



Astrobees: current status and use in JAXA's Kibo Robot Programming Challenge



Jose V. Benavides
Project Manager, Astrobees Facility
February 2021



Astrobee Project Description

Based at Nasa Ames Research Center, the ISS Astrobee Facility provides a free-flying robotic system for ISS research and ISS STEM outreach. The Astrobee free-flying robotic system consists of three cubed-shaped robots, software, and a docking station used for recharging. The project provides sustaining engineering tasks for ensuring the facility operational readiness on ISS. The project provides payload support to users from academia, private industry, NASA, and other government agencies in the execution of ISS approved research and STEM objectives.



Chris Cassidy, GMT 248 2020



Overview

Why Free Flyers on ISS? Provide a risk-tolerant testbed to:

- Enhance & Enable Human Exploration (e.g. Gateway)
 - Astrobee can potentially perform a range of Intra-Vehicular Robotics (IVR) caretaking tasks to help maintain and protect the Gateway, particularly during uncrewed mission phases.
- Perform Fundamental Research

Objectives

- Ensures the facility readiness for ISS Astrobee test sessions
- Provides real-time ISS test session Ops support, and Increment Planning
- Supports a diverse user community of government, commercial, and academic investigators to enable Free-Flyer research

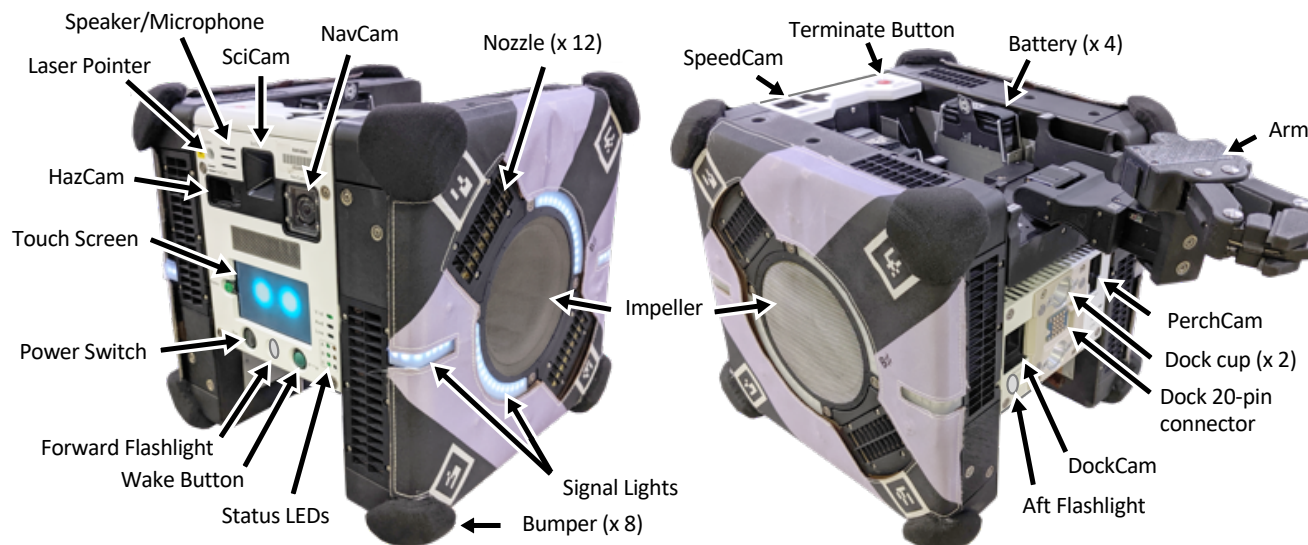
Current activities

- Completing Astrobee commissioning activities
- Maintaining & Operating Astrobee
- Facilitating Free Flyer user community
 - Periodic Astrobee Working Group (AWG)
 - International Partners: JAXA (Int-Ball) and DLR/Airbus (CIMON)
- Supporting over 9 Astrobee users in various stages of integration





