



# CryoSat-2

## 14+ Years of Successful Flight Operations

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# Cryo2ice Symposium 2024



## An old mission – still going strong

14 ½ years

>76648 Orbits

>65000 Passes

12-13 per day, ~87 per week

99.5% Successful Passes

Typically, ~20 passes per year not fully successful. X-band data loss is exceptional, because downlink only started when uplink established.

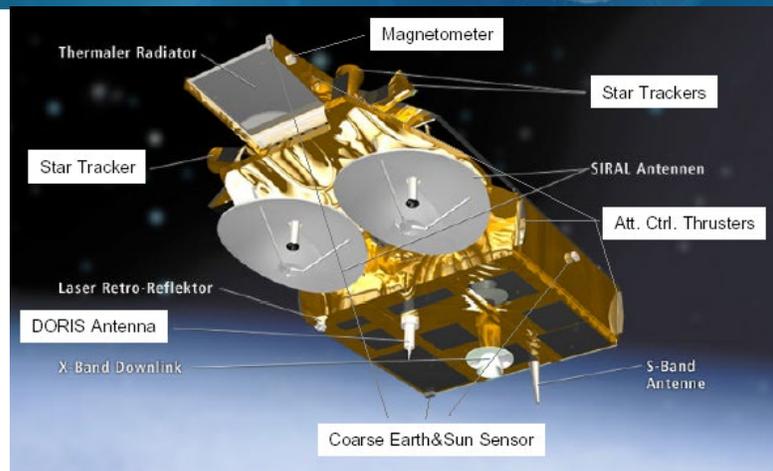
## Robust space segment

CDMU-A with B backup

MMFU-B used as prime since 2021 keeping MMFU-A backup

RCS-B used as prime since 2023 keeping RCS-A as backup

**SIRAL-A and DORIS-A fully nominal and operational!**

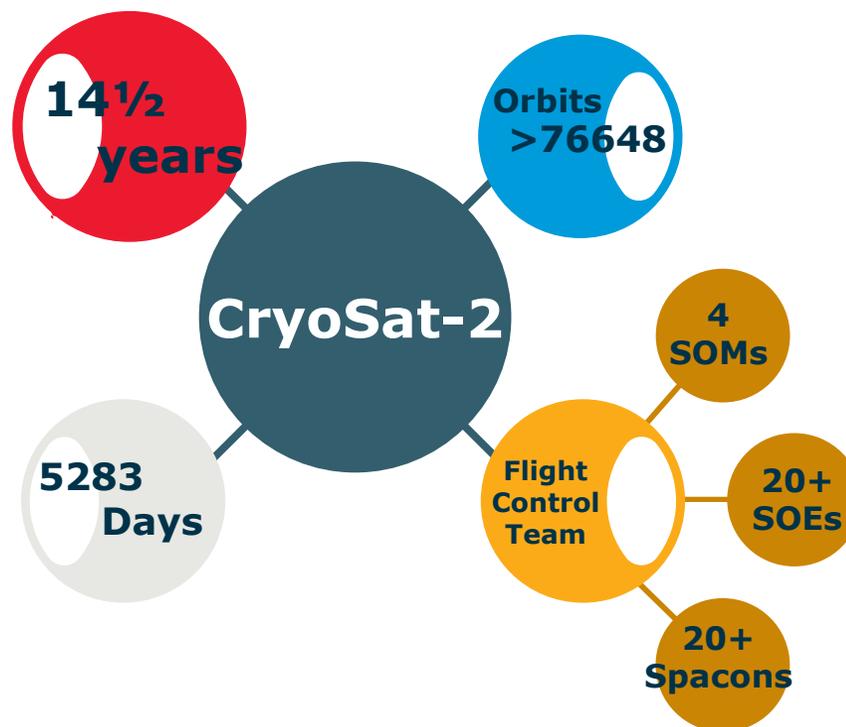


## Aging with grace

- ✓ Systems fully operational and performant after more than four times the nominal mission duration
- ✓ Several mission extensions
- ✓ Aging monitored ... better than expectations!
- ✓ Other missions use Cryosat expertise (tracking, CAMs, ...)!

