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DEVELOPMENT OF PREDICTIVE CONTROL FOR AUTONOMOUS DEEP-SPACE SYSTEMS

Abstract

We report on research that is being conducted toward the development of an autonomous, robust mission design and controller to enhance spacecraft performance in close-proximity Near-Earth Object (NEO) operations while safely satisfying predetermined mission requirements. NEOs are asteroids and comets that approach Earth's orbit, and pose both a threat and opportunity for humanity. In order to properly analyze, mine, relocate, or mitigate the threat posed by a NEO, spacecraft will need to operate properly in the close-proximity NEO environment. NEO close-proximity operations pose a challenging spacecraft navigation problem due to a NEO's tenuous and complex gravitational field, rotational state, and other perturbing forces (i.e., solar-radiation pressure and third-body perturbations). As a result, there is a need to develop a specialized spacecraft control algorithm to properly fulfill mission requirements. Additionally, there is a need for autonomy with the spacecraft control methodology due to the delay times in communication between the spacecraft and mission control. With the information received from the Hayabusa mission to asteroid (25143) Itokawa, a sophisticated computer simulation was created that allows us to test control theories in a "real-world" environment for this research project. We have found that for most orbits about such a small asteroid, without active control the spacecraft is quickly ejected from the system or impacts the asteroid. It has been observed that certain orbits tend to be more stable than others and these can be exploited for enhanced mission design. Our initial efforts in autonomous control using simple and well-known Proportional, Integral and Derivative (PID) controller have driven us to consider more sophisticated controllers. We are currently merging orbital mechanics and more advanced control theory to create a smart controller as a more effective tool for close-proximity autonomous NEO operations. We expect this predictive control method will provide more efficient and less invasive mechanisms to accomplish the mission tasks around well understood NEOs as well as first encounters with new NEOs with uncertain characteristics.