EMIRATES LUNAR ROVER NAVIGATION CAMERA MAST AND GIMBAL

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ABSTRACT

Primary objective of the Emirates Lunar Mission (ELM) is technology demonstration and obtain useful measurements on the lunar surface. The Rashid rover is a small size rover (10 kg) for the exploration developed by Mohammed Bin Rashid Space Centre (MBRSC) and funded by the ICT Fund as part of the Mars 2117 Strategic Program.

SENER has been assigned to develop a Mast and gimbal Subsystem to provide a better surface visibility by the rover's navigation camera through the increase of the camera's height.

1. INTRODUCTION

The mast and gimbal (MAG) of the Rashid rover is a subsystem composed by a mast, to elevate the position of the navigation camera, a two axis mechanism to provide azimuth and elevation movement capability, a hold down and release mechanism (HDRM), to maintain an stowed position from launch until landing, a deployment mechanism to change the mast from stowed to deployed configuration, and an electronic board to control azimuth and elevations actuators, and the HDRM.

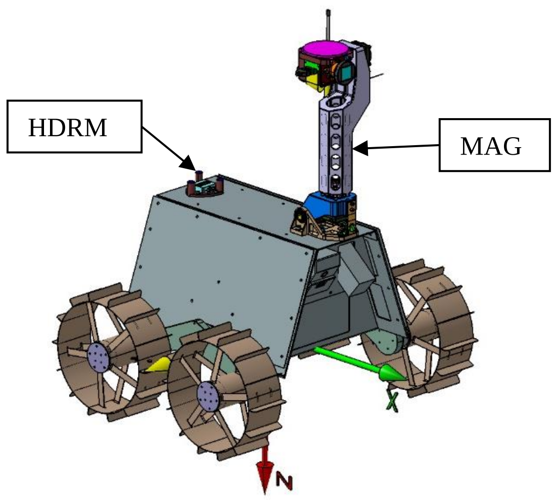

Figure 1.Mast and Gimbal overview

The mast will also serve as support structure for communication elements, such as the primary and secondary antennas, and a probe for atmosphere composition measurements

2. DESIGN REQUIREMENTS

The major requirements for the MAG can be summarised as follows:

2.1. Functional Requirements

- Gimbal azimuth range ±179º
- Gimbal elevation range ±75º
- MAG shall have a hold down mechanism
- MAG shall have a deployment mechanism

2.2. Structural stiffness

- First natural mode frequency higher than 160 Hz in stowed position.

2.3. Mass

- Mass less than 1.4 kg including harness and control board.

2.4. Volume

- Maximum height in stowed position, less than 120 mm from the rover top cover.
- Inside Rover top view in stowed position

2.5. Environmental requirements

- Static acceleration of 28 g in mounting plane perpendicular direction, 24 g along mounting plane
- Random vibration environments of 14.1 grms out of plane.
- Sinusoidal accelerations of 24 g in mounting plane perpendicular direction, 16 g along mounting plane.
- Mission temperature range -30ºC +77ºC (Lunar surface temperature at 45 latitude from 2 hours after sunrise to 1 hour before sunset)

2.6. Gimbal Control Board (GCB)

- CAN 2.0B interface with the rover On Board Computer (OBC)
- GCB dimensions in accordance with cubesat standards

3. DESIGN DESCRIPTION

MAG is fixed in the top panel of the rover, during launch, approximation and landing the mast is stowed parallel to the top panel of the rover by means of a hold down. Once the rover has landed, and before starting exploration, the hold down of the mast is released, and the mast deploys to its final position, vertical with respect to the top panel of the rover.

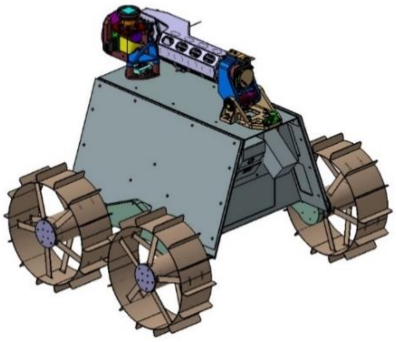

Figure 2.MAG installed in the rover. Stowed position

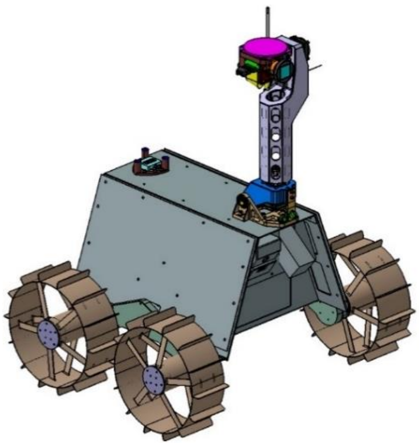

Figure 3. MAG installed in the rover. Deployed position

3.1. Hold Down Release Mechanism

HDRM is located close to the camera, which represents the 71% of the payload mass.. To prevent the rotation of the elevation actuator the hold down has three hemispheric contact points.