## Lights-off Operations since October 2023

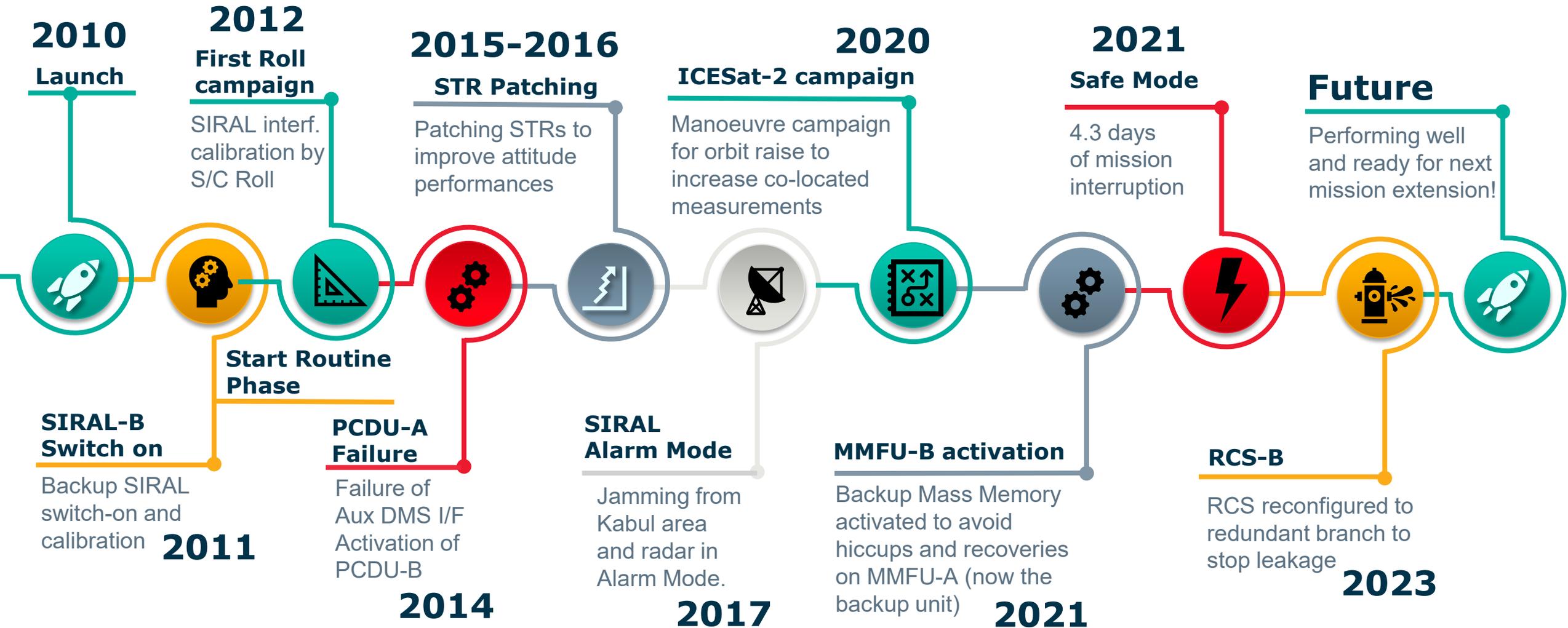
- ✓ No more spacons on console for 10 hours per day, 7 days per week.
- ✓ Team of 8 spacecraft operations engineers shared with Swarm - and other Earth Explorers in the future
- ✓ On-call engineer or other team members present in control room for checks during working days only, mission planning and special operations execution.
- ✓ On non-working days 2 on-call engineers are available performing a single daily check on spacecraft and ground segment status.
- ✓ Key events are notified by SMS since 2019.



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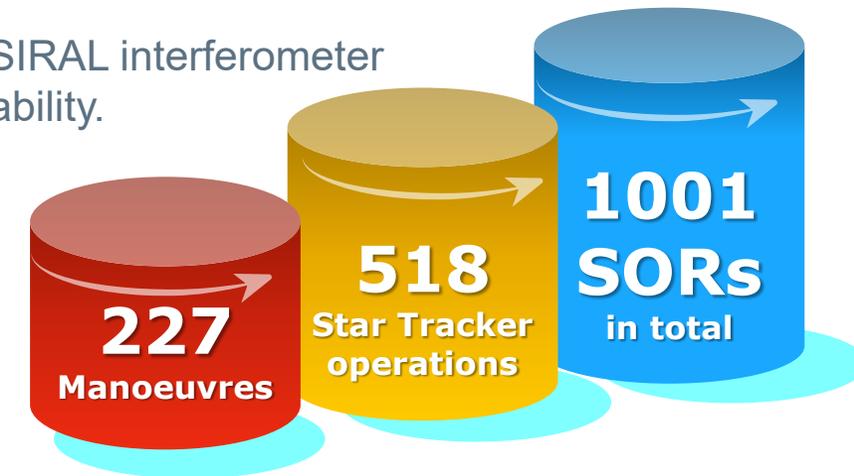
## CryoSat-2: Key events of almost 15 years



