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THE LISA DFACS: PRELIMINARY MODEL PREDICTIVE CONTROL DESIGN FOR THE TEST MASS RELEASE PHASE

Abstract

Purpose: This paper presents a preliminary control design for the test mass release phase of the LISA gravitational wave observatory mission. This activity was carried out under the Technology Development Element program of the European Space Agency. LISA consists of a constellation of three spacecraft carrying cubic test masses, whose relative position is measured by means of laser interferometers. In order to observe gravitational waves, the test masses must be left free-floating inside the spacecraft using a drag-free controller. However, when the spacecraft reaches its operational orbit, the test masses are initially locked with a mechanical system. Before entering science mode, the test masses must be released and controlled by an electrostatic suspension. Unfortunately, the mechanical system provides very high initial velocities to the test masses, as experienced in LISA Pathfinder mission. This is a critical problem for the electrostatic suspension, which provides only few nN/nNm of total force/torque, making the test mass capture a difficult task. Moreover, test masses should avoid hitting the cage walls for two main reasons: 1) the test mass polished surface could be scratched and science interferometry could be affected 2) when the test mass hits the cage electrode, a short circuit occurs and the electrostatic suspension is no longer able to measure the test mass states until there is no more electrical contact. During the TM release, the spacecraft attitude control shall keep a reference attitude and compensate for the solar pressure and the back-action of the internal electrostatic suspension.

Methodology: Model Predictive Control is a suitable control technique for the release control of the test masses, as it allows to provide optimal control inputs by solving a constrained optimization problem online. In our case, the cost function is to minimize the test mass states and the input effort in presence of constraints such as very low input saturations and geometrical bounds on the test mass states. First, the nonlinear model of the plant was obtained in order to set up a simulation environment. Then, the nonlinear model was linearized, obtaining the internal predictive model of the MPC. Finally, the MPC controller was designed and tuned in simulation.

Results: Preliminary simulation results are successful.

Conclusion: MPC proved to be a promising control technique for the test mass release phase of LISA and could be considered for the next phases of the LISA development program.