MTG SCAN LAUNCH LOCKING MECHANISMS

C. Compostizo[1], A.Sacristán[1], E. Larrabeiti[1], I.Angulo[1]

[1] *SENER-Structures & Mechanisms Section, Av. Zugazarte 56, 48930 Las Arenas (Vizcaya) Spain,*
Email: andrea.sacristan@sener.es

ABSTRACT

Within the framework of MTG-Scanner programme, this paper provides a synthesis of the main configurations studied for the locking mechanism and description of the detail design of the selected solution developed.

Results of the development model tests are presented showing the comparison between predicted and measured resistive torques. Emphasis is given in the determination of the contributors of the resistive torque for the application of the corresponding ECSS uncertainty factors.

1. INTRODUCTION

MTG, Meteosat Third Generation, mission will encompass two different satellites concepts, Imager and Sounder, both of them hosting in turn different payloads. FCI and IRS instruments will be part of the Imager and Sounder respective payloads. MTG Scan Assembly, MTG-SCA, constitutes the subsystem in charge of the scanning function of mirror M0 of the FCI and IRS Telescope Assemblies.

The main objective of this subsystem is to achieve the TA M0 mirror scanning by orienting M0 in two axes as requested according to the defined scan law. The high pointing performances required for the scan lead to the selection of a two axes scan axes defined by flexible pivots. The nature of these devices makes them quite weak and hence unloading mechanisms are required to allow them to survive during launch. In addition, the need to provide mechanical filtering of the micro-vibrations perturbations of the environment leads to implement a set of membranes and flexible blades in the remaining degrees of freedom, which makes more difficult the fixation of the masses during launch.

At the same time, the launch locking devices should be resettable on ground by remote means, which implies the need of the development of a motorized mechanism.

During the MTG SCAN development, the selection of the optimum design of the Launch Locking mechanisms has been one of the most difficult tasks, not only due to the complexity of the required mechanism due to the large amount of flexible and weak elements of the system, but also due to the tight mass constraints.

2. DESIGN REQUIREMENTS

The following requirements were drivers of the mechanism design:

- Provide 20kN Preload to the mechanism
- Power consumption 4W
- Locking / Unlocking operations remotely resettable
- Partial Preload for storage conditions
- Same design for both instruments (IRS and FCI)

Apart from that, due to the tight constraints in the mass budget, it was required to perform a mass saving study and different designs based on diverse technologies were studied.

3. CONCEPT DEFINITION AND TRADE-OFFS

M0 mirror shall be able to rotate around two axes which are made of multiple flexible elements. Therefore, the locking device shall block both axis during launch to prevent damages on those elements, each with its corresponding preload, and being also compatible for both instruments IRS and FCI. Fig.1 shows general scheme of the instrument and the required preload.

The baseline of the design was based on the use of a mechanism which was able to fix the mirror to the yoke and after, the yoke to the interface plate with one mechanism actuated by only one motor. The required preload was achieved by a preload arm and a cam mechanism.

However, improvement of the mass required the optimisation of the actuation chain to enter in the budget and other four configurations were developed; they are presented by the element which provides the mechanical advantage: a pair of gears plus cam design, roller screw design, a cam plus quadrilateral linkage design and finally, the selected option, a spindle plus a linkage design.

Proc. '16th European Space Mechanisms and Tribology Symposium 2015',
Bilbao, Spain, 23–25 September 2015 (ESA SP-737, September 2015)