Astrobee HW Overview

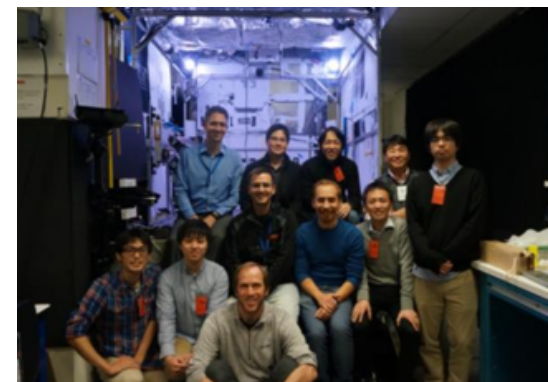


- Free flying robot inside the ISS
- 32 cm wide, ~9.1kg (2 batt., no arm)
- All electric + fan-based propulsion
- Robot arm for “perching”, ~1kg
- Three smartphone computers
- Three payload bays for expansion
- Microphone not currently enabled
- The three Astrobee’s on ISS are named:
 - Honey (Yellow)
 - Queen (Green)
 - Bumble (Blue)
- More: www.nasa.gov/astrobee



Kibo-RPC 2020 Summary

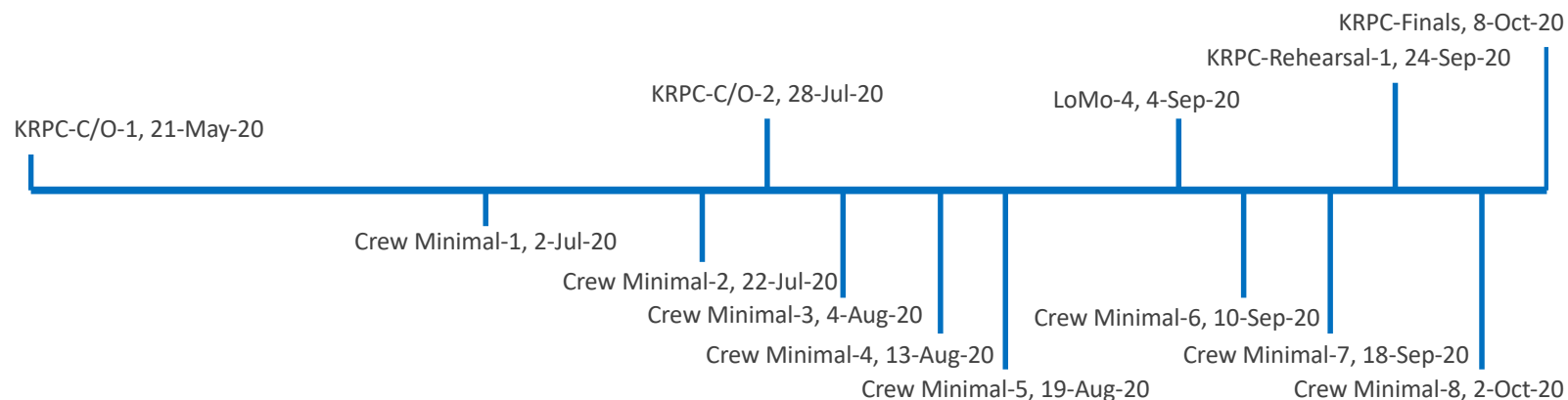
- JAXA / NASA Collaboration on free-flyers started in late 2017
 - Initial IntBall-1 and Astrobee team communications
- Teams corresponded visits to Tsukuba Space Center and Ames Research Center between 2018 and 2019
 - 2018 trip to Tokyo/Tsukuba Japan - U.S. Open Platform Partnership Program (OP3)
 - 2019 trip to Tsukuba
 - 2018 trip to Ames
 - 2019 trip to Ames
- Kibo Robotic Programming Challenge idea defined in July, 2019
Students would program Astrobee to visit various locations at the JEM and using Scicam decode QR and AR codes until reaching a position where Astrobee points its laser to a target.
 - Students first pass a round based on simulation. Teams with best scores upload their APKs to Astrobee at the JEM and compete during the final round.





Summary

Kibo RPC Activity Timeline



- Activities both crewed and not-crew tended, started on 2020-04-30 and ended with the final round on 2020-10-08
 - Number of Crew-tended Kibo-RPC activities: 4
 - Number of Crew