MAIN PORT MECHANISM FOR PRISMA

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ABSTRACT

A high complexity Main Port Mechanism (MPM) has been designed and produced by Selex ES in co-operation with HighFTech Engineering, an Italian PMI, in the frame of PRISMA (PRecursore IperSpettrale della Missione Applicativa) instrument.
The Main Port Mechanism is located at the entrance of the Optical Head having the function of opening and closing a door.
The paper describes the requirements drived the conceptual design, the detailed design and the qualification tests performed on the mechanism. A description of the foreseen test flow and set-up is also given.

1. INTRODUCTION

The Main Port Mechanism MPM is located at the main entrance of the Optical Head of PRISMA instrument. This Hyperspectral Payload is an Electro-Optical Instrument composed of a high resolution spectrometer, able to take images in spectral bands VNIR and SWIR, optically integrated with a medium resolution panchromatic camera [1].

The PRISMA mission is fully funded by ASI (Agenzia Spaziale Italiana) and the prime contractor is a consortium of Italian companies. In this context Selex-ES has the full responsibility of the Payload and developed the presented mechanism in cooperation with Highftech Engineering, an Italian PMI.
The covered hyperspectral range of PRISMA is the Visible and Near Infrared (VNIR) and the Short Wave Infrared (SWIR), with Panchromatic (PAN) images provided at higher resolution, co-registered to the hyperspectral ones, so as to allow images fusion techniques. The VNIR and SWIR detectors are cooled down to 185K and 140K respectively, by means of a passive radiator.
Contamination is considered a critical issue for this instrument and the adoption of a entrance cover mechanism is the proper solution to reduce the risk of internal parts contamination and its detrimental effects on the optical performances.

2. MPM GENERAL OVERVIEW

The function of the Main Port Mechanism is therefore the opening and closing of OH entrance cover (*Fig.1*). Open position allows earth observation, while the closed position protects the instrument internal optics from particulate and molecular contaminants. During ground transportation and launch phase the cover must be in closed position.

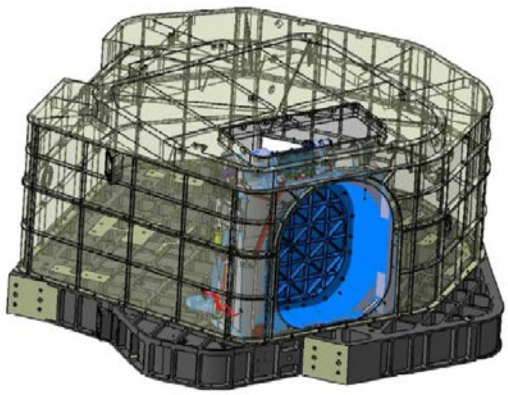

Figure 1 – PRISMA main port cover external view

The adoption of the cover allows to perform other operations of fundamental importance for this kind of instrument: the calibration and sun protection.

The spectral and solar calibrations are performed when the cover is closed. The light beans coming from the internal calibration sources and/or the sun light coming from a solar port can do the entire optical path till the focal planes thanks to the reflection on the inner surface of the cover that is treated as a light diffuser.

'15th European Space Mechanisms & Tribology Symposium – ESMATS 2013'
Noordwijk, The Netherlands, 25–27 September 2013

Fig. 2 shows a schematic view of the spectral calibration optical path based on the parabolic shape of the internal surface of the cover, reflecting the light coming from the Internal Calibration Unit (ICU).