## Special Operations Requests to ensure the mission

Almost every week the CryoSat Flight Control Team has performs a few **Special Operation Requests (SORs)** dealing with:

- **Star Tracker**
  - **CCD images** at specific temperatures to evaluate the performances
  - **annealing** to provide significant improvements of the CCD performances
  - **selection** change: change the selection based on sun/moon blindings and temperature optimization
- **Orbit Control Manoeuvres:**
  - Orbit Control Manoeuvres to keep CryoSat in the required ground track deadband of the Reference Orbit
  - Series of orbit Control Manoeuvres to acquire and change reference orbit
  - Collision Avoidance Manoeuvres (CAM) to avoid high-risk conjunctions
- **SIRAL Interferometer Roll campaign:** precise yearly (15 months) calibration of the SIRAL interferometer over Pacific and Indian Ocean to assess the interferometric baseline evolution and stability.
- **Power subsystem:**
  - Battery **End Of Charge** management to extend the battery lifetime
- Software Maintenance, anomaly recovery and other rare activities.



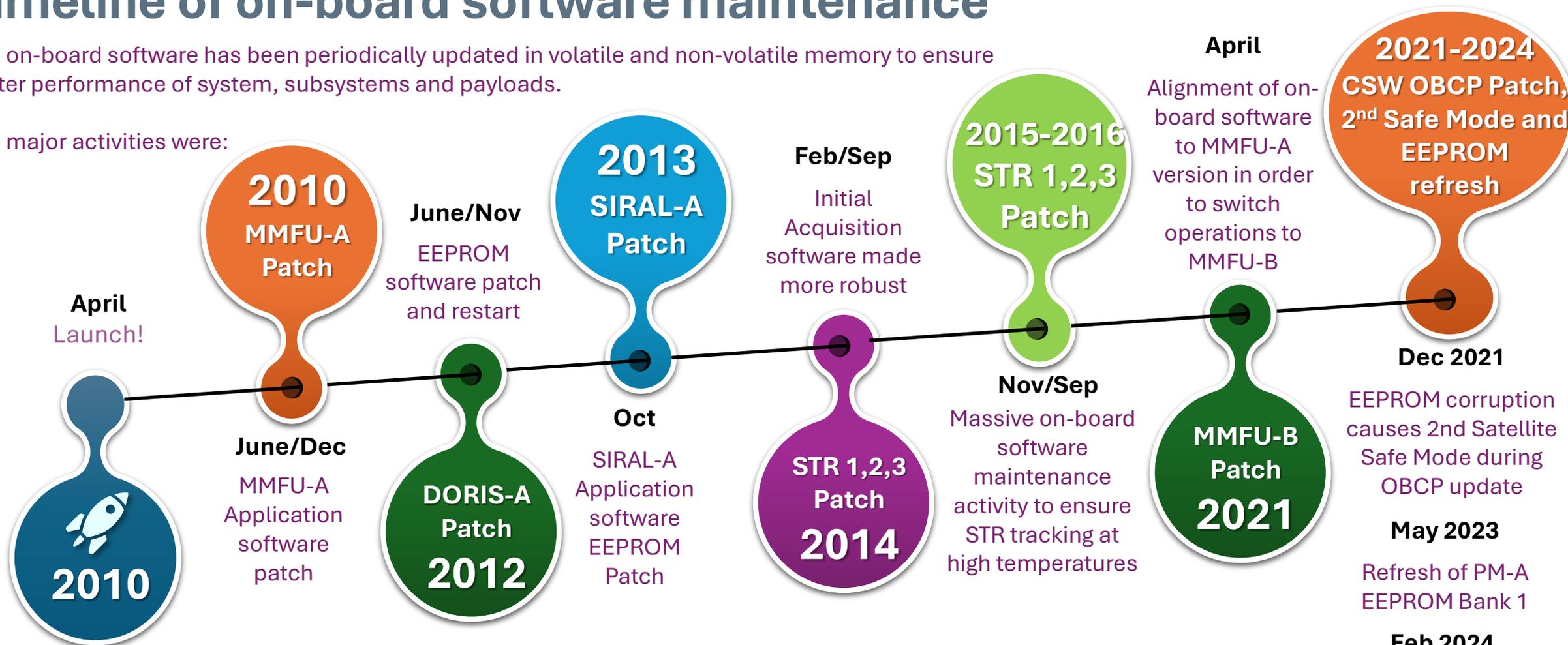
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## Timeline of on-board software maintenance

The on-board software has been periodically updated in volatile and non-volatile memory to ensure better performance of system, subsystems and payloads.

