SPACE SYSTEMS SYMPOSIUM (D1)
Enabling Technologies for Space Systems (2)

Author: Mr. Matteo Duzzi
CISAS – "G. Colombo" Center of Studies and Activities for Space, University of Padova, Italy

Mr. Francesco Branz
CISAS – "G. Colombo" Center of Studies and Activities for Space, University of Padova, Italy
Mr. Gilberto Grassi
University of Padua, Italy
Mr. Lorenzo Olivieri
CISAS – "G. Colombo" Center of Studies and Activities for Space, University of Padova, Italy
Prof. Alessandro Francesconi
University of Padova - DII/CISAS, Italy

SPACECRAFT JOINING USING A TETHERED ELECTROMAGNETIC PROBE

Abstract

Automatic systems to make viable the connection of two or more satellites in space are recently gaining importance for several perspective applications, most of them related to on-orbit servicing. Currently, spacecraft joining can be performed with autonomous chaser satellites that accurately fly around targets up to docking, or with the aid of robotic arms that place the two spacecraft in contact. In the first case (docking) the chaser must be capable of very high GNC accuracy in order to reach the target with specific relative position and velocity conditions. Very precise sensors are required to monitor the satellites relative motion during this phase as well as high propellant consumption, due to the multiple correction manoeuvres. In the second case (berthing) there is the need of a dedicated platform to host the robot and significant complexity is related to the robotic arm configuration and control, to safely manage unexpected situations and transmitted loads.

In such context, this paper presents a novel docking concept, where a tethered electromagnetic probe is ejected by the chaser toward a receiving electromagnetic interface mounted on the target spacecraft. The generated magnetic field drives the probe to the target and realizes an automatic alignment between the two interfaces, thus reducing control requirements for close approach manoeuvres as well as fuel consumption necessary for them. After that, hard docking is accomplished by retracting the tether and bringing the two spacecraft in contact. Controlled rewind is also exploited to damp the two spacecraft relative motion and stabilize the whole system.

This paper presents a thorough numerical analysis of the proposed docking procedure, simulating a real scenario and the mutual interactions between the chaser and the target during the manoeuver, and comparing it to traditional docking approaches. The two docking interfaces are modeled as magnetic dipoles, which are subjected to mutual interactions in a 3D environment, and the two bodies dynamics are described in terms of spacecraft position and attitude. The results demonstrate the benefits of the tethered approach with respect to standard close rendezvous strategies, which allows to save a significant amount of fuel, guarantee the repeatability of the manoeuvre and reduce the requirements for the docking sensors. Some preliminary experimental results are also presented to verify the reliability of the numerical model used for the study, focusing on the peculiar magnetic guidance and self-alignment capability.