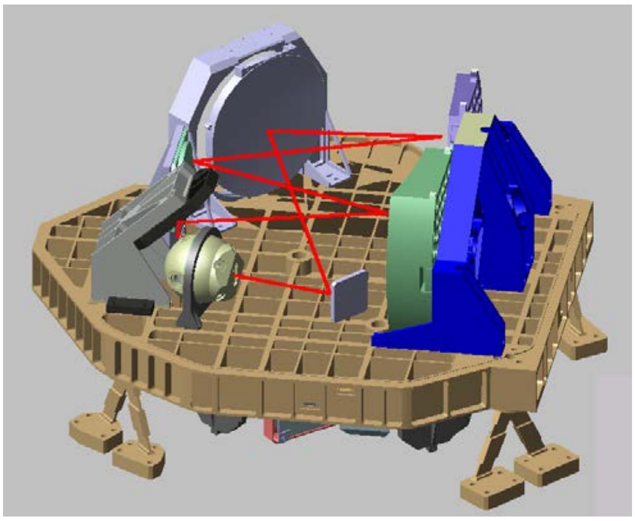

Figure 2 – PRISMA spectral calibration optical path

To perform calibration, the position of the diffuser surface must be located with very high accuracy and repeatability with respect to the internal OH system both during flight and ground operation.
The sun protection is necessary in case of satellite maneuvers that could lead the sun light to enter directly in the optical path used for earth observation with consequent detrimental effect for the optical system and the detectors. The port closing before to start maneuvers avoids the occurrence of this situation.
The design of the MPM has considered the requirements to allow on-ground testing of the operational states: open/closed. To avoid the motor oversizing due to the gravity of the cover, a removable counterweight has been adopted for ground testing.
When in closed position the cover must be secured for unwanted movement or hammering against the seat that could affect the following positioning precision. Due to relevant inertia of the cover, the motor detent torque is not sufficient to prevent such occurrence during ground and launch phase therefore a Launch Locking Device (LLD) has been implemented. Even if this subassembly is only one shot mechanism in flight, it has been designed for a reversible operation needed for ground testing and transport.
Considering the very high reliability required to the cover opening system, which failure would cause the Payload loss, although it is based on well proven and reliable concept and components, the MPM is also equipped with an Emergency Actuator Device (EAD) able to force the door in open position in case of failure of the main drive system.
The EAD is required to be able to force the cover also in closed position in order to ensure the closing for sun protection and calibration.
The EAD is an high reliability mechanism, designed to open/close the cover starting from whichever position of the cover for the specified number of actuations.
A detailed description of MPM, its main subsystems and the use of proven technologies as far as possible, is given in the following.

3. MPM MAIN DESIGN REQUIREMENTS

A list of the main performance requirements is following:

- Port maximum dimensions 245 x 270 mm
- Port angular closed position 0°
- Port angular open position 90° 0/+5°
- MPM total mass 5800 grams
- MPM cover mass 1045 grams
- Time for open/close < 10 s
- On orbit lifetime 15200 cycles
- On ground lifetime 500 cycles
- Envelope dimensions…L365 x W190 x H375 mm

4. DESIGN DESCRIPTION

The general external view of the Main Port Mechanism is shown in the *Fig.3* and *Fig.4* with the cover in closed and open position.

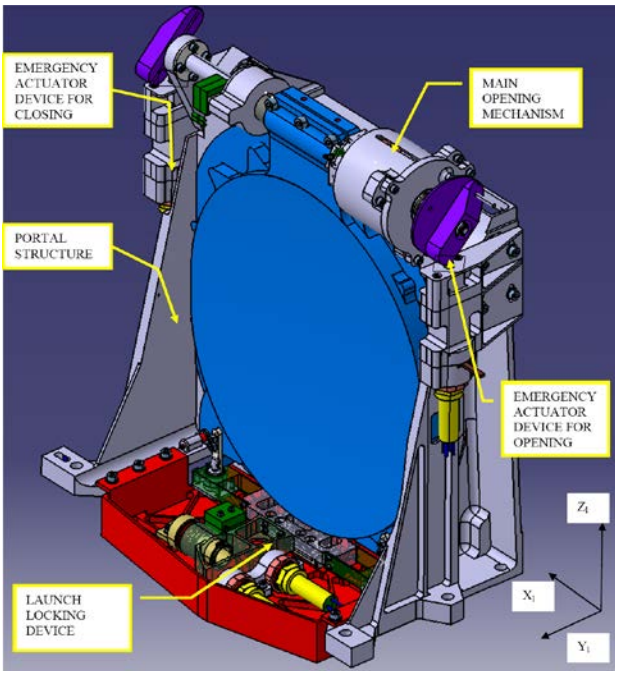

Figure 3 – MPM in closed position

The different sub-systems of the MPM mechanism, are mounted on a aluminium structural frame named “Portal Structure”.

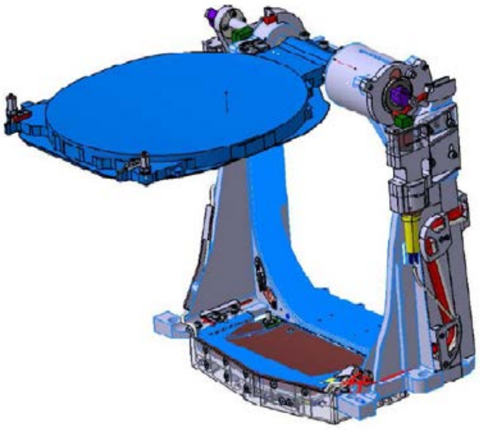

Figure 4 – MPM in open position

The base of the Portal Structure provides the mechanical interface to connect the MPM to the PRISMA optical bench allowing also position adjustment of the assembly for optical alignment of the cover diffusive surface.
The three main sub-assemblies constituting the MPM are:

- Main Open/Close Mechanism
- Launch Lock Device (LLD)
- Emergency Actuator Device (EAD)

