EPIC OPS-CAL meeting

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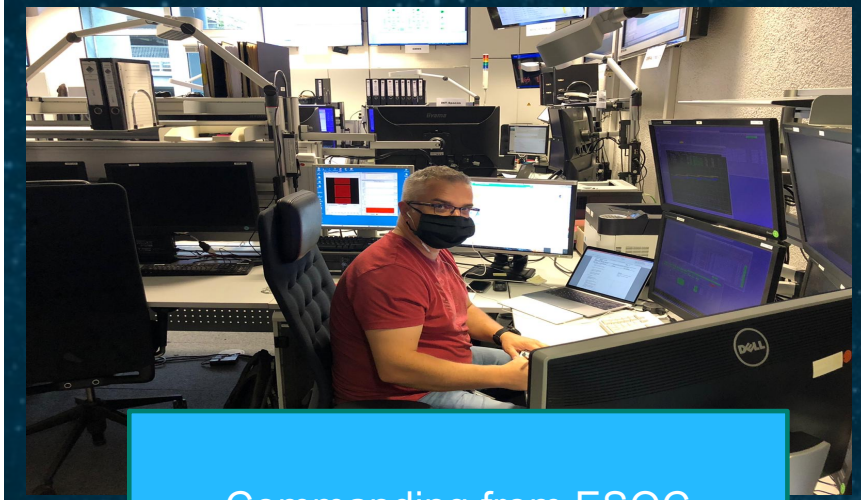
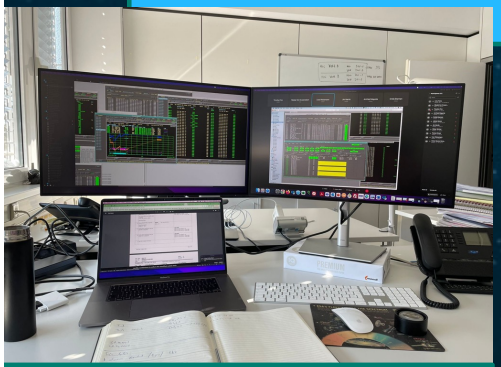
April 2022

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

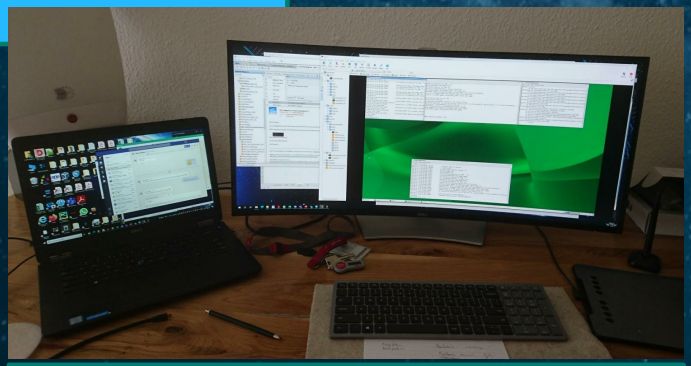
Post - COVID ?



Commanding from ESOC



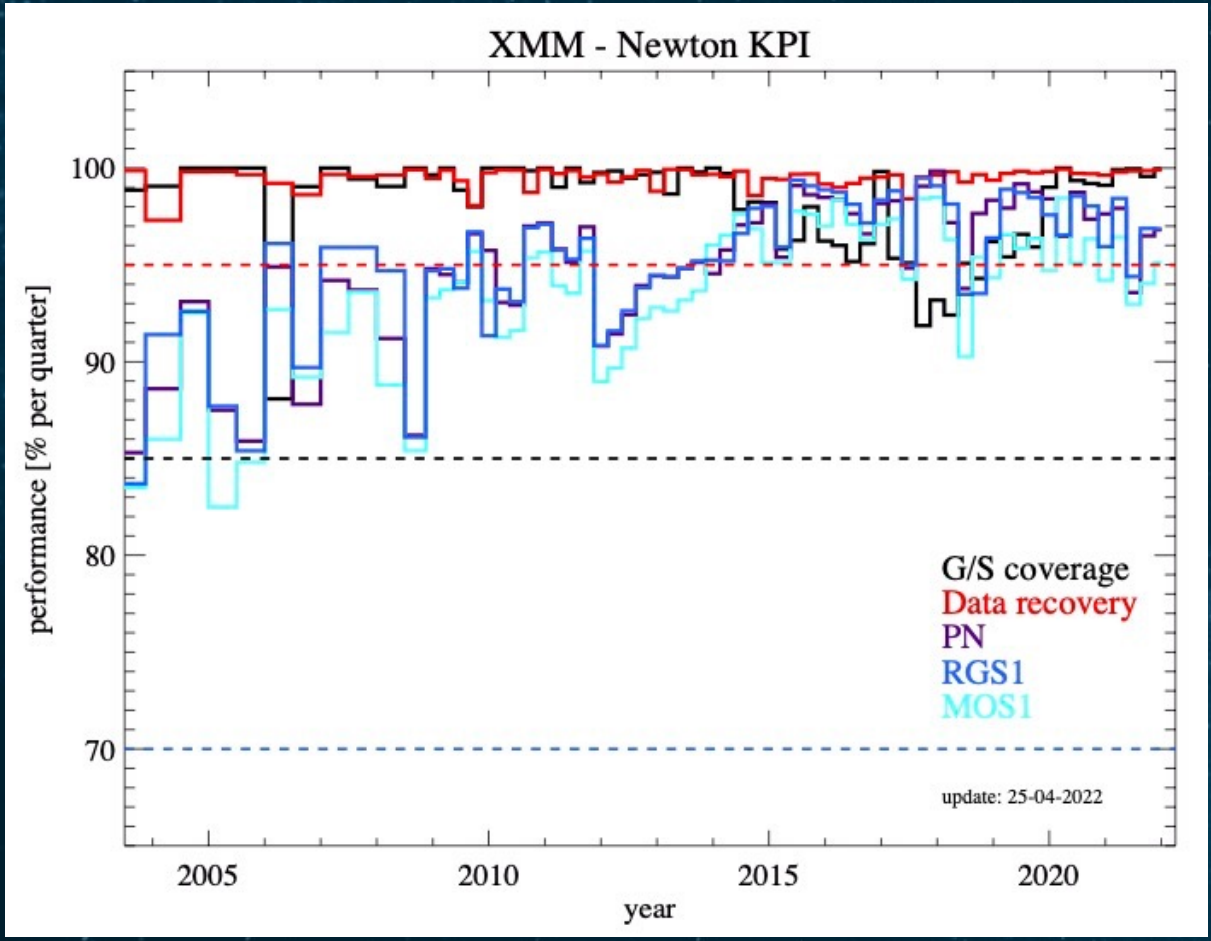
OPS Preparation and monitoring from ESOC



