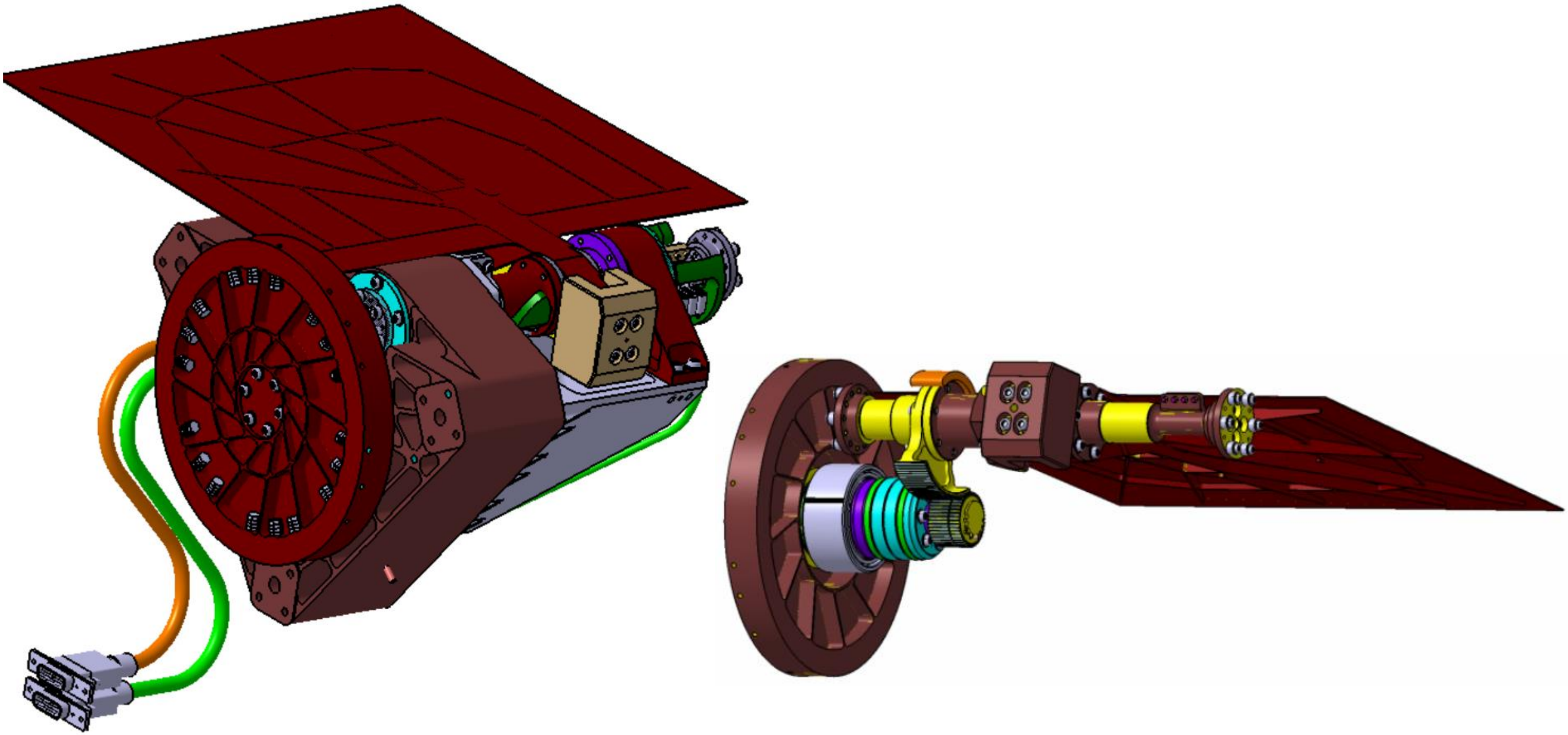
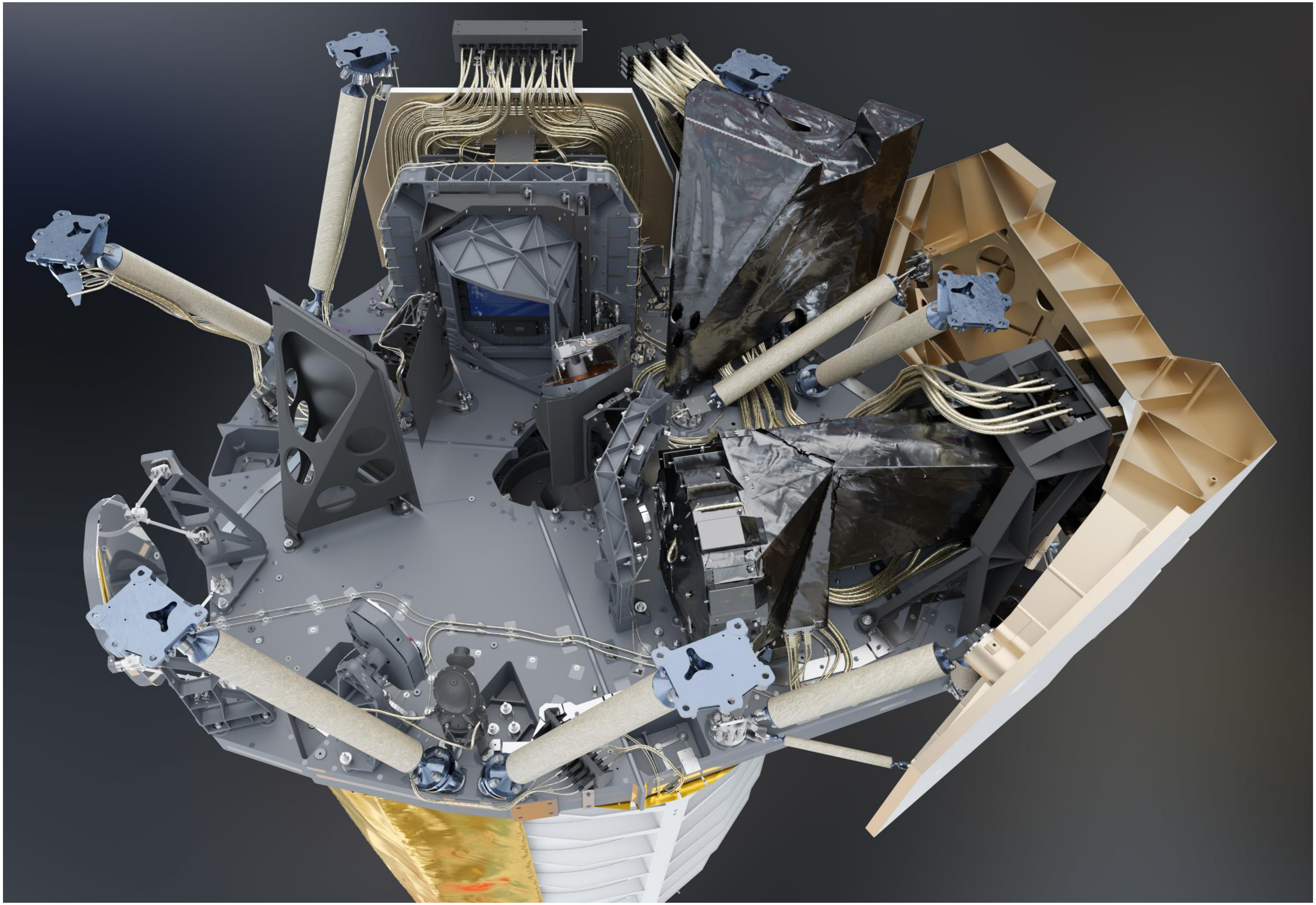


The EUCLID/VIS Read-out Shutter Unit (RSU)