The overall dimensions of the mechanism are shown in *Fig. 5*

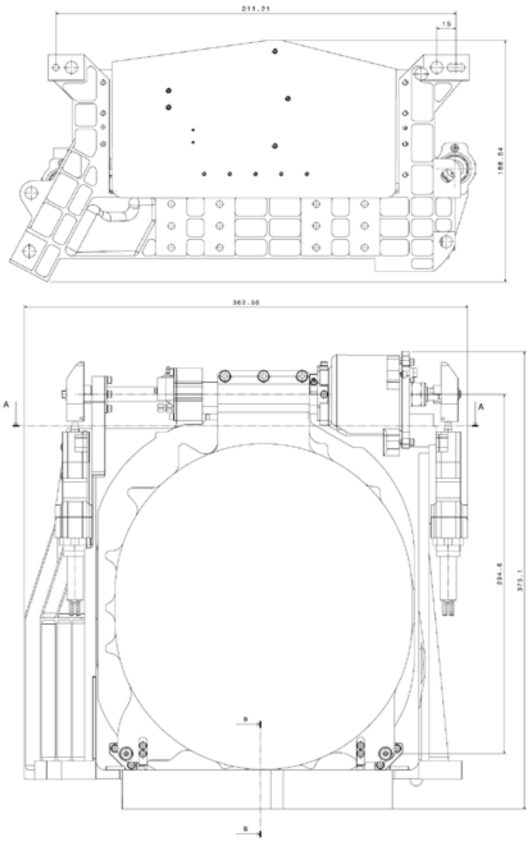

Figure 5 – MPM overall dimensions

4.1. Main open/close Mechanism

The main open/close mechanism is devoted to the support and actuation of the port, its main components are:

- Portal Structure
- Port
- Shaft and bearings
- Frameless Motor
- Position monitoring sensors

The **Portal Structure** is the main supporting structure of the whole subsystem and consists of an aluminium structure machined by a block as shown in *Fig.6* where the MPM reference system is reported too. The mounting interface is located in the bottom side and the fixation to the PRISMA interface is obtained by means of 6 M8 LN screws.
The rotating shaft of the main open/close mechanism that supports and drives the port rotation, is located on the top of the portal structure where the seats of the bearings are positioned.
The **Port** is an aluminium structure machined starting from plate and it is weight lightened on the external side where stiffening ribs are machined.

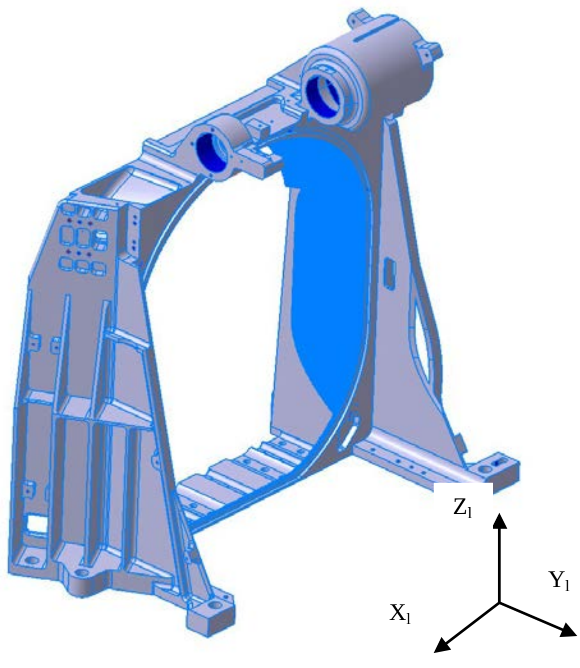

Figure 6 – Aluminum Portal Structure

The back side (the internal one respect to Prisma instrument) has the function of optical diffuser with parabolic shape and optical surface finishing. The *Fig. 7* shows the optical diffuser surface during the machining at the single point.
To ensure the port position accuracy for calibration, the closed position is defined by means of two adjustable mechanical end stops (Fig.8). They are pressed by the

motor torque against the respective seats placed on the Portal Structure.