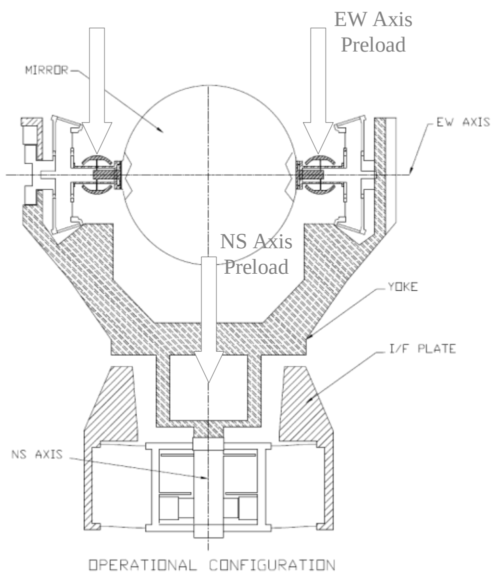


Figure 1.- SCAN Design

3.1 Stepper + Gears + Cam

This was the baseline which consisted on a cam – roller follower system, actuated by a stepper motor. Due to the geometry constrains, a pair of bevel gears were necessary, which also were used to increase the transmitted torque. Consequently, it results in a heavy solution, which involved having a structure around the NS axis, reducing the available space for NS axis item, such as the motor, encoder, etc.

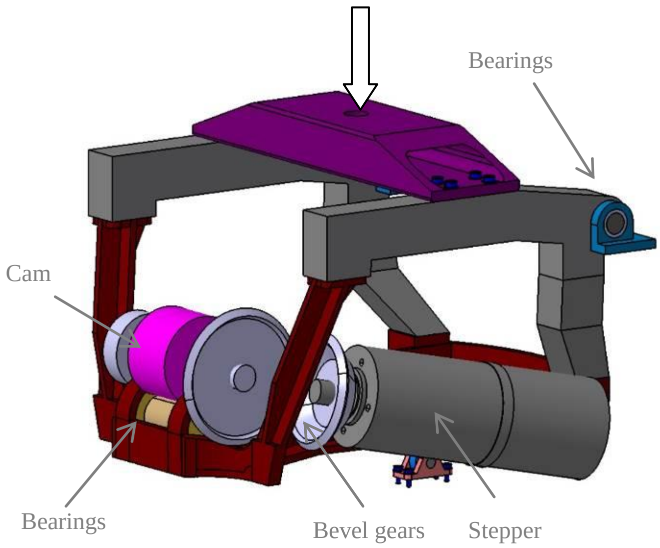


Figure 2.- Initial Baseline: Stepper+Gears+Cam

In an attempt to optimize the previous design, the cam was situated in the upper part of the interface plate, resulting in a more compact and light system, as seen in Fig2. However, the mass reduction was not enough, as the motor size was determined by the cam profile as a multi- turn cam was unable to be implemented due to the lack of space.

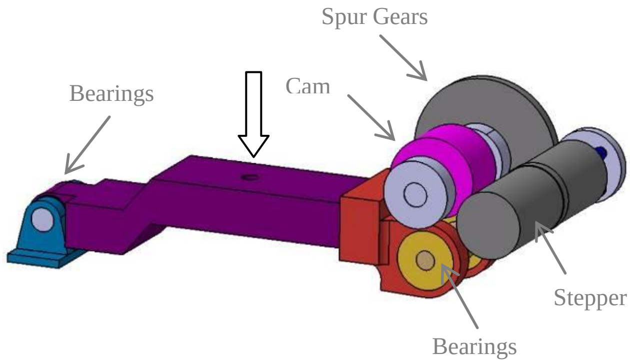


Figure 3.- Optimize Stepper+Gears+Cam

3.2 Stepper + Gears + Roller Screw

In this case, the cam was replaced by a roller screw, which was actuated by a worm gear in order to avoid the backdriving of the system. Bevel gears were still required in order not to violate the envelope.

Two different configurations were design; in the first one, the roller screw applied the force laterally. In the second one, the roller screw pulled from the system centered.

