A Strain Free Lock and Release Mechanism for an Elastically Suspended Two-Axis Gimbal

Armond Asadurian
Moog Inc., Chatsworth Operations, 21339 Nordhoff Street, Chatsworth, CA 91311
Tel: 001-818-341-5156
Fax: 001-818-341-3884
Email: aasadurian@sch.moog.com

Abstract

A single-point-actuated, multi degree-of-freedom restraining launch latch mechanism was developed for a two-degree of freedom tilt table antenna gimbal. The design of the launch latch protects the gimbal pivots and actuators through launch vibration, and precludes any high forces on sensitive gimbal components as a result of operation of the latch mechanism itself. At the same time, stringent requirements on stiffness for the latched gimbal and payload are met.

The launch latch design was carried through to qualification largely as initially conceived; however, detail design changes and improvements were made during development as a result of prototyping and development testing.

Introduction

Both the structure and the actuation paths of efficiently designed spaceflight mechanisms are typically not sized to carry the inertial loads generated by launch vibration acting on the mechanism payload. When this is the case, additional structural load paths are required during the launch phase. Subsequently, the structure so introduced must be removable on command to allow normal on-orbit operation of the mechanism.

Mechanism payloads typically are articulated in one or two degrees of freedom (although there can be more), and constrained otherwise by the mechanism joints. If the mechanism power sources are capable of position holding in the launch phase, usually power off, then the phase of the mechanism is nominally fixed. The launch lock device then must support that mechanism configuration with parallel load paths, which are adequately sized for launch loads; so that no damage or degradation of the structure, links, or bearings occurs during launch.

Addition of redundant parallel load paths to a completed mechanism creates concern that local overloading of mechanism elements by the simple act of engaging the locking device could occur. This is a primary design driver for the locking device itself. Stiffness parameters of the locking device elements must be tailored in such a way as to avoid high loads in cross-axis directions when the lock is engaged.

Functionally, launch latches vary from a simple single degree of freedom constraint (e.g. pin joint), to more complex multiple degree of freedom restraints, depending on payload size and mass and other requirements. The subject of this paper is a clamping-type launch latch, which fully restrains the payload.

Launch Latch Requirements

The gimbal actuators control the output platform angular orientation actively in the power-on condition and maintain it passively in the power-off condition. However, in the launch phase of the mission, both stiffness and load carrying capability must be enhanced in all six degrees of freedom. For this application, a launch latch has been designed integral to the main gimbal pivot.

The specific design requirements for the launch latch are as follows.

Stiffness: ~50% increase in gimbal natural frequency over unlocked configuration.
Interface Parallelism: ±TBD° between mounting I/F plate and payload I/F plate
Life: 1 on-orbit unlatch + 50 latch/unlatch cycles during pre-flight testing
Reliability: Single fault tolerant electrical operation
Status Indication: Position sensing must provide feedback for latched/un-latched mechanism status.
Environment: 1200g shock, 30g sine vibration, 26grms random vibration
Operations: Mechanism must be re-settable with a quantifiably controlled preload

Launch Latch Design

The Antenna Pointing Mechanism (APM) two-axis gimbal is a tilt-table gimbal operable in two degrees of freedom. It consists of an output platform mounted on a center pivot, tilted in two axes by orthogonal linear actuators articulated between the output platform and a similarly shaped base plate which mounts the assembly to the spacecraft. The center pivot is a two degree-of-freedom assembly of elastic flex pivots configured as a Cardan joint. Angular range of the elastic flex pivots is sufficient to support the gimbal motion. The gimbal is designed to minimize required envelope, which results in a derived requirement for compact design of the latch mechanism to fit in the available space between the center pivot assembly and the two linear actuators. The requirement for pre-launch access to reset the mechanism results in challenging ergonomic and for packaging the constraints. (See Figure 1)

The launch latch mechanism is designed to rigidize and strengthen the center pivot of the tilt table gimbal. Its function is to tie the gimbal output platform directly to fixed structure through four spring beam members arrayed in a circular pattern surrounding the center pivot. The stiffness of the launch latch members protects the center pivot, and the combination of the center pivot suspension and the launch latch is sufficiently stiff to prevent damaging loads from being transferred to the linear actuators. (See Figure 2)

The operational range of the gimbal is from 3 to 5 deg of tilt on each axis. Therefore, displacement of the gimbal output plate is relatively small near the pivot. The launch latch mechanism is located near the pivot, so that the motion of the restraining members upon release can be small, while accommodating the operational envelope of the gimbal output plate.