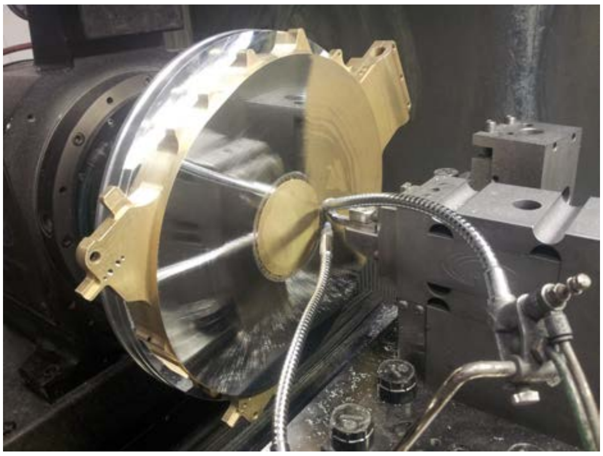

Figure 7 – Port optical diffuser machining

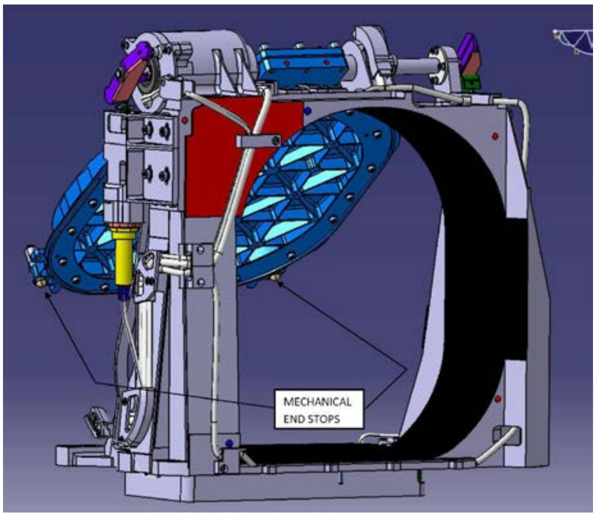

Figure 8 –Mechanical end stops for Port positioning

In this solution a little gap remains between the Port and the Portal Structure in order to avoid any contact besides the mechanical end stops. To avoid the remaining gap could allow particles and/or light entering a labyrinth trap is implemented on the cover external edge by means of a circumferential lip entering in a groove of Portal Structure when the port is close.
The Port is driven by a shaft supported by one couple face to face pre-loaded angular bearings and one radial bearing (*Fig.9*), all of them with un-lubricated ceramic balls and with PGM-HT cage.

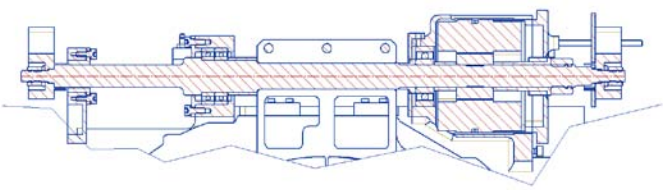

Figure 9 – 2D shaft section

In addition to the bearings, two radial bushes are placed to support the shaft at both end side. In normal working conditions the shaft is not in contact with such bushes (a radial gap of 0.1 mm exists), as the scope of these bushes is to limit the shaft deflection caused by the lateral load exerted by the Emergency Actuator Device when activated.
The **Motor** rotor for cover actuation is mounted directly on the shaft. The motor is a frameless Limited Angle Torque (LAT) type with double winding for cold electrical redundancy.
The motor stator is mechanically fixed to the Portal Structure.
The frameless motor solution has been selected in order to minimise mass and envelope dimensions. In order to avoid oversizing of the motor, before performing the on ground functional test, the "g" effect was annulled by means a service balancing mass installed on the top of the cover (*Fig.10*).

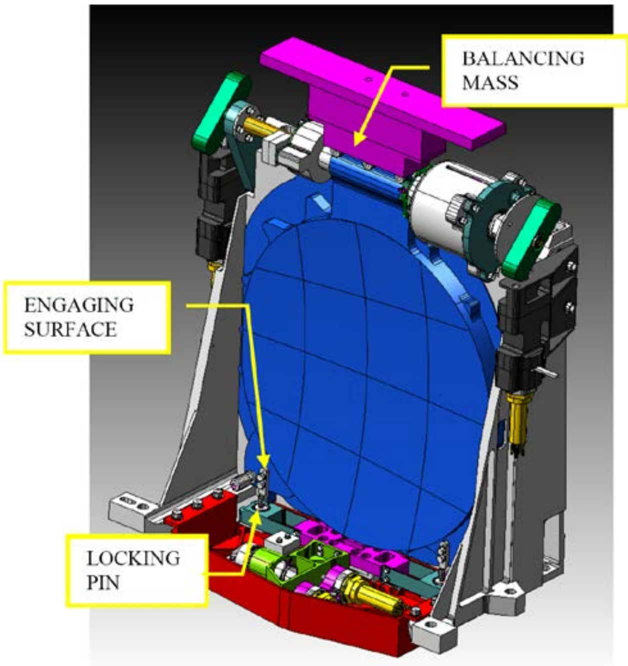

Figure 10 – Cover balancing mass

Both open and close positions are held with motor un-powered thanks to the cogging torque provided by an especially designed motor. Such a cogging torque holding the port against its mechanical end stops guarantees the open position holding and the repeatability of the close position for calibration purpose.
The mutual angular position of rotor and stator has been correctly fixed during integration phase.
Open/close positions of the cover are monitored by means of hall effect sensors detecting the extreme port positions. The corresponding magnets are glued in the port. The sensors for both open and close position are redounded.

4.2. Launch Lock Device (LLD)

The Launch Lock Device has the main function to lock the port during launch phase applying a far higher torque than the cogging torque of the motor. After launch it will be un-locked and will not work anymore.
The LLD has been designed to allow the re-locking of the port for ground needs.

