Front cover for space optical telescopes. a legacy from ROSETTA to JUICE

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Abstract. The reliability of a telescope's front cover for a space mission constitutes its primary demand, not to compromise the functionality of the entire instrument. Avoidance to expose possible reference surfaces to the external environment and contamination often drives the selection of the motion of the cover. The Front Door Mechanism (FDM) for the OSIRIS experiment of the ROSETTA mission has been developed and optimised to provide protection of the telescope, reliable functioning and being single point failure tolerant. Its combined translational and rotational motion allowed also the preservation of internal calibration surface for the entire duration of the mission. The ROSETTA mission was launched in 2004 and reached the comet in 2014 after several gravity assists, and deep space hibernation. It has been orbiting around the comet for roughly two years collecting enormous amount of data of the peculiar celestial body and ended in September 2016. As legacy of the successful design of the front cover for the ROSETTA mission, another cover mechanics (Cover Mechanism – COM) for the JANUS Optical Head Unit of the JUICE mission has been prepared with minor modifications to the initial design. All qualification has been performed and the JUICE mission has been launched successfully on 14 April 2023 and is now travelling towards Jupiter and its moons.

Introduction

Observation and collection of scientific data by means of telescopes is a very widely used approach for instrumentation for space missions. Such instruments allow coverage of very wide spectral ranges, with applications ranging from infrared to X-ray bands and with various techniques from imaging to spectroscopy.

To provide the quality needed to achieve the increasingly demanding scientific objectives, the instruments have to be protected from external contamination that would dramatically degrade the performance. Protection must take place both before and during the mission lifetime, especially with the increase of duration of planned space missions. Cleanliness measures are put in place during the entire assembly phases at different levels, from unit, to instrument, to satellite and also, after integration into the launcher, including purging, where needed.

After the fairing separation, still at low altitudes, the possible contamination comes from residual air density and from auto contamination from satellite outgassing. Finally, for missions with celestial bodies or planetary observation, the presence of an atmosphere or of emissions from the surface can constitute an important source of contamination.

Contamination protection of observation instruments such as telescopes can be increased by the usage of cover systems that close the telescope's baffle opening, thus avoiding direct exposure of the inner parts of the instrument.

By their own nature, covers constitute also one of the highest risks for the instrument itself. A failure of actuation of the cover would in fact result in the entire loss of the instrument.

Reliability of such systems plays therefore the main focus in their design and development, and redundant solutions to make them failure tolerant is one of the prime objectives of a proper cover design approach.

Several papers have been published describing the design and test results of the Front Door Mechanism (FDM) of the OSIRIS instrument [2, 3]. This paper deals mainly with the main concepts and the relevant aspects that enhanced the proven robustness and flexibility of the FDM and the heritage of its design for the JANUS instrument of the JUICE mission, The two missions are significantly different, but with similar telescope's protection needs.

FDM design

OSIRIS (Optical, Spectroscopic and Infrared Remote Imaging System) is one of the instruments of the ROSETTA mission, an ESA cornerstone science spacecraft launched in 2004 to study in close proximity a comet.

The OSIRIS instrument is composed by two telescopes, the Wide Angle Camera (WAC) and the Narrow Angle Camera (NAC) providing wide and detailed optical imaging of the comet. Some subsystems of both telescopes are identical, such as the Front Door Mechanism (FDM), the Shutter Mechanisms (SHM), the Shutter Electronics (SHE), the Filter Wheel Mechanism (FWM) [1].

Among the peculiarities of the ROSETTA mission, for the instruments protection concept, the long journey in hibernation to reach the comet and the long observation period around the comet during its rising activity while approaching the Sun are the two main drivers of the conceptual selection for the protection cover system for both telescopes. Rather than a significantly simpler one-off opening system, a fully reversible mechanism approach has been chosen to allow the repeated closure and protection of the telescope in case of adverse conditions.

