CHEOPS

From re-entry in 25 years to 5 months

Anthony Maldonado
David Modrego, María José González, Naiara Fernández de Bobadilla, María Fuentes

INTA (Spanish National Institute of Aerospace Technology)

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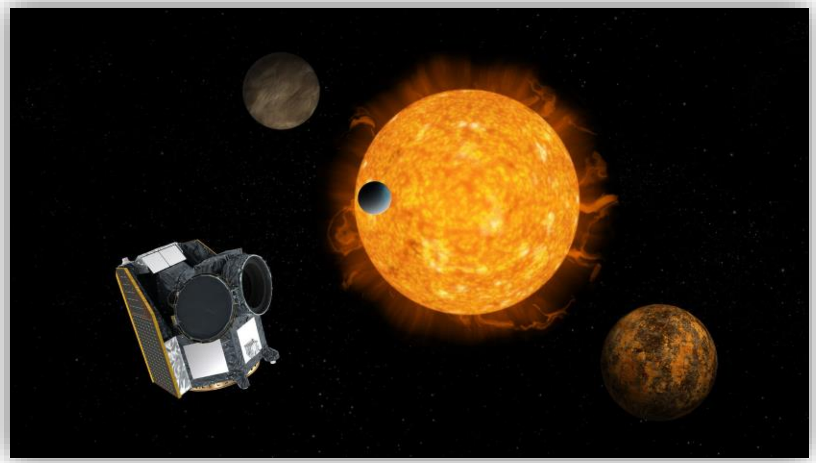
CHEOPS Mission and Operations

ESA Mission for Exoplanet Characterisation

Introduction

CHEOPS (**CH**aracterising **E**x**OP**lanet **S**atellite) is the first mission dedicated to studying bright, nearby stars that are already known to host exoplanets, in order to make high-precision observations of the planet's size:

- Planets smaller than Saturn
- Period less than **50** days
- Stars brighter than magnitude **12**



CHEOPS mission

CHEOPS SATELLITE

- Based on the platform AS-250
- Single payload: Ritchey-Chretien telescope

CHEOPS is the first ESA S-class mission**:**

- Total cost for ESA: 50 M€ including launch
- Development time not exceeding 4 years

Great impact in operations:

- Downgraded AS-250: GPS unit not included + units with lower performances
- Automated operations planned to reduce operation costs

CHEOPS Ground Segment

Mission Operations & Control Centre (MOC)

- Send TCs and receive science and HK TM
- S/C monitoring & control
- Attitude & orbit determination and control
- Automatic operations

Science Operations Centre (SOC)

- Planning of science activities
- Receive and process science data

INTA Ground Stations

CHEOPS Operations

CHEOPS is in a **sun-synchronous** orbit at a height of 700 km:

- **LTAN**: 06:00 a.m. ± 20 minutes
- ~**15** daily orbits → Only **4-6 orbits** pass over the nominal G/S
- 2-3 passes before 07:30 UTC and 2-3 passes after 17:00 UTC
- Pass duration < **11** minutes

Mission timeline

2019 | 2020 | 2023 | 2026 | 2027

December 18th
Launch

December 22nd
LEOP completed

March 25th
Commissioning completed
Start of routine operations

September 30th
End of nominal mission

October 1st
Start of extended mission

December 31st
End of extended mission
Start of decommissioning phase
START OF POSSIBLE 2nd EXTENSION (2029)

July 1st
End of decommissioning phase

Initial De-orbiting Strategy

- De-orbiting Plan
- Fuel Budget

De-orbiting Plan

Relevant dates:

- **30/09/2023** → end of nominal mission

Constraints:

- Re-entry in less than 25 years after passivation
- Passivation conditions → no remaining fuel