The system consists of:

- supporting structure
- linear guide
- locking sledge
- return spring
- 2 actuators (with electrical redundancy)
- 2 micro-switches limiting actuators' end stroke

The operation of the locking device is based on the movement of a locking sledge obtained by means of two paraffin actuators and a counteracting return spring that disengage or engage the parts realizing the locking itself.

As shown in *Fig.11* and *Fig.12* the locking device is accommodated in a vane in the bottom of the Portal Structure just between the mounting interfaces.
The locking sledge is mounted on the sliding carriage of the linear guide ensuring the translation movement in X direction. The sledge supports two locking pins at its ends.

In the locked position the pins press the cover to the engaging surfaces on the port to remain in closed position. The locking force acting on +Y direction is generated by the locking sledge thanks to the deformation of elastic blade imposed by the slope of the engaged surface.

The unlocking is obtained giving power to two paraffin actuators that move the sledge in +X direction disengaging the locking pins so allowing the port to open by acting on the main motor.

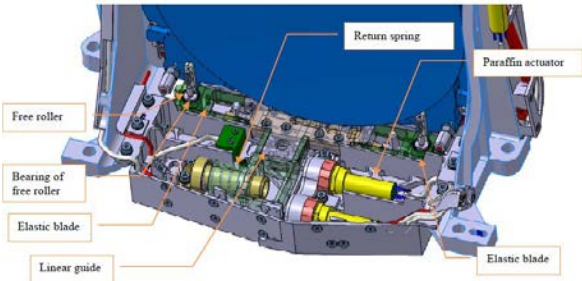

Figure 11 – Launch Lock Device - Locking position

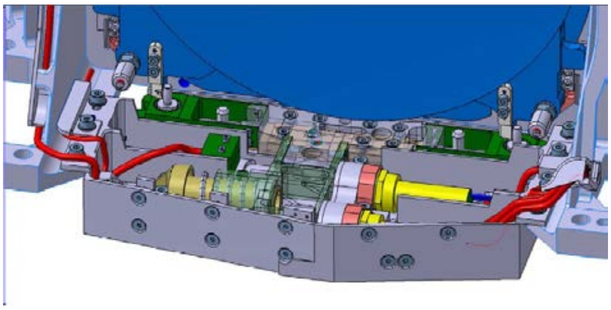

Figure 12 – rest position: port close

Once the actuators get to the end stroke and the cover is open, the return spring push back the locking sledge until the "rest position" (Fig.12), where the pins are stopped beyond the position of the engaging surfaces on the port. From now on the port can be opened and closed.
Fig.13 shows a detail of the pin engagement in the three different assumed positions.

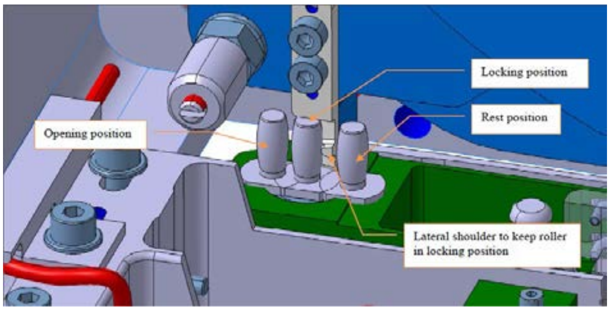

Figure 13 – different pin engagement position

The locking/unlocking operation can be performed many times just combining properly the movement sequence of the main motor and paraffin actuators.
The LLD has been designed to obtain 200 N of locking force by each pin. In order to be sure to apply the design load when the LLD is locked, the position of the LLD and the consequent deformation of the blades, is adjusted during the integration of the Portal Structure by means of a dedicated setting tool.

4.3. Emergency Actuator Devices (EAD)

The emergency actuator devices consist in two identical subsystems, having the function to open and close the port in case of main port mechanism failure.
They are mounted on the left and right side of Portal Structure as shown on *Fig.3*.
The main design driver of EAD is the required number of actuations in case of failure of the main open/close mechanism. This number has been specified in 100 open/close actuations.
The EAD is a mechanism based on the same paraffin actuators used for the Locking Device and it is able to provide a torque higher than 10 times the maximum

torque of the LAT motor including ECSS torque margin. This torque transmitted to the rotating shaft corresponds to the force each EAD actuator is able to provide for 1000 actuations, and will be even higher for the minimum requested number of actuations.
As shown on *Fig.14* and *Fig.15* the forced aperture of the port is performed inducing the rotation of the shaft with a pusher acting on a cam fitted to the rotating shaft. The cam profile has been designed to obtain the needed stroke to open /close the port and to have a maximum force of 220 N.
The pusher is moved by the paraffin actuator.

