions better with reality, where possible
- Recent battery reconditioning activities show a trend of capacity reduction for BAT1 (details to be confirmed)
- Options for new operations concepts in case of failure or reduction of unit performance are discussed
- Potential end of life tests of SOHO may benefit XMM

XMM-Newton Orbit

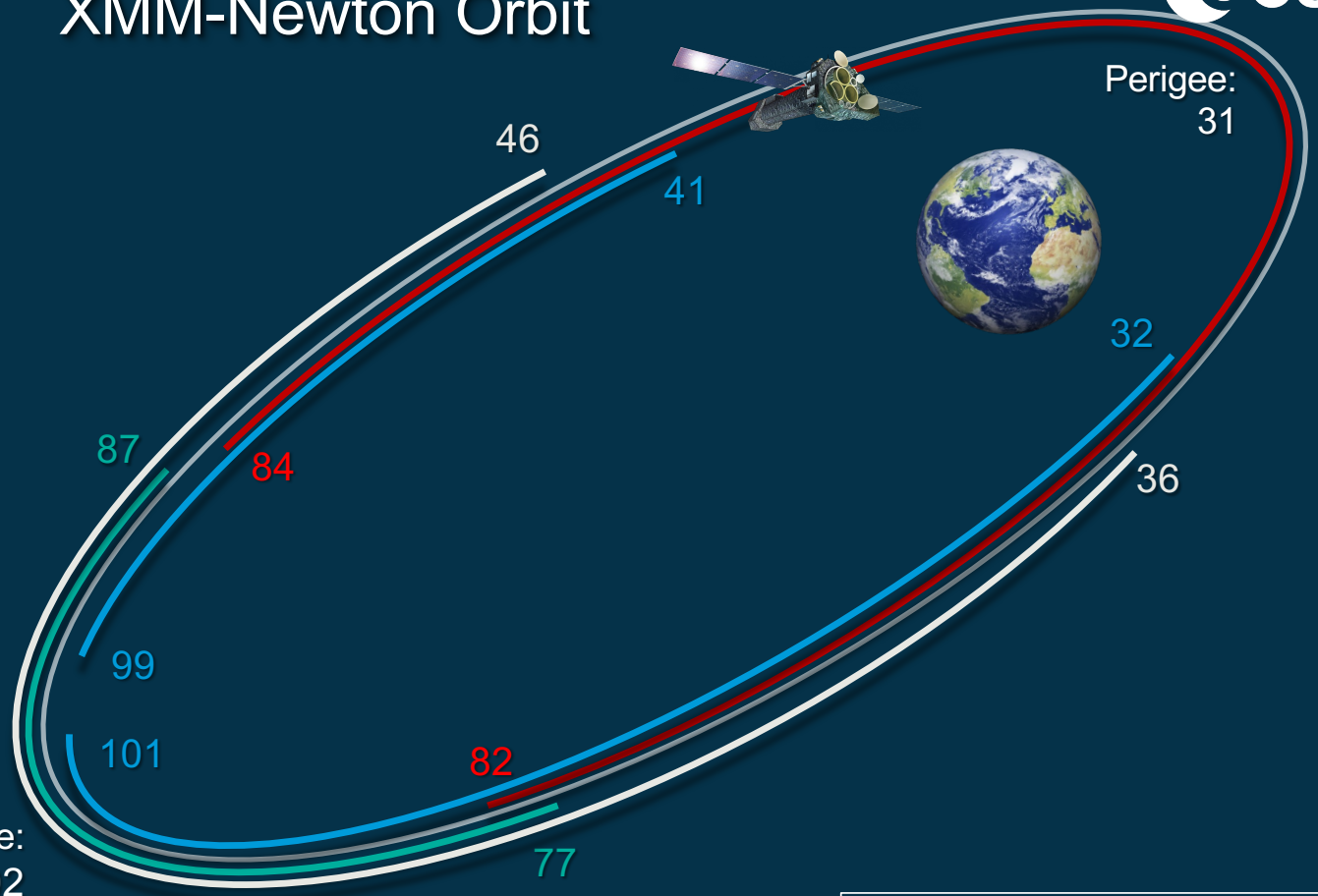
Kourou (ESTRACK)

