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LISA PATHFINDER FIELD EMISSION THRUSTER SYSTEM DEVELOPMENT PROGRAM

Abstract

The paper presents the design and development logic of the field emission thruster system (or FEEP system) development program for the LISA Pathfinder spacecraft. LISA Pathfinder is the first demonstration spacecraft of the joint ESA/NASA LISA (Laser Interferometer Space Antenna) mission. LISA Pathfinder is built by ESA and will fly as a payload the NASA Disturbance Reduction System. The core technologies under development at ESA and to be verified in orbit are the inertial sensor and the field emission thrusters. On LISA Pathfinder ISA Pathfinder is an experiment to demonstrate Einstein's geodesic motion in space more than two orders of magnitude better than any past, present, or planned experiment, except for LISA. The concept that a particle falling under the influence of gravity alone follows a geodesic in spacetime is at the foundation of General Relativity, our best model of gravitation, yet. Within General Relativity, gravity is not a force acting on material particles, but instead is identified with curvature in spacetime geometry. Particles, in the absence of forces, travel in the straightest possible way in curved spacetime: this path is called a geodesic. In absence of gravity, spacetime is flat and geodesics are simply straight lines traveled at constant velocity. Achieving high purity geodesic motion is made difficult by non-gravitational forces acting on masses, accelerating them away from the geodesic lines. LISA Pathfinder's experiment concept is to prove geodesic motion by tracking two test-masses nominally in free-fall through laser interferometry with picometre distance resolution. LISA Pathfinder will show that the relative parasitic acceleration between the masses, at frequencies around 1 mHz, is at least two orders of magnitudes smaller than the value demonstrated so far or to be demonstrated by any planned mission. The basic elements to achieve and prove geodesic motion are the following: free floating test masses equipped with motion sensors in all degrees of freedom and free of dynamical disturbances (3 1014 m s2 Hz at1mHz ¡), low-thrust (10 N), low-noise (0.1N / Hz) proportional thrusters to push the spacecraft to follow the test masses, a high resolution laser interferometer to measure test mass relative displacement, 18-degree of freedom dynamical control laws, gravitationally "flat" (¡ 510-11g) and gravitationally stable spacecraft to host the test masses. Three enabling technologies needed new advances to make this realization possible: low-noise test-mass charge control, a precision test-mass release device, and micro-Newton thrusters. By using the geodesically moving test masses as reference for a drag-free control system, also the spurious acceleration of the spacecraft will be suppressed more than three orders of magnitude better than for any other existing or planned mission. In combination with its high stability and low self-gravity design, LISA Pathfinder spacecraft will then demonstrate the most perfect inertial laboratory available for Fundamental Physics experiments. LISA Pathfinder will also realize a high precision differential dynamometer of unprecedented resolution, paving the way for a new generation of force experiments, like searches for 1/r2 law violations, spin-spin interactions, and spin-mass interactions, aimed at searching for new long range interactions beyond the Standard Model. The high resolution test-mass to test-mass tracking demonstrated by LISA Pathfinder is an essential step for enabling a similar tracking of test masses even when they are located in different spacecraft, at large distance, and in interplanetary space, like in LISA, but also at short distance in low Earth orbit, like in future geodesy missions. LISA Pathfinder hardware has been designed to be transferred directly to LISA. However, it is obvious that many other possibilities are opened by the results of LISA Pathfinder. LISA Pathfinder is indeed at once

a mission in General Relativity and in Precision Metrology and will open the ground for an entirely new generation of missions not just in General Relativity, but in Fundamental Physics at large and in Earth Observation.