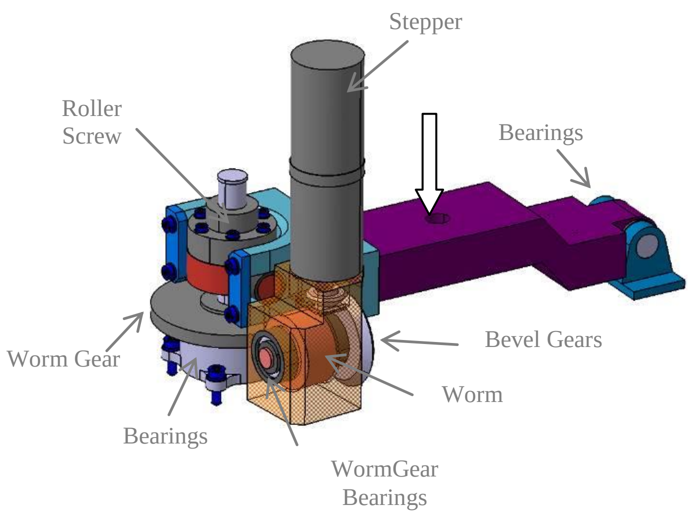


Figure 4.- Stepper+Gears +Lateral Roller Screw

Finally, due to the high reduction ratios in the power transmitting elements, the preload duration resulted inadmissible. Apart from this, because of the high loads on resistive components, the motor size could not be reduced since the friction component was very high with respect the useful one for preload, being a poorly efficient mechanism.

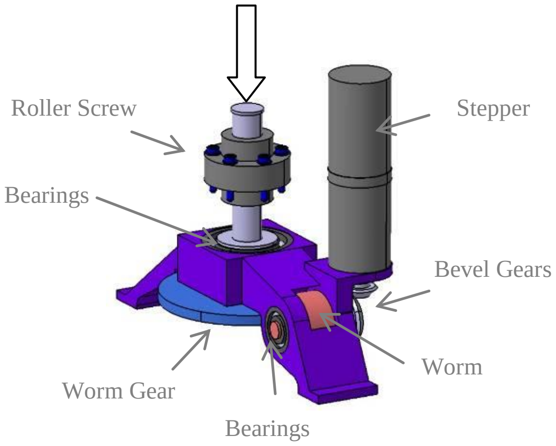


Figure 5.- Stepper+Gears +Centered Roller Screw

3.3 Stepper + Cam + Linkage

With the same aim of increasing the mechanical advantage of the mechanism and getting back to the baseline of using a cam, it was included a quadrilateral linkage. Two different arrangements of the linkage bars were studied, as show in Fig.6.

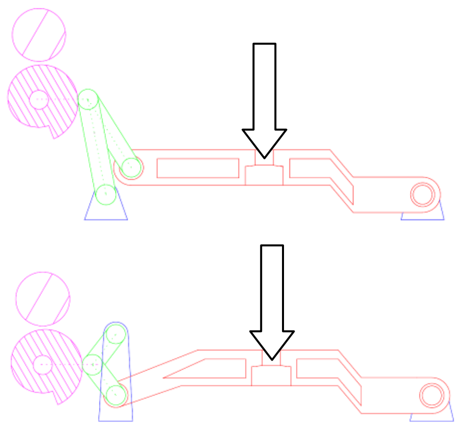


Figure 6.- Stepper+ Cam +Linkage

The resulted mechanisms were quite effective; however, it was impossible to fit the system inside the provided enveloped.

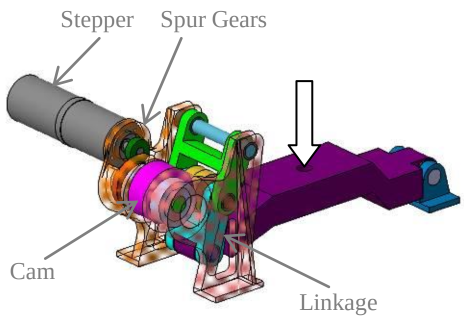


Figure 7. - Stepper+ Cam +Linkage detail

3.4 Stepper + Spindle + Linkage

To make possible the arrangement of all elements inside the provided space, the cam was replaced by a spindle actuated directly by means of the stepper.

Thanks to the reduction ratio in the spindle nut, the required torque was decreased and consequently the motor size, resulting in the most efficient power/weight system.