The potential for overstressing of the elastic suspension members of the center pivot exists. Avoiding this potential problem is a key issue addressed in the design of the launch latch. Four pins on the underside of the gimbal top platform are engaged by spring beam members when the launch latch is engaged. The spring beam members move radially outward to engage the pins, generating a symmetrical set of radial forces which have no net resultant force on the center pivot assembly. A rotating ring guided by the center pivot assembly Rotation of the ring produces two orthogonal sets of equal opposing forces, and no net lateral reaction on the center pivot. (See Figure 3)

Engagement of the rotating ring member with the pins and beams is a manual function. Rotation of the ring moves its rollers into contact with the ramp faces of the spring beams, moving the beams outward by cam action. The outer faces of the spring beams contact the locking pins, and the spring beams are captured and compressed between the rollers and the locking pins. When all parts are fully engaged, the ring is secured by a latch mechanism, which holds it in position. The gimbal then stays in the latched configuration until the ring is released by an Unlatch command. The Unlatch command extends the plunger of a hot wax actuator, releasing the ring latch and freeing the gimbal.

Latched Position

The ring, the member designed for manual rotation to the latched position, is equipped with four roller assemblies. Each roller assembly is positioned to engage an adjacent spring member and locking pin. As the ring is manually rotated, the roller assemblies simultaneously contact the spring beams and deflect them outward toward the locking pins. Once contact is made between the spring beam and the locking pin, an integral spring establishes the desired preload in the joint. The ring continues to rotate until its arm engages a locking pawl, which latches it in the launch latched position. (See Figure 3)

Preload Latching Point

The deflection of the preload spring feature is limited to prevent oscillation of the spring under vibration. The preload spring bottoms on a stop, with its further deflection due to higher loads (higher than the preload) prevented. The stop is formed by an adjustable set screw in one arm of the spring member.

The latched position and the preloads on the locking pins are established when the arm on the rotating ring engages the locking pawl. The locking pawl rotates on a fixed pivot. Its engagement with the arm on the locking ring is so configured that the line of action of the contact force passes through the pawl pivot, and no component of that force tends to unlatch the pawl. The mechanism is self-locking until released by the Unlatch command. (See Figure 4)

Unlatched Position

Unlatching occurs when the hot wax motor output is extended on command. The force exerted on the pawl by the actuator rotates the pawl out of the latched position. The torque exerted is adequate to overcome the contact friction between the pawl and the locking ring arm and releases the pawl from the ring. The torque component of the roller-to-spring beam preload forces causes the ring to rotate out of the latched position, and the ring then rotates back to its original unlatched position. (See Figure 5)

Trigger Mechanism

The launch latch assembly is accessible from one side of the gimbal (Fig.1). The arm on the locking ring is oriented for access from the side, and is configured with a threaded receptacle. Resetting is accomplished by installing a resetting tool in the receptacle and rotating the ring to the latched position.

The trigger mechanism consists of the wax actuator, the locking pawl, and the latch arm (integral with the rotating ring). A manual input force is exerted on the latch to rotate the ring, allowing the locking pawl to engage the latch and prevent rotation of the ring. The locking arm pawl engagement is maintained by the preload applied at the contact point between the locking pawl and the ring. This preload is due to the lateral components of the forces at the spring beam-to-roller contacts, and the resulting torque on the ring. A torsional spring is used to return the pawl to its latched position, regardless of the orientation of the ring. Release of the latch is initiated by applying power to the wax actuator. The actuator output rod extends, contacting the locking pawl as shown in the figure below, and inducing a torque on the locking pawl to release it from the latch arm. With the locking pawl rotated away from the latch arm, the ring is free to rotate and relieve the preload on the locking pins. (See Figure 5 & 6)

Development and Testing

Development test hardware was constructed to prove out the launch latch design. The test hardware was designed to simulate the main gimbal pivot and the launch latch mechanism. On one gimbal axis, a previously built linear actuator was used to simulate the mass and CG location of the flight actuator, for accurate system dynamic simulation and also for the capability of tilting the platform on that axis in subsequent testing. An articulated dummy link, again simulating the mass and CG location of the flight actuator, was used in the orthogonal location of the second actuator. The launch lock mechanism moving parts were free of any wet lubricant, to prevent contamination of the payload, and sliding surfaces were coated with Tiolube 1175 dry lubricant. Dicronite dry lubricant was used in the rollers for the launch latch to reduce sliding friction in the mechanism during engagement. The payload mass and center of gravity location were simulated by tooling as shown in the figure to provide a valid configuration for dynamic testing (i.e. shock, random vibration, and sine vibration). (See Figure 7)

Lessons Learned

Lessons learned in the development of the launch latch mechanism involved issues of materials compatibility, linkage design, optimization, ergonomics, and structured optimization. The resulting design changes were incorporated in the development test unit. (See Figure 8)

Material and Surface Compatibility.
The launch latch design is not friction-based, and sliding contact of heavily loaded members is generally avoided. However, some sliding contact does occur. Titanium is used as the basic material in the latch mechanism, chosen for its low weight and high stiffness. The surface properties of titanium are not ideal for highly stressed or sliding contacts, and therefore surface modification through anodic coatings and lubricant films was pursued. Tiodize surface conversion treatment and Tiolube lubricant films were used. The highest contact forces occur between the spring beam and the locking pin and between the roller and the spring beam. With the original untreated parts, some galling was observed at these interfaces. After the surface treatment of the titanium spring beam and roller, no further galling occurred.

