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ASTROBEE'S MULTI-YEAR ACTIVITIES AT THE INTERNATIONAL SPACE STATION'S JAPANESE EXPERIMENTAL MODULE

Abstract

This paper reports on the multi-year on-orbit activities accomplished by the Astrobee free-flying robots in the Japanese Experimental Module (JEM) at the International Space Station, giving special attention to JAXA's 1st and 2nd Kibo Robot Programming Challenge (RPC) and the mapping processes and tools created to enable Astrobees' autonomous operation. The JEM is an ever changing, dynamic environment where light settings, cargo, payloads, and crew members are constantly moving and interacting with one another.

The 1st JAXA Kibo RPC event, a collaboration between JAXA and NASA, was held in 2020. Students from several countries in the Asia-Pacific region competed in programming challenges with a simulated Astrobee. The finalists were then invited to run their code on an actual Astrobee in the JEM. For the final round, students programmed Astrobee to visit three different locations to obtain data that would instruct the robot to complete a final task with the participation of ISS crew. The first competition was a tremendous success, leading to an equally successful 2nd JAXA Kibo RPC in 2021 with even larger participation. The 3rd JAXA Kibo RPC will occur in 2022 expanding further to incorporate US participants.

These activities led to several firsts in Astrobee's history: operation of an Astrobee free-flying robot without crew supervision in preparation for on-orbit operations, autonomous image acquisition towards updates of the navigation map, non-NASA code running on the robot (both from JAXA and participating students), two heterogeneous free-flying robots from two different space agencies working together (Int-Ball and Astrobee) during the final event in 2020, the first payload using Astrobee, and having Astrobee controlled from a non-NASA location (Tsukuba Space Center).

The preparation towards these activities involved constant evaluation of the different components of Astrobee's systems, specially mapping and localization. The paper describes the evolution of these systems such as the improvements made in localization to reduce localization drift by using graph-based optimization instead of the extended Kalman Filter localizer. Additionally, it reports on the mapping process and analysis tools created to validate map consistency across different activities in the constantly changing JEM environment. These enhancements have enabled the Astrobee facility to successfully execute over 100 ISS activities supporting over a dozen researchers and partners around the world.