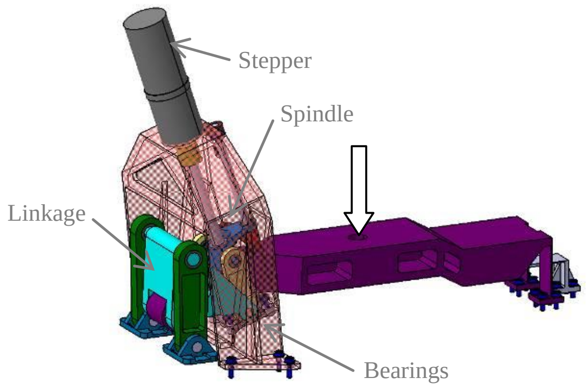


Figure 8.- Final configuration

The main disadvantage of the solution was the preload duration, as the admissible stepping rate limited the actuation speed. The detail description of this solution will be described in next chapter.

Tab.1 shows a summary of the studied configurations, as well as their principal design parameters.

Table 1.-Trade Off Summary

	Mass [kg]	Motoreducer Torque [Nm]	Preload duration [min]
Gears+Cam	4.4	9.2	2.4
Gears+Roller Screw	4.1	6.8	160
Cam+Linkage	3.5	6.2	2.5
Spindle+Linkage	2.9	2.4	60

4. FINAL DESIGN DESCRIPTION

The final Launch Locking Device (LLD) design is based on a simple four-bar linkage mechanism moved by a spindle nut system, which is actuated by a stepper motor with a planetary gearhead. The linkage pushes an arm that preloads the mirror to lock both N/S and E/W rotating axis.

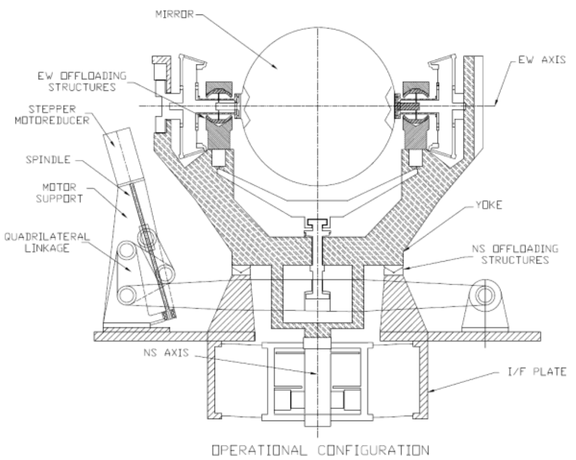


Figure 9.- Final design concept

Fiberslip bushings have been included in the linkage beams joints. To support the spindle, the system includes a pair of superduplex angular contact ball bearings in a face to face configuration.. To reduce the induced forces in the actuator, a flexible coupling has been included, made of flexible blades that only transmit torque.