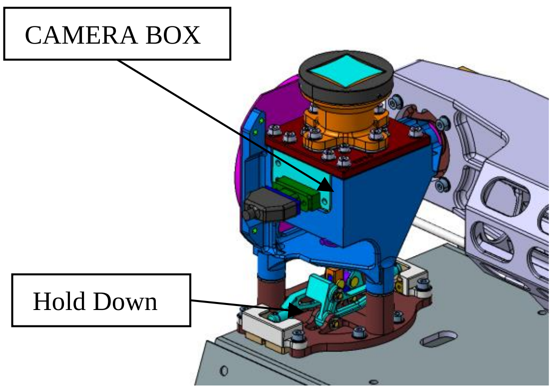

Figure 4. Hold Down

Hold Down is based in a fuse wire system, with full redundancy. Configuration selected to reduce weight and complexity of the system.

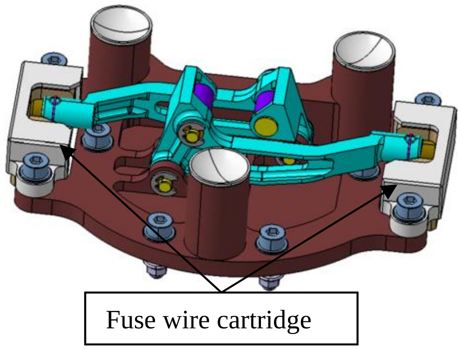

Figure 5. Hold down fixed part

3.2. Deployment Mechanism

Deployment mechanism consists in a spring actuated hinge. The spring is preloaded when the mast is placed in launch position, once the hold down is released, the spring returns its elastic energy to rotate the hinge. The complete movement of the hinge is 90º. The remaining force of the spring is able to maintain the mast in deployed position during operation, nevertheless, a latching system is placed as redundancy to maintain the deployed position of the mast. This latch can be reset on ground by hand, without the need of special tooling.

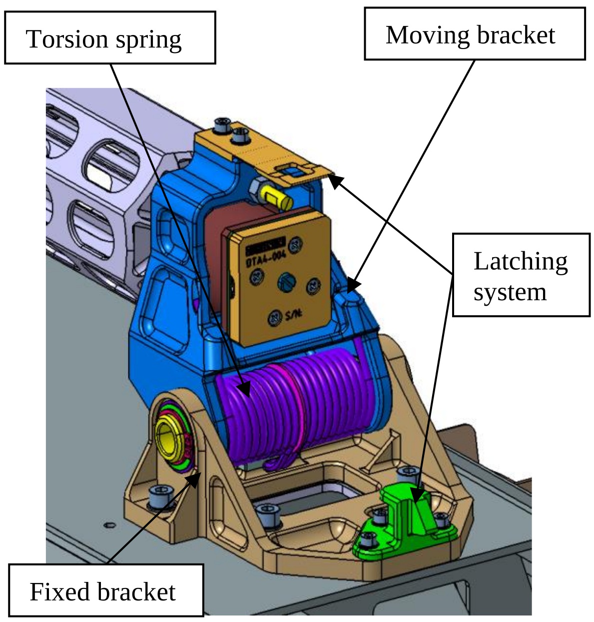

Figure 6. Deployment mechanism

3.3. Gimbal

The gimbal functionality of the mast is done with two actuators. The azimuth actuator is located in the bottom of the mast, reducing the mass in the tip of the mast, in addition reducing the required deployment torque due to gravity effect. This configuration has a better distribution of masses in launch configuration. The elevation actuator is located in the top of the mast at the same level of the navigation camera.