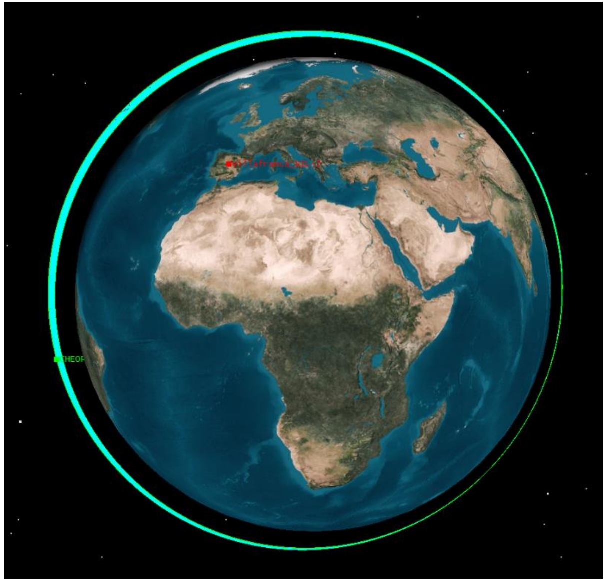
De-orbiting Plan

Disposal from Mission Analysis:

- Lower perigee to 490 km for a re-entry in 25 years

Manoeuvres to consider:

- Launcher correction
- Collision avoidance manoeuvres (CAM)
- De-orbiting



Fuel Budget

- **Initial estimation**

	Delta-V [m/s]
Initial Propellant	**220,96**
Launcher correction	21
Total Collision Avoidance	7,2
Deorbit (SDMR)	43
Propellant Margin (recomended 11 m/s)	**149,76**

- **Reassessment after nominal mission**

	Delta-V [m/s]
Initial Propellant	**220,96**
Launcher correction (IOCR)	1,5
CAM 1	0,015
CAM 2	0,08
Total Collision Avoidance	0,095
Deorbit (SDMR)	43
Propellant Margin (recomended 11 m/s)	**176,365**

- Launcher correction: much lower than estimated due to accurate injection in final orbit
- Collision avoidance manoeuvres: smaller than expected

Remaining ΔV ~ 176 m/s

Upgraded De-orbiting Strategy

- De-orbiting Plan
- Fuel Budget
- Operations Plan

De-orbiting Plan

Relevant dates:

- **31/12/2026** → end of extended mission 1

Constraints:

- Re-entry in less than 25 years after passivation
- Passivation conditions → no remaining fuel + reassessment of subsystems qualification for extended use

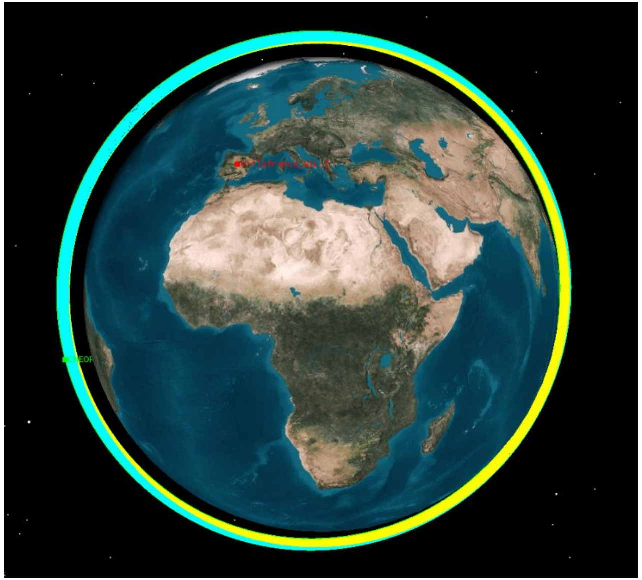
De-orbiting Plan

Disposal from analysis done for MEOR:

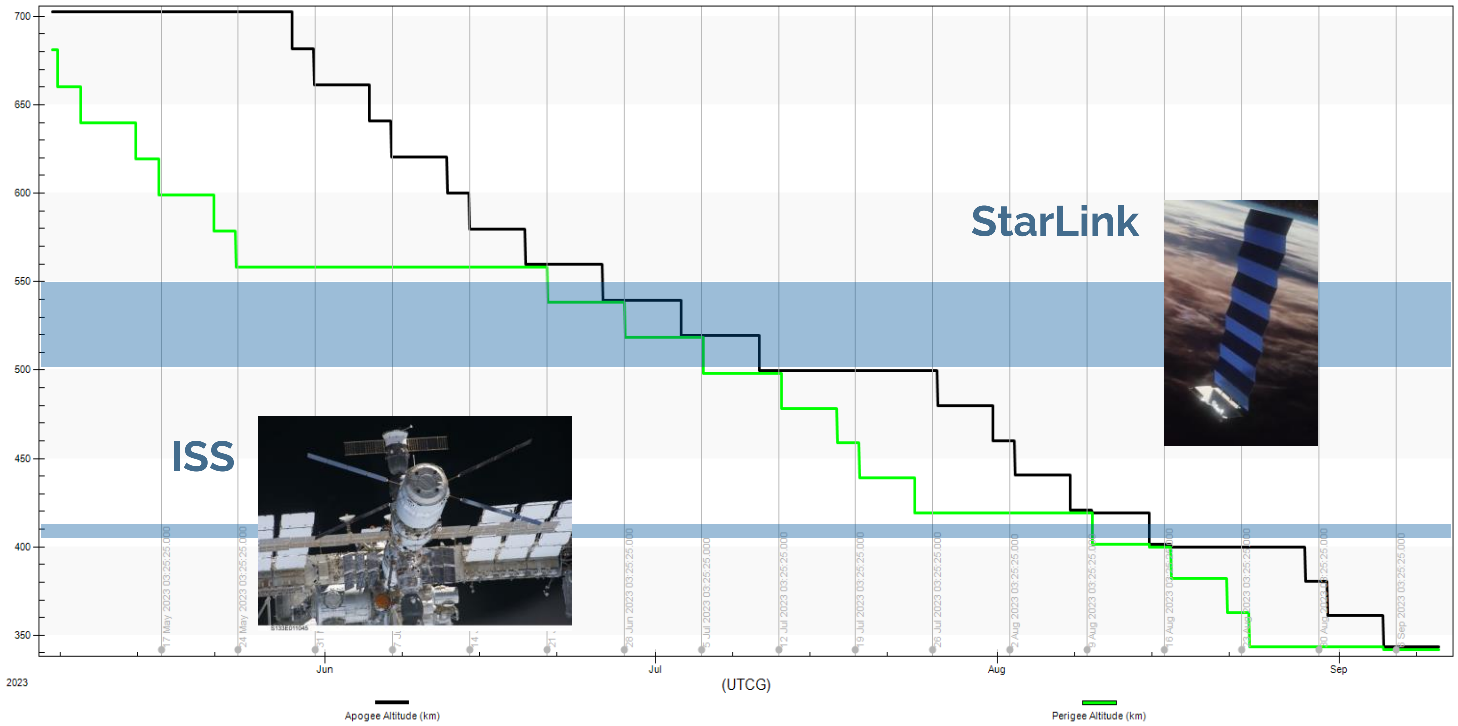
- Lower to a 350 km circular orbit for a re-entry in five months → minimum height for controllable attitude

Manoeuvres to consider:

- Launcher correction
- Collision avoidance manoeuvres (CAM)
- LTAN maintenance manoeuvres
- De-orbiting