The major activities were:



Many more small patches have been applied through the years on STRs, DORIS, SIRAL and System

1st Satellite Safe Mode was Jan 2011 due to ADA exception in a temporary investigative patch.

Refresh of PM-A EEPROM Bank 0

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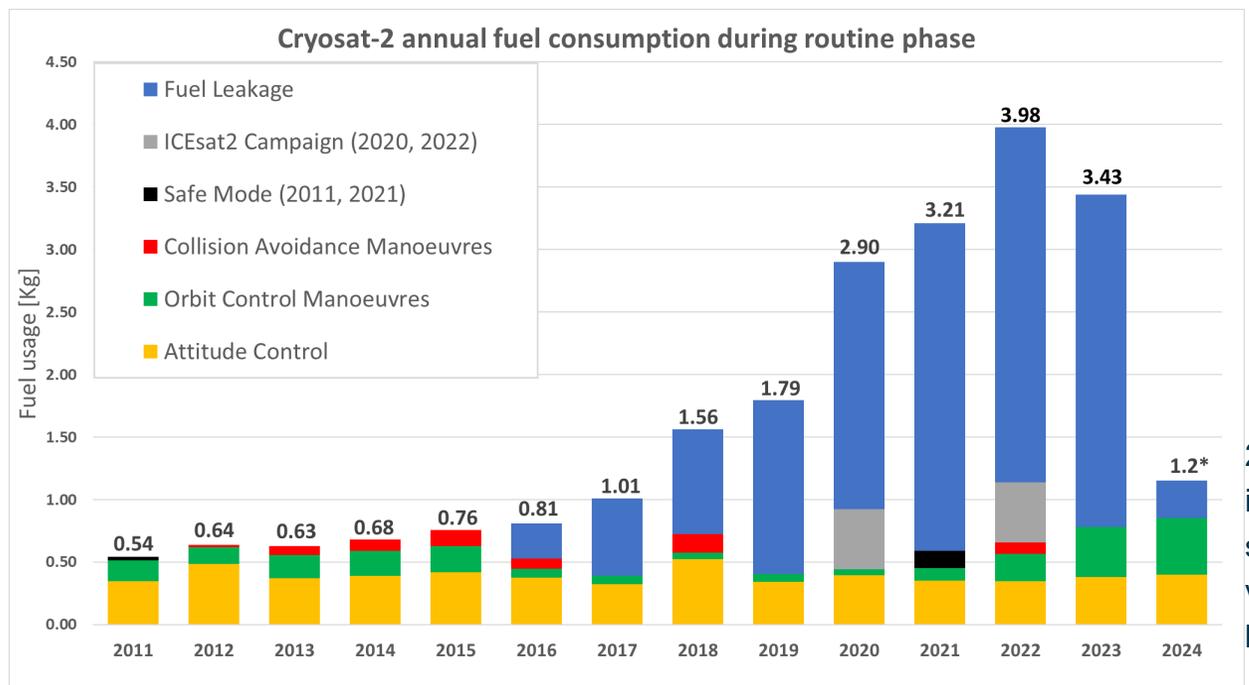
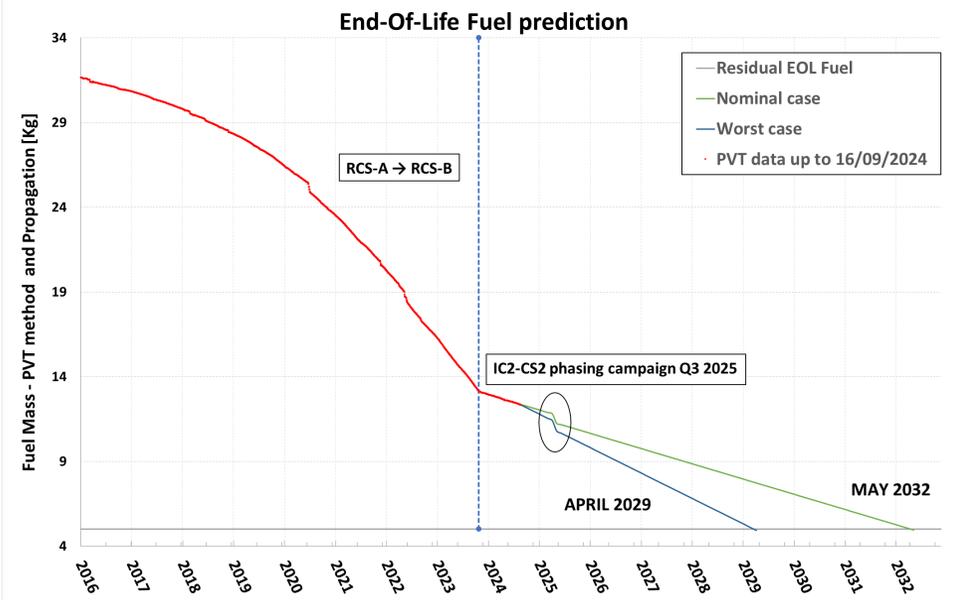


## Nitrogen leakage stopped in 2023

- Difference between **Thruster Pulse Count (TPC)** and **Pressure-Volume-Temperature (PVT)** propellant mass estimation methods starts increasing in mid-2015 and accelerating.
- Leakage located in Low Pressure Section of RCS-A branch, specifically ACT-A4 thruster due to surface damage of seat and/or seal and embedded particle in the seal.
- Reconfiguration to RCS-B branch executed in November 2023, stopping the leakage, however thruster under-performance without a significant effect on the attitude control and pointing accuracy
- RCS-A remains available as backup in case of failure of RCS-B.

### RCS: AT A GLANCE

- ~ 12 kg of nitrogen propellant left
- Propellant leakage reached ~3 kg/year
- Switch-over to the redundant RCS in Nov 2023 - consumption now ~1 kg/year
- End Of life now beyond 2028





## Keep us safe: a history of Collision Avoidance

Many **Collision Avoidance Manoeuvres** were executed, decreasing the collision risk between CryoSat-2 and different types of chasers: fragmentation debris, active satellites, CubeSats, unknown objects... and even the intact upper stage of the only successful British space (1971)

### Space Debris Office notification

Collision warning is raised by ESA Space Debris Office based on US or European databases



### Assessment

Mission Control Teams assess **collision risk** and start plan for avoidance manoeuvre

Flight Dynamics at ESOC prepares scenario



### Decision and uplink

If risk is confirmed, the **manoeuvre** is delivered, checked and uplinked by Flight Control Team



### Manoeuvre executed

Finally, CryoSat-2 is moved from its orbit to decrease **collision probability** level.

If needed a return manoeuvre is also prepared.



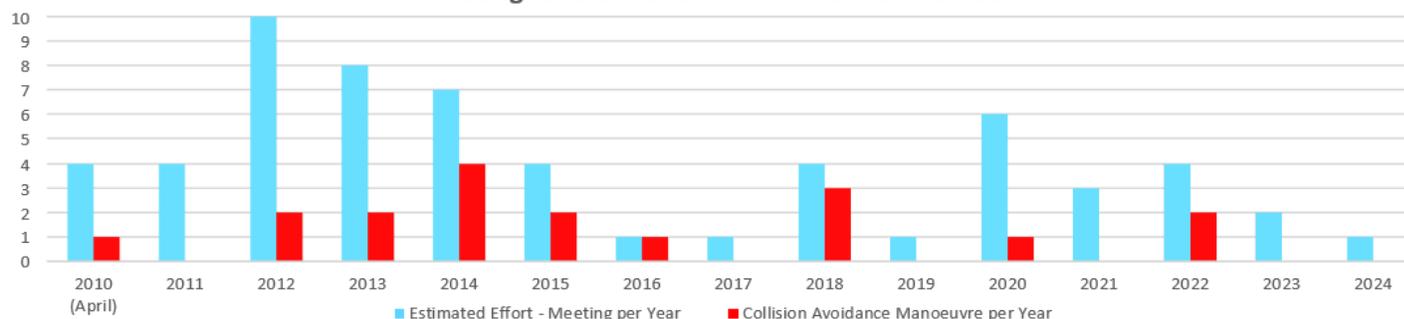
### Success!

**135** Collision Warnings received since launch

**60** were discussed in dedicated meetings

**18** collision avoidance manoeuvres executed, and a few more routine manoeuvres modified

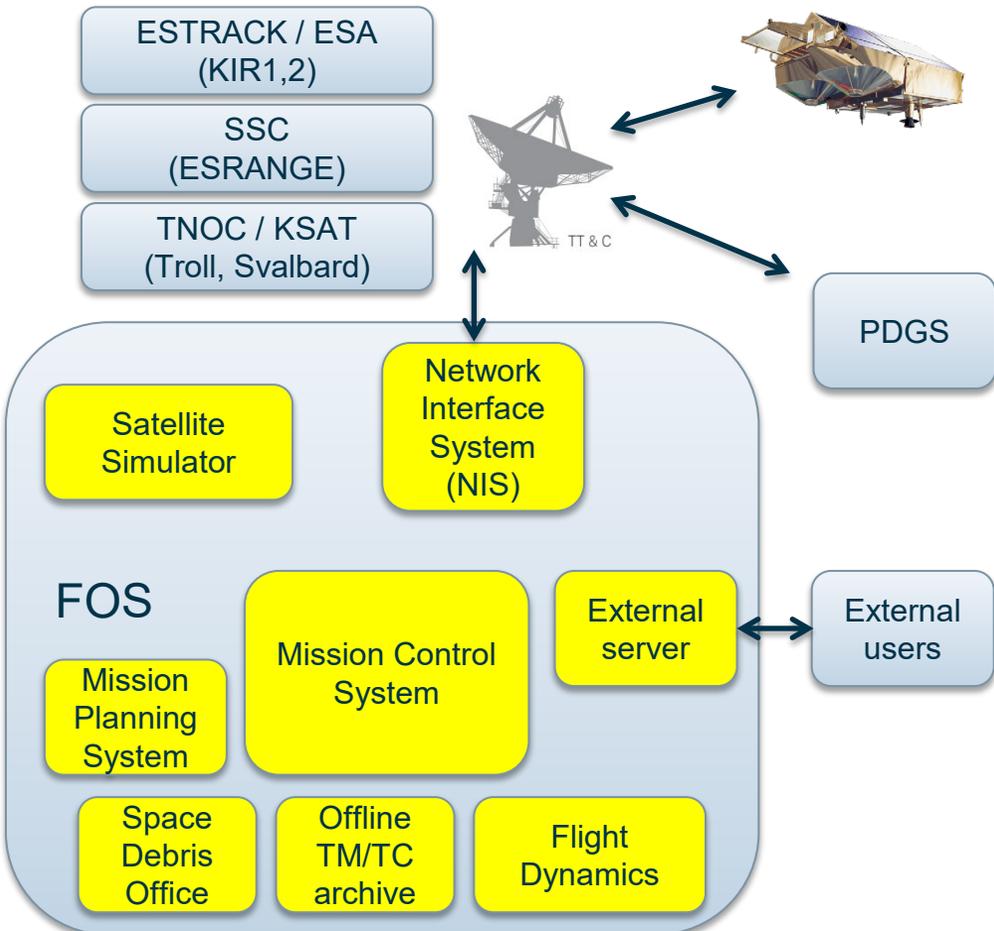
Meetings and Collision Avoidance Manoeuvres



16 meetings and 5 manoeuvres due to debris of the Iridium 33 / Kosmos 2251 collision on 10 Feb 2009

9 meetings and 4 manoeuvres due to Fengyun 1C debris created 11 Jan 2007

## CryoSat-2 ground segment and FOS element: many upgrades



- 2010 One of first EO mission at ESOC to take passes in **automation**: commands released 24/7 at precise time to connect stations and dump MMFU
- 2016 Start of MCS migration activities: a long process
- 2018 Mission Control System **migration** to mostly virtual servers, shared physical servers and new external servers – much legacy software remains
- 2019 REALS **SMS notifications** of anomalies in place
- 2020 COVID times: **remote working** expanded, but control room remained occupied
- 2022 Major upgrade of KIR-1 and KIR-2 ground station (front end, x-band and s-band converters, CORTEX)  
Upgrade of clients and screens in control room (2-4 HD to 4K screens)
- 2023 Start of lights-off operations
- 2024 New Mission Planning system (EGOS MPS) compatible with future MCS used operationally, to prepare for further MCS evolution

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## CryoSat-2 Operation Teams – then and now