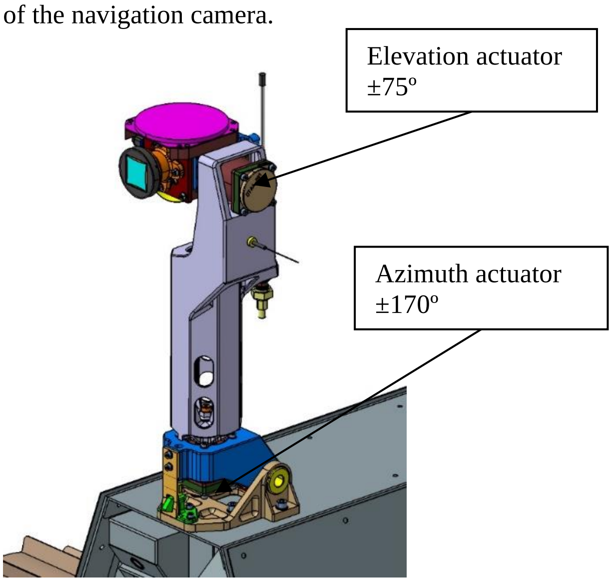

Figure 7. Deployment mechanism

3.4. Actuators

SENER developed a version of its qualified DTA-4 actuator optimized for MAG requirements. Attending to the newspace philosophy of the project, winding redundancy it is not necessary, allowing a reduction in the volume and mass of the actuator, one of the driving parameters of the MAG subsystem.
Each actuator including harness and connector is below 185g.
Main technical data of DTA4-004 actuator is shown in Table 1.

Figure 8. SENER actuator. DTA4 family

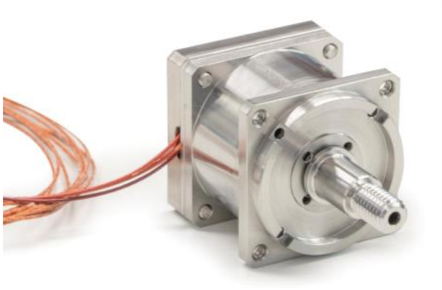

Figure 9. SENER actuator. DTA4-004(ELR version)

Output Step Angle	1.8	Degrees
Steps per revolution	200	N/A
Motor Step Angle	1	Degrees
Max output step rate	100	Step/s
Non-operating temperatures	-60/120	ºC
Operating temperatures	-40/110	ºC
Power (max)	2.9	W
Holding Torque	150	mNm
Running torque	100	mNm
Minimum backdriving torque	25	mNm
Mass	185	g

Table 1. SENER actuator. DTA4-004 technical data

3.5. Gimbal Control Board (GCB)

The electronic subsystem of the MAG is mainly composed by the GCB. Its main functions are driving the actuators, controlling the HDRM and communicating with the OBC through a CAN bus interface. The dimensions follow the CubeSat standard, fitting in the PCB stack with the rest of the boards.

The GCB follows a NewSpace philosophy, an innovative approach that allows a significant cost reduction in favour of accessibility to the space market.
One of the consequences of this philosophy is the use of Rad-tol or enhanced products for the electronic design, instead of its ultra-reliable Rad-hard counterparts that are traditionally used for deep-space missions. This limits the resources without compromising the performance for missions with a short life cycle.

3.6. Manufacturing processes and materials

In accordance with the newspace philosophy of the project, additive manufacturing processes has been chosen to reduce development times, reduce components mass, and allow the manufacturing of complex parts, maintaining the final costs. Fused Deposition Melting (FDM) is the technology selected to manufacture all the parts made of ULTEM 1010. Main structural parts like the mast, and deployment hinges are made of this material.

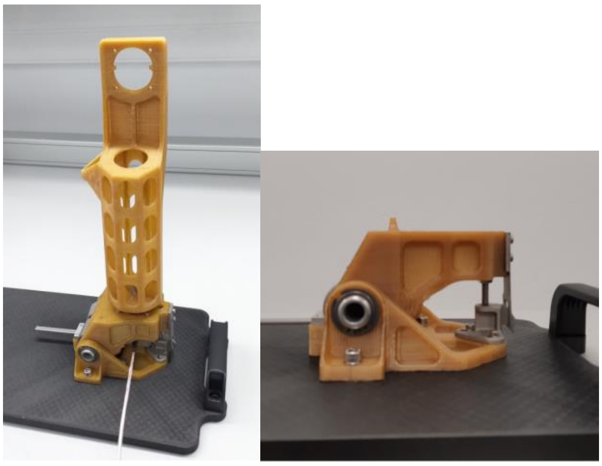

Figure 10. ULTEM 1010 parts. Mast & deployment hinge assy.

Selective laser melting (SLM) technology has been used to manufacture most of the metallic parts made of titanium and aluminium.

The short lead time of these manufacturing methods has allowed quick iterations during development phase.

4. ENGINEERING MODEL

An engineering model with the current design has been manufactured and tested. This model is also going to be used as a qualification model at rover subsystem level. Test campaign for the engineering model (EM) included verification campaign at actuator level and functional test at MAG Assembly level.

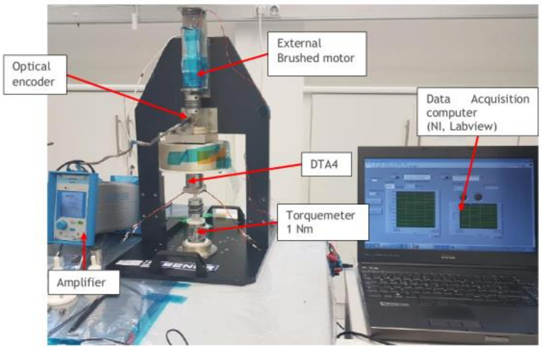

Figure 11. DTA4 holding torque test setup.