Yatharagga (SSC)

Santiago (SSC)



Tolhuin (KSAT/ CONAE)



Distance spacecraft to ground in thousands of km

XMM automation on board

- by design only **very limited onboard autonomy**
  (mainly related to spacecraft safety) and only very limited storage capabilities, but no Mission Timeline on-board
- CDMU "autonomy" functions are limited to a small **time-tagged command buffer** and a number of mission specific monitoring and control tasks
  - time-tagged command buffer is used to ensure instruments are commanded safe before perigee passage, maintain instrument thermal control during eclipse, since a platform thermistor failure in 2009 to maintain tank heater control)

- 1999 launch version CDMU S/W: **monitor and control task to command instruments safe in case of ESAM**
- 2001 patch: **monitor and control EPIC-pn instrument CCD temperature**
- 2015 patch: **thermal duty cycle and thermal closed loop function**
  - parallel control of a number of heater circuits by commanding the heater transistor switch to a predefined duty cycle
    → fuel migration and tank replenishment
  - closed loop control of a number of heater circuits by monitoring the associated thermistor temperature and commanding the heater switch to maintain a limit cycle between minimum and maximum values:
    - tank temperature control in between tank replenishing events
    - autonomous instrument heater control during and after eclipses affected by long ground station gaps
      → spin off: more efficient use of batteries during eclipse (-30 %)
- **2025 NSM patch: fuel less safe mode plus further instrument monitoring and onboard safety**
-

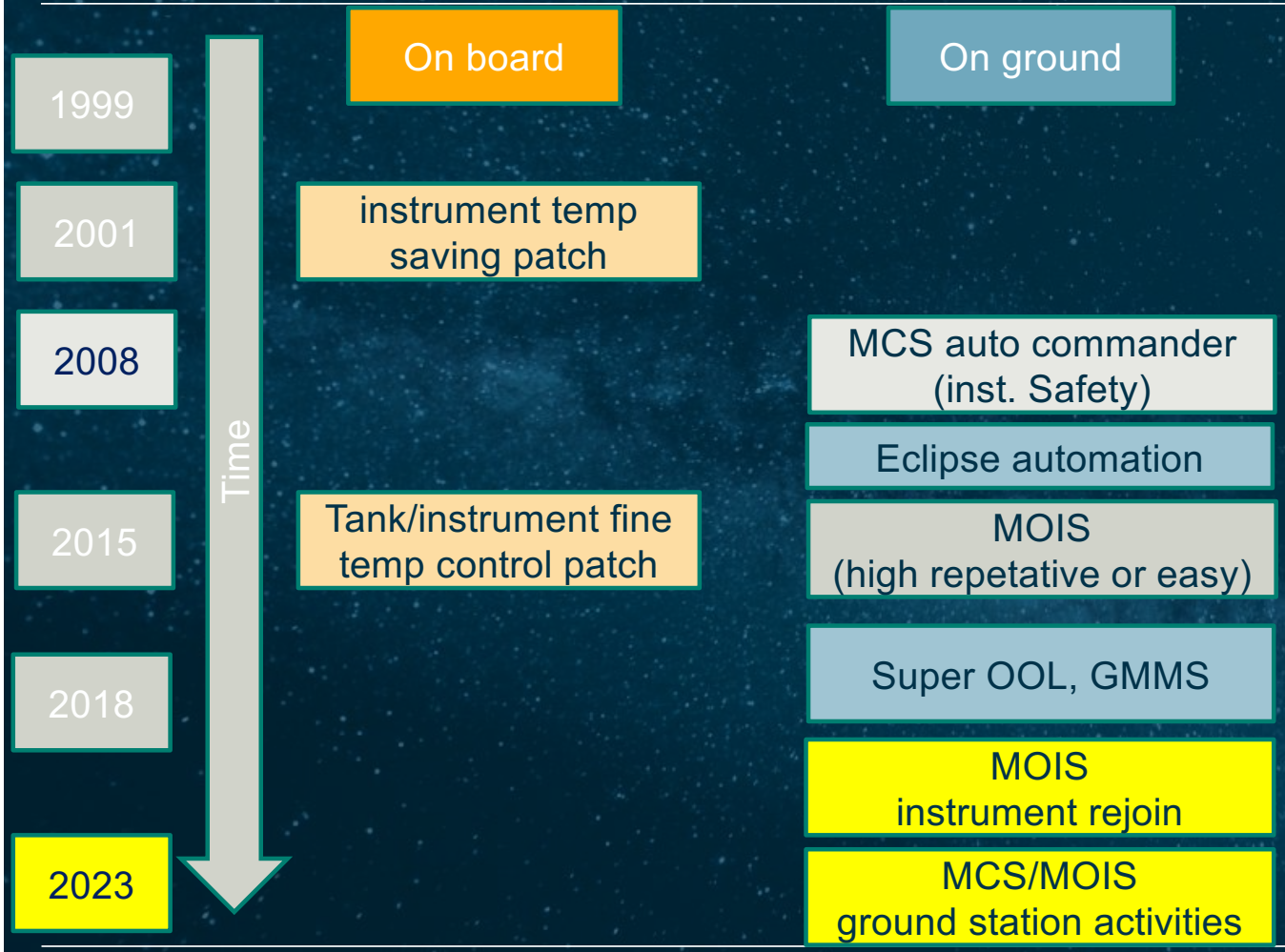
XMM Ground Automation 3.0 (2020-2023)