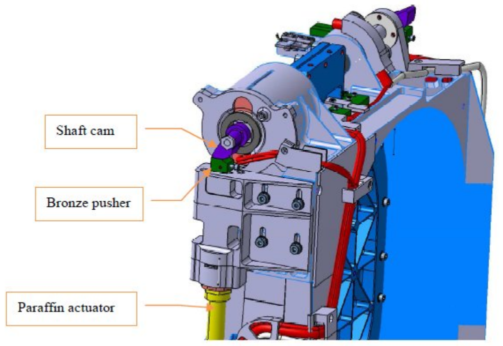

Figure 14 – emergency opening system - Port in close position

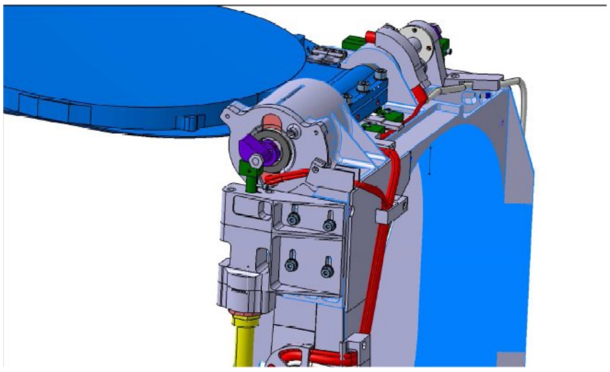

Figure 15 – emergency opening system - Port in open position

5. ENGINEERING MODEL AND TEST

An Engineering model of the MPM identical in all to the FM model, has been manufactured and tested.
Fig. 16 and Fig. 17 show the EQM model of the Main Port Mechanism. A dedicated electronic unit Tester has been developed to support the whole test campaign of the mechanism including life test.
The Unit tester is based on the electronics implemented inside Main Electronics (ME) of PRISMA instrument having the task to drive all the electromechanical component of the MPM mechanism. The current control of the motor has been developed in synergy with the design of the LAT motor with torque characteristics to have a very simple current profile controlling the movement of the motor without the need of a closed loop position control.

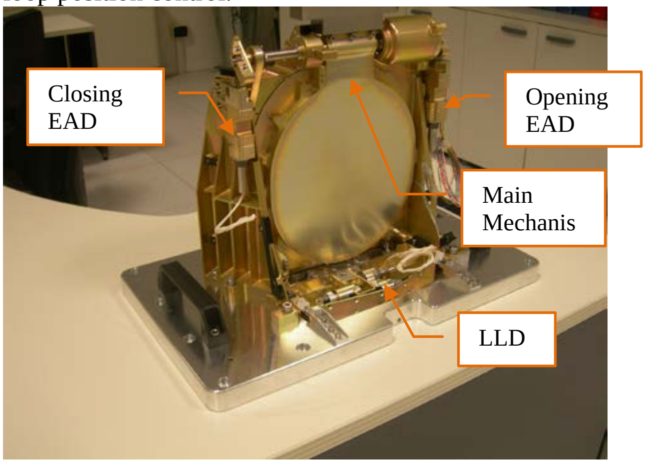

Figure 16 - Main Port Mechanism (inside wiew)

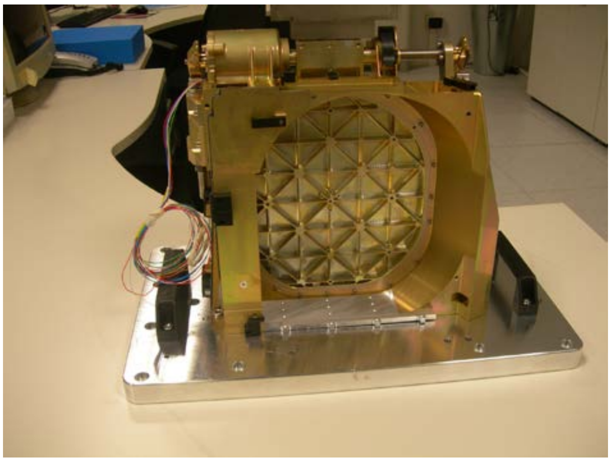

Figure 17 - Main Port Mechanism (outside wiew)

The block diagram in *fig.18* shows the development plan of the MPM mechanism, including both EQM and FM.

All parts of EQM and FM have been manufactured in the same batch. The FM assembly started after successful completion of final and performance test on EQM.

