IAF ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations - IAF ASTRODYNAMICS SYMPOSIUM (IP)

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MODELING AND SIMULATION OF POST-IMPACT DYNAMICS INTENDED FOR REAL-TIME IMPLEMENTATION ON SPACECRAFT ROBOTIC SERVICING AND ASSEMBLY MISSIONS

Abstract

Next generation space-based architecture and exploration will require autonomous on-orbit servicing and assembly capabilities. Such capabilities include inspection, anomaly correction, cooperative relocation, upgraded installations, in-space refueling, tug-based assembly, and self-assembly. As such, the requirements for increasing manipulator performance, coupled with mass reduction motivated by energy efficiency, will continue to play a critical role in space-based robotic servicing, assembly, automation, and control.

As a more immediate application, this research focuses on the in-space anomalies that once lead to spacecraft end-of-life, but may soon be able to be repaired using spacecraft robotic servicing platforms. Such missions require robotic servicing spacecraft to rendezvous, grasp, repair/relocate/refuel, and release a client satellite in an effort to extend its mission life. The grappler/end-effector interaction sequence between a servicing vehicle and client is of particular importance due to the fact that any unintentional energy transfer during contact could potentially damage the client satellite and/or servicing vehicle. And so, the ability to accurately model the dynamic interaction between free-floating bodies is a key component towards the implementation of real-time spacecraft robotic servicing and assembly, particularly in the understanding of how flexible components, such as solar panels, antennas, booms, and robotic arms affect the combined system dynamics, which are critical to mission operations. Excitation of flexible modes could potentially damage appendages and lead to unstable interaction between the two vehicles, thereby jeopardizing the entire mission. Additionally, if flexible-body motion significantly contributes to the combined system dynamics, proper avoidance of exciting these modes can be taken into account.

As a first validation effort, this research develops a combined rigid- and flexible-body spacecraft dynamics model based on a generalized formulation of the Newton-Euler equations, in order to assess flexible mode excitation during a robotic servicing grapple maneuver. Results include a discussion regarding the impact of flexible body dynamics on end-to-end servicing/assembly missions, which include interaction forces during a grapple maneuver along with time-histories of simulated pose and rates for a satellite body with flexible appendages. Simulated results will be compared against commercial multibody dynamics software, as well as correlated with an air-bearing mass sled made to resemble an orbital contact dynamics scenario.