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Space Structures III Design, Development and Verification (Orbital infrastructure for in orbit service & manufacturing, Robotic and Mechatronic systems, including their Mechanical/Thermal/ Fluidic Systems) (3)

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CAPTURE AND ATTITUDE TAKEOVER CONTROL SIMULATION FOR ON-ORBIT SERVICING BY SPACE ROBOT

Abstract

Following the launch of Sputnik 1, countless satellites have been placed into orbit, and the number of end-of-life satellites has steadily increased. A significant portion of satellite development costs goes toward the payload, but even among end-of-life satellites, there are cases where the payload remains fully functional. These satellites can extend their operational lifespans and be reused through on-orbit servicing. Historically, on-orbit servicing missions were carried out via periodic human visits—for instance, servicing the Hubble Space Telescope. However, persistent safety concerns have led to recent efforts to develop satellites equipped with robotic arms to replace astronaut-based maintenance. To extend a satellite's lifespan, the servicing satellite typically undergoes several phases: Far and Close Rendezvous, Impact and Capture, and Post-capture Stabilization. When the target satellite has lost orbit control ability and is tumbling, docking and post-capture operations become especially critical. This study focuses on simulating the on-orbit servicing process, particularly the docking and post-capture stabilization, using a multibody dynamics program. A servicing satellite equipped with robotic arms docks with a target satellite and subsequently performs attitude control for the combined spacecraft. To dock with a tumbling target, the servicing satellite matches its translational and rotational velocity concerning the target during the close proximity operations. The target's adapter ring, one of the rigid parts of the target satellite, is then captured using the end-effector attached to the robotic arm. After the docking process, the robotic arms unfold due to reduce attitude maneuver time following the post-stabilization step. Finally, using reaction wheels on the servicing satellite, the combined spacecraft is stabilized and oriented to the desired attitude via a Proportional-Derivative (PD) feedback attitude controller. The proposed feedback controller adjusts the gain values by considering the angular velocity of the combined satellite and angle error with respect to the desired attitude. As a result, it was observed that the system maneuvered to the desired attitude in a shorter time compared to using conventional gain values. Furthermore, a comparison between numerical analysis results and multibody dynamics simulation results confirmed that the two datasets were consistent, demonstrating that the two spacecraft move as a single rigid body after docking.