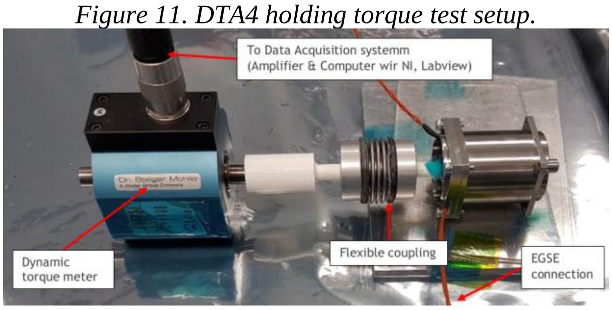

Figure 12. DTA4 running torque test setup.

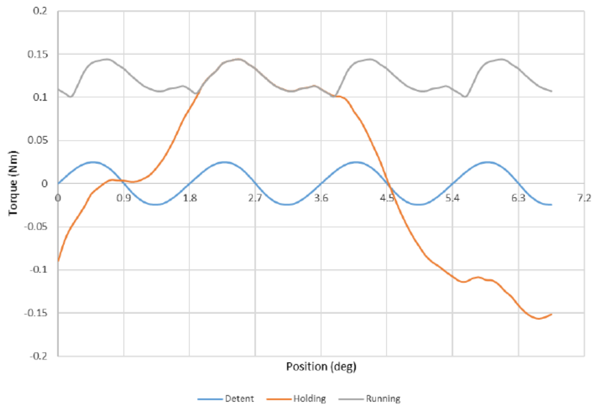

Figure 12. DTA4 torque results.

Functional test philosophy for the complete MAG subsystem is based on verification at ambient temperature and validation with heritage and by similarity with measurements made to similar mechanism of SENER, always in line with the newspace Approach of the project.

Friction in the deployment mechanism, friction in the latching system and motorization margins were successfully verified.

Several Hold down release test has been successfully performed, indistinctly fusing main or redundant cartridge. Contact surface materials have been selecting according to SENER heritage in this type of mechanism to prevent any kind of failure.

Measurement of the accelerations to be withstood at camera level at the end of the deployment, was taken to ensure navigation camera survival of this shock event.

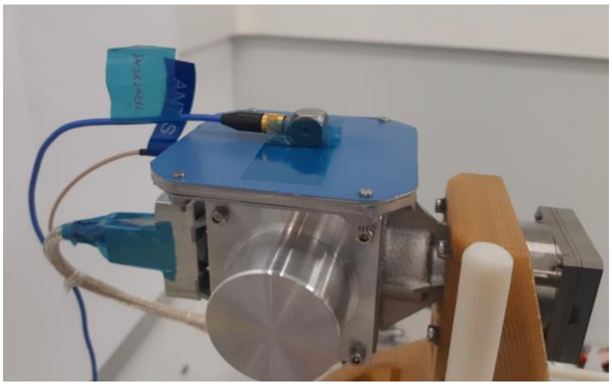

Figure 14. Accelerometer placed over camera box dummy.

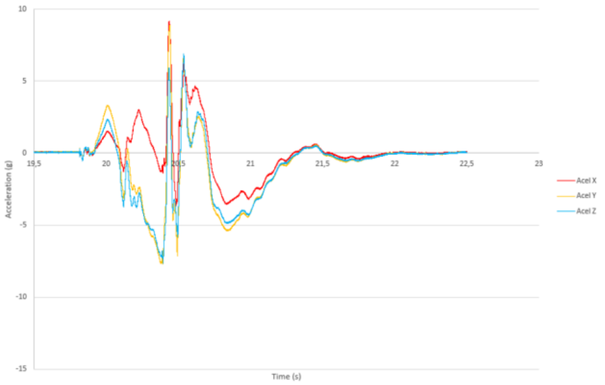

Figure 15. Measured acceleration at camera level.

Total mass of the engineering model is 1,237 kg including harness, GCB, and interface bolts.

Figure 16. MAG subsystem total mass.

5. CONCLUSIONS

Additive manufacturing methods allows maximum weight optimization in components designed to maximize its stiffness. Design flexibility also allows to minimize the number of components.

Short lead times of these manufacturing methods also allow to manufacture early designs to learn about the system, which in the end shortened the development time and the final cost.

Additive manufacturing methods are pushing for new material like ULTEM 1010 used in this project which is a high-performance thermoplastic, with a wide temperature range, and low outgassing values, very suitable for space application.