Latch Design:
A perceived problem with the locking ring arose during development testing. Although the locking ring is loosely suspended on the center pivot base, and the bearing surfaces are dry film-lubricated, the simple large size of the bearing led to the concern that the locking ring might be prevented by friction from reaching its full unlatched position. This possibility was addressed both by the application of dry film lubrication to the locking ring bearings surfaces, and to the addition of a secondary cam surface to the pivoting latch pawl. After triggering of the unlatching function- and after the high force demand on the hot wax actuator- continued travel of the pivoting pawl engages the cam surface with a mating follower ramp on the arm of the locking ring, insuring its full travel.

Latch/Reset Force:
During development testing, the force required to reset the latch mechanism was found to be undesirably high from the standpoint of operator ergonomics. Operator effort was reduced, and adequate latched stiffness preserved, by modifying the width and thickness of the spring beam members.

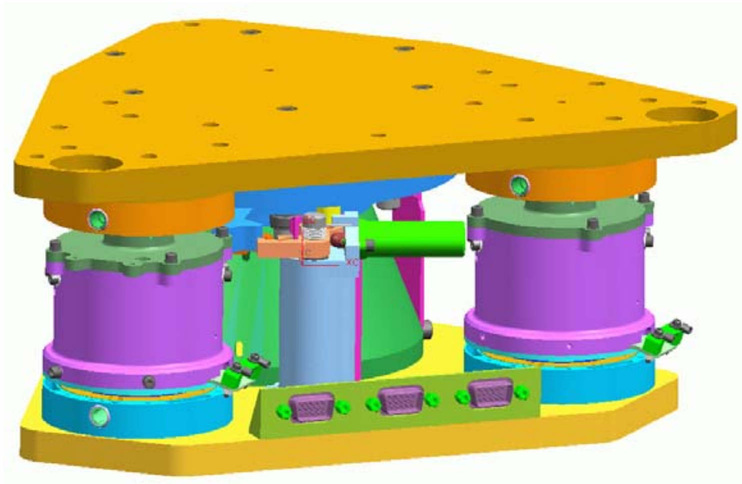
Upper Plate Deformation:
Bending of the upper plate, or output member, of the gimbal was observed in testing, as a result of the high forces applied to the locking pins by the latch mechanism. Design changes to the plate were made to

increase stiffness at the locking pin mounting points, and this change eliminated plate bending as a problem.

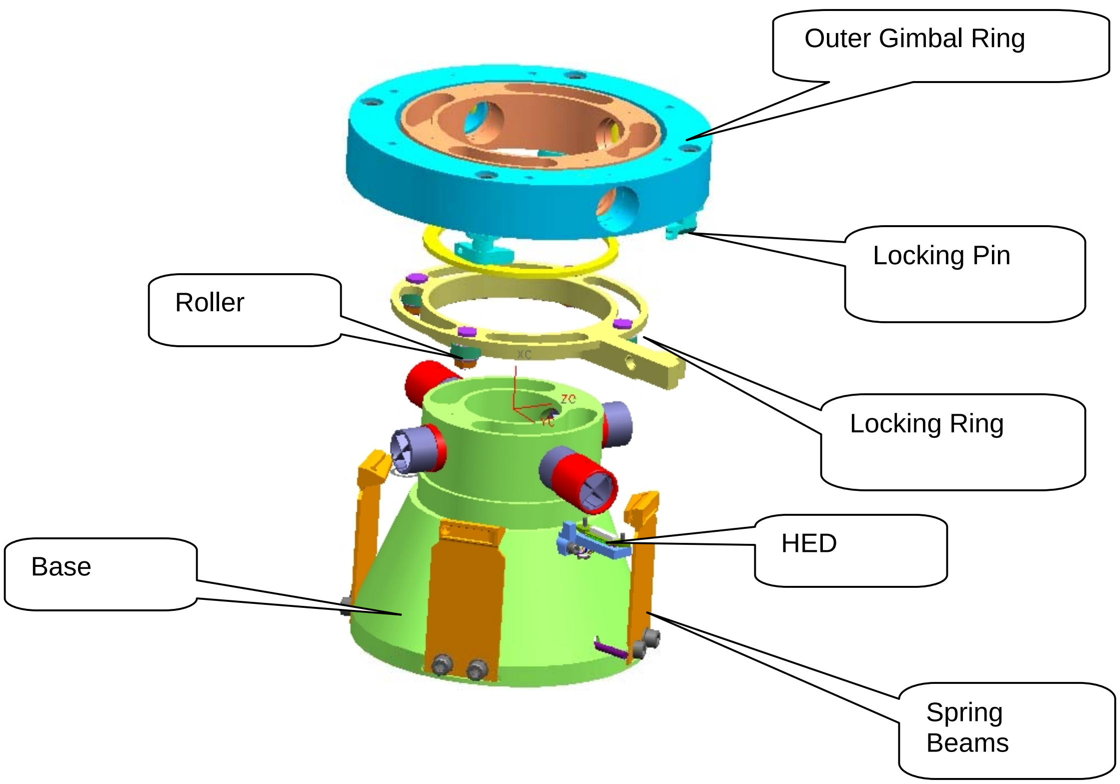
Latch Point Engagement:
Because of manufacturing tolerances and the curved motion of the spring beams, some dimensional allowance must be made at the beam-to-latch pin contact point. In the initial design, the allowance was generous, and the holding ability of the latch in the Z direction was augmented by frictional forces. In fact, mating surfaces were textured by grit blasting in order to enhance friction. It was found in testing that texturing actually aggravated galling of the mating surfaces, and that design feature was deleted. Smooth surfaces were used instead, with surface treatment for hardening. Tolerances were tightened, and it was then possible to reduce the dimension of the pocket in the spring beam in which the locking pin seats. The upper and lower shoulders of the pocket offer positive restraint of the locking pin which is not dependent on friction.