Or similar from homeoffice

- XMM was operated since mid March 2020 under COVID conditions
  - **Practically only SPACONs were at ESOC**
  - Engineers/Analysts were allowed to be on-site for special activities
  - ESA infrastructure helped with new ways to access the different LANs securely from home
- "post COVID" working environment is now different from before COVID:
  - SPACONs are on site
  - Provision of equipment for home office
  - more flexible home/office schemes
  - on site overall workplace structure may change
  - Engineer on call service at or close to ESOC

mission performance indicators – no change



- **Requirements:**

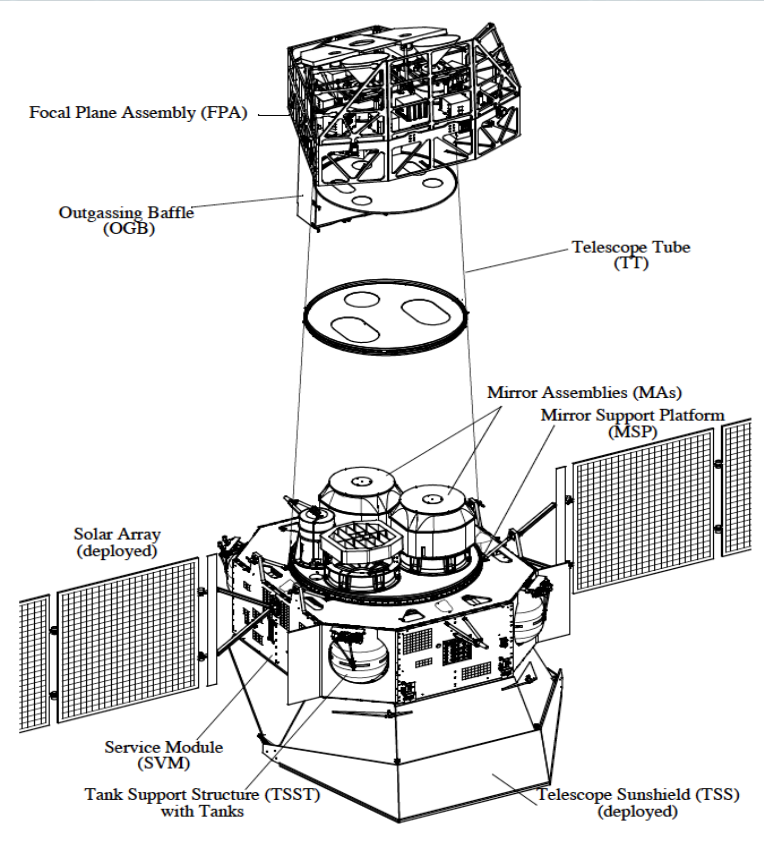
Ground Segment availability: > 85 %

Data Recovery: > 95 %

Science Operations Efficiency: > 70 %

- indicators are **well above the requirements** throughout the mission life time
- **No COVID effects**

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

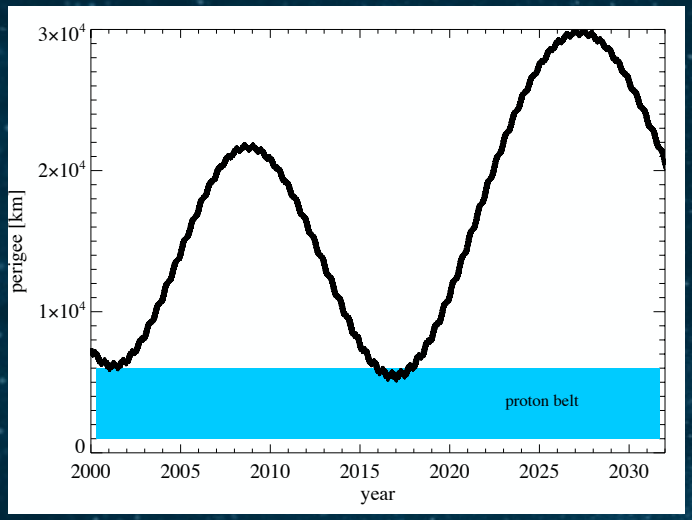
Money	Funded until	End 2020/2022
Fuel	remaining Use per year Mileage	**~36.2 Kg** < 2.5 kg/year 2032+
Thruster pulses	Remaining use per year Mileage	400 (200000 qualified) <4 500 2022 (B-system with full redundancy available, industry recommends to stay on A)
Solar array power	Maximum required Current margin	**~ 1350 W** **~ 400 W**
Battery	According to industry	15+ y
Gyros/(IMUs)	Usage	< 34 %
Reaction wheels	Usage	< 60 %
Optocouplers	Mileage	~ 2028 +
RF switches **Transponder switches**	Usage	Stuck at one position Back up not used instead transponders are switched TX A LCL switches <2100 TX B LCL switches <2100 (Qualified to 25000)

