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Design and testing of an improved LISA grabbing, positioning and release mechanism

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LISA will be the first gravitational waves observer in space, consisting of three spacecraft in a triangular formation trailing the Earth along its orbit. Within each spacecraft, two gravitational reference sensors (GRSs) enclose cubic test masses (TMs), which are free-falling during the science phase. Besides providing a safe environment for the TM, shielding it from non-gravitational forces, the GRS includes the mechatronic system responsible for the TM handling during non-science phases.
The grabbing, positioning, and release mechanism (GPRM) is responsible for the TM injection into its geodesic trajectory, which is pivotal for the start of the science phase. It is composed of two symmetric units located at two opposite sides of the GRS, actuating two cylindrical-shaped end effectors (fingers) designed to grab and center the TM inside its housing. Starting from the grabbed configuration, in which the two fingers hold the TM, two small tips, coaxial to the fingers, are extended towards the TM, while the fingers are retracted, maintaining an ideally constant preload on the TM. Thanks to this procedure, called handover, the TM is held by the GPRM tips with a reduced contact area and holding force prior to the release. The TM release to the geodesic trajectory is performed by means of a simultaneous and rapid retraction of the two tips, followed by the retraction of the fingers.
The GPRM flown in LISA Pathfinder (LPF) showed an unexpected performance, consisting in a large TM velocity, non-compliant with the requirements. Analyzing the LPF telemetry data, the most consolidated hypothesis for the non-compliance of the mechanism is associated to unexpected impacts between the mechanism fingers and the TM at the release. Indeed, at the end of the handover, the nominal gap between the fingers and the TM is equal to 10 μm only. Moreover, alignment tolerances, mechanism vibrations and anomalous motion of the end effector easily reduce the available gap and dramatically increase the risk of impacts. An intense research activity is focused on the identification of the main parameters which concur in the gap erosion and on the exploration of possible strategies to mitigate the non-compliance.
Possible improvements of the GPRM for LISA are focused on increasing the nominal gap and on limiting the non-ideal motion of the fingers. As a first step in this direction, the improving strategies are embedded in a breadboard of the mechanism, which has been tested at the University of Trento. The results of the testing gave important guidelines to increase the mechanism performance in view of LISA.

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