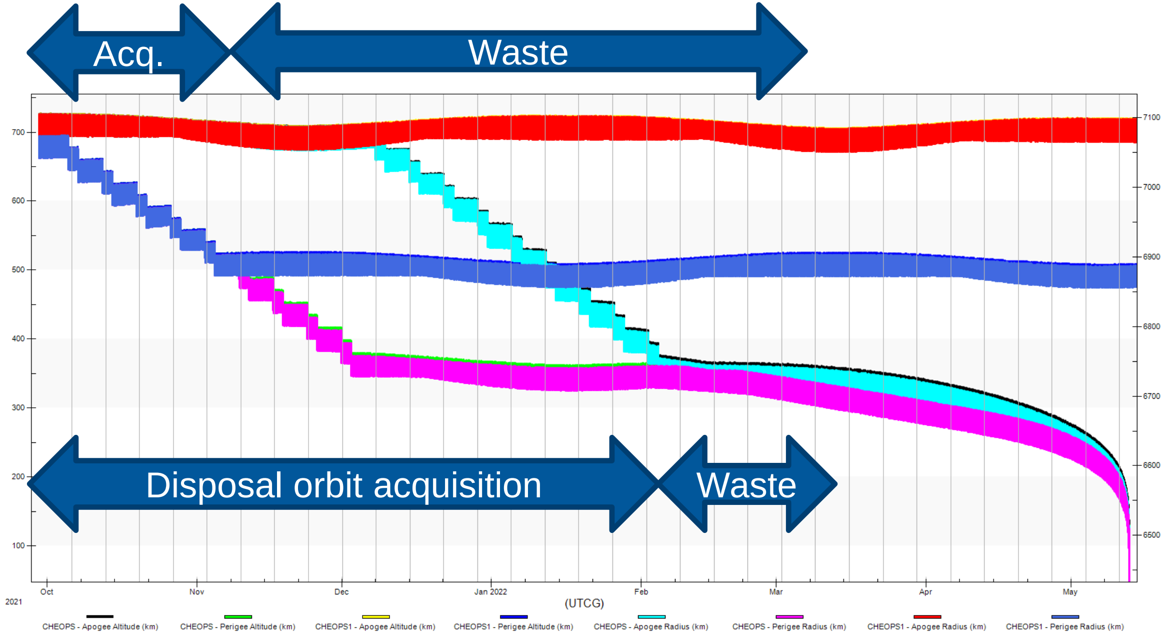


De-orbiting Plan



De-orbiting Plan - Comparison

- Minimal disposal:
  - 1,5 months for orbit acquisition
  - 4 months for propellant waste manoeuvres
- Maximal disposal:
  - 4,5 months for orbit acquisition
  - 1 month for propellant waste manoeuvres



Fuel Budget – Collision Avoidance

2020

- CAM - October 2nd

2021

- Warning - February 2nd
- Warning - February 24th
- Warning - October 6th

2022

- Warning - February 8th
- Warning - July 22nd
- **CAM - September 29th**

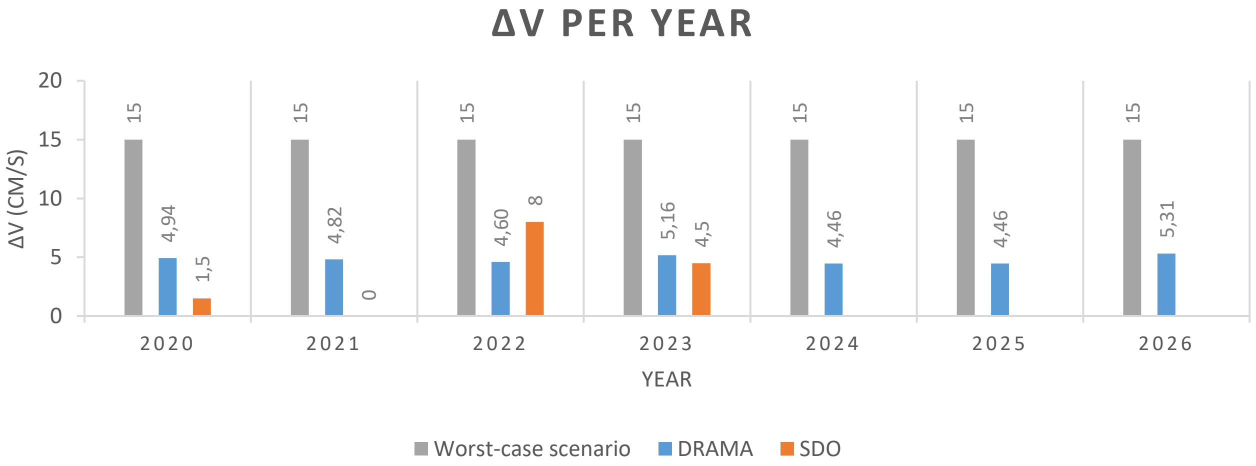
2023

- Warning - January 8th
- **CAM - March 6th**
- Warning - Sept 20th
- **CAM - Oct. 12th**

- 4 out of 11 warnings required a manoeuvre
- Less than 0,15 m/s used during nominal mission

