IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (2) (6)

Author: Prof. Carlo Novara
Politecnico di Torino, Italy

Mr. Luigi Colangelo
Politecnico di Torino, Italy
Mr. Simone Vidano
Politecnico di Torino, Italy
Prof. Enrico Canuto
Politecnico di Torino, Italy
Dr. Jonathan Grzymisch
European Space Agency (ESA-ESTEC), The Netherlands

LISA L3 GRAVITY WAVE OBSERVATORY: NON-LINEAR MODELLING AND POSSIBLE DFAC METHODS

Abstract

Recently, we witnessed the revolutionary discovery of gravitational waves (GW) by a ground-based laser interferometric observatory: a potentially game-changing observation tool in astronomy. Hence, the opportunity of setting up a space-based GW observatory, including their low-frequency spectrum not accessible from the ground, is gaining more and more support. In this framework, the Laser Interferometric Space Antenna (LISA) mission has been proposed within the European Space Agency selection of the L3 launch opportunity. Hence, LISA might be the first space mission scanning the sky to retrieve both polarisations of the GWs simultaneously, and to measure their source parameters; in a bandwidth spanning from 10^{-4} to 10^{-1} Hz. The latest LISA mission concept, nominally lasting 4 years in science mode, encompasses three identical satellites in a triangular constellation, in an Earth-trailing heliocentric orbit about 50 Mkm from the Earth, whose three arms, averagely long 2.5 Mkm, are endowed with six optical links for laser interferometry. This aims to measure, with pm accuracy, the distance variations among the free-flying test masses hosted in the three spacecraft. As a result, each spacecraft is drag-free and forced to follow its two test masses, along each of the two interferometric axes they define with the companion satellites. In this paper, we review the main system aspects of the LISA mission, including those successfully tested in LISA Pathfinder experiment. Further, an overall non-linear modelling of LISA mission dynamics is proposed to describe the several degrees of freedom, the different actuators and sensors, and the external and internal perturbations affecting the spacecraft free-falling motion. In turn, the resulting highly coupled MIMO system is analysed to derive linearizing and decoupling strategies simplifying the non-linear model and streamlining the control design process. Such a modelling phase will pave the way to the design of an innovative drag-free and attitude control (DFAC) for the LISA Science Mode. The control unit has been designed according to the Embedded Model Control methodology and is organized in a hierarchical way, ensuring frequency coordination among the loops. To this aim, the decoupled state equations are used to build the discrete-time Embedded Model. In turn, this Embedded Model is completed by a disturbance estimation dynamics, to bridge the gap between model and non-linear plant reality by adding an active disturbance rejection term to the control laws. Simulated results prove the DFAC concept validity, and show that the control performances are in agreement with the defined requirements.