Status of S/C 2021: healthy

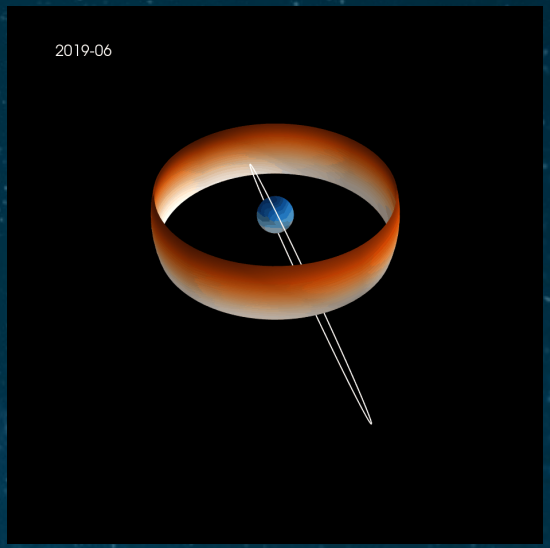
orbit has healthy perigee

40 000 km

Perigee
> 10000 km



67 deg inclination

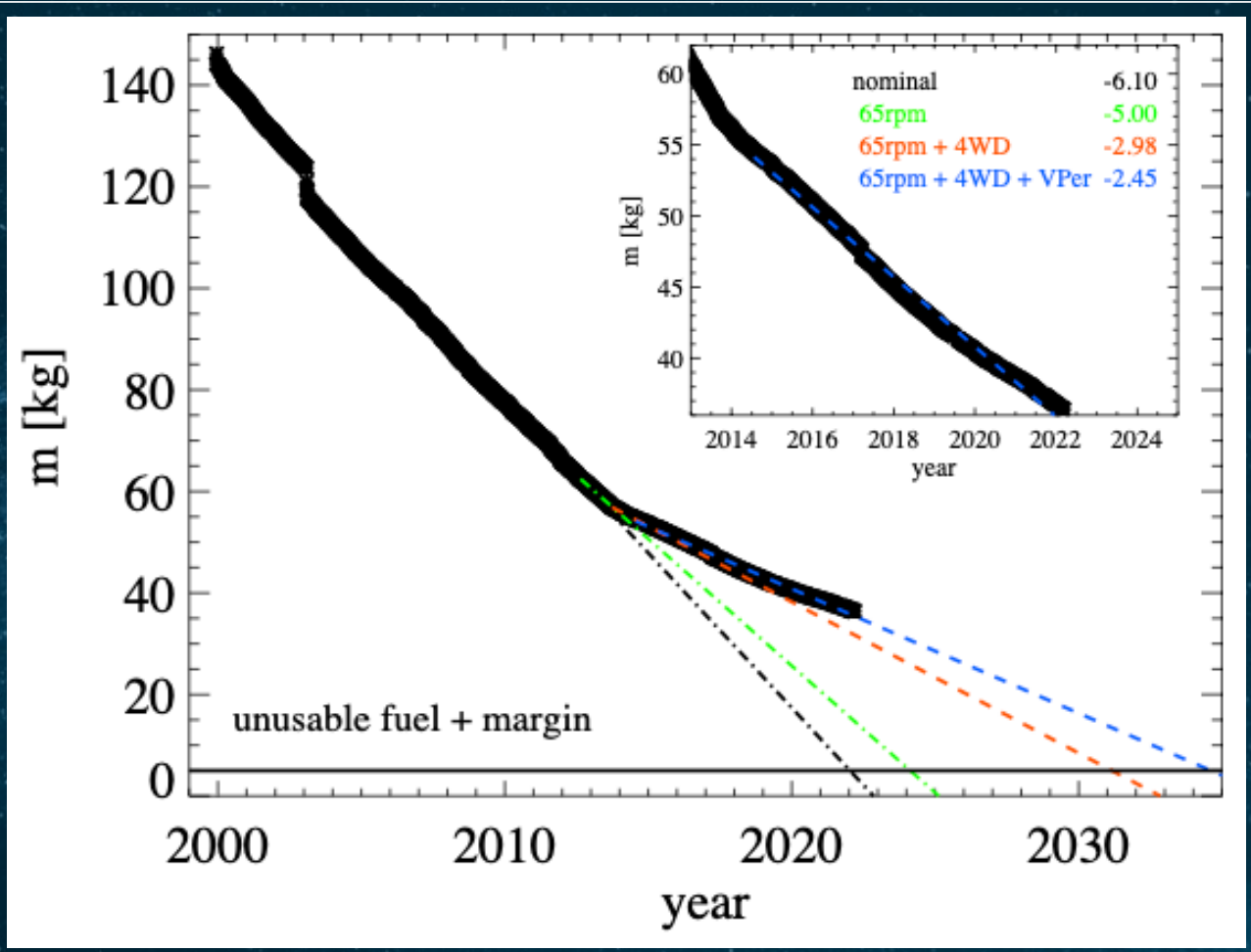


Apogee
~120 000 km

two periods 2021-2023 and 2027/28 with elevated debris flux in GEO Equator necessitates operational collision avoidance

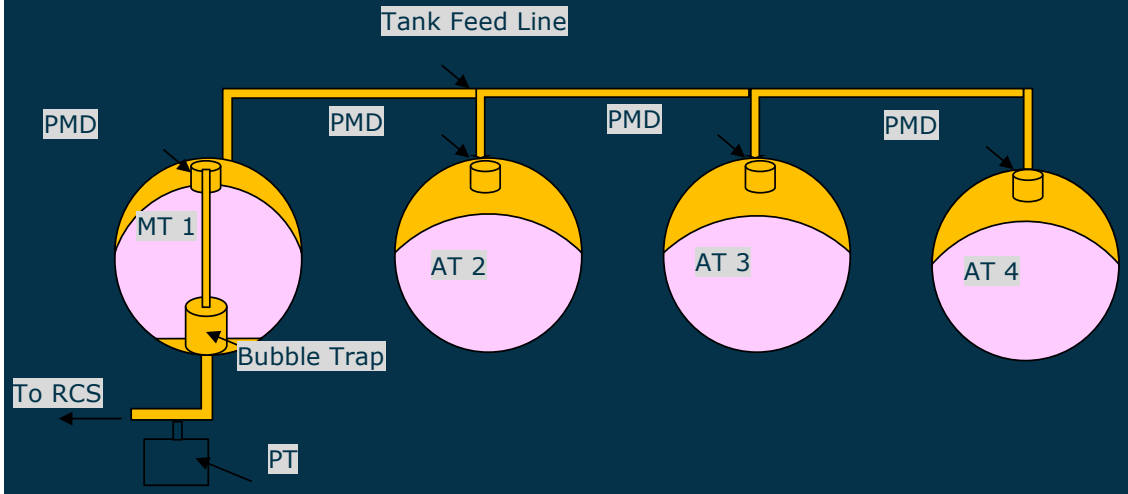
fuel estimates 2021 give life time > 2032