E. Bozzo, L. Genolet, S. Paltani (Univ. of Geneva, Switzerland)

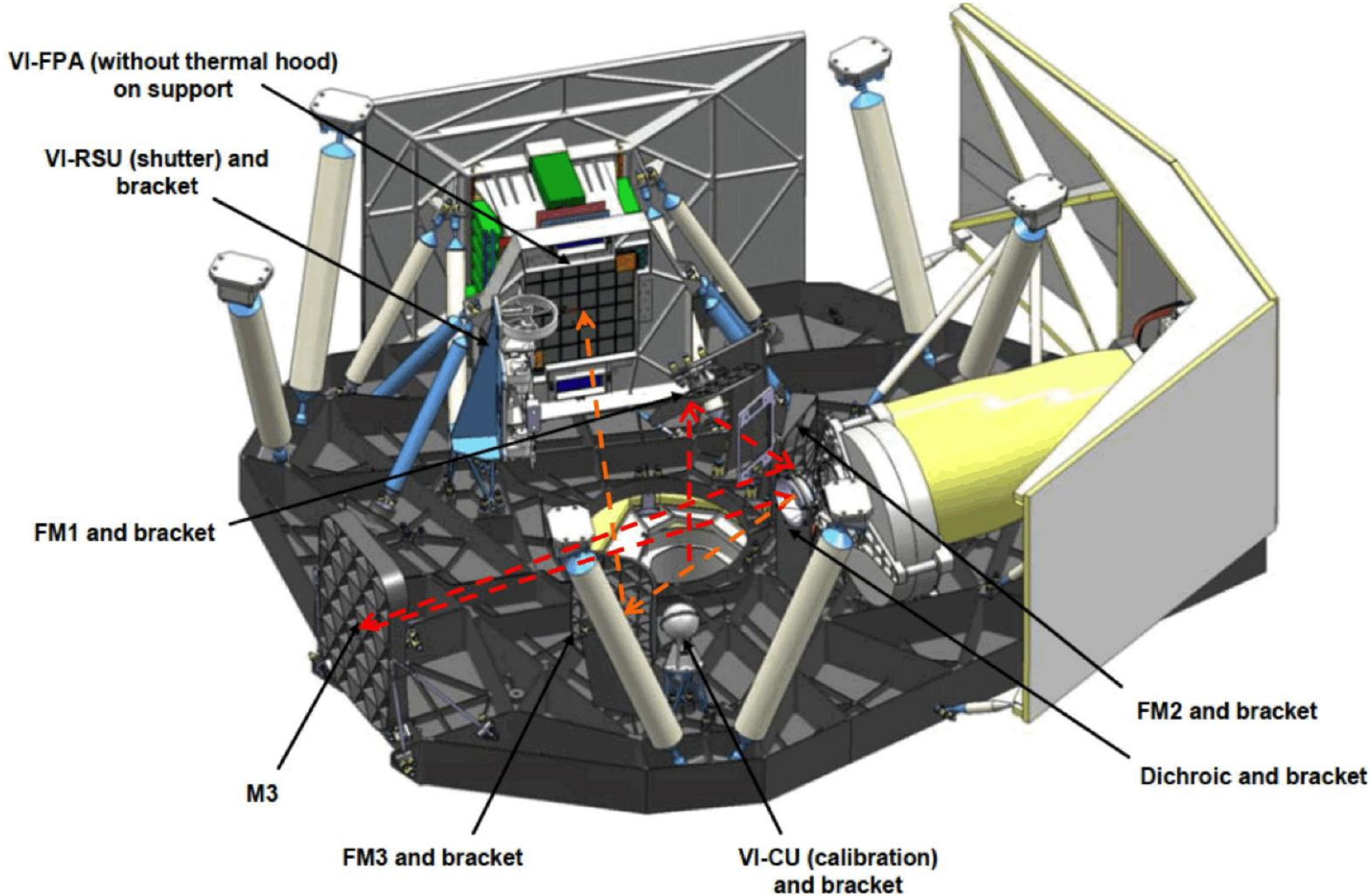
In collaboration with APCO Technologies (Switzerland)

The EUCLID/VIS RSU

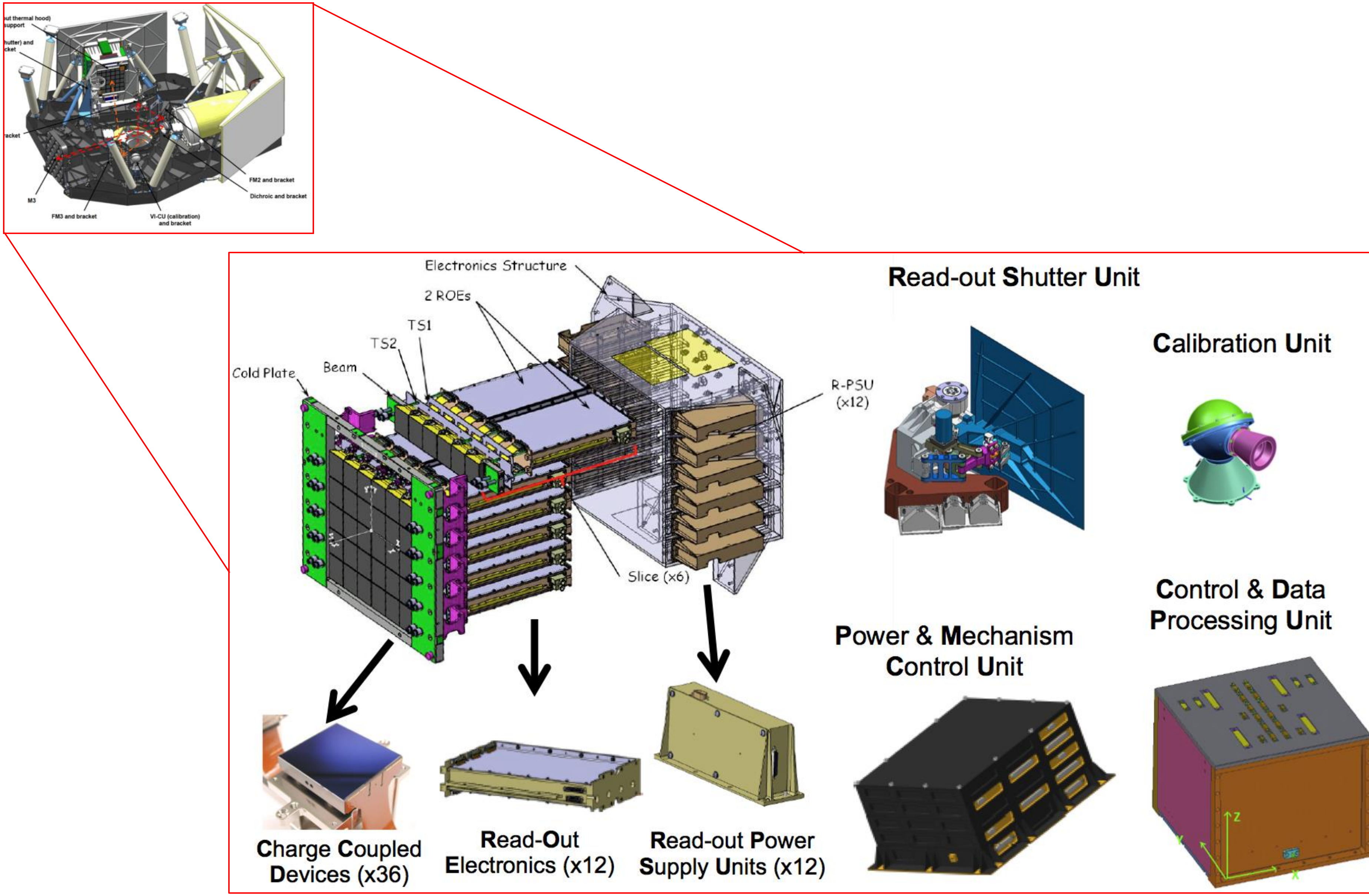


The EUCLID/VIS RSU

Euclid Consortium

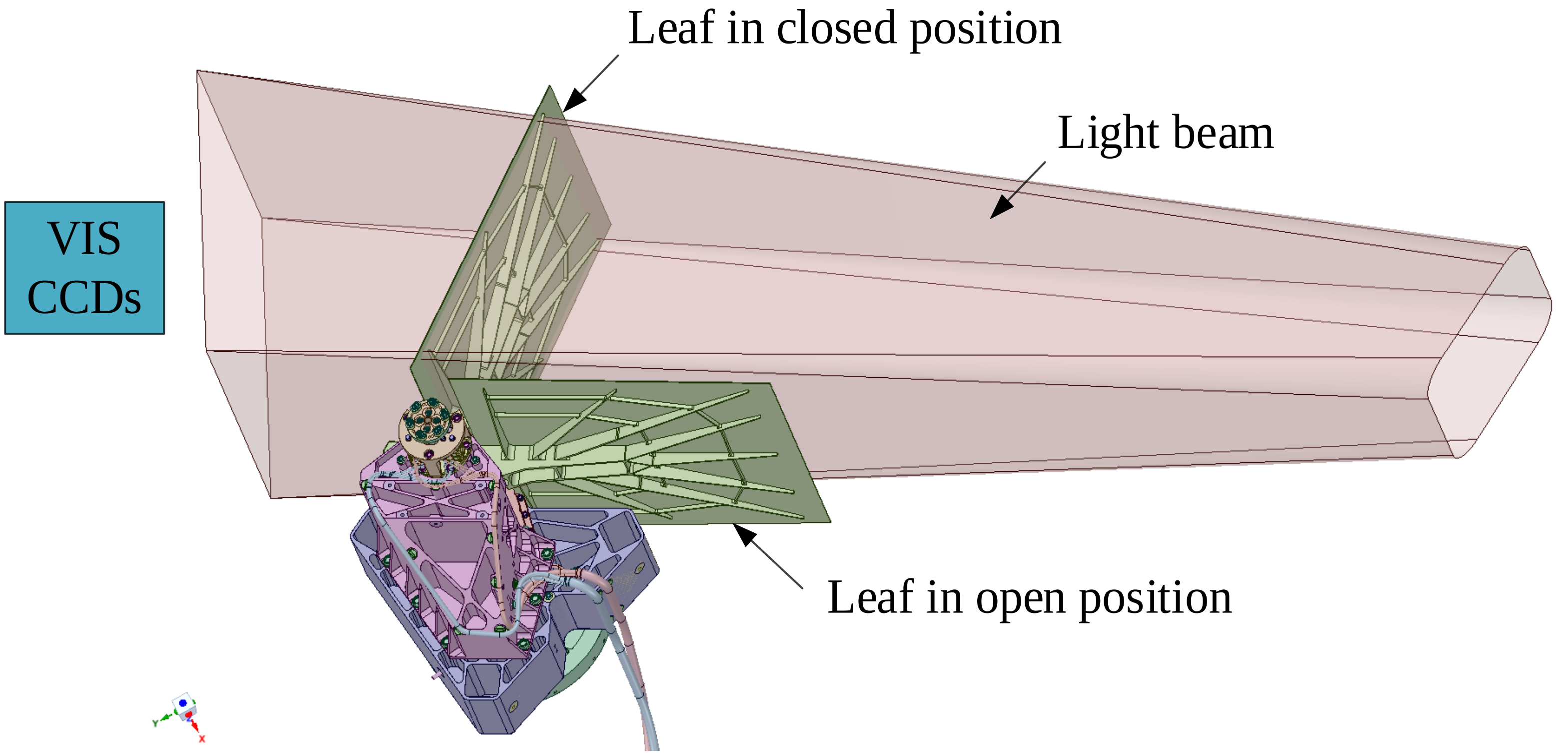


The EUCLID/VIS RSU



RSU Overall Design

- RSU prevents the science beam from the telescope to arrive onto the focal plane of the VIS instrument, while the latter is reading out the CCDs at the end of each scientific exposure
- RSU is equipped with a hatch, which occults the surface area of the focal plane, and a stepper motor, which is used to drive the rotation of the hatch



