The Janus COM mechanism onboard the JUICE probe to the Jovian system

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Abstract. After the successful launch of the JUICE (JUpiter ICy moons Explorer) on the 14th of April 2023 all the on board subsystems and instrument are testing their functionalities. The JANUS (Jovis, Amorum ac Natorum Undique. Scrutator) telescope is the imaging system on board the spacecraft and is an optical camera devoted to the study of global, regional and local morphology and processes on the Jovian moons, and to perform mapping of the clouds on Jupiter. Following the heritage of the successful design of the OSIRIS WAC camera, on board the Rosetta mission, the group of researchers at CISAS "Giuseppe Colombo"- Università degli studi di Padova, led by prof. S. Debei, in collaboration with colleagues of the Leonardo spa Company developed the mechanism responsible for the protection of the telescope during cruise phase. The COver Mechanism (COM) provides the external closure of the JANUS Optical Head Unit (OHU). It shields the optical parts from contamination, it is light and dust tight and works in the plane of the telescope entrance window avoiding the exposure of the inner surface of the cover itself and the core part of the telescope to the external dust and pollution. The lower part of the cover provides, also, a reference surface for the in-flight calibration of the telescopes. The main functional and environmental requirements of this mechanism can be identified and summarized as follows: the door provides optics and detector protection from sunlight and contamination; the subsystem, located at the main entrance of the JANUS OHU outer Baffle, provides the function of opening and closing of the cover. The opened Cover allows the JANUS OHU and detector to face the outer environment to perform planetary observations during science mission phases and to perform in-flight calibration observation of different targets (e.g., moons, stellar fields). This paper presents the design, the mechanical solutions adopted for a reliable system and the results of the test performed on ground in order to qualify the JANUS COM mechanism before flight.

Introduction

The astonishing JUICE mission, launched early this year, will perform a very detailed exploration of the ocean layers and analysis of subsurface water reservoirs; it will study the Ganymede's intrinsic magnetic field, its topographical, geological and compositional maps. The JUICE mission was designed to investigate the physical properties of the icy crusts and of the internal mass distribution of jovian moons [1]. It will arrive at Jupiter in January 2031 after 7.6-years using an Earth–Venus–Earth–Earth gravity assist sequence.

Among the JUICE payload, JANUS (Jovis Amorum ac Natorum Undique Scrutator) is the narrow-angle camera selected as the visible (from near UV to NIR) imager onboard JUICE. An overview of the scientific goals of JANUS, together with measurements needed to fulfil the specific goal, is given in the following. The detailed investigation of the Galilean icy satellites, which are believed to harbor subsurface water oceans, is central to elucidating the conditions for habitability of icy worlds. Visible wavelength imaging is needed to determine the formation and characteristics of magmatic, tectonic, and impact features, relate them to surface forming processes, constrain global and regional surface ages, and investigate the processes of erosion and deposition [2]. The JANUS instrument is composed by the following functional (and physically independent) subsystems:

- Optical Head Unit (OHU), mounted on the S/C Optical Bench
- Proximity Electronics Unit (PEU), located close to OHU on S/C Optical Bench
- Main Electronics Unit (MEU), located in the S/C vault
- Interconnecting harness

The COver Mechanism (COM) provides the external closure of the JANUS Optical Head Unit (OHU). It protects the optical parts from contamination; it is dust tight and works in the plane of the entrance window avoiding the exposure of the inner surface of the cover itself and the core part of the telescope to the external dust and pollution. The lower part of the cover provides, also, a reference surface for the in-flight calibration of the telescopes.