The EQM model at the end shall be subjected to a qualification campaign including the following test:

- dimensional check
- visual inspection
- initial functional and performance test
- vibration test (sine and random)
- functional and performance test
- thermal vacuum test
- final functional and performance test
- life test

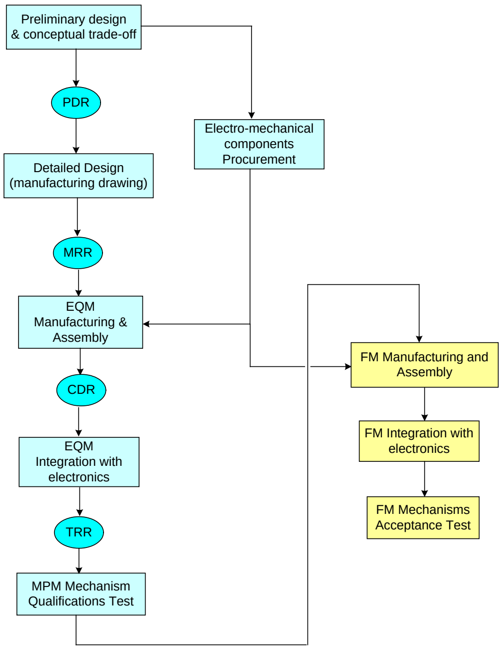

Figure 18 – MPM Development plan

5.1. LLD and EAD Force measurement

Functional and performance test on both LLD and EAD performed before and after environmental test included direct measurement of forces throughout the whole stroke of actuation. *Fig. 19* and *Fig. 20* show test set-up for force measurement. It allowed force monitoring after each environmental test confirming the forces always under the maximum specified values.

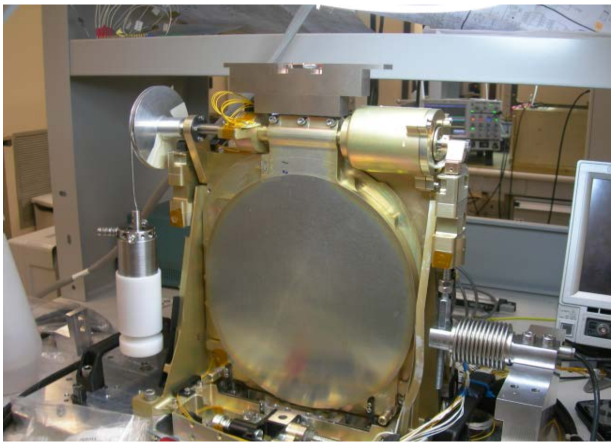

Figure 19 - Force measure setup for EAD opening

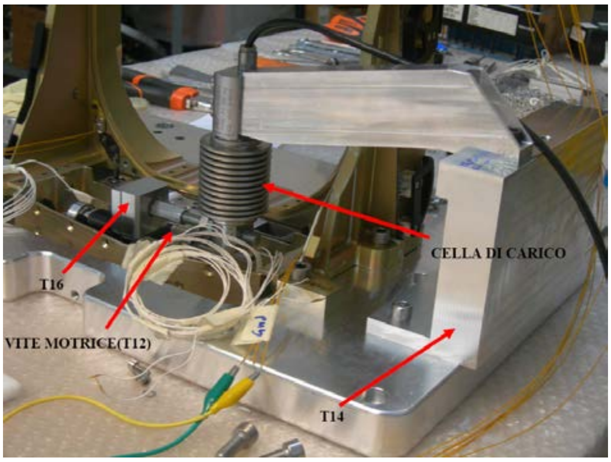

Figure 20 - Force measure setup for LLD

5.2. Mechanical Vibrations

The test started with resonance search for each axis applying a level of 0.5g in the frequency range 5 to 2000 Hz. The sine vibrations spectrum in *fig.21* and *fig.22* has been applied. The Random Vibration Loads Spectrum in *fig.23* and *fig.24* has been applied. After Sine and random vibrations test a resonance search has been repeated on each axis.

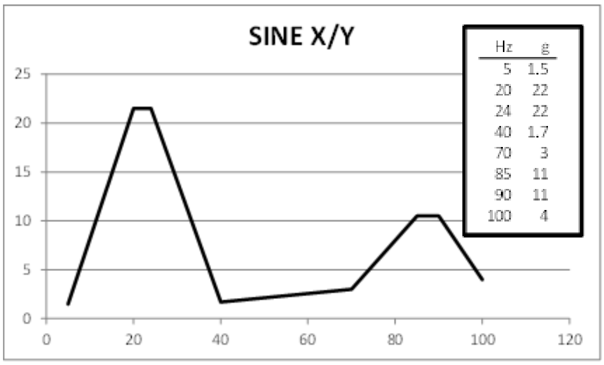

Figure 21 – X,Y Sine levels [g/Hz]

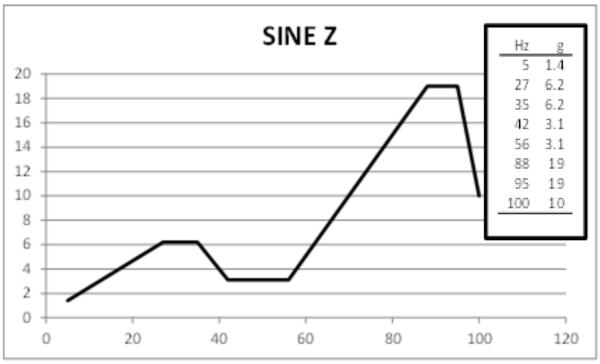

Figure 22 – Z sine levels [g/Hz]