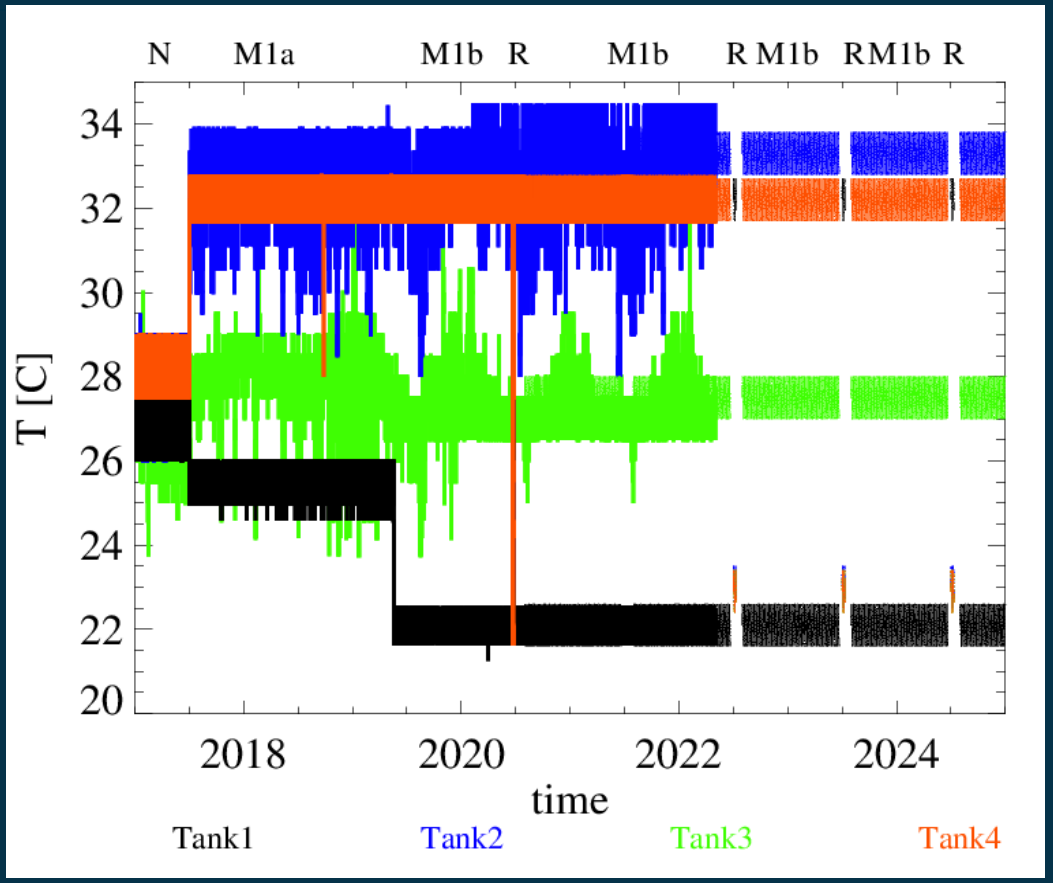
- **Reaction wheels are the primary actuators** for attitude control. **Thrusters are only used for wheel unloading**.
- Changed in 2013 the onboard attitude control software to use **4 reaction wheels instead of 3** before (use the back up wheel)
  called 4 wheel drive **(4WD)**
- the degree of freedom 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**



fuel (migration – status)

- Migration A performed 2017
  (Tank1 colder)
- Migration B performed 2019
  (higher temperature delta → more efficient migration)
- **1st Replenishment performed successfully 2020 June**
  (moving fuel from AUX tanks to Main tank including gas transfer by temperature excursions)
- **Next one 16-20 May 2022**





ground stations

- **Working horses:** Santiago and Kourou
- **Alternatives:** New Norcia, Villafranca, Maspalomas, Yatharagga, Canberra
- Potential apogee gap as of 2028
- **Additional station** from new external provider to diversify.
  - Contract negotiations finished.
  - New comms network equipment and frequency and timing system to be installed
  - **Operational readiness expected by Q3**

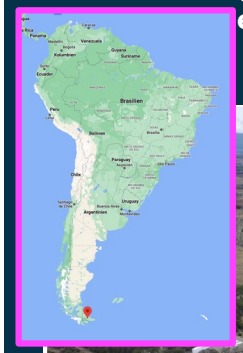


Figure 2-2: Tolhuin, antenna to the left is the 13.5 meter for XMM

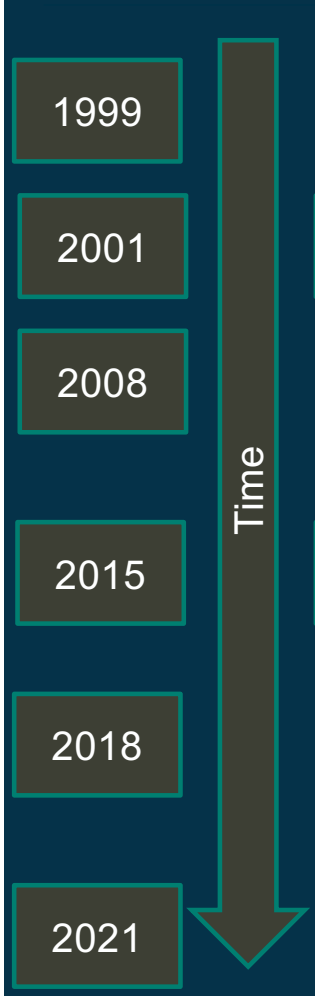
Station	STATUS OF FREQUENCY LICENCE	PROVIDER
Kourou (French Guiana)	No expiration	ESA
Santiago (Chile)	up to the service provider	SSC
Villafranca & MSP (Spain)	up to the service provider	INTA
New Norcia (Australia)	Expires and is extended at the end of every year	ESA
Yatharagga (Australia)	up to the service provider	SSC
Canberra (Australia)	up to the service provider	NASA NASA ESA agreement no-cost
Tolhuin (Argentina)	up to the service provider	KSAT

space craft disposal – not possible

- **XMM has not enough fuel to perform a disposal** (known since many MEORs)