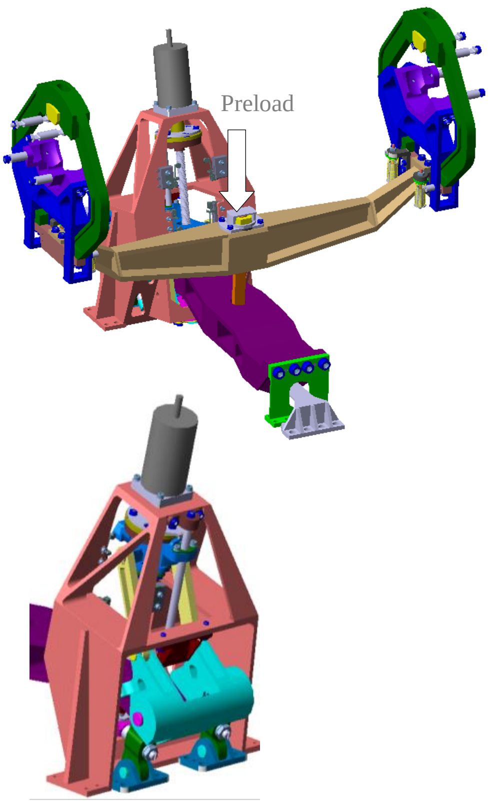


Figure 10.- Final configuration Assembly

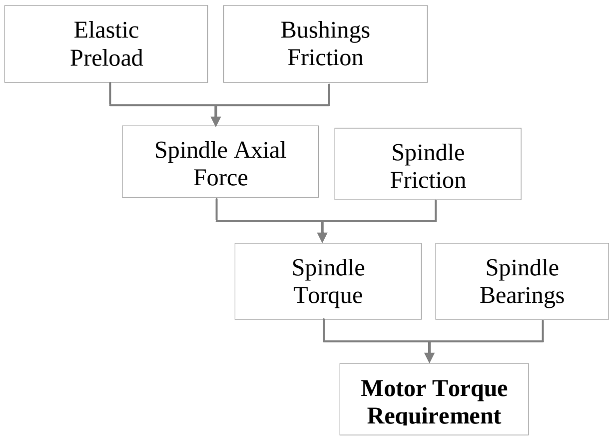
In the offloading structures, dissimilar materials have been used as 15-5PH steel and Ti6Al4V coated with Balinit©. The contact surfaces geometry consists in torus – torus profiles for the EW offloading structures and, Cone- Sphere for the NS ones.

The locking status is kept without motor supply thanks to the overcentre position of the linkage, where the locked position is defined by the overcentre configuration of the linkage. Apart from this, the spindle screw profile together with the nut friction coefficient leads to an irreversible system by design. To release both axes, the actuator must be actuated in reverse direction, so the spindle rotates in the opposite direction, moving the linkage from the overcentre status.

The locking/unlocking status of the system will be detected by microswitches located at the extreme positions of the nut.

5. TORQUE REQUIREMENT CALCULATION

To estimate the required torque of the stepper motor, the different components to be considered are the following:



According to the previous diagram, to obtain the motor torque requirement, the next procedure is to be followed:

1. Obtain the force to be provided by the spindle to the linkage to preload the system (elastic) and to overcome the internal frictions (bushings).
2. Transform the force to torque in the spindle taking into account the efficiency of the spindle.
3. Include the friction of the spindle bearings.

Note that to apply the corresponding ECSS uncertainty factors, two different situations have to be considered:

- When locking the system, the spindle has to provide the force to the linkage to preload the system.
- When unlocking, the spindle has to retain the force of the linkage, seen as a compressed spring, to get the unlocking of the system in a controlled way. Note that the frictions will help to retain the elastic force.

Different approaches were performed for the calculation of the motor torque requirement. As a result, two different behaviours of the mechanism were obtained:

- **Motor working as a brake**

The motor has to actuate as a brake when unlocking the system, due to the fact that the elastic force at linkage level is higher than the friction component. In this situation, to be conservative, the elastic component is increased by the spring factor, whereas the friction in all elements of the power chain is excluded.

- **Motor working as an actuator**

This happens at the initial steps of the unlocking and during the preloading for locking. In this situation the motor has to pull from the system.

In this case, as the elastic force is a resistive actuating against the mechanism, uncertainty factors for both elastic resistive torques and friction resistive torques have to be considered. Finally, the resultant torque has to be factorised by the required motorization margin.

6. TESTING

A demonstration model (DM) of the LLD was built to validate the design and to get feedback for further design of the STM unit. The stepper motor was not in the scope of the verification; therefore, during some tests it was replaced by a handle, to provide the required torque manually.

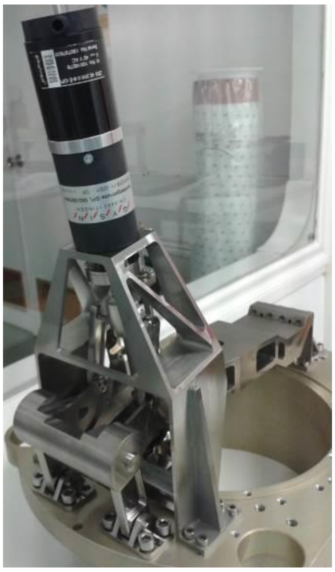


Figure 11.- LLD Demonstration Model

6.1 Locking / Unlocking Test

Fig.12 shows the test setup for locking/unlocking test. A dummy to represent the stiffness of the SCAU was used. The torque was provided by means of a handle, and it was registered by means of a multiturn torquimeter. The preload provided to the system was measured by means of a load cell.

