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NOVEL APPROACHES TO THE DESIGN OF FRACTIONATED CLUSTERS FOR LONG-TERM EARTH OBSERVATION MISSIONS

Abstract

A cluster of fractionated spacecraft typically suffers from perturbations, which causes a gradual disintegration of the cluster making long-term EO missions impossible. We are presenting two novel approaches how such long-term EO missions using fractionated spacecraft are enabled. In this paper the innovative concept of fractionated spacecraft is taken advantage of to design a fractionated space infrastructure, which is composed of four functional modules and capable to support a variety of EO payload modules. In the fractionated space system all modules fly in a cluster that behaves functionally as a virtual monolithic satellite through wireless links. The requirements on the cluster therein are at least fourfold. First, the wireless network shall be maintained in the cluster. Second, collision avoidance or safe operational distances between any two modules in the cluster shall be considered. Third, the cluster shall be scalable and allow to add and remove modules. Fourth, the cluster keeping shall be passive to avoid continuous consumption of onboard propellant even in the presence of perturbations.

Two methods are presented to design a cluster that complies to the requirements given above. Those methods are not only applied to circular, but also to eccentric reference orbits. The first design method is based on the design of bounded relative motion for spacecraft formation flying, i.e., formation flying is used to implement the required cluster. Essentially, this method matches the mean semimajor axes of orbits. By means of this method in-plane clusters, cross-track clusters and clusters with general geometrics can be designed. The second design method considers the drift rate of each module with respect to the reference orbit as the key design parameter. It is similar to the design of J2-invariant formation flying, where J2 indicates dominant perturbations due to the oblateness of the earth. By matching the drift rates of modules, a stable cluster can be established. On the other hand, by imposing duration constraints as well as the constraints of maximum and minimum operation distances on the drift rate, a distance-bounded cluster can be constituted.

To determine the stability of each cluster designed, all clusters are propagated in time in the presence of the J2 perturbation. When the designed cluster deviates from the nominal configuration after some propagation period, the cost of cluster keeping maneuvers is quantified. The goal of this effort is to optimize the design of the fractionated cluster for long-term EO missions.