- **long term debris issue calculation** has been performed (XMM-EOL-MEM-00203-OPS-GR)
  - over the next 200 years XMM-Newton will spend approximately half the time on an orbit which crosses the GEO protected zone.
  - actual **time spent within the protected zone is in the order of one month per century**
  - no manoeuvre strategies available which could avoid GEO crossings
  - large manoeuvres (10 m/s (~15 kg of fuel)) have been found to change the GEO zone dwell time by only about 10 %

automation history – make OPS more robust and efficient



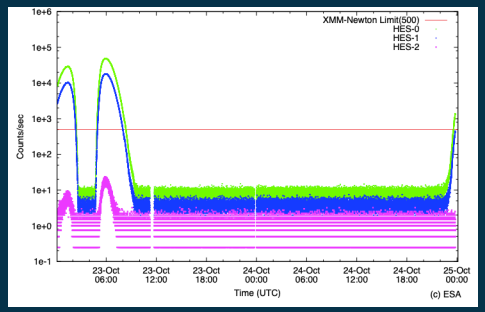
On board	On ground
	launch 1999: Manual Command Stack Auto-stack (timeline from ground)
	radiation danger in combination with inefficient radiation monitors requires new on-ground code based on instrument in-situ data to safe instruments in case of high radiation manually
instrument temp saving patch	
	controller teams: • SOC: 6 Instrument Controller • MOC 6 Spacecraft Controller
	MCS auto commander (inst. Safety)
Tank/instrument fine temp control patch	change 2008: combine XMM(MOC+SOC) and INTEGRAL controllers 6+6+6 → 6 at MOC (introduction of "Auto-commander" for instrument radiation safing)
	MOIS (high repetative or easy)
	Super OOL, GMMS
	MOIS instrument rejoin
	change 2018: combine XMM/INT/Gaia controllers 6+3>6
	MCS/MOIS ground station activities
	in total : combined 6+6+6+3 → 6 (factor 3.5)

automation 2.0 – news on the horizon

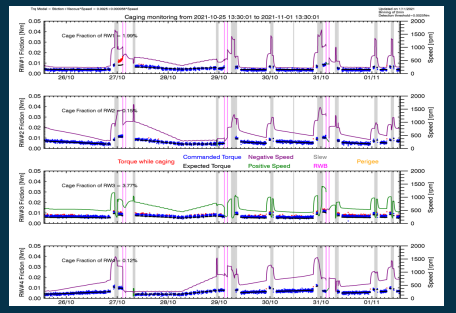
future automation activities will focus on:

- **automated simulator training scenarios** for SOE and SPACONS

- further **automation of ground stations and on board antennae handover**



- **further instrument end to end automation**
  (re. radiation switch off and on again)



- **near realtime data analysis** (new webserver infrastructure currently build up)

- **inclusion of AI** into nominal operations (temperature/current prediction for special OPS (i.e. eclipse, or special pointing), decision support tools for routine and anomaly activities)

MOC system evolution - scheduled and started

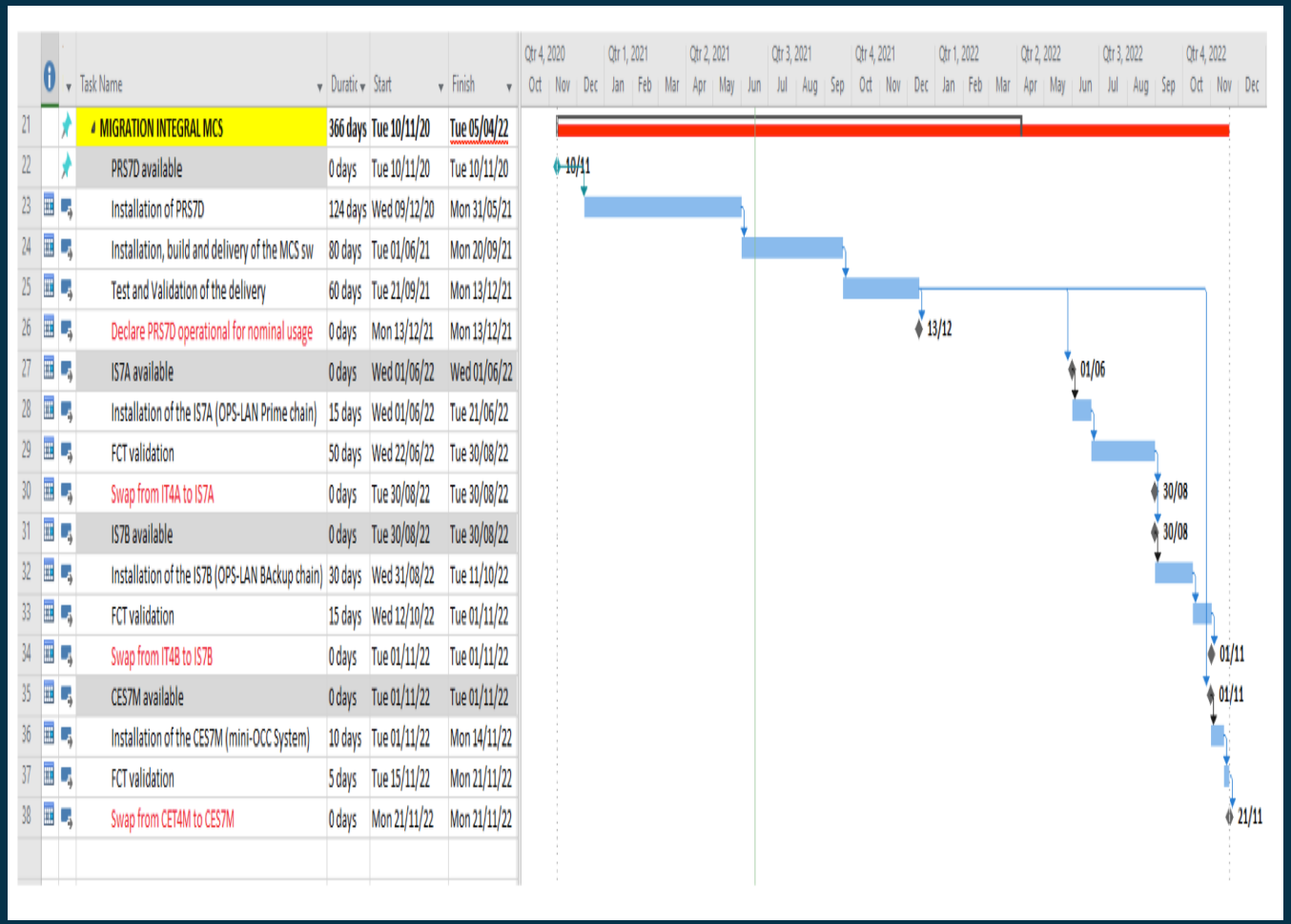
- **Mission Control System Migration:**
  Maintain Solaris baseline (10) with control domain only on Solaris 11
  →No Application porting required (configuration only)
  High commonality with INTEGRAL, MEX. Initial prototyping with MEX MCS gave promising results
  →**Effort expected to be less than previous migration(s)**

- **Operational D/B review and re-organization ongoing**

- **automation platform MOIS migration** to new operating system on virtual machines
- **MUST archive migration to ARES**

- for reason's of obsolescence the **radiation monitoring system Lela needs migration** from it's out-of-date Windows baseline. This upgrade will also address a better integration of the system with the existing Solaris 10 MCS baseline.

