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Analysis and test of a critical mechanism for the LISA mission

LISA Pathfinder (LPF) is an ESA mission which served as technology precursor for the first space-based gravitational waves detector, named LISA (Laser Interferometer Space Antenna). The scientific payload of LPF includes two Gravitational Reference Systems (GRS), each one containing the free-falling cubic test mass (TM) that constitutes the sensing body for the interferometric measurement. After commissioning, to start the science phase the TM is released into a geodesic by the Grabbing, Positioning and Release Mechanism (GPRM). The GPRM is composed of two similar halves, each one containing a cylindrical end effector, named plunger, which is moved along its longitudinal axis with a piezo-walk actuator. The plungers engage two indents machined on two opposite faces of the TM. A gold tip, coaxial to each plunger, is moved by a voltage-controlled piezo-stack actuator. When the voltage is applied, the tip protrudes from the plunger head engaging the TM. When the voltage is shorted, the tip is retracted by a pre-loaded discs spring injecting the TM into a free-fall state.

The TM release in LPF showed some anomalies, producing a release dynamics different from the nominal one. Therefore, part of the extended mission phase was dedicated to understanding the release and find risk-reduction strategies in view of LISA. Following analyses demonstrated that the anomalies could be explained by undesired interactions between the TM and the GRPM end effectors, causing excessive and non-compliant TM linear and angular velocity components at the release.

At the University of Trento an experimental setup is used to perform on-ground testing of the release procedure with the LPF Engineering Qualifying Model of the GPRM. By subtracting the effect of the undesired interactions from the in-flight data, it is shown that the on-ground tests correctly estimate the TM state in the absence of the anomalous TM-end effectors interactions. This information is used in a preliminary TM velocity budget after injection, focusing on the time lag admissible for the retraction of the release tips.

In this scenario, possible improvements regarding the increase of the nominal gap between the plungers and the TM at release and the reduction of the unwanted lateral motion of the GPRM are studied with a Breadboard Model tested at the University of Trento. These activities are part of the GPRM delta-development for LISA.

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