Paper ID: 19204
oral

ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (1) (8)

Author: Dr. Giorgio Mingotti
University of Strathclyde, United Kingdom, giorgio.mingotti@strath.ac.uk

Prof. Colin R. McInnes
University of Strathclyde, United Kingdom, colin.mcinnes@glasgow.ac.uk

RELATIVE ORBITAL DYNAMICS OF SWARMS OF FEMTO-SPACECRAFT

Abstract

A new class of femto-scale spacecraft is arising through recent advances in spacecraft design exploiting MEMS (micro-electromechanical systems) with sensing, computing, bi-directional communicating and micro-power. Low-cost manufacturing and launch of a great number of small spacecraft - which can be used in the framework of swarm application - are enabled by these developments. A set of future missions are then possible: distributed devices for Earth observation and communication, autonomous on orbit self-assembly, diagnostic or environmental detection in the proximity of a large satellite. Moreover, enhanced remote sensing applications are possible - such as ionospheric mapping, UWB radar and high resolution radar imaging - which can take advantage of the synergetic behavior of the system. Among them, the concept of distributed aperture radar appears to be one of the most interesting. In particular, applications that include sparse aperture sensing or stellar interferometry are able to exploit the geometrical pattern which can be generated by a swarm of femto-spacecraft. The elements would be free-flying in space, either controlled by active or natural forces for each element to stay within a prescribed volume.

The barycentric motion of a swarm of femto-spacecraft is investigated in this work. The exploitation of orbital dynamics at small length-scale and so high area-to-mass requires entirely new techniques for modelling and formation-flying control. Solar radiation pressure and aerodynamic drag can become dominant with respect to the Earth's gravity. Beginning from the linearised formulation of relative dynamics of the femto-spacecraft in close proximity, around a spherical Earth in a circular low-Earth orbit placed in the ecliptic plane, the dynamical model is generalised and extended to a wider class of orbits, including the main orbital perturbations. A differential Hamiltonian approach is then introduced in order to describe analytically the relative motion. If a suitable phase space is assumed, the swarm dynamics can be seen as the relative orbital evolution of the swarm elements on different phase space lines. A control method without propellant consumption is developed to design and maintain the relative orbits of the swarm. The devices are assumed to be coated with an electrochromic material, such that the optical properties of the elements change when an electrical current is applied. Therefore, the relative motion within the formation is controlled via the modulation of the differential solar radiation pressure.