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ADAPTIVE ON-ORBIT SOFTWARE RECONFIGURATION OF SPHERE-1 EYE AOCS HARDWARE FAILURE

Abstract

In recent years, the rising significance of small satellites has transformed the landscape of space exploration, bringing about increased space utilization and business opportunities. This paper investigates the Attitude and Orbit Control System (AOCS) operations of SPHERE-1 EYE, a 6U CubeSat developed collaboratively by the University of Tokyo, Sony Group Corporation, and JAXA. Launched in January 2023, SPHERE-1 EYE stands as a testament to the democratization of space, empowering general users to freely select viewing angles and capture images of Earth and space.

The AOCS flight software of SPHERE-1 EYE is based on the Command Centric Architecture (C2A), enabling on-orbit reconfiguration at the level of small units known as Block Commands, allowing granular rewriting. The C2A framework played an essential role in dynamically reconfiguring SPHERE-1 EYE, addressing challenges associated with the time-intensive and communication-intensive nature of uploading the entire program to the satellite. This capability addressed various challenges encountered during its operation, providing flexibility by allowing detailed changes without the need for traditional program rewrites.

An illustrative example includes the handling of the complete breakdown of one of the three reaction wheels, a vital AOCS component. Instead of resorting to conventional reprogramming, the C2A facilitated the reestablishment of three-axis control using the remaining two reaction wheels and magnetorquers by combining pre-existing functions. This adaptive approach, validated through prior ground-

based software-in-the-loop simulations, restored three-axis control capabilities without necessitating a new control algorithm, underscoring the efficacy of in-orbit software reconfiguration.

After restoring three-axis control, another reaction wheel exhibited signs of malfunction, prompting a strategic shift in SPHERE-1 EYE's operational policies. Initially, the plan was to consistently use reaction wheels for three-axis control. However, to minimize the usage of reaction wheels and prevent further malfunction, a reconfiguration was implemented to refrain from employing reaction wheels during periods other than imaging and downlink operations. Once again, the inherent flexibility provided by the C2A architecture played a pivotal role in swiftly adapting to the evolving operational needs, contributing to the satellite's overall reliability.

The adaptability demonstrated by SPHERE-1 EYE, crucial in addressing unforeseen challenges and modifying operational policies without resorting to time-consuming and resource-intensive reprogramming, offers valuable insights for the ongoing development of ONGLAISAT, a 6U CubeSat set to launch this year. The innovative use of on-orbit software reconfiguration showcased in this study exemplifies its potential to enhance the operational resilience of small satellites, paving the way for future advancements in space exploration and utilization.