- Full end to end operations of nominal instrument ops including radiation rejoin (2023)

- Full ground stations and on board antenae* handover without manual interaction neither of FCT nor ground station staff (2023, *2024)

→ very hugh reduction of SPACON workload in time for Euclid joining the SPACON team

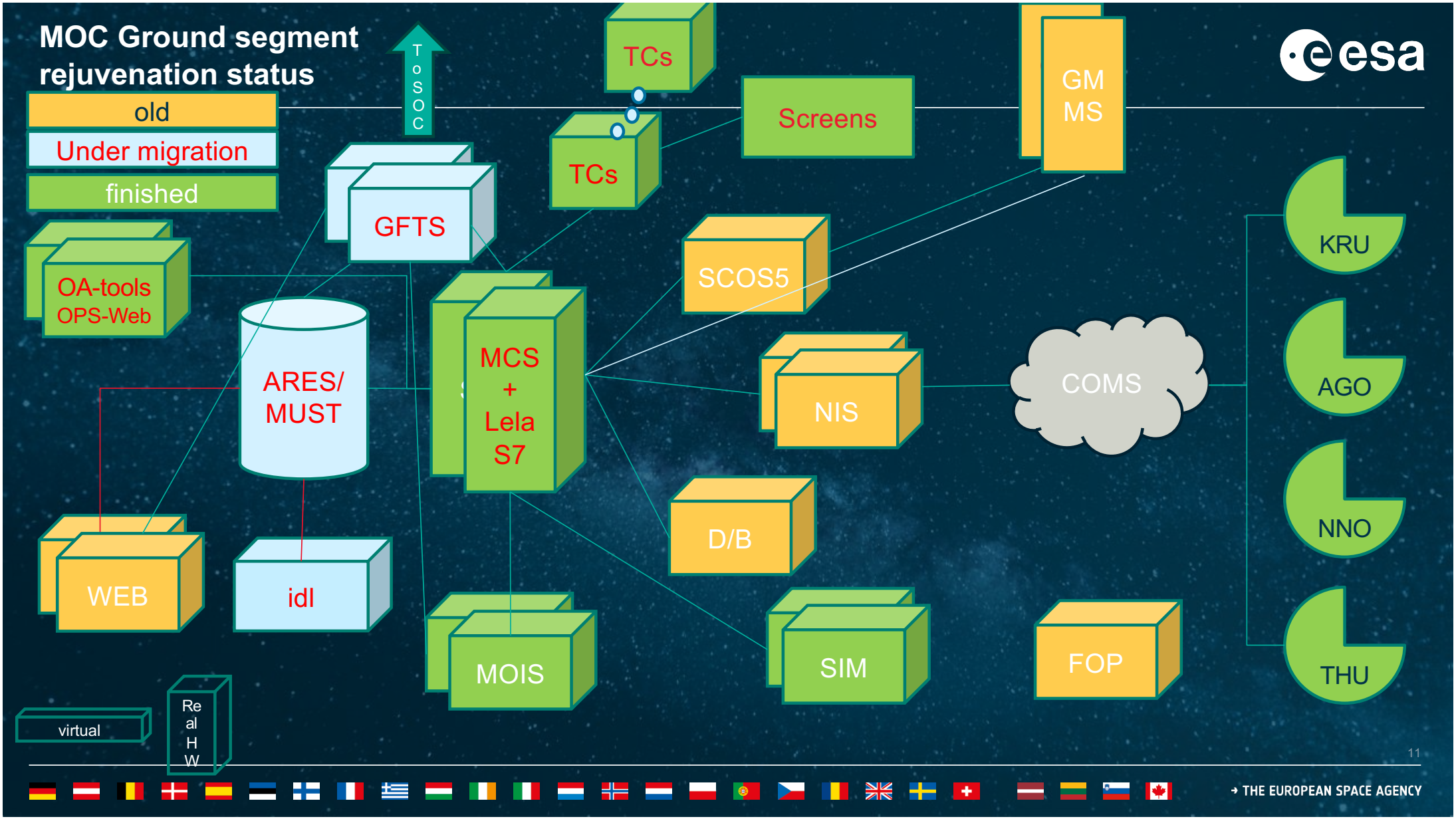
XMM Automation History



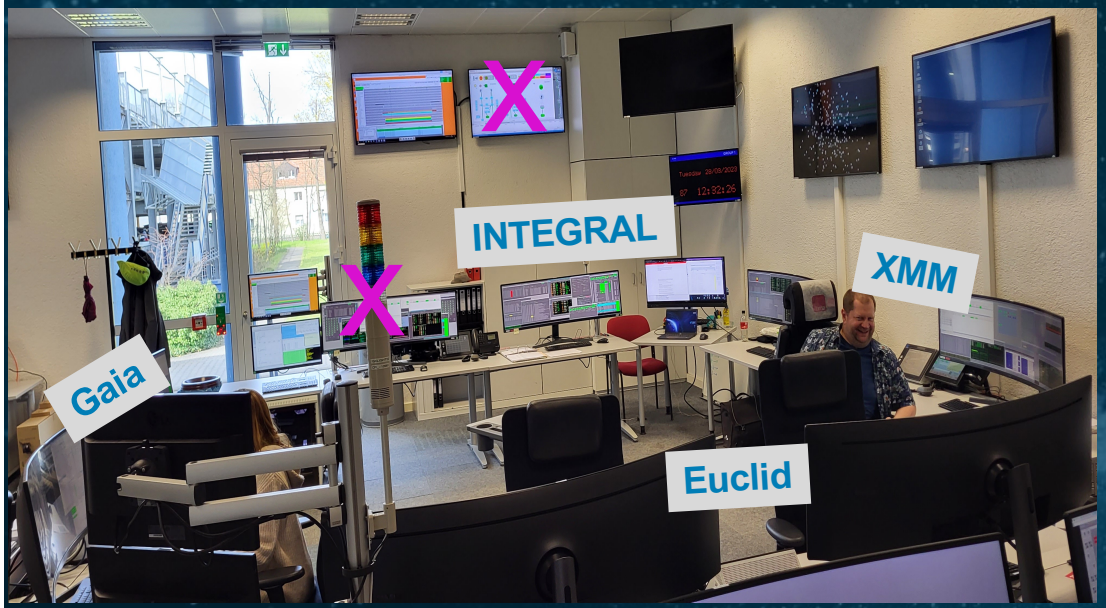
- Launch 1999: Manual Command Stack Auto-stack (timeline from ground)
- Radiation danger in combination with inefficient radiation monitors requires new on-ground code based on instrument in-situ data to safe instruments in case of high radiation manually
- Controller teams:
  - SOC: 6 Instrument Controller
  - MOC 6 Spacecraft Controller
- Change 2008: combine XMM(MOC+SOC) and INTEGRAL controllers
  6+6+6 → 6 at MOC
  (introduction of "Auto-commander" for instrument radiation safing)
- Change 2018: combine XMM/INT/Gaia controllers 6+3>6
- In total : combined 6+6+6+3 → 6 (factor 3.5)