- new webserver infrastructure including near-realtime system



	Task Name	Duration	Start	Finish
21	MIGRATION INTEGRAL MCS	366 days	Tue 10/11/20	Tue 05/04/22
22	PRS7D available	0 days	Tue 10/11/20	Tue 10/11/20
23	Installation of PRS7D	124 days	Wed 09/12/20	Mon 31/05/21
24	Installation, build and delivery of the MCS sw	80 days	Tue 01/06/21	Mon 20/09/21
25	Test and Validation of the delivery	60 days	Tue 21/09/21	Mon 13/12/21
26	Declare PRS7D operational for nominal usage	0 days	Mon 13/12/21	Mon 13/12/21
27	IS7A available	0 days	Wed 01/06/22	Wed 01/06/22
28	Installation of the IS7A (OPS-LAN Prime chain)	15 days	Wed 01/06/22	Tue 21/06/22
29	FCT validation	50 days	Wed 22/06/22	Tue 30/08/22
30	Swap from IT4A to IS7A	0 days	Tue 30/08/22	Tue 30/08/22
31	IS7B available	0 days	Tue 30/08/22	Tue 30/08/22
32	Installation of the IS7B (OPS-LAN BAckup chain)	30 days	Wed 31/08/22	Tue 11/10/22
33	FCT validation	15 days	Wed 12/10/22	Tue 01/11/22
34	Swap from IT4B to IS7B	0 days	Tue 01/11/22	Tue 01/11/22
35	CES7M available	0 days	Tue 01/11/22	Tue 01/11/22
36	Installation of the CES7M (mini-OCC System)	10 days	Tue 01/11/22	Mon 14/11/22
37	FCT validation	5 days	Tue 15/11/22	Mon 21/11/22
38	Swap from CET4M to CES7M	0 days	Mon 21/11/22	Mon 21/11/22

roadmap MOC - available

MIssic	System	2020	Q4 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
XMM	MCS-main-HW	Oracle T4			Oracle S7/2												
	MCS-main-OS	Solaris-10			Solaris-10/11											end of ExLiTi	
	MCS-main-SW	S2K 3.1			S2K 3.1												
	MCS-sub-HW	VM															
	MCS-sub-OS	SLES-11				SLES15											
	MCS-sub-SW	SCOS 5				SCOS 6											
	MCS-Archive (LTA)	NETAPP															
	Vis. Layer HW																
	Vis. Layer OS																
	Vis. Layer SW			SGD update													
	GFTS-HW	Oracle T4			MMaaS												
	GFTS-OS	Solaris-10			SLES15												
	GFTS-SW	GFTS 2.2.12			GFTS 3.1.6												
	NIS-HW	VM				VM or MMaaS?											
	NIS-OS	SLES11				SLES12/15											
	NIS-SW	EGOS-NIS 4.2.2				EGOS-NIS 5											
	GMMS-HW	PC				PC upgrade						PC upgrade ?					
	GMMS-OS	Windows Server				Windows ?						Windows update?					
	GMMS-SW	COTS				upgrade COTS?						COTS update ?					
	MPS-HW	included in MCS															
	MPS-OS	as MCS															
	MPS-SW	as MCS															
	ODB-HW	included in LELA	VM (multi user)	VM (multi user)													
	ODB-OS	Windows 7	Windows 19	SLES15													
	OBD-SW	MS Access	MS Access	DABYS													
	Lela-HW	PC	Potential backup for ODB	include in MCS													
	Lela-OS	Windows 7		Solaris-10													
	Lela-SW	Lela Matlab 12.1		N.A													
	MOIS-HW	PC (shard INT/CLU)		VM							???? Meeting with Francois						
	MOIS-OS	Windows 2008		Windows 2019													
	MOIS-SW	MOIS-6			MOIS-7												
	MUST-HW	PC		disccontinued													
	MUST-OS	Windows		disccontinued													
	MUST-SW	MUST		disccontinued													
	ARES-HW			MMaaS													
	ARES-OS			MMaaS													
	ARES-SW			MMaaS													
	OBSM-HW	SUN-SPARC	Oracle T4			Oracle S7/2											
	OBSM-OS	Solaris 2.5	Solaris 2.5 compatibility mode in Solaris 8 container under Solaris 10			Solaris10+6											
	OBSM-SW	Ada Compiler	Ada Compiler			Ada Compiler											
	SIM-HW	VM						VM (optional)									
	SIM-OS	SLES11						SLES15 (optional)									
	SIM-SW	SIMSAT4.3.5						SIMULUS(optional)									
	FOP-HW	PC/VM	check if can be go to VM only														
	FOP-OS	Windows															
	FOP-SW	MS Access															
	Webserver-HW	VM		VM													
	Webserver-OS	Linux		Linux													
	Webserver-SW	php		wordpress + phyton													

family of mission operations and knowledge management established

24/7 live operations: SPACONS + engineer full on call service from MOC (S/C and instrument)

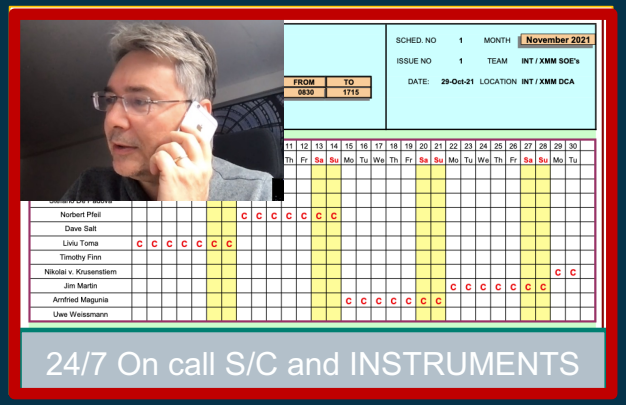
shared SOEs for XMM/INT

New simulations and training plan (ESA-XMM-TRG-PL-0001)