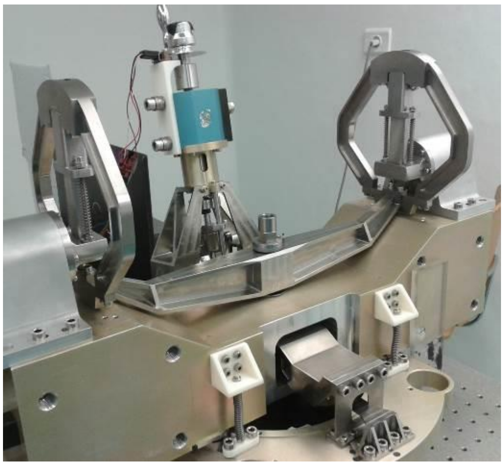


Figure 12.- LLD Test Setup

Fig.13 shows some of the test results obtained which represents the required locking and unlocking torque as a function of the spindle turns.

In all cases, the required torque to move the system was a torque that had to be provided by the handle to move the mechanism; in other words, it was demonstrated the irreversibility of the mechanism in all positions.

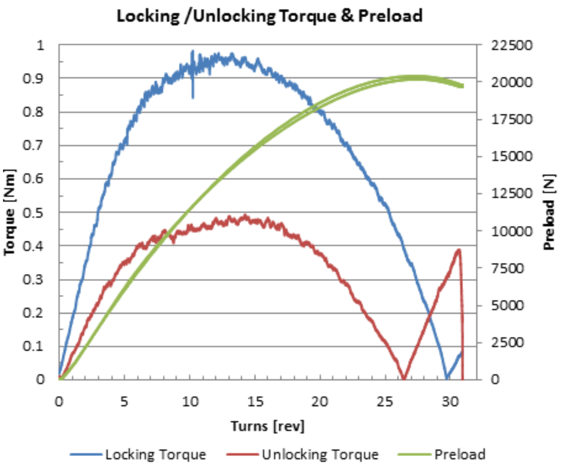


Figure 13.- Test Results

6.2 Results and analysis correlation

Test results are compared with predicted theoretical values, Fig.14 shows the comparison for the locking operations and Fig.15 for the unlocking. In order to compare the measured values to the predictions, it will be assumed in the calculation that all uncertainty margins are equal to 1, as well as the motorization margin. In this way, the results will be directly comparable.

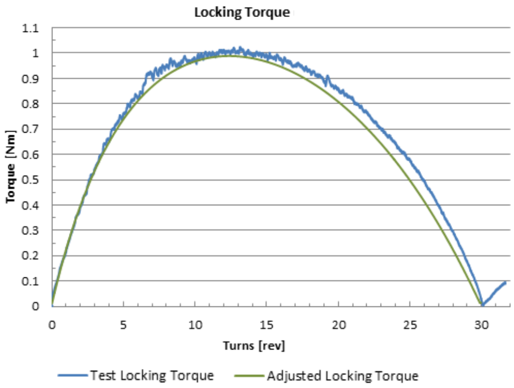


Figure 14.- Locking Torque Adjustment

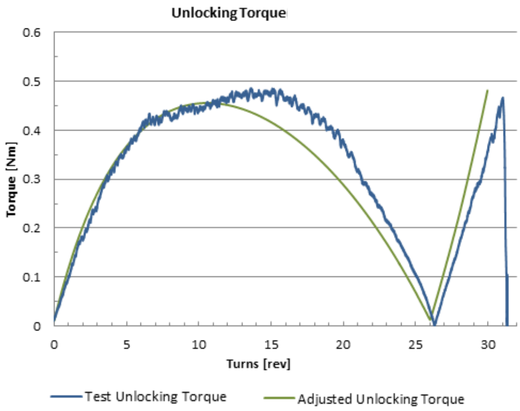


Figure 15.- Unlocking Torque Adjustment

6.3 Torque Contributors

In order to obtain the contribution of the elastic component and the friction effects in the required torque separately, the system was totally preload and right after unloaded until its initial configuration. The elastic contribution to the torque was obtained from the difference between the measured locking torque at a specific preload and the measured unlocking torque at the same level of preload.