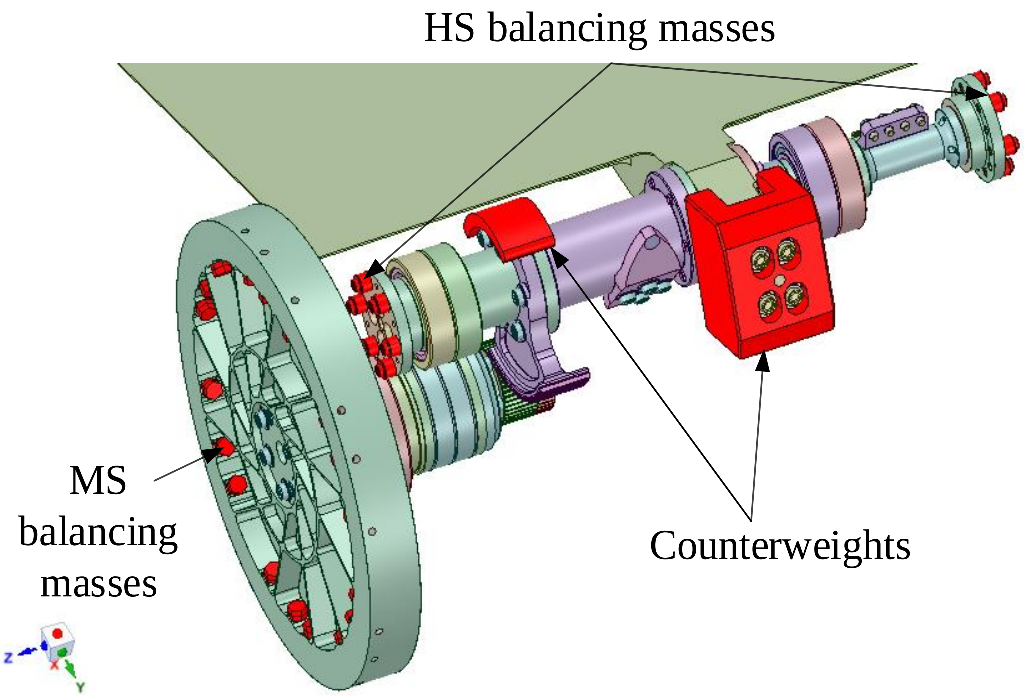
RSU Challenging Requirements

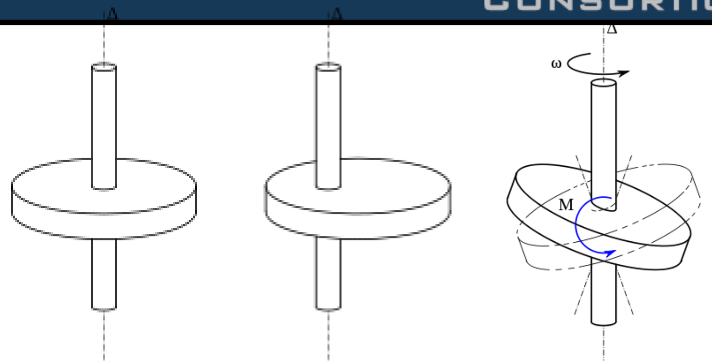
- High S/C stability needed to achieve the VIS instrument pointing accuracy

  - RSU operated during the scientific observations and its motion (~3 s) is too short to be actively compensated through the usage of the spacecraft attitude and orbit control system (AOCS, reaction time ~60s) → the design of the unit shall minimize the de-pointing of the satellite and the excitation of its critical vibration modes.

  - This is achieved mainly through the use of a flywheel and the accurate balancing of the different moving RSU sub-assemblies, adjusting their center of gravity and moment of inertia with an exquisite precision during the manufacturing process and the assembly.

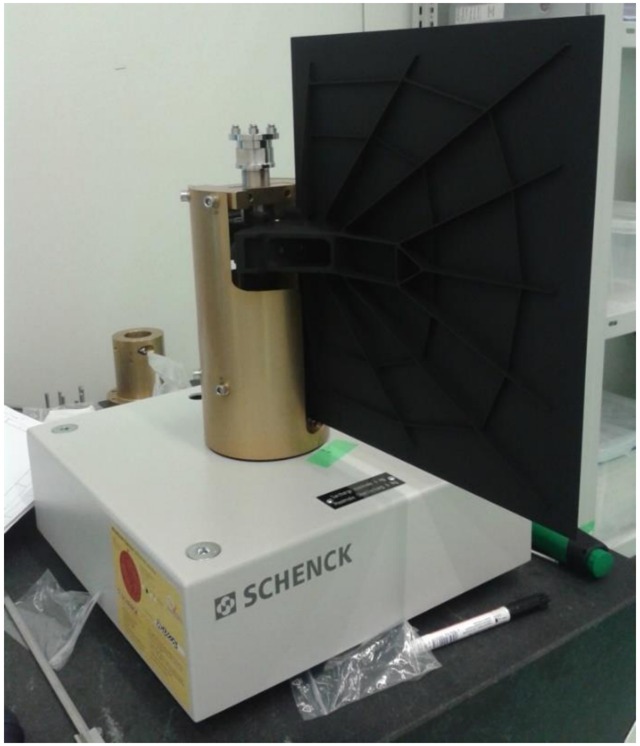
RSU Challenging Requirements





Static & dynamic unbalance

Machine procured by the project to achieve the 0.1% needed precision



RSU Challenging Requirements

- Life-time of the unit (operations foreseen for more than 6 years) and its operations in a strictly controlled environment

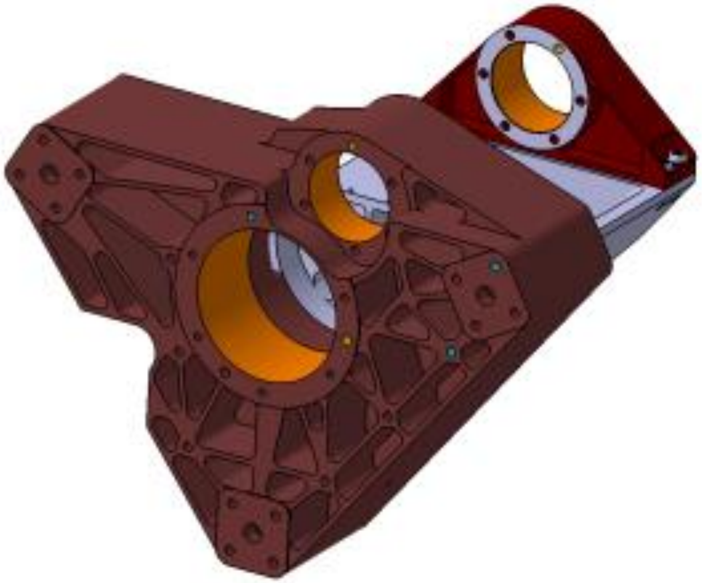
  - RSU will perform more than 350'000 opening and closing cycles at 110-160 K.
  - RSU operations at these cold temperatures are required due to the proximity of the shutter to the FPA
  - Proximity of critical optical surface → strict requirements on the cleanliness and stray-light level
  - The size of the leaf, as well as the overall RSU mass and volume, driven by the need to occult the light from the telescope (rectangular beam of 250x275 mm).
  - For tests and integration activities, the RSU is also requested to be fully functional at room temperature.

