Stabilisation of the triangular formation of the LISA satellites

J. Bik (1), P. Visser (1), O. Jennrich (2)

(1) Department of Earth Observation and Space Systems, Faculty of Aerospace Engineering, Delft University of Technology, the Netherlands (2) ESA/ESTEC, the Netherlands

The joint ESA-NASA mission Laser Interferometer Space Antenna (LISA) consists of a triangular formation of three satellites. LISA will directly measure gravitational waves generated by compact binaries within our Galaxy and black hole binaries and mergers throughout the Universe. The gravitational waves are detected by measuring the stretching of space-time between the satellites with laser interferometry.

The satellite formation is a general circular solution of the Hill-Clohessy-Wiltshire equations. This means that in linearised approximation the satellites will describe a circle around a reference point, maintaining a fixed position with respect to each other. The reference point, the centre of the triangle, orbits the Sun in a circular orbit, trailing the Earth at twenty degrees.

When evaluating the complete equations of motion of the satellites, the distance between the satellites will vary about one to two percent. The angle between the arms from one satellite to the others will vary about one degree over the course of one year. Because LISA should be able to measure variations of the arm lengths as accurate as 40 *pm* it is crucial that the pointing stability of the telescopes to the connecting laser beam is 7 *nrad* and that the variation of the arm lengths stays as small as possible.

The LISA satellites are equipped with six micro-Newton engines to perform the so called ‘drag free’ control. This control should manoeuvre the satellite around its two cubical proof masses that float in almost perfect free fall within the spacecraft, that protects them from non-gravitational forces like the solar pressure. It is examined if the LISA satellites can be controlled using these micro-Newton engines such that the formation of the satellites stays constant. If this can be achieved no actuation of the telescopes is needed to align them with the incoming Laser beam.

In order to estimate the needed control forces the accelerations caused by the Sun, the planets and relativistic effects are analysed. In this study an open loop control is applied to counteract the gravitational and solar pressure accelerations that cause the variation of the distance between the LISA satellites and the angle between the connecting laser beams. A simple PID control is applied to account for the noise of the micro-Newton thrusters. A fuel cost estimation is made and the maximum distance between the satellites for which the formation can be kept constant with the micro-Newton thrusters is examined.