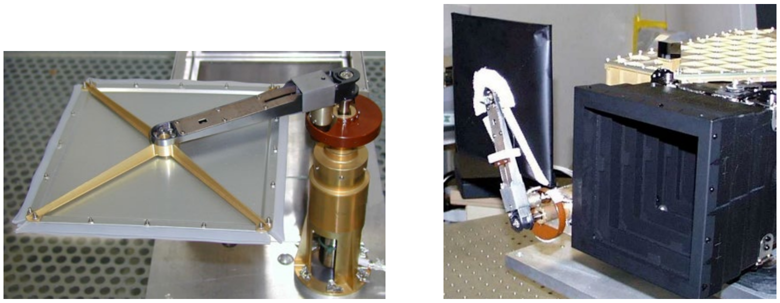

Figure 1: Front Door Mechanism Flight Model in open position during characterisation (left) and mounted on the Flight Model WAC telescope (right)

The possibility to select a variable lift of the cover from the baffle, appeared quickly as a significant advantage allowing the selection of tightness of the closure and avoiding any possible adhesion risk during the long hibernation phase. The inner surface of the cover is used as reference for the instrument internal calibration, and as such, avoiding its direct exposure to the external space, to avoid its contamination, became also a concept driver. A 3D motion achieved by the combination of a double cam system, linked by an internal pin has been finally selected for the actuation mechanism.

The Front Door Mechanism (FDM) during the opening motion performs four different phases:

1) Unlocking

2) Initial translational lift
3) Rototranslation to achieve final lift and rotation of 90 degrees
4) Locking

The cover motion is determined by the joint interaction of the internal pin, the fixed external cam and the moving internal cam, driven by a stepper motor. Fig. 2 explains the coupling concept. By the definition of the shape of the internal and external cam the desired motion can be achieved. This allows great flexibility in the motion to be performed by the cover.

One peculiarity of the cam design is its self-locking feature, both in closed and in open position. This allows the maintenance of the position without any power and is obtained by the kinematic design of the cams. A rotation of the inner cam of more than 45 degrees is needed to unlock the system from any of the two locked positions. No motion of the cover (except for compliance in the cams and couplings) is possible before the resting position, fully closed or fully open, is unlocked.

Various measures are also implemented to minimise any risk of jamming of the relative motion between the cams, pin and cover shaft, including main guiding bearings, various bushes and additional kinematical bearings. Moreover, on top of the standard redundancies included in the mechanism design, another additional fail-safe system, completely independent from the nominal motion and capable of opening irreversibly the field of view has been implemented inside the cover arm.

Light and dust tight closure is achieved by preloading the cover against the baffle using the stiffness of the arm, and also variable preload is possible.

On top of verification of the qualification requirements tests, including lifetime tests (> 10000 activations) on the QM model, an accurate characterisation of the performance and the repeatability of the parameters, especially those available in the telemetry, has been performed for each model.

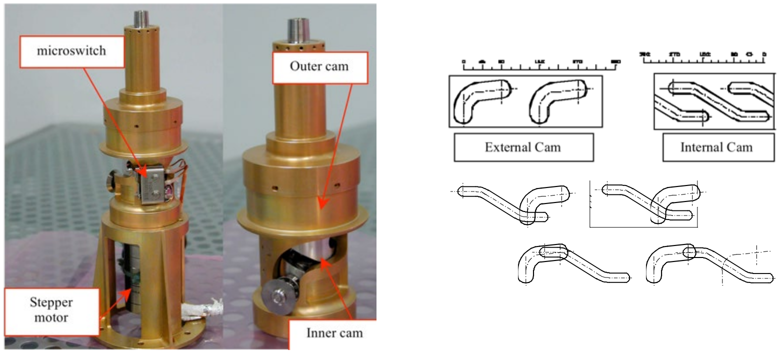

Figure 2: Front Door mechanism description (left) and cam design and conceptual interaction during the four phases(right)

In orbit

ROSETTA was launched on 2nd March 2004 for a long journey toward the encounter with the comet 67P/Churyumov-Gerasimenko that eventually happened in August 2014, after a series of gravity assist manoeuvres, Mars and asteroids fly-bys and after more than three years of hibernation and six months of orbits correction and approach to manage orbiting around the comet with a newly discovered and quite irregular shape [4].