Conclusion

It was found possible to design an effective gimbal launch latch for a very restricted space. Rather than maximizing the radius of action or the length of the lever arms from the gimbal articulation point to the points of fixity, the arm were kept tot a minimum. The restraints, rather than being simple point restraints, are multi-axis lengths clamp points with a higher degree of restraint. The possibility of generating high loads and overstressing the protected structure is avoided by design of the clamping mechanism to accommodate the strength and stiffness properties of the gimbal. A single release point for the multi-point latch mechanism maximizes simplicity and reliability, and also meets operational access and ergonomics criteria. The concept has growth potential to cover larger diameters and heavier payloads.



Antenna Pointing Mechanism
Figure 1



Exploded View of Gimbal and Launch Latch
Figure 2

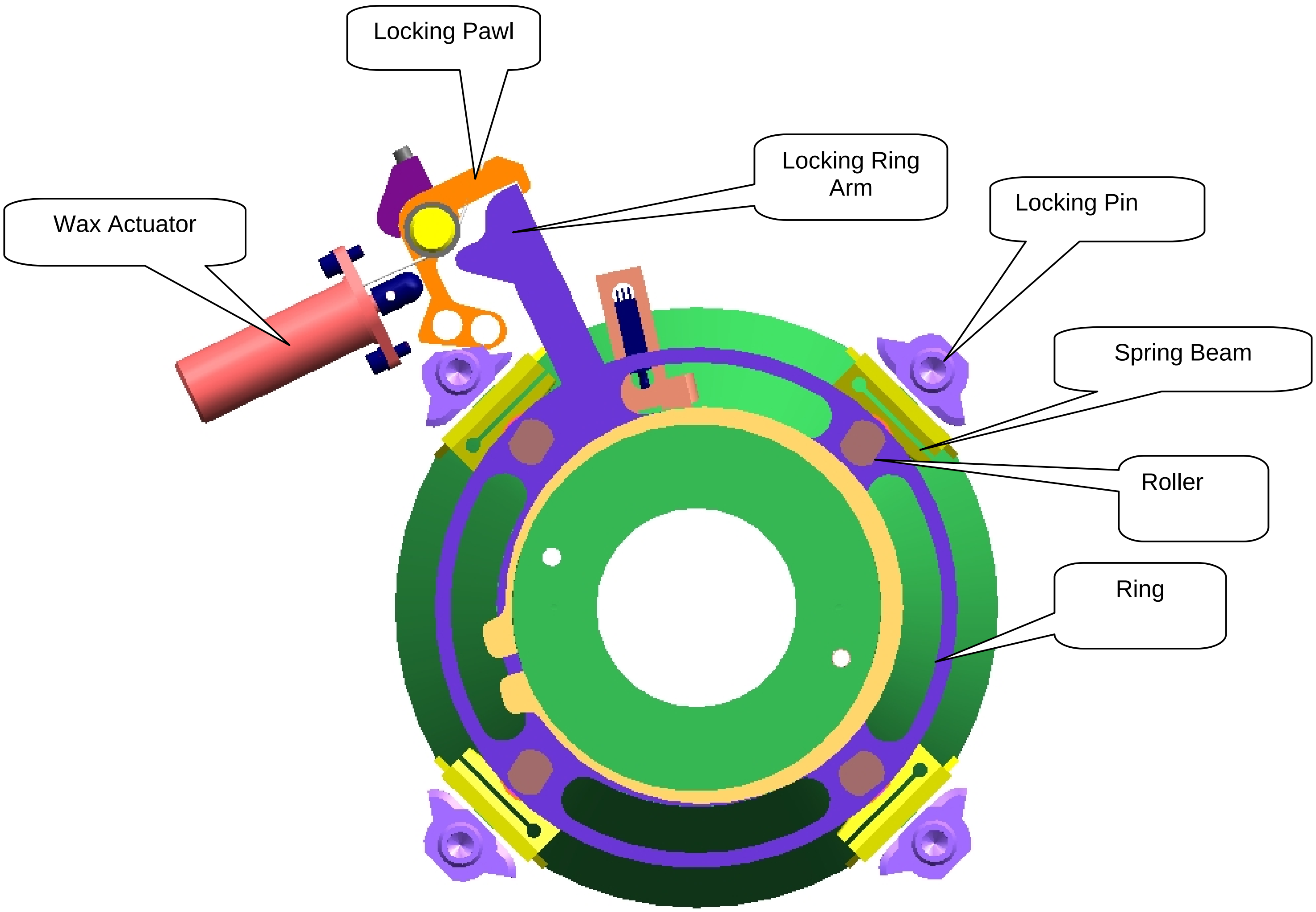

Locking Pawl
Locking Ring
Arm
Wax Actuator
Locking Pin
Spring Beam
Roller
Ring

Figure 3

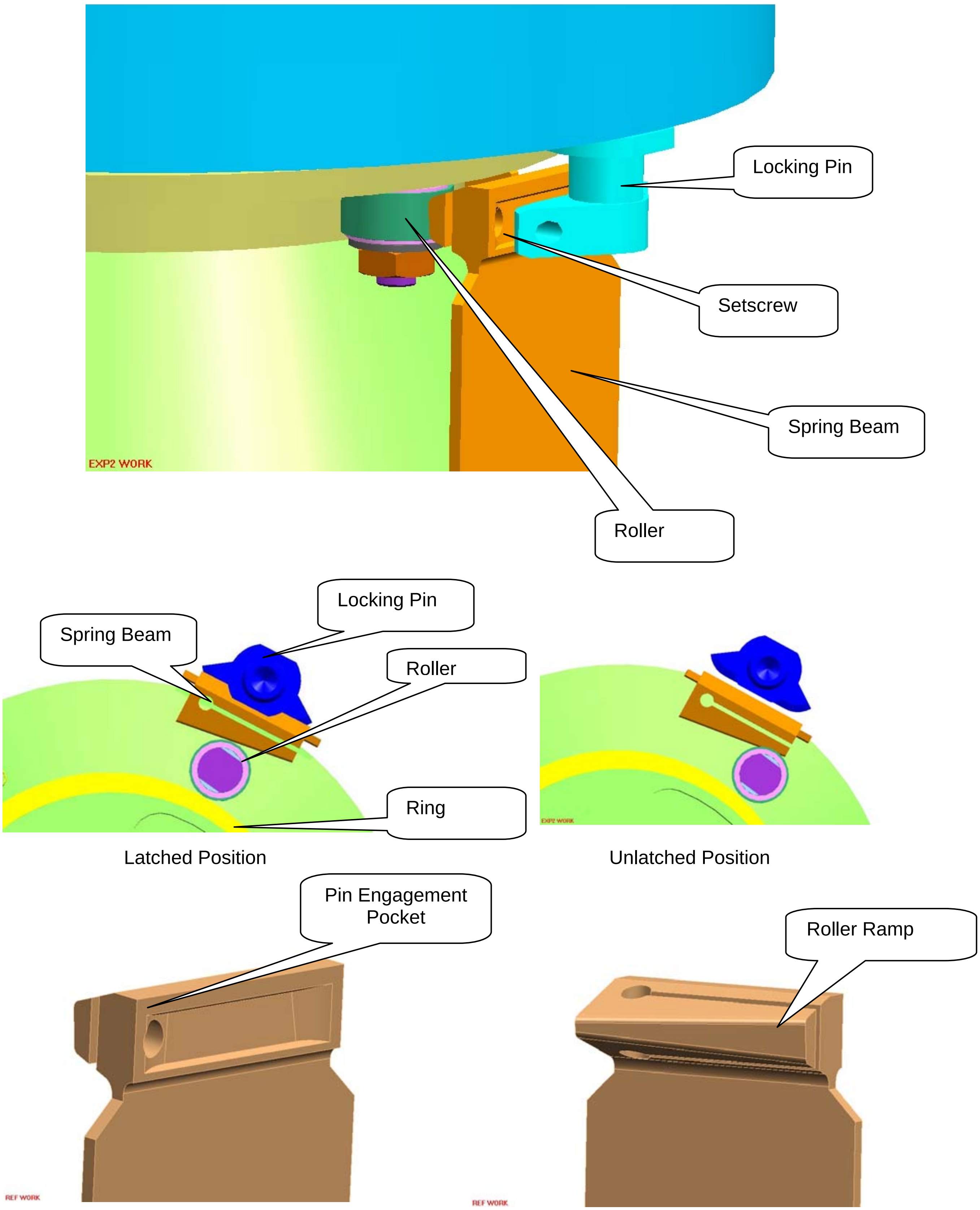

Locking Pin
Setscrew
Spring Beam
Roller
EXP2 WORK
Spring Beam
Locking Pin
Roller
Ring
Latched Position
Unlatched Position
Pin Engagement Pocket
Roller Ramp