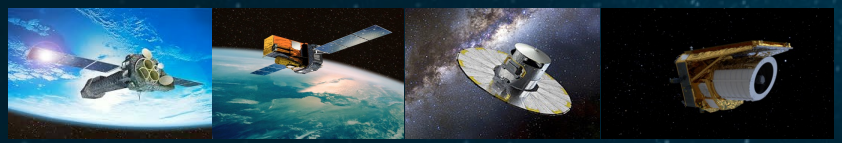
XMM Ground Automation 4.0 + (2024-2025)

- 4.0 (incremental approach)
  - Flight Dynamics PSF and EPOS automation (with help of external consultancy and ESOC AI/automation initiative) (done)
  - CDMU reset recovery (done)
  - Tank Replenishment operations (underway)
  - Automated re-join of instruments for non nominal determined cases (slew failure and TM/TC gap) and finetuning (planned)
  - Near realtime data analysis/awareness using ARES instead of MUST (planned)


MOC Ground segment rejuvenation status
old
Under migration
finished
To SOC
TCs
TCs
Screens
GM MS
GFTS
OA-tools OPS-Web
ARES/ MUST
MCS + Lela S7
SCOS5
NIS
COMS
KRU
AGO
NNO
THU
D/B
WEB
idl
MOIS
SIM
FOP
virtual
Real HW
11
THE EUROPEAN SPACE AGENCY

family of mission operations runs smoothly



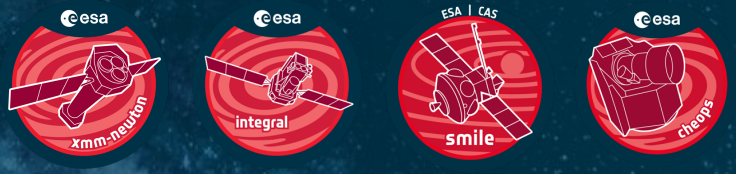


- Joint SPACON team includes Euclid
- Joint Analyst team and combined engineering team for XMM/INTEGRAL under new Service Level Agreements
- D/B consolidation between missions using Dabys underway (2025)
- MUST archive migration to ARES (2024)
- LELA (radiation monitoring) will be migrated to new MCS (2024)
- New webserver infrastructure including near-realtime system in 2025
- AI system prototype for controller/engineering support (→OCAI: "ESOC google on all systems")

- Gaia will need less support soon and will discontinue science OPS early 2024
  → no need for super alarms anymore
  → preparation for normal MCS monitoring underway (keeping however some non hot redundant capabilities from GMMS)
  → descoping of deconflicting tools and/or integration into OPSWEB (new ESOC monitoring tool)

Team changes

- ESA:
  - Jim Martin INTEGRAL SOM as of 03/2024 (retiering 04/2025)
    → new XMM Deputy SOM Greta De Marco (joined 05/2024)
  - MK unit head of new merged XMM/INTEGRAL unit supporintg as well Cheops and Smile (gradually less XMM involvement)



- Contractor services
  - New service approach for engineering and real time operations
    - lead engineer for XMM: Uwe Weissmann
    - lead engineer for INTEGRAL: Tim Finn
    - both engineering and real time OPS team now fully with consortium led by TPZ
  - Detlef Webert will retire early 2025 → new analyst Matthias Bissinger ramping up in Q4

ESOC changes

- ESA is investing in a new control center at ESOC and will refurbish the site
- Timeline
  - New building 2025-2027
  - Move OPS from old to new
  - Sharing phase of buildings while refurbishing others
  - Finalization by 2029
- Mitigation measures needed to reduce OPS impact to a minimum

conclusions and Outlook

- XMM-Newton S/C is in very good shape and scientific performance remains outstanding
- fuel limits life time to > 2034
- New service approach for engineering and real time operations
- Stability of the whole ground segment system is a key ingredient for successful operations and automation
- Fuel replenishment will be a key activity
- New safe mode and z-flip alla INTEGRAL might extend mission towards the launch of NewAthena
- proficient team and knowledge management are key factors