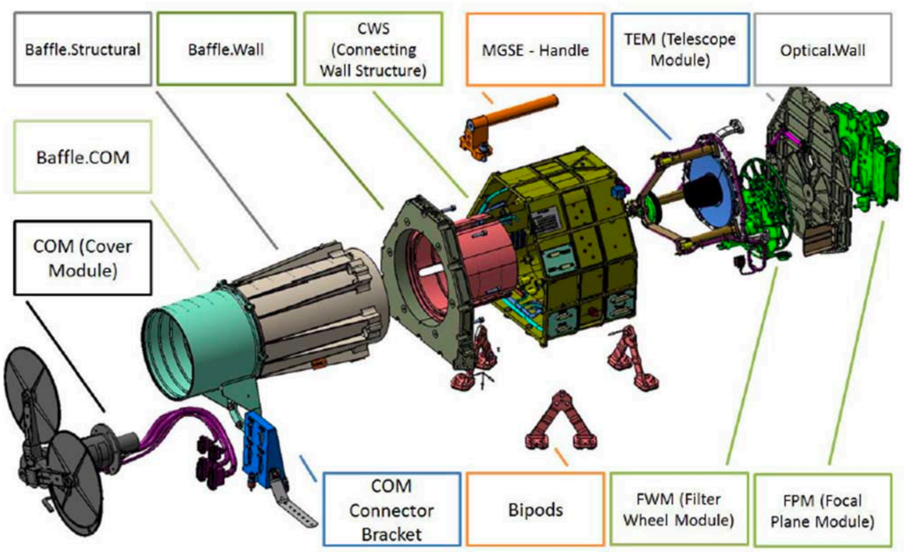

Fig. 1. OHU unit layout overview; on the left side of image the JANUS COM subsystem [1].

COM Subsystem Requirements and Baseline Design

The main functional and environmental requirements of this mechanism can be identified and summarized as follows:

- the cover provides optics and detector protection from sunlight and contamination;
- the subsystem, located at the main entrance of the JANUS OHU outer Baffle, provides the function of opening and closing the door;
- the subsystem mechanism implements the following needed functionalities in each flight condition:
  - Closed - Locked position: to protect of the optical elements and detector from contamination by the inner part of the door during launch (pre-loaded);
  - Closed - not Locked (Cruise) position: to protect the optical elements and detector from contamination during the cruise phase and to prevent long-term sticking of the COM door and the OHU Baffle I/F;

  - Open - Locked position: to allow the JANUS OHU and detector to face the outer environment to perform planetary observations during science mission phases and to perform in-flight calibration observation of different targets (e.g., moons, stellar fields).
- single-point failure tolerance requires redundancy and the ability to open the door permanently in the case if an irreversible system failure occurs (fail-safe device);
- requirement to validate open and closed positions;
- dynamic load during launch;
- non-operational temperature range (−40 to +35 °C) implies a design for high differential thermal loads within the mechanisms.

COM Subsystem

The COM subsystem is mainly composed by the following parts, which can be seen in Figure 2:

- the stepper motor (MT) for controlling the position of the cover;
- the interface flange (FL) for fixing the mechanism to the baffle of the telescope;
- the main body (BD) were the mechanical parts for allowing the movements are present;
- the main shaft (MS) governing the vertical movement;
- the bracket (BR) holding the cover shield;

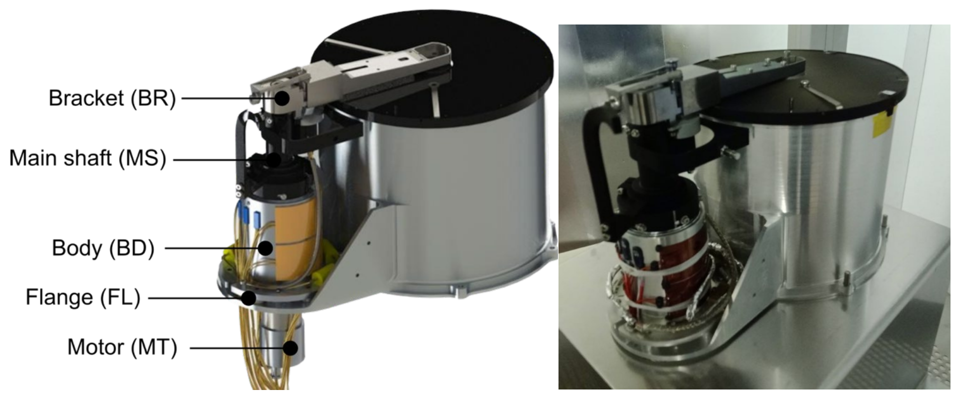

Figure 2: COM subsystem together with its components; left image: rendering; right image: flight model.

Mechanism Functional Test and Calibration

To demonstrate that mechanism functionality in the presence of environmental loads a life test has been executed during the thermal cycles. Due to waiting time between each activation, all the activations have been divided in 3 slots. The activations have been distributed along each cycle at different temperatures. The total activations are 5520 cycles divided as shown in Table 1.
The mechanism open and closed position has been calibrated with repeatability tests. Figure 3 shows repeatability test performed on EQM, data collected on 15 runs, both resistant torque and the switch status are reported, and highlights the repeatability of the mechanism performances.