Figure 4

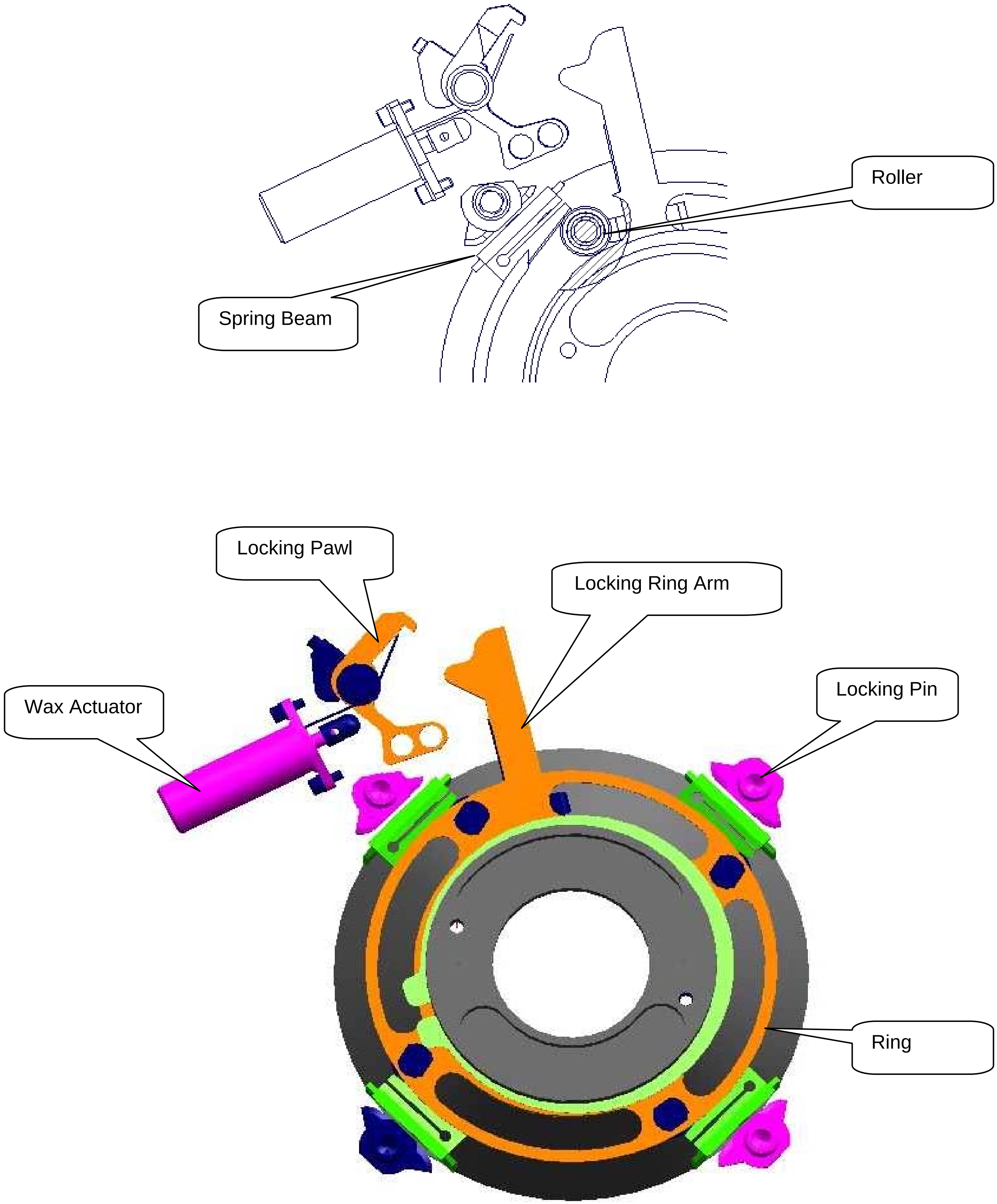