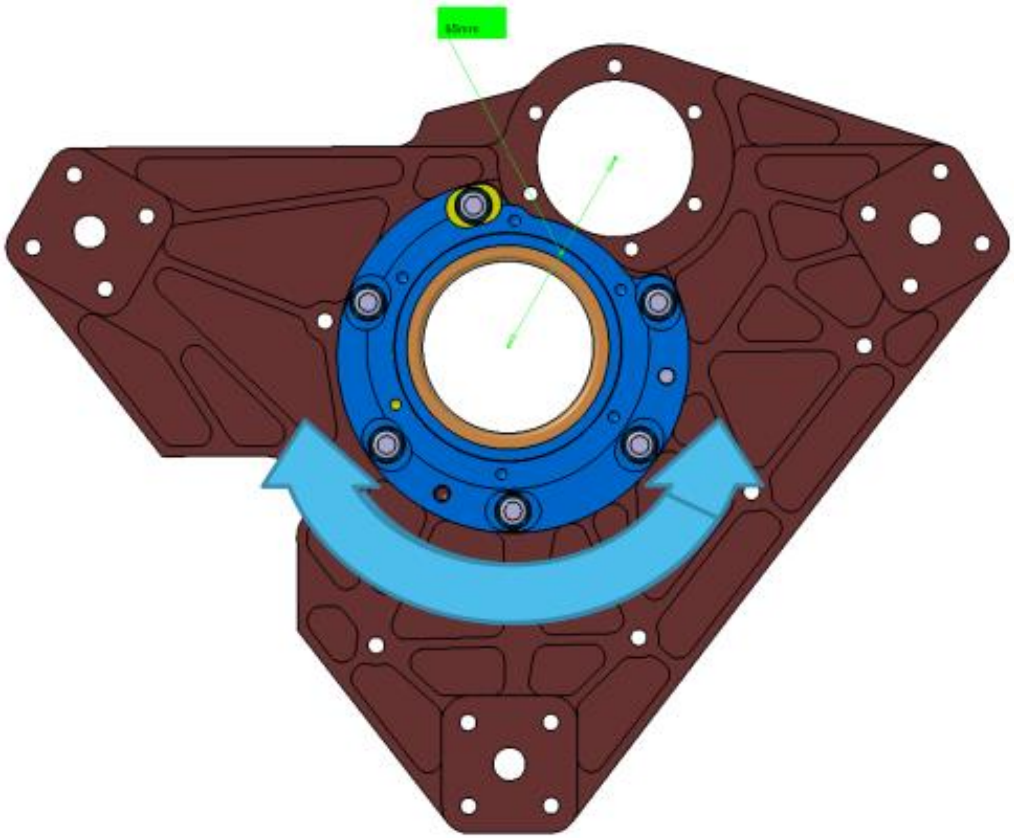
RSU sub-assemblies

1. A Support Structure composed of
   - A two-part Base Plate
   - Support brackets for the drivetrain, stepper motor (stator), etc…
2. A Flange supporting a group of End switches to detect open and closed position
3. A Drivetrain composed of
   - A Motor Drivetrain composed of
     - A flywheel
     - A stepper motor (rotor)
     - Ball bearings
     - The Gearhead and anti-backlash system
     - Support parts (shaft, etc…)
   - A Hatch Drivetrain composed of
     - A Gear
     - The Hatch
     - Ball bearings
     - A counterweight
     - A balancing system
     - Support parts (shaft, etc…)
     - Fasteners and other small hardware
4. A Harness connecting the electrical components to the commands at instrument level

RSU sub-assemblies

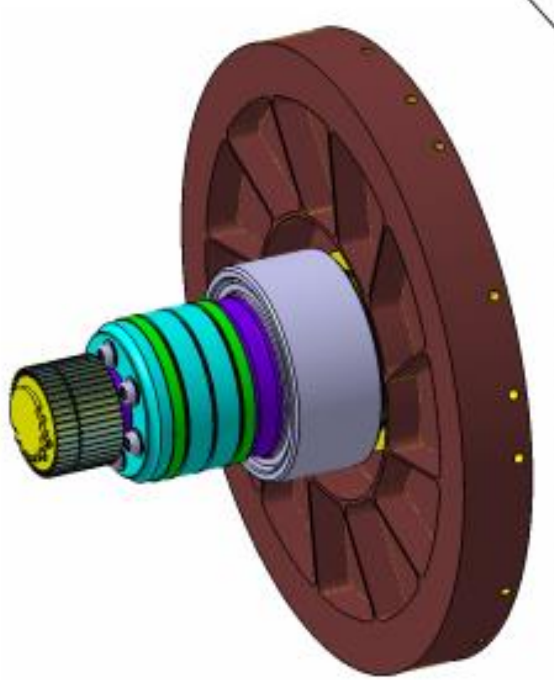
1. A Support Structure composed of
   - A two-part Base Plate
   - Support brackets for the drivetrain, stepper motor (stator), etc…

