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FAR RANGE FORMATION FLIGHT WITH HIGH RISK DEBRIS IN LOW EARTH ORBIT USING RELATIVE ORBITAL ELEMENTS

Abstract

In order to avoid future fragmentations, disused satellites and rocket upper stages should be removed from Low Earth Orbit to reduce the buildup of new space debris, as suggested by the Space Debris Mitigation Guidelines. The Institute of Space Systems at the Technische Universitaet Braunschweig compiled a priority list for objects that are posing great risk of being fragmented, based on their environmental criticality. Active debris removal is considered for these objects. Such elaborate and costly missions have to be planned carefully to fulfill their purpose and must not generate new debris in case of unexpected failure. This paper analyses the far range formation flying concept for an exemplary active debris removal mission. After a brief description of a representative mission profile and the introduction of the relative motion dynamics and parametrization via relative orbital elements (ROE), the orbit guidance, navigation and control strategies are presented. The focus here is particularly laid on the safe formation configuration and the low fuel consumption.

Although Gauss' variational equations have been first derived to offer a mathematical tool for processing orbit perturbations, they are suitable for several different applications. If the perturbation acceleration is due to a control thrust, Gauss variational equations show the effect of such a control thrust on the keplerian orbital elements. Integrating the Gauss' variational equations offers a direct relation between velocity increments in the local vertical local horizontal (LVLH) frame and the subsequent change of Keplerian orbital elements. For proximity operations, these equations can be generalized from describing the motion of single spacecraft to the description of the relative motion of two spacecraft. This paper derives a general low thrust control concept for formation flying using a description of the formation in ROE instead of the classical Cartesian description since the ROE provide a direct access to key aspects of the relative motion and are particularly suitable for relative orbit control purposes and collision avoidance analyses.

The passive safety concept for the formation flight with high risk debris is based on the Eccentricity/Inclination (E/I) vector separation. Originally developed for the collocation of geostationary satellites, this method can be adapted to proximity operations and allows the inclusion of the main perturbations in low earth orbit, namely J2 Earth's oblateness effects and differential drag. Based on the orbit determination uncertainties a safety zone is defined in terms of relative orbital elements which once penetrated will trigger a collision avoidance maneuver.