During all the phases of the mission the Front Door Mechanism both of WAC and of NAC cameras operated flawlessly from the commissioning phase to the end of mission. They allowed the tight closure of the telescopes baffles openings during the initial phases, provided the telescopes' internal calibration reference surface and protected from contamination the optical elements during the spacecraft journey and when the instrument was not in use.

Its design proved its robustness, versatility and reliability allowing the extraordinary achievements of the OSIRIS experiment of the pioneering ROSETTA mission [5, 6, 7].

Legacy: JANUS instrument for the JUICE mission

On 14th April 2023, almost 20 years after the launch of ROSETTA, the JUICE satellite was launched, carrying onboard as one of the instruments JANUS, a narrow angle camera imager in the visible range. The JUICE mission aims to explore the Jovian moons (Ganymede, Europa and Callisto), including ocean layers and subsurface water reservoirs, magnetic field and geological features. It will reach Jupiter in January 2031 after a 7.6-year travel with various Earth–Venus–Earth–Earth gravity assist manoeuvres. JANUS instrument will enable visible wavelength imaging, crucial for understanding the formation and characteristics of various geological features, surface processes and erosion/deposition processes on icy satellites.

JANUS consists of independent subsystems, including the Optical Head Unit (OHU), Proximity Electronics Unit (PEU), Main Electronics Unit (MEU), and Interconnecting harness. The COver Mechanism (COM), used to protect JANUS and its delicate optical elements, is a direct derivation of the innovative design used for the FDM for the OSIRIS telescopes. It ensures protection of the OHU from contamination and provides a reference surface for telescope calibration during the mission [8].

Considering the very successful design of the Front Door Mechanism (FDM) for the OSIRIS experiment on ROSETTA, along with similar requirements and the nominal operation of the mechanism throughout an Interplanetary mission, it was decided to adapt the FDM to craft the COver Mechanism (COM) for JANUS.

The main functional and environmental requirements for JANUS' cover mechanism are in fact similar: protection of optics and detectors from sunlight and contamination, offer different positions for various flight conditions (closed-locked for launch, closed-not locked for cruise, open-locked for observation and calibration. Reliability and single-point failure tolerance is also obviously required, as it is the case for all instrument covers, as already discussed.

The main differences in the design of JANUS' COver Mechanism (COM) compared to ROSETTA's FDM are as follows.

Some geometric parameters needed adjustment such as the arm size and the body height and a partial redesign of the fail safe system. The geometry of the internal cams was also optimised for minimal resistant torque. Moreover, the material for the sealing under the door has been modified, while maintaining the same goals of dust and light tightness and vibration damping.

Fig. 3 shows the JANUS COM subsystem final design and flight model.

Figure 3 : COM subsystem and its components in rendering (left), flight model (centre), during vibration tests (right).

The JANUS COM successfully underwent the full qualification campaign maintaining its functional performance unaltered. It has been successfully integrated in JANUS instrument and onboard JUICE satellite and successfully launched in April 2023.

Conclusions

The innovative design of the cover system developed for the protection of the telescopes of the OSIRIS experiment of the ROSETTA mission, allowed a variety of options in its utilisation, from full dust and light tightness, to just partial detachment from the baffle surface and also provided the reference surface for internal calibration of the instrument.

Its reliability and robustness in wide range of operative conditions has been the main focus due to the extreme criticality of its potential failure, and it has been demonstrated during the entire mission

Acknowledgements:

This paper has been intended as a short overview and reflection on how a robust and adaptable design of a space unit could serve the needs of very different missions, decades away in time. Gratitude goes to all the many ones who contributed in several ways to realisation of the units from the very first prototype to the recently flown ones. A special mention and memory is deserved for our colleague and friend **Stefano**. He made, among many other things, also this legacy possible. We all owe him a lot!

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