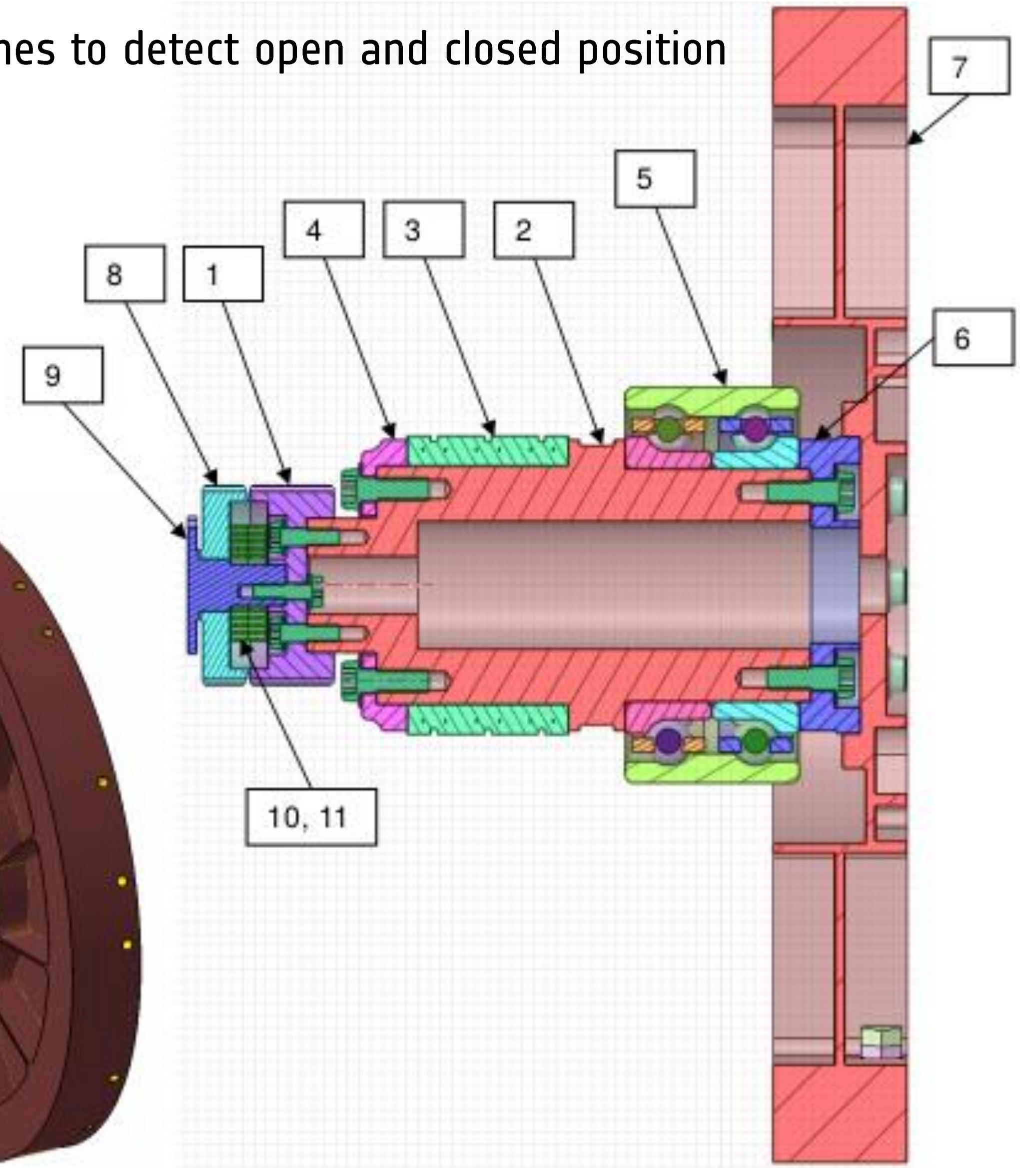




RSU sub-assemblies

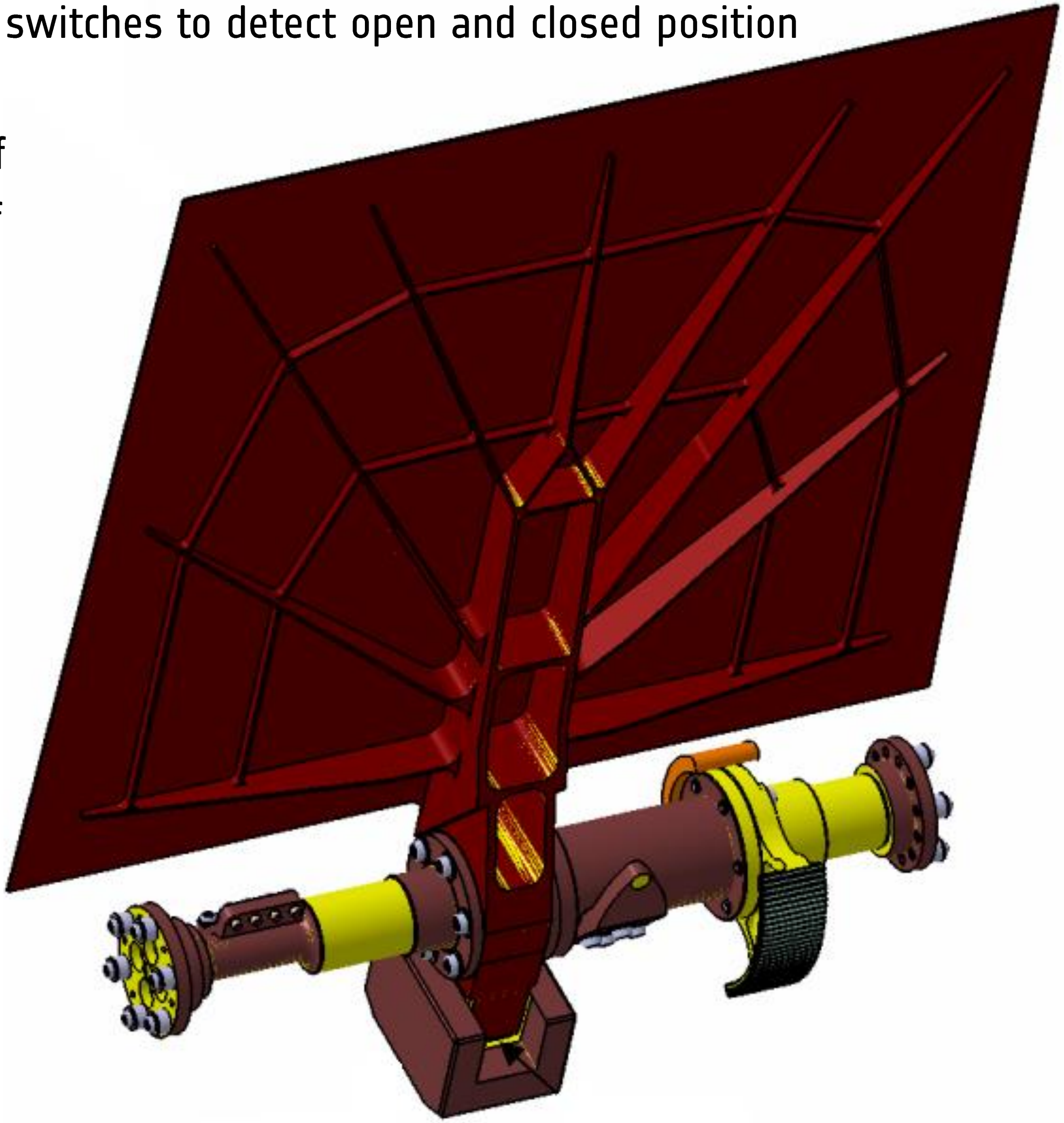
2. A Flange supporting a group of End switches to detect open and closed position
3. A Drivetrain composed of
   - A Motor Drivetrain composed of





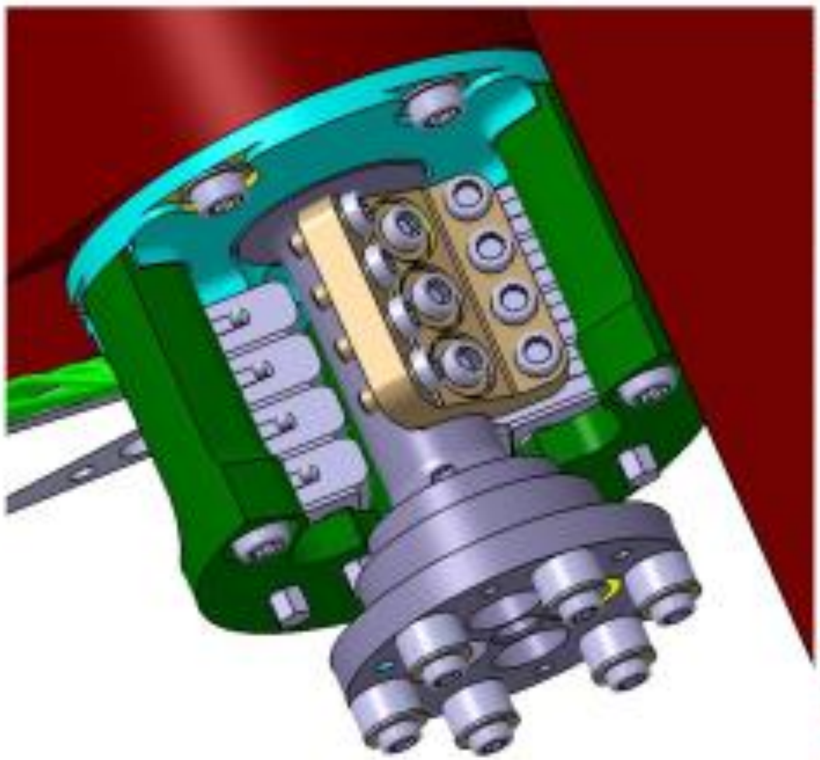
RSU sub-assemblies

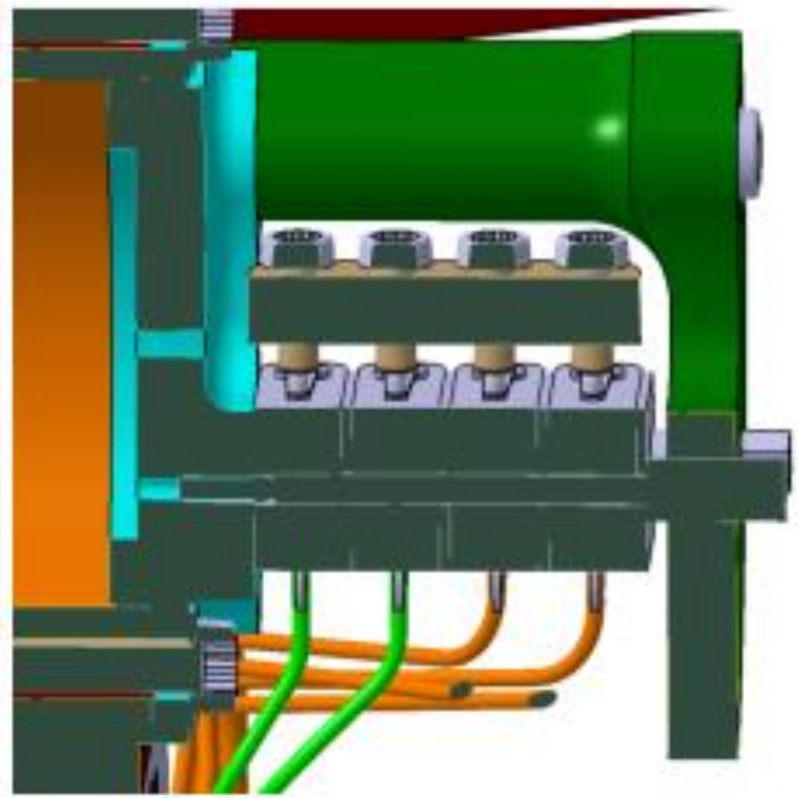
2. A Flange supporting a group of End switches to detect open and closed position
3. A Drivetrain composed of
   - A Motor Drivetrain composed of
   - A Hatch Drivetrain composed of



RSU sub-assemblies

2. A Flange supporting a group of End switches to detect open and closed position



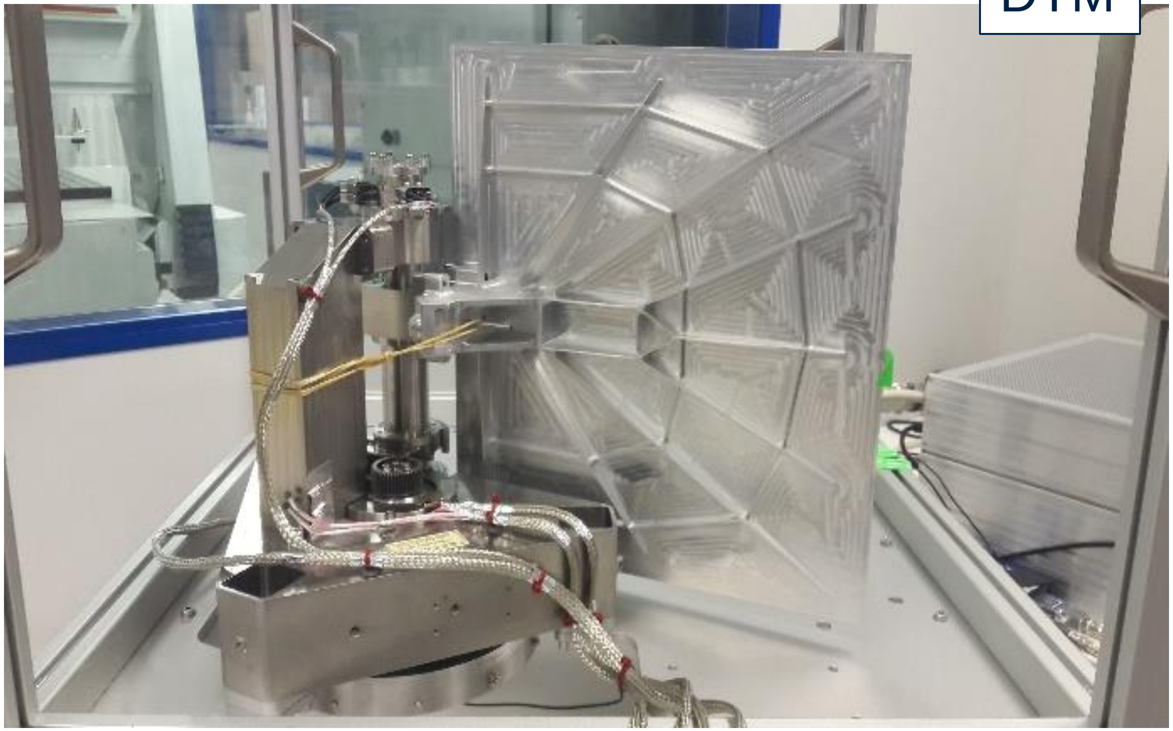


RSU Model Philosophy

The entire RSU development program foresees the production of four different models:

- the drive-train model (DTM)
- the structural and thermal model (STM)
- the electrical model (EM)
- the bread-board model (BM)
- the qualification model (QM)
- the flight model (FM)
- the flight spare (FS)

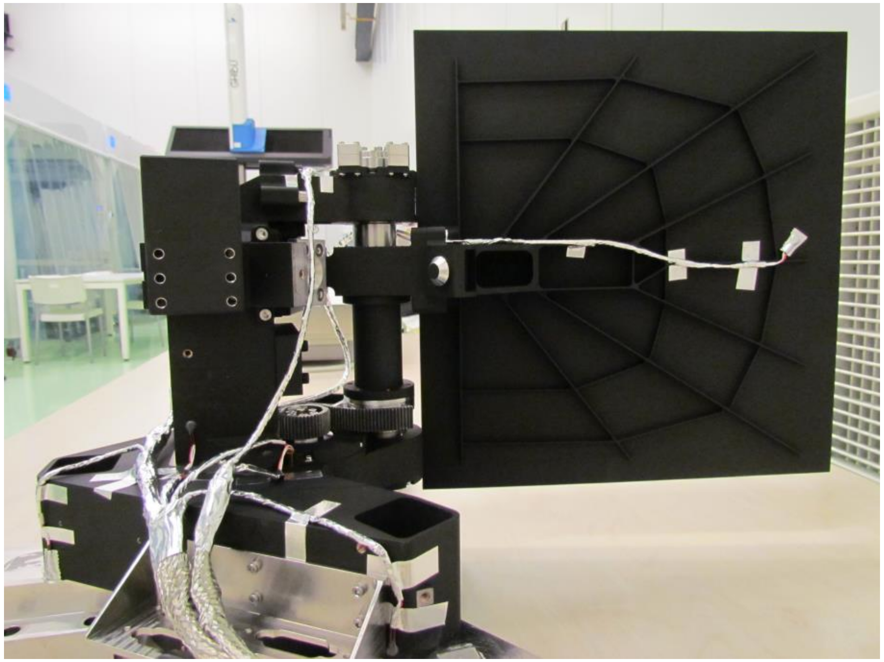
DTM

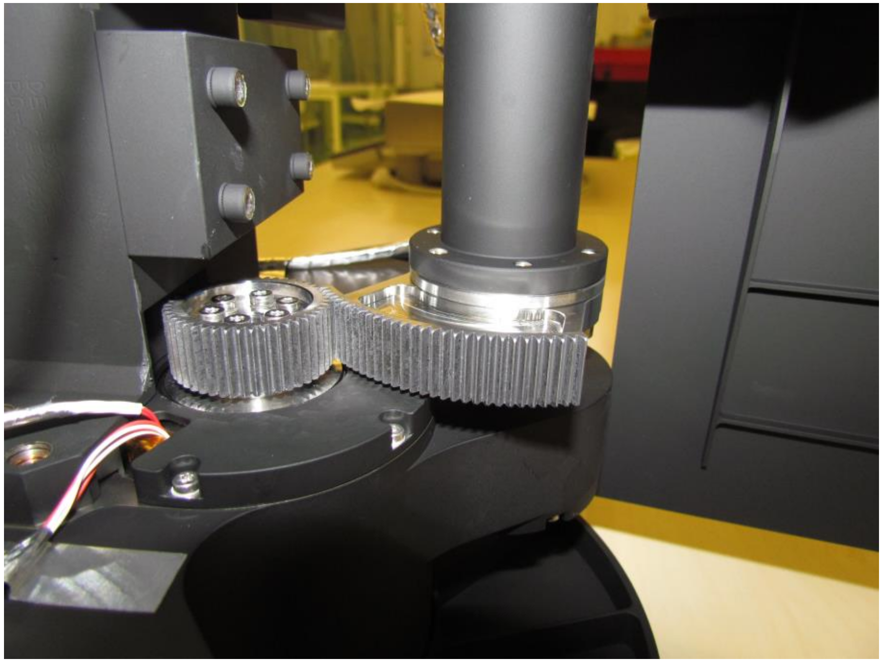


RSU STM

Simplified model designed to be representative of the FM predicted mass and moment of inertia and being used for structural and thermal tests:

- Non critical components replaced by mass dummies
- all other elements are fully representative of the foreseen FM design, including materials and surface thermal properties.

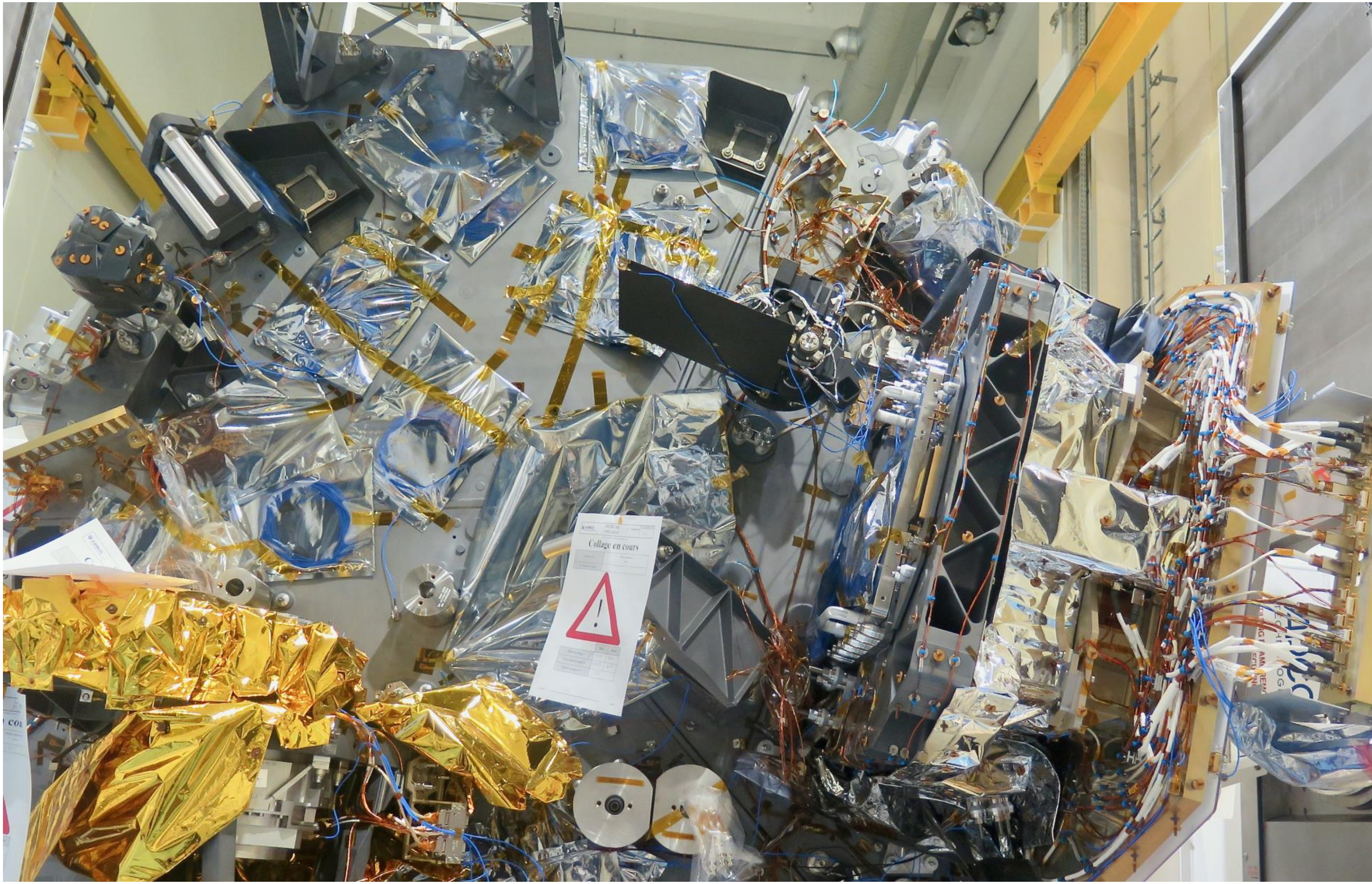




The STM passed the vibration and thermal tests in 2015. It is now assembled on the STM model of the Euclid spacecraft