New SPACON training plan (ESA-XMM-INT-OPS-MAN-0001)

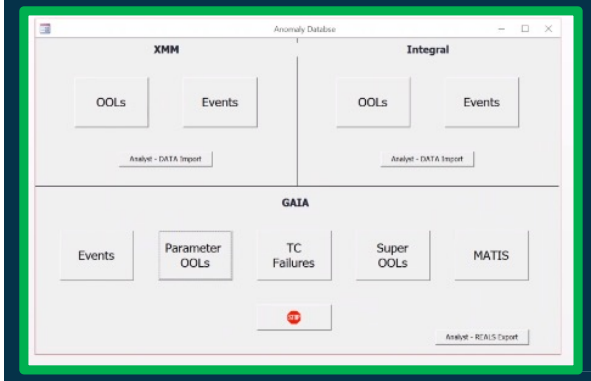
Systems training review and videos/audio presentation for individual subsystem available

(can be used for individual re-training or new commers)



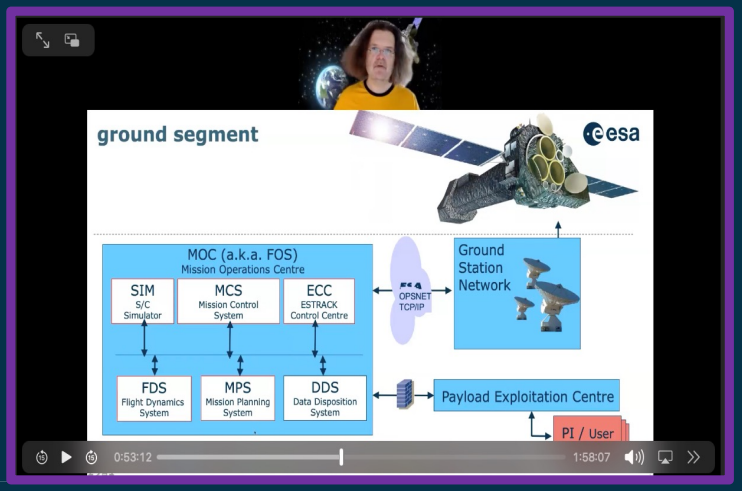
Joint Analyst service team building up

Joint SPACON team will include Euclid soon



D/B consolidation between missions using Dabys

Improved X-references in place (merged 6 into 1), and working on online version ala Gaia



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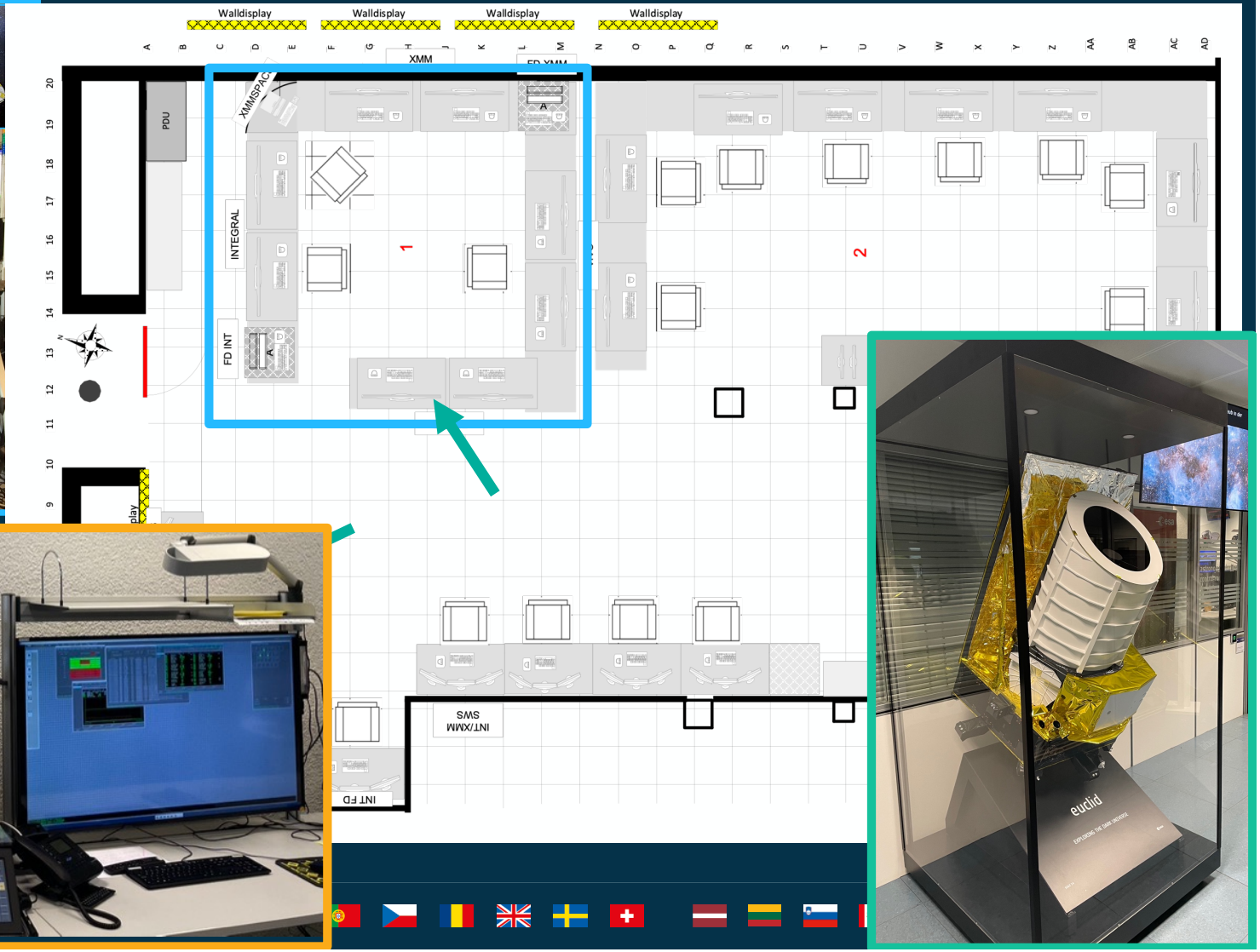
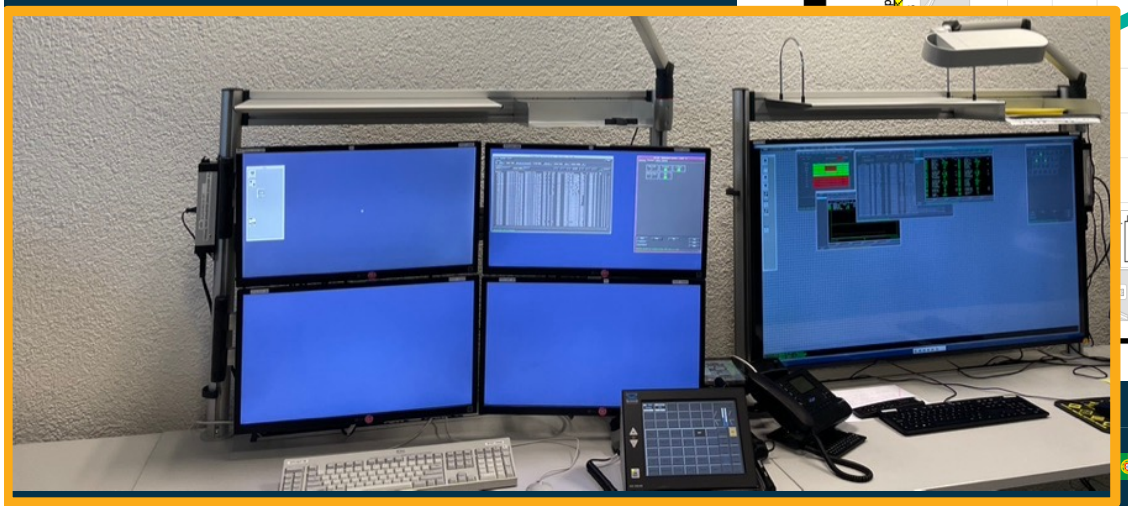
long term knowledge transfer needs to be fostered and continuously performed