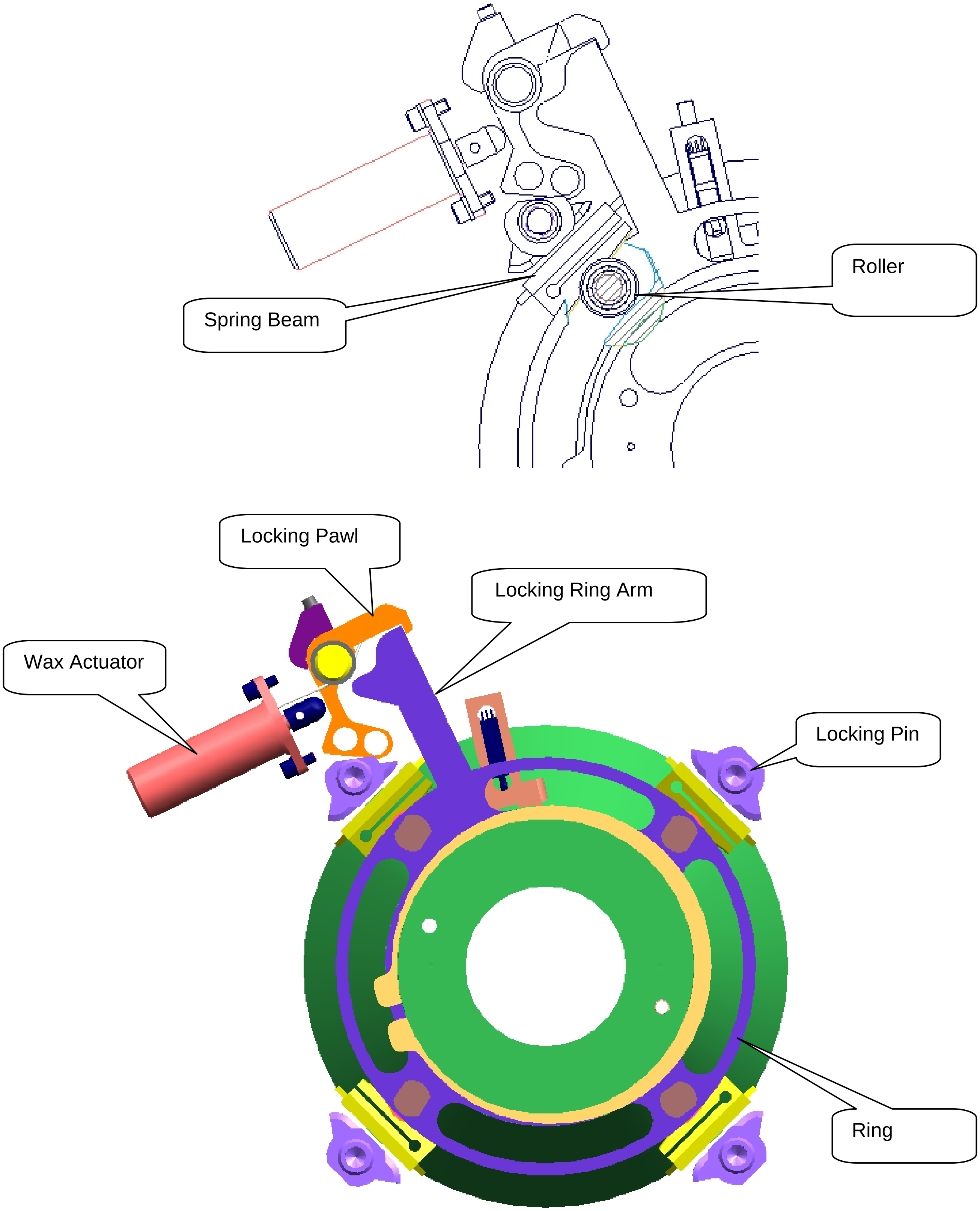