Table 1 COM lifetime test activations

Phase	P [Pa]	T [°C]	Cycles
1	amb	amb	500
2	5e-3	Ambo	500
3	5e-3	-45…-20	2880
4	5e-3	-20…+10	720
5	5e-3	+10…+35	920

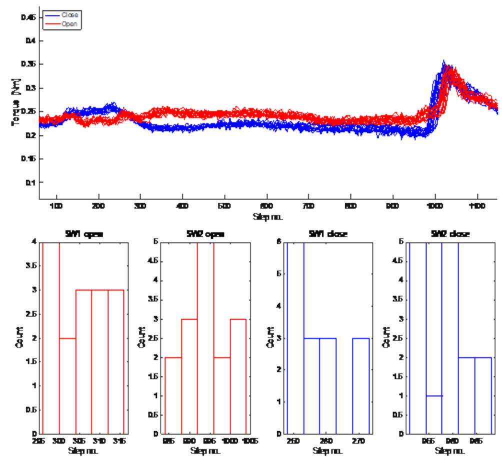

Figure 3: Repeatability test performed on EQM, data collected on 15 runs, both resistant torque and the switch status are reported, and highlights the repeatability of the mechanism performances.

Thermal Monitoring

COM temperature is measured by five Pt1000 thermistors, three are located on the external surface of the COM close to the heaters (see Figure 4), other two are mounted on the motor chassis.

COM temperature is controlled by means of two heaters (2 nominal and 2 redundant) located on the COM external surface. The survival thermal control subsystem is composed by the three Pt1000 plus two magnetically self-compensating heaters on the COM mantle.

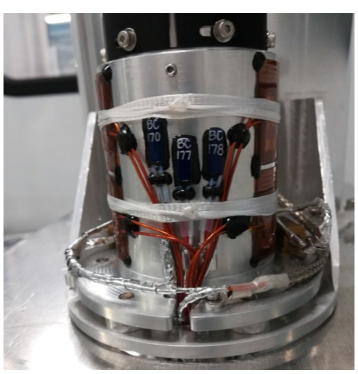

Figure 4: Monitoring PT1000: located in COM main body near the thermal regulation heater.

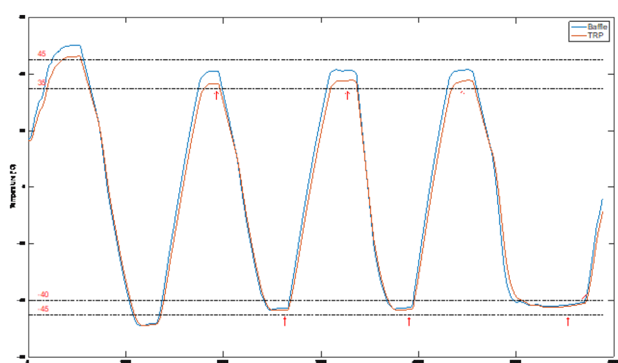

Figure 5: Thermal cycles (-45°C…+45°C); red arrows show the activation events; red cross shows the SMA activation event d highlights the repeatability of the mechanism performances.

Conclusion

The JANUS COM Team members are very grateful to prof. Stefano Debei for his inspiring scientific activity and for all the precious suggestions he gave us for the design, development and testing of the last space exploration equipment he lead at the CISAS "Giuseppe Colombo" space center of the University of Padova and for his valuable ideas collaborating with the members of Leonardo SPA- Florence company.

References

[1] Grasset, Olivier, et al. "JUpiter ICy moons Explorer (JUICE): An ESA mission to orbit Ganymede and to characterise the Jupiter system." Planetary and Space Science 78 (2013): 1-21. https://doi.org/10.1016/j.pss.2012.12.002

[2] Della Corte, Vincenzo, et al. "Scientific objectives of JANUS Instrument onboard JUICE mission and key technical solutions for its Optical Head." 2019 IEEE 5th International workshop on metrology for aerospace (MetroAeroSpace). IEEE, 2019. https://doi.org/10.1109/MetroAeroSpace.2019.8869584