Euclid introduction into control room and new equipment



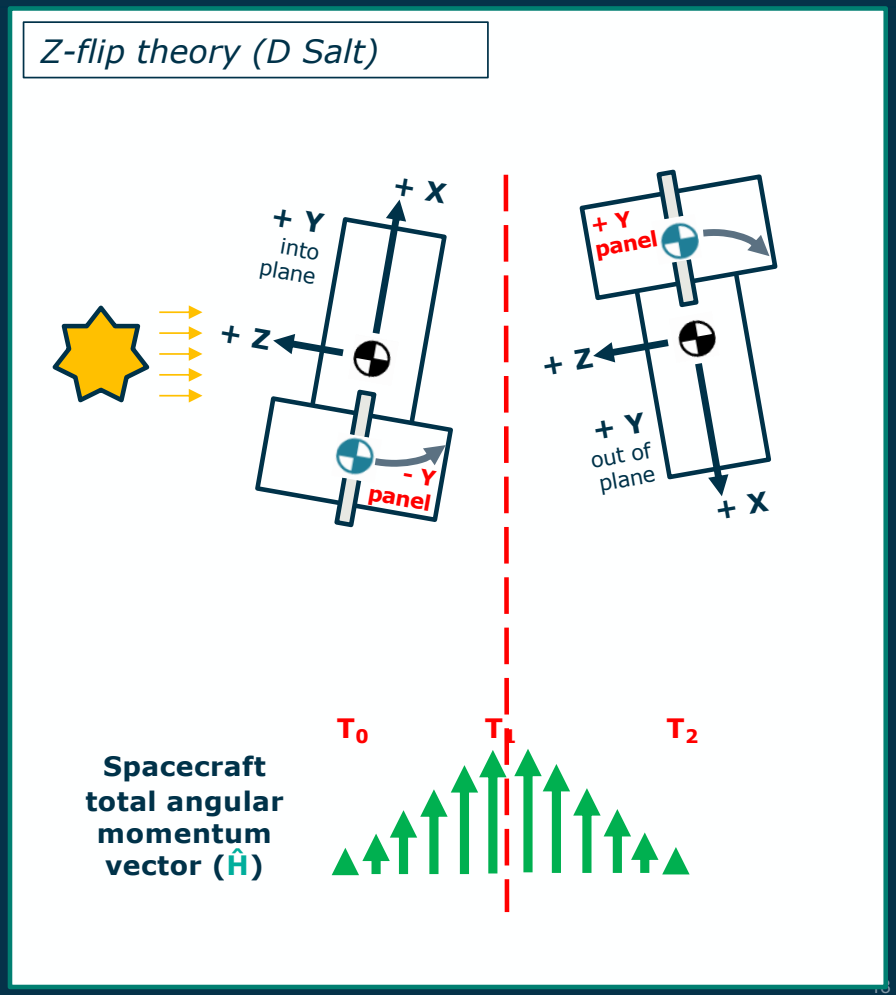


Potetial Next Generation Control Rooms

Potential Next Generation Control Rooms

INTEGRAL Z-flip – an option for the (very) last years? >203x+

- **INTEGRAL**
  - performs after the failure of its Reaction Control System (RCS) a so called Z-flip momentum control, where it rotates about sun line over momentum planning period to control solar radiation pressure
    → **0 fuel consumption**
  - mission planning and observation strategy needed changes but is not significantly affecting the observation efficiency (<5%)
- **XMM did initial study** with industry → Results:
  - XMM Z-flip strategy like INTEGRAL appears a **feasible** way to have very long periods (perhaps indefinitely long) without RCS operation (to save fuel for later/safe modes, or in case of a future problem with RCS)
  - constraints: mission planning S/W and Flight dynamics S/W updates
  - test could be performed soon



XMM-MOC - getting ready for one more decade

- XMM-Newton S/C is in very good shape
- fuel limits life time to > 2032 . . .

- fuel replenishment will be a key activity, z-flip needs to be investigated
- ground systems are being made ready and state of the art to serve for one more decade
- automation plays a key role in future operations to increase safety and efficiency
- stability of the ground segment systems is a key ingredient for successful automation
- proficient team and knowledge management are key factors