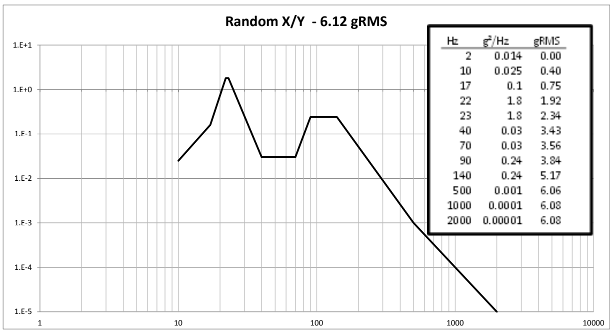

Figure 23 – X,Y Random levels [g^2/Hz]

Figure 24 – Z Random levels [g^2/Hz]

Fig. 25 shows the mechanism on the vibration tables for X,Y axes.

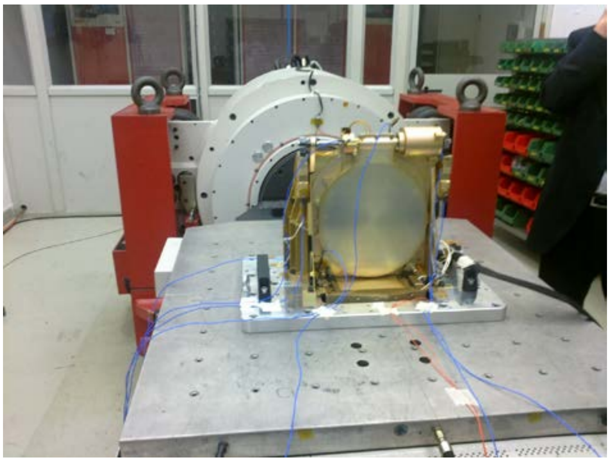

Figure 25 - Mechanical Vibration X,Y-axes

5.3. Thermal Vacuum

The thermal cycles in *fig.26* have been applied during Thermal Vacuum test, reduced functional and performance tests have been performed during the first and the last cycle at each step signed with marks.
Fig. 27 shows the mechanism inside thermal vacuum chamber.

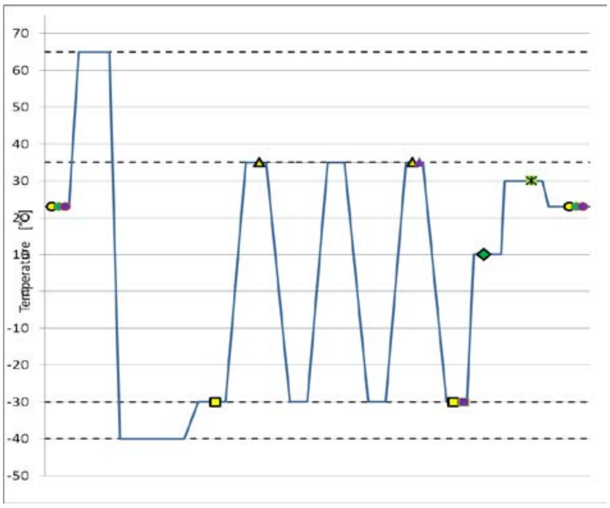

Figure 26 – Thermal vacuum cycling

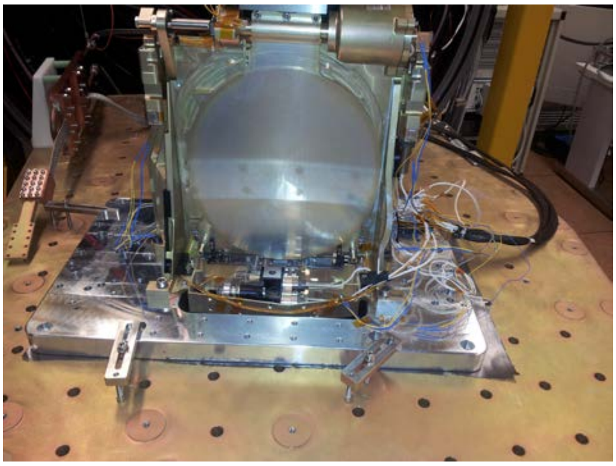

Figure 27 – MPM mechanism inside Thermal vacuum chamber

6. CONCLUSIONS

Selex-ES with Highftech have developed the Main Port Mechanism for PRISMA, which includes the main open/close mechanism, the launch lock device and the emergency actuator devices. The paper described the design features, the verification process and the first results which confirm analysis results and specification compliance.

7. REFERENCES

1. M.Meini, F.Battazza, R.Formaro, M.Dami, E.Fossati, L.Giunti – *Hyperspectral Payload for PRISMA Mission*, Small Satellites Systems and Services - The 4S Symposium, 4-8 June 2012 Portoroz - Slovenia