Fig.16 shows the torque measured as a function of the spindle turns. Negative or positive sign in the measured torque is due to the direction of the torque in the torquemeter but, in all cases, it was a torque provided by the handle.

Note that when the system is being preloaded “locking”, the force in the spindle due to the elastic component of the linkage and the friction one actuate in the same direction, whereas during unlocking, before reaching the overcentre position, it is in the opposite. However, due to the irreversibility characteristic of the design, it is always necessary to provide torque to the system to move it.

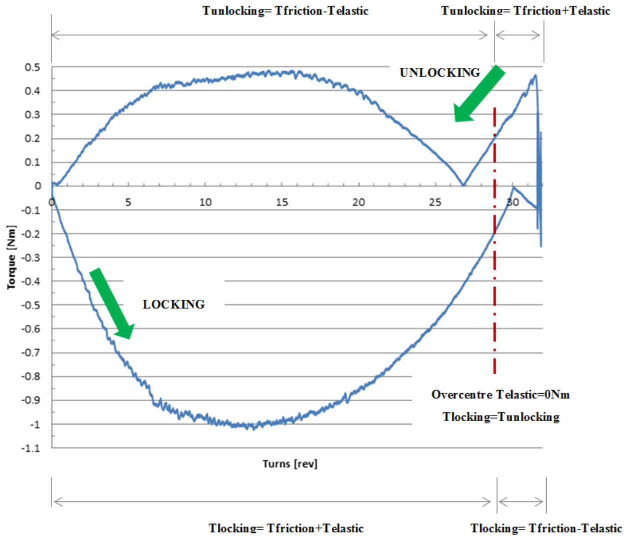


Figure 16.- Torque Contributors

6.4 ECSS Factors Application

After measurements of the resistance torque sources we were able to properly applied the uncertainty factors and after the torque margin.

Fig.17 shows the motor torque requirement along the movement of the mechanism for both operations locking and unlocking.

When the elastic effect helps to move the system, it was considered as a spring actuator; therefore, the factor applied was 0.8. In the rest of situations, the elastic factor considered was 1.2.

In addition to uncertainty factors, the motorization margin has been also considered. For locking, as it is an operation performed on ground, a margin of 1.5 has been applied. However, for unlocking, the margin applied is 2 as defined by ECSS.

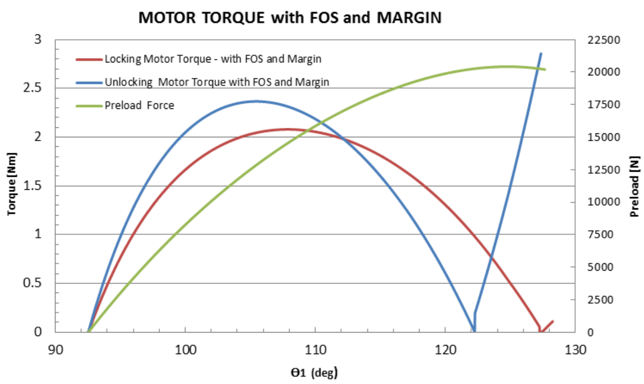


Figure 17.- Motor Torque with ECSS factors

7. CONCLUSIONS

This paper provides an overview of some of the Launch Locking Device developed for MTG SCAU IRS and FCI instruments. The final design achieved the targeted requirements except for the preload duration that is longer than required.

During the Locking/Unlocking tests on the LLD DM, the elastic and the friction components of the resistive torque have been obtained. Theoretical predictions have been correlated with test results, being possible to apply the corresponding uncertainty factors defined by ECSS depending on the nature of the load.

8. ACKNOWLEDGEMENTS

The authors would like to sincerely thank the many individuals whom were key to the success of the MTG LLD final design: Christian Koerner from OHB with the collaboration of Martin Humphries for their involvement in the proposal of different options and determination for improvement and Manfred Falkner and Hans-Jurgen Luhmann from ESA for their assistance in the development of the different designs.