Roller
Spring Beam
Locking Pawl
Locking Ring Arm
Wax Actuator
Locking Pin
Ring

Figure 5



Roller
Spring Beam
Locking Pawl
Locking Ring Arm
Wax Actuator
Locking Pin
Ring

Figure 6

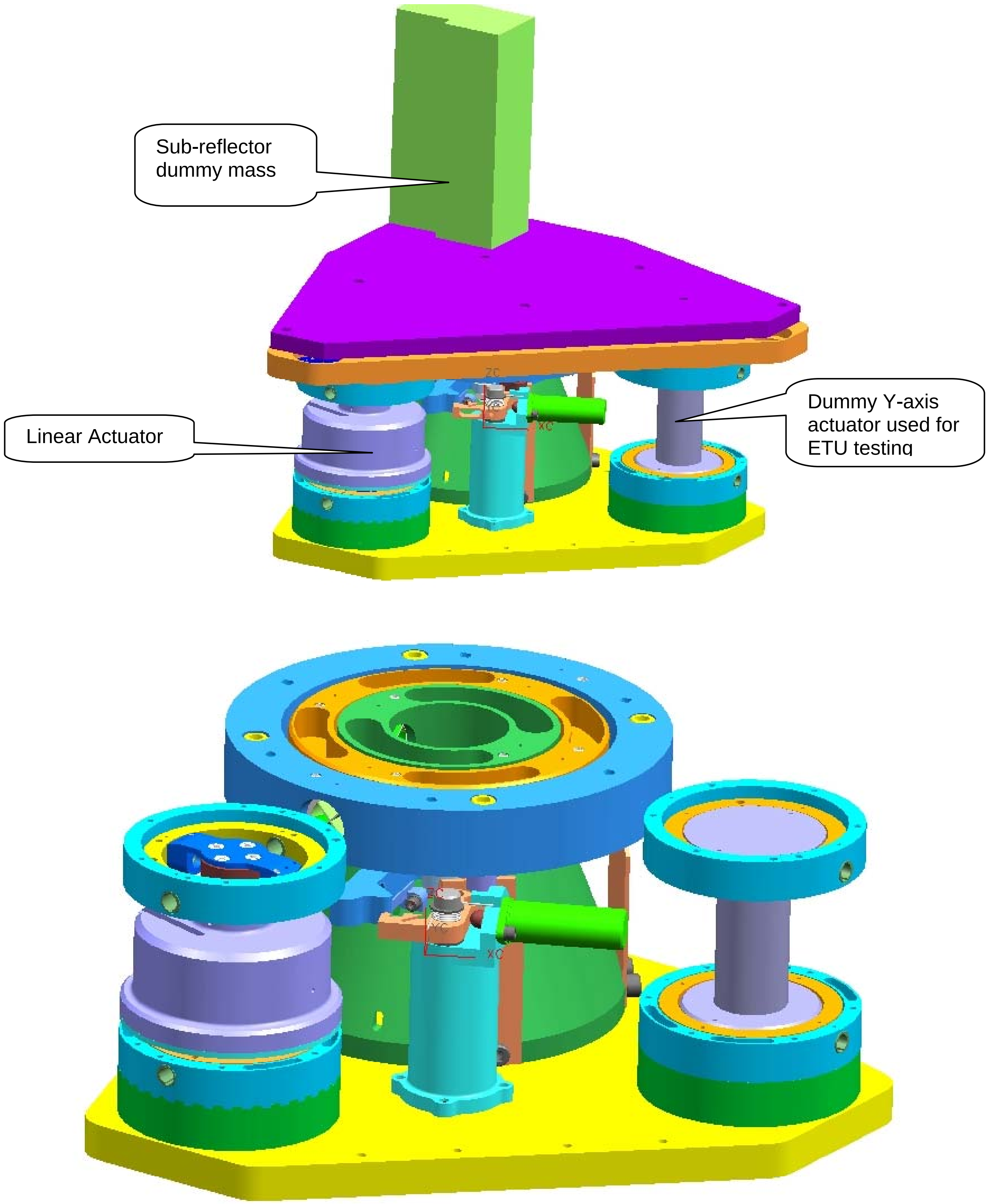

Sub-reflector dummy mass
Linear Actuator
Dummy Y-axis actuator used for ETU testing

Figure 7

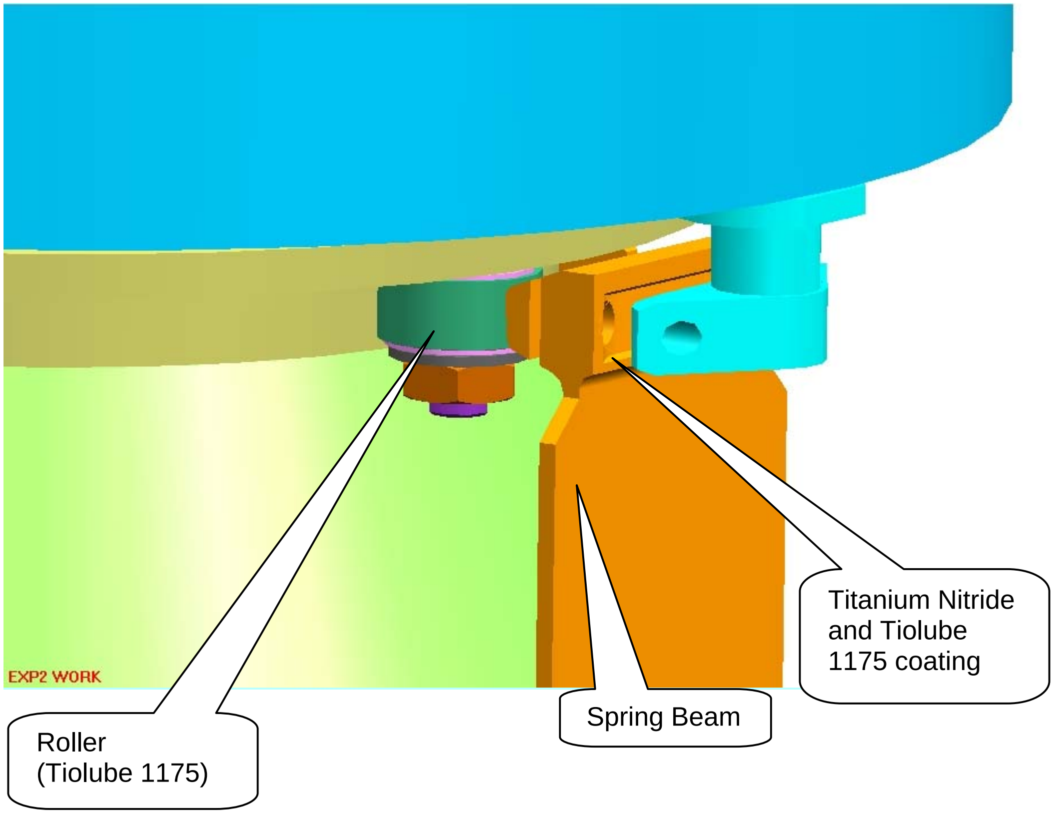

EXP2 WORK
Titanium Nitride and Tiolube 1175 coating
Spring Beam
Roller (Tiolube 1175)

Figure 8