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# Design and testing of a roto-translational shutter mechanism for planetary operation

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ABSTRACT

This work describes the design and testing of a shutter mechanism for a miniaturized infrared spectrometer developed for the ESA ExoMars Pasteur mission. Unlike most usual cover mechanisms, the conceived one provides a roto-translational motion. This feature allows the sealing of the interferometer main entrance window from dust contamination, in addition to the usual function of shuttering the instrument field of view. Although this characteristic is strongly desired because it avoids dust deposition and optics contamination while the instrument is not operating, it makes the mechanism design significantly more complex. Moreover, challenging design constraints were faced: the mass budget allowed for no more than 30 g allocation, the expected working thermal range extended down to $-80$ °C and high vibration levels with an acceleration peak of 670 m/s$^2$ were predicted during Mars landing. To complete the picture, the mechanism cover was required to provide also a calibration target for the 2–25 μm spectral range of the spectrometer. The resulting system is made by a calibrating/shutter cover moved by a purposely designed out of plane cams system which provides the desired motion. A mechanism mockup was assembled and successfully tested in the predicted thermal and mechanical environments.



## 1. Introduction

Though not commonly made, roto-translational motion would be often a desired characteristic for shutter mechanisms for space borne instruments, mainly on those devoted to planetary surface operation. For these devices opening of instrument field of view (FOV) can be achieved by a rotation while cover translation would allow to generate a pressure on a compliant gasket around the instrument entrance window. This is the best way to achieve the sealing against external contamination caused by dust or condensation, since in comparison with purely rotary covers, that achieve sealing during the last phase of the rotation, the advantage of a linear motion lays in the possibility to generate a uniform pressure distribution over the seal.

Apart from the front door mechanism of OSIRIS-Rosetta experiment [1], in literature no solutions about this kind of combined movement were found. OSIRIS mechanism however was not scalable to our case since the design had to cope with an allowed total mass ten times lower than OSIRIS one. Our instrument mass budget was 1 kg [2], therefore a new shutter/calibrating mechanism had to be conceived and designed.

Cover rotation is provided by out of plane cams which work faced and axial movement is possible since the shutter is guided by an external fixed cam. The most remarkable characteristics of the conceived mechanism are its compactness and lightweight. It suffices to say that the overall mass was lower than 30 g. The mechanism is

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powered by a commercial gearbox motor Portescap R10 with a nominal output torque of 0.1 Nm, a temporary working with 0.15 Nm limit and low mass and size. This off the shelf motor was not compatible with space application because of the materials outgassing characteristics, therefore it was selected as temporary solution for the breadboard development phase. Moreover, the operating temperature range declared by the motor manufacturer has a lower limit of −40 °C, therefore not compatible with the required operating temperature of about −80 °C. A specific re-design of the motor unit to achieve compliance with environmental requirements was planned in the cover development plan.

The mechanism development is presented in the following: Section 2 describes design requirements and constraints, mechanism working principle and the cover and mechanism designs; performance and environmental tests are presented in Section 3 and the paper is eventually concluded in Section 4.

## 2. Mechanism design

### 2.1. Design constraints

The mechanism was developed for the Mars Infrared Mapper (MIMA), a miniaturized infrared spectrometer selected for mounting on the 2007 configuration of the ExoMars high-mobility rover devoted to Mars surface observation. Beside complexity owing to the double motion, design challenge was increased by strict mass and size constraints [2]. Moreover minimum rotation of 60° was required to achieve the instrument unobstructed FOV.

Expected mechanical environment was characterized by high acceleration levels:

- a quasi-static acceleration of 670 m/s$^2$ corresponding to the landing shock; and
- a sine acceleration amplitude of 330 m/s$^2$ was specified within the 30–100 Hz frequency range; and

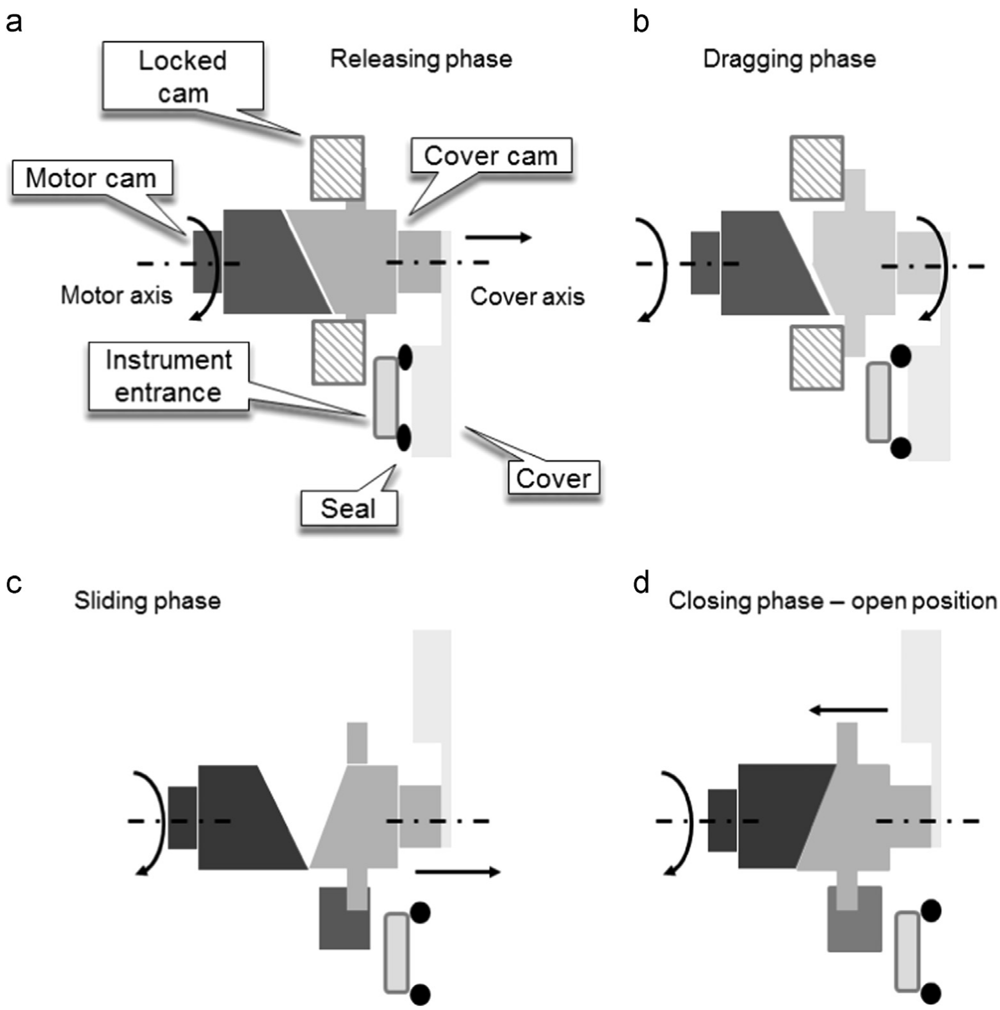


**Fig. 1.** Mechanism working principle (a) System starts from a fully closed position with zero axial relative distance between motor and cover cams. Motor starts rotating and cams slide up to cover cam release. (b) Dragging starts and cover rotates. (c) Cover cam reaches the open position and sliding process restarts. (d) System backs to zero axial displacement and stable open position is provided.