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ON-ORBIT DEMONSTRATION OF SPACECRAFT HOPPING MANEUVERS USING THE NASA ASTROBEE FREE-FLYERS

Abstract

'Orbital hopping' offers a method of performing proximity maneuvers among co-orbiting spacecraft, with no use (or reduced use) of propellant. Instead of using jet thrusters, an orbiting spacecraft equipped with a robotic manipulator can 'spring off' another orbiting spacecraft and exchange momenta with it. For orbital hopping, the only required resource is electrical power, which is renewable via solar charging.

A campaign of experiments named 'Astrobatics' has been conducted by the NPS Spacecraft Robotics Laboratory, in collaboration with NASA and the Space Test Program, to demonstrate orbital hopping maneuvers in Earth orbit. The Astrobatics campaign of experiments uses the NASA Ames Astrobee free-flyers, designed to fly autonomously inside a module of the International Space Station (ISS). To date, four flight activities have been conducted, commanding the Astrobee vehicles through an increasingly complex set of orbital hopping maneuvers to experimentally field-test this strategy for spacecraft proximity maneuvers. To the authors' best knowledge, the experimental campaign Astrobatics achieved the first demonstration of spacecraft orbital hopping in Earth orbit.

Each NASA Ames Astrobee free-flyer used in the Astrobatics campaign is equipped with a two-degree-of-freedom robotic perching arm and an impeller-driven propulsion system. At the beginning of each Astrobatics flight experiment, an ISS crew member perches an Astrobee free-flyer either on a handrail inside the space station or on a free-floating handrail grasped by another Astrobee. A perching-arm joint is then activated to accelerate the Astrobee body. Finally, the perching gripper is opened, and the Astrobee hops away; from then on, its momenta are approximately conserved for the rest of the maneuver, until the impeller-based propulsion is commanded. The resulting motion is tracked by the Astrobee navigation system and used to compare models of orbital hopping performance.

The proposed paper provides an overview of the Astrobatics experimental campaign, including a description of the research objectives, ground testing, ISS activities, results, and lessons learned. Telemetry data and videos from the completed Astrobatics activities will be presented, as well as insights gained from the authors' experiences using the Astrobee free-flyers. The paper also presents the equations of motion for hopping maneuvers of free-floating spacecraft from fixed and floating platforms. The mathematical and experimental results support the feasibility of proximity hopping maneuvers for orbiting space vehicles.