RSU STM

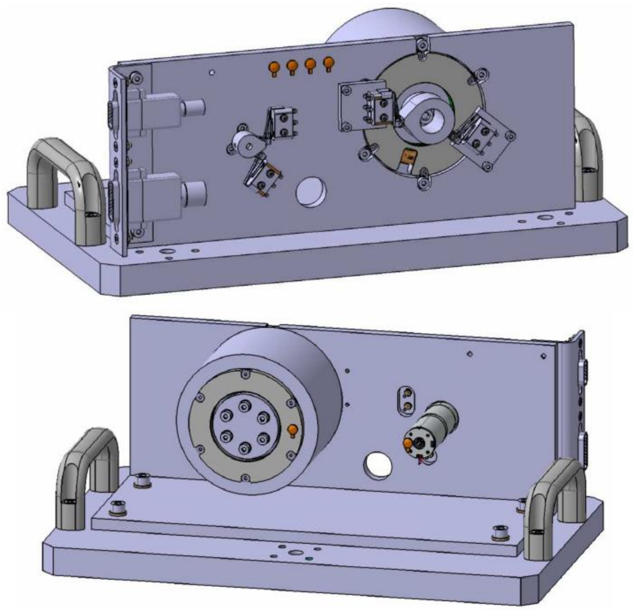
RSU STM

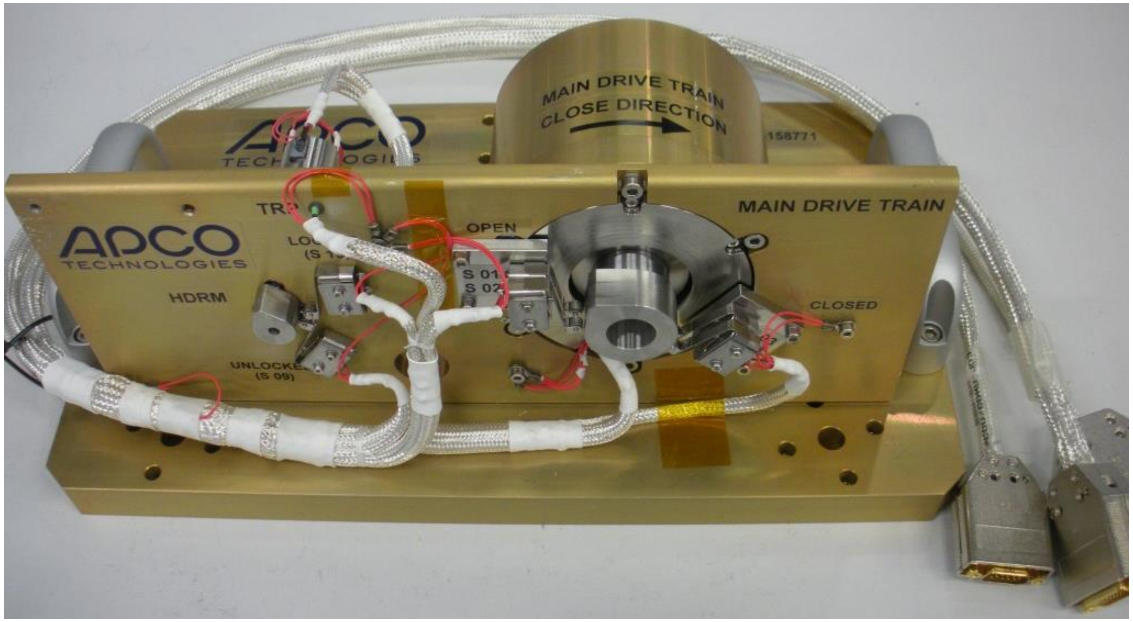


RSU EM

Designed to mainly validate all electrical functions and interfaces of the units, verifying its ESD robustness and EMC properties.

- all electronic components of the EM have been procured to comply with the established flights standard.
- the harness is representative of the FM design in terms of lengths, wire gauges, and shielding.



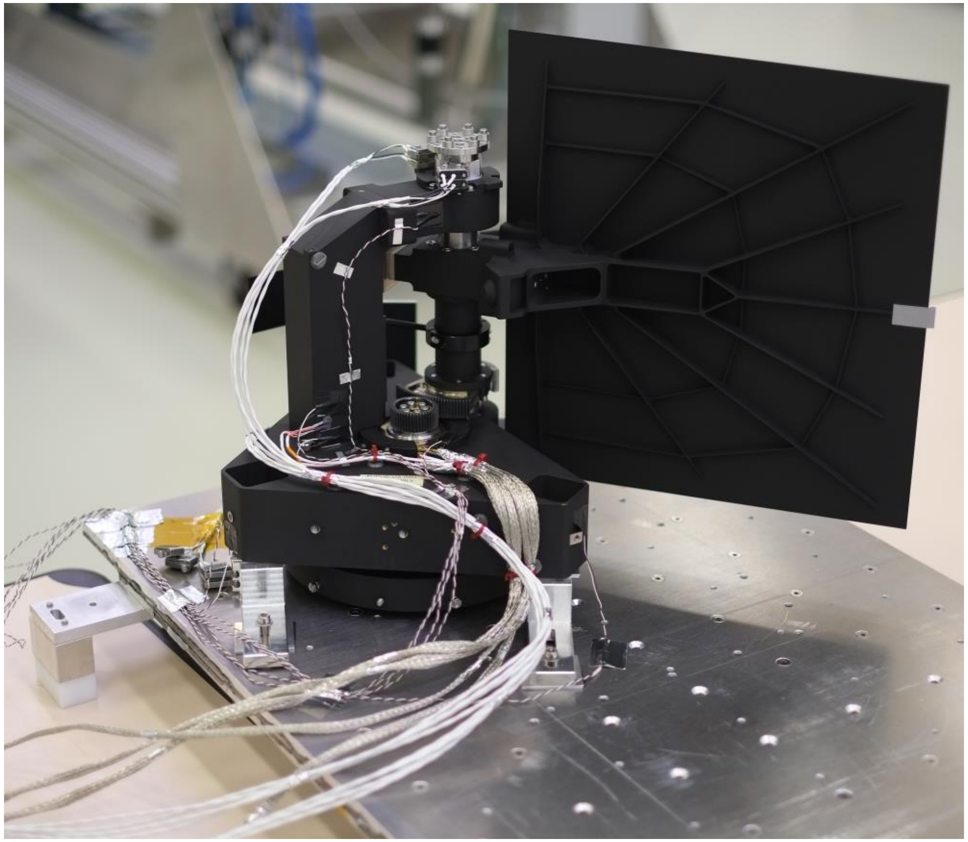


The foreseen ESD and EMC tests of the EM were successfully passed at the end of 2015. I/F test performed successfully with the PMCU. RSU EM delivered to MSSL in 2016.

RSU BM

RSU BM:

- includes all micro-disturbance sources identified by previous analyses
- LS and FwS fully representative of FM in terms of materials, geometry, lubrication, assembly, adjustment and balancing procedure
- first life-time test of the unit (July-Sept. 2016) & micro-vibration (Sept. 2016)
- Lifetime test repeated in 2017



The BM passed successfully all tests.

Manufacturing of the QM, FM, FS

RSU BM

RSU QM & FM

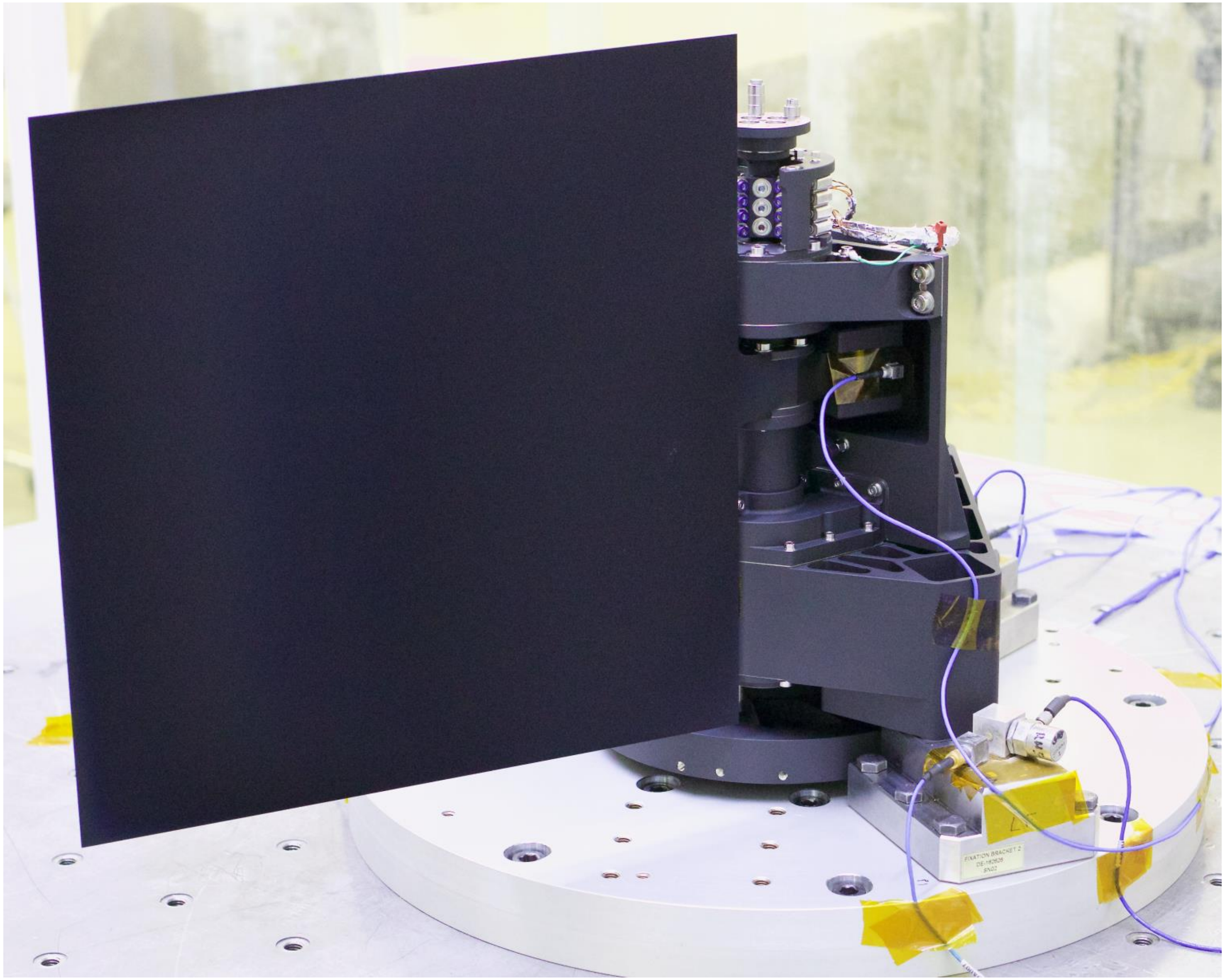
RSU QM:

- Full qualification of the unit (vibration, micro-vibration, lifetime test)
- End of test campaign in late 2019, partial failure of the lifetime test.
- Gears re-design and optimization on-going
- Another lifetime test planned for summer 2020 with the new gears

RSM FM:

- Acceptance campaign successful
- Currently at AIRBUS for assembly & tests at spacecraft level
- It will be dismounted in spring 2020 and refurbished with new gears

RSU QM & FM



The Acktar vacuum black coating

Acktar Advanced Coatings

Acktar Black™

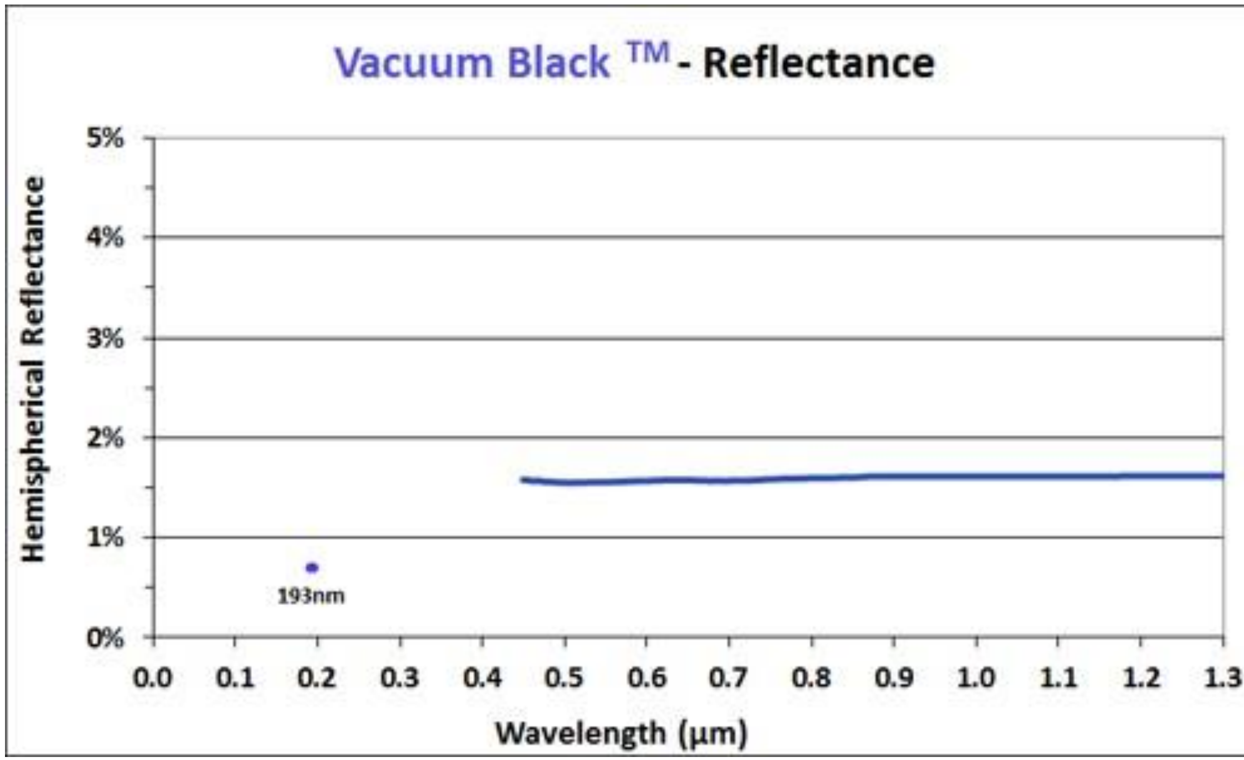
World's Blackest Coatings

By Industrial Vacuum Deposition Technology

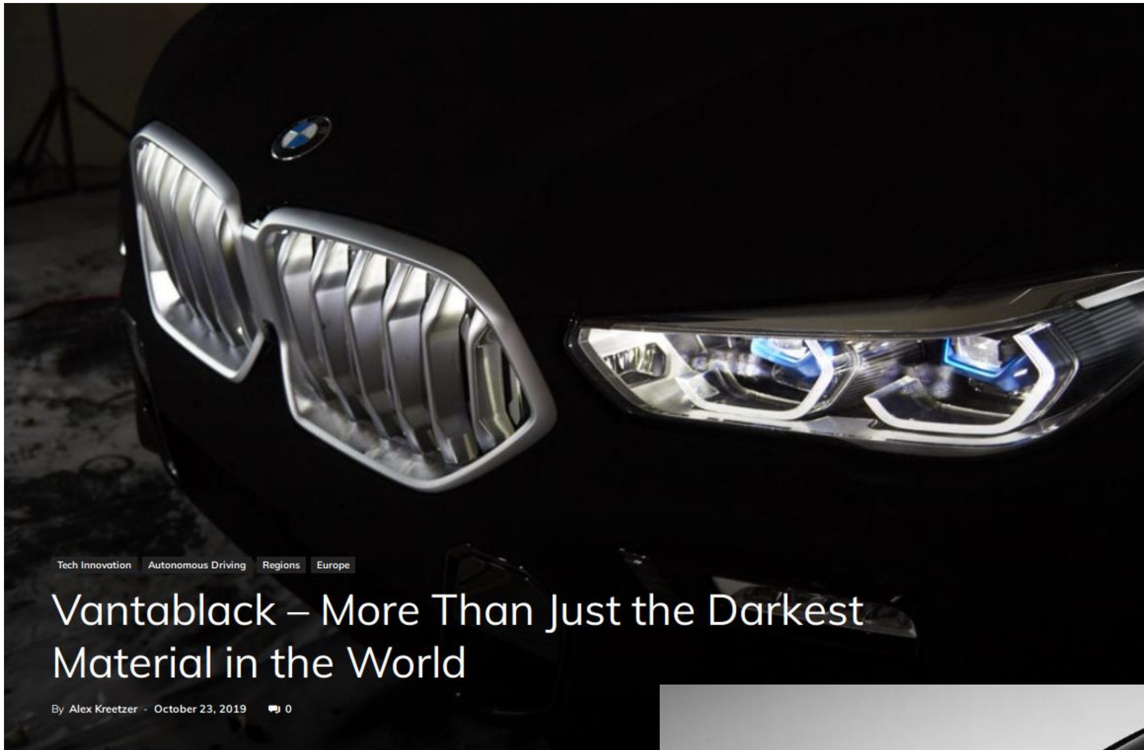
RSU leaf painted with Acktar coating to minimize reflections

Vacuum black qualification performed by UoG in collaboration with APCO and ESA

Thickened substrate necessary to avoid degradation due to the effect of humidity



The Acktar vacuum black coating



BMW VBX6
Surrey nanosystem (UK) vantablack

Absorbing 99.965% of visible light

Thank you!

Thank you!

RSU Challenges: depointing

- Motion of the LS generates an angular momentum → a de-pointing on the spacecraft compensated by the motion of the FwS in the opposite direction.

    - A gear ratio of 3 between the FwS and the LS is implemented to improve the achievable resolution in the position of the LS and decrease by a factor of 3 the inertia of the FwS with respect to that of the LS

- The residual de-pointing left after this corrective measure is mainly due to:

    - The inertia mismatch between the LS and the FwS → Schenck machine to measure moment of inertia down to an accuracy of 0.1% + adjustable counterweights and choice of materials to minimize the thermal expansions/contractions

    - The gear backlash: the FwS angular momentum generated in the initial stages of the RSU actuation not counter-balanced by the LS rotation until the pinion of the FwS gets in contact with the LS gear → limit as much as possible the spur gear backlash and shorten the initial uncompensated motion of the FwS

    - Static imbalance due to the offset of the center of gravity (CoG) of the different RSU parts with respect to the main rotation axis → iterative sequence of measurements and re-machining before assembly

RSU Challenges: μ-vibrations

As the leaf occulting the science beam is relatively large, a significant number of structural modes can be excited starting from 130 Hz (first mode of the RSU @134 Hz) mainly due to the RSU stepper motor and generate additional angular momenta:

- operated in micro-stepping mode and it is designed with a large inductance, reducing the maximum speed achievable by the motor but also smoothing the profile of the currents passing through its windings.

- We are also studying different options for the motor actuation profile and duration (between 8 and 15 s) in order to further minimize the generation of any additional micro-vibrations.