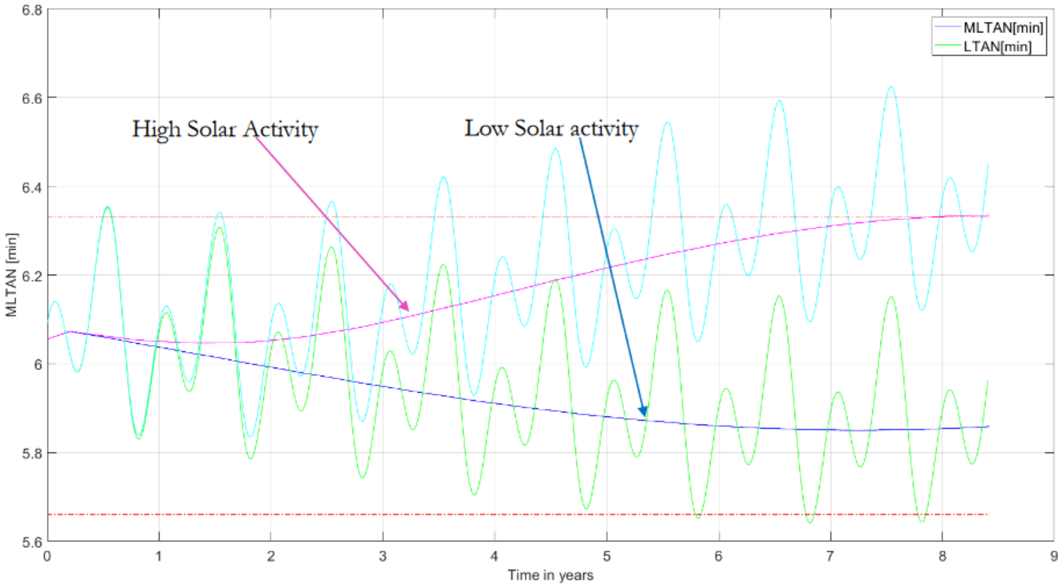
Fuel Budget - Expected Risk Evolution

- **ΔV worst-case scenario (DRAMA tool):** from mission analysis
- **ΔV DRAMA:** recalculated considering collision probability reduced from $2 \cdot 10^{-5}$ to $1 \cdot 10^{-9}$
- **ΔV SDO provided:** real operations



Fuel Budget – Maintenance Manoeuvre

- The results of the analysis of the LTAN correction manoeuvre depends on the drag prediction determined by the solar activity



Fuel Budget

	Low Drag	High Drag
	Delta-V [m/s]	Delta-V [m/s]
Initial Propellant	**220,96**	**220,96**
Launcher correction (IOCR)	1,5	1,5
CAM 1	0,015	0,015
CAM 2	0,08	0,08
CAM 3	0,025	0,025
CAM predicted	1,68	1,68
Total Collision Avoidance	1,8	1,8
LTAN Orbit Maintenance 1	17	20
LTAN Orbit Maintenance 2	-	21,4
Deorbit (SDMR)	179,74	164,74
Propellant Margin (recommended 11 m/s)	**20,92**	**11,52**

- Remaining propellant ensures operations until 2039

Remaining ΔV 2039 (worst case) ~ 11 m/s

Decommissioning Operations Plan

Decommissioning Preparation

- De-orbiting Strategy
- Simulations
- Trained Operators

Operation

- Instrument Deactivation
- Manoeuvre Determination and commanding
- G/S operation
- S/C Passivation
- Collision Avoidance

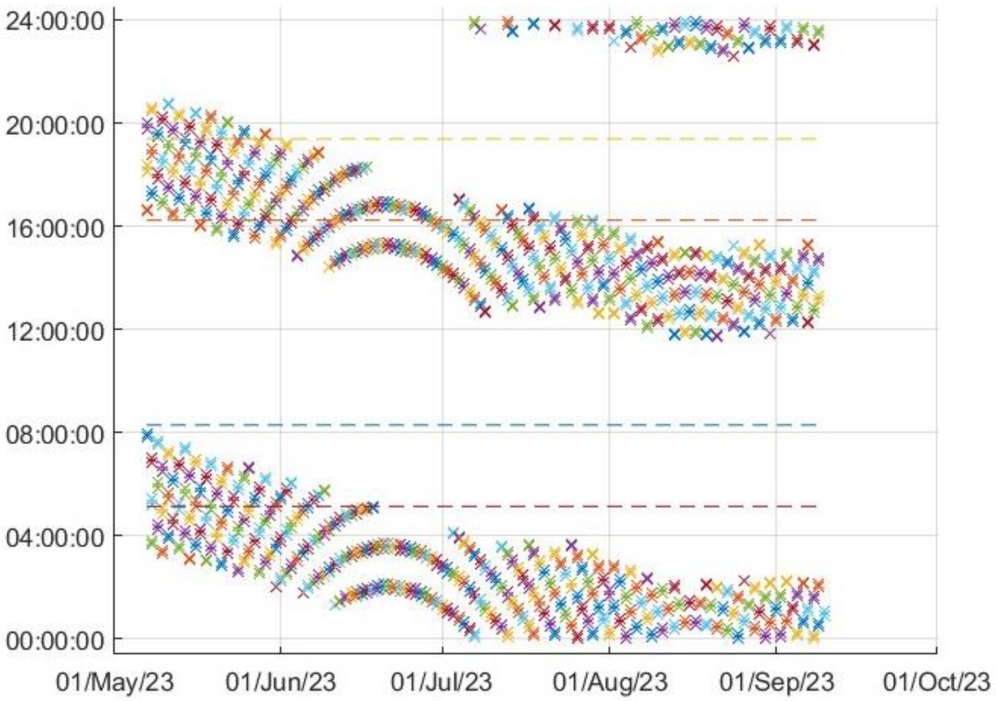
Decommissioning Report

End of Life Report

Operations Plan – G/S

Visibility times will drift as the SMA is lowered:

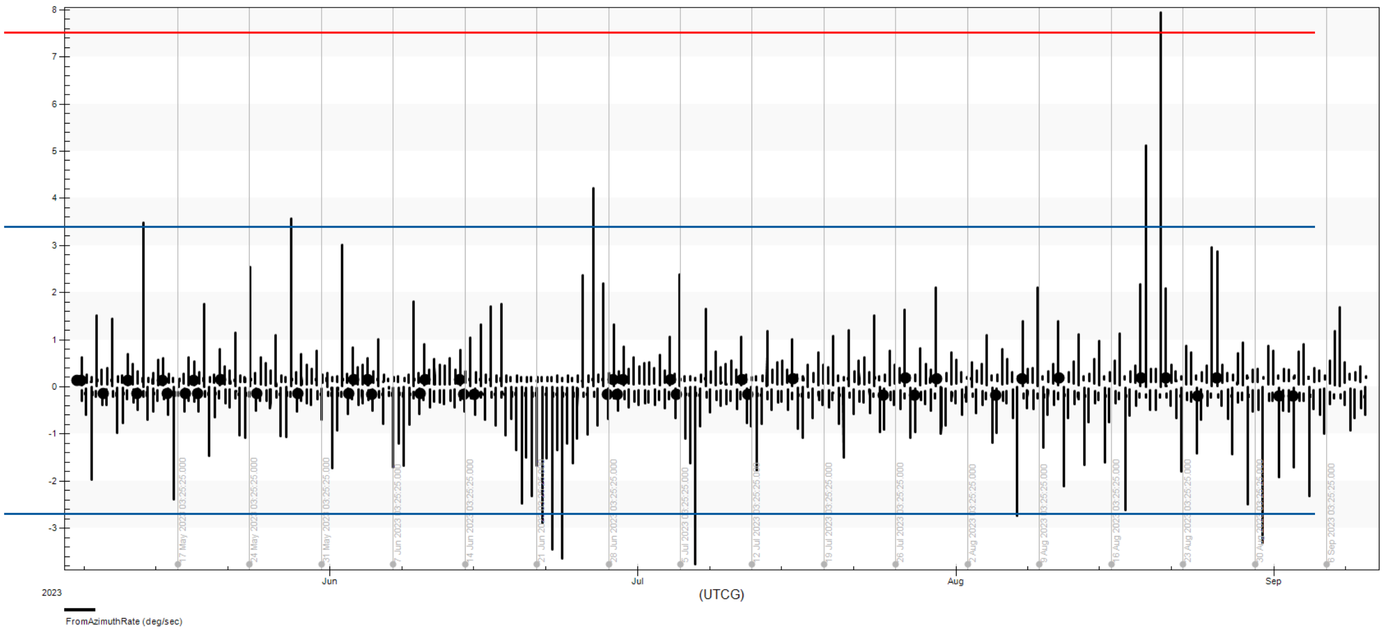
- Morning/Evening sessions will change into midnight/noon sessions
- Conflict with PAZ in TRN will disappear (dotted lines)



The reduction in path loss will increase the received power by 6dB in both directions.

- The G/S transmitted power can be decreased so no harm to the onboard Rx
- A 6dB increase will not saturate the G/S receiver

Operations Plan – G/S keyhole

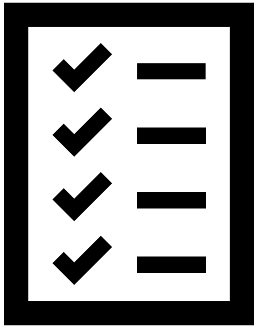


- TRN has a train axis, no keyhole in any case.
- VIL2 maximum Azimuth rate in low configuration is 7º/s, only 1 pass. The planned upgrade will allow 15º/s
- VIL1 maximum Azimuth rate is 3º/s, 11 passes affected

Operations Plan - SDO involvement

Development of a detailed plan with SDO:

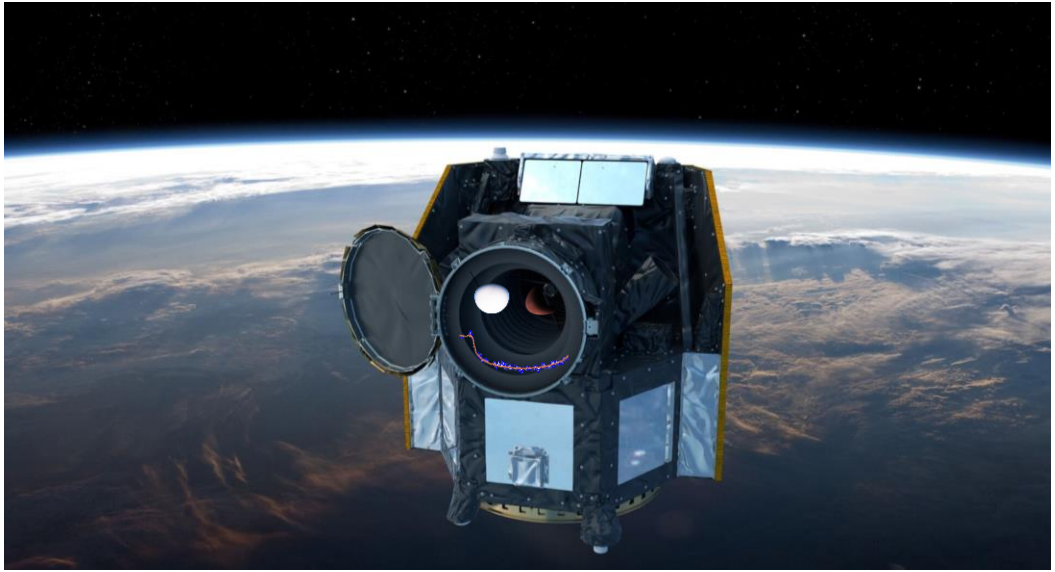
- Continuous provision of orbits with and without manoeuvres
- Restrictions: at least one day between manoeuvres and a maximum Delta-V for screening precision
- Potential interruptions by CAM leading to postponed disposal manoeuvre



Operations Plan – Final Passivation

Passivation details include:

- SW patch so safe mode points SA to anti-Sun → avoid battery charge and explosion
- Emptying of propellant and pressurant
- TRCV config so they are not switched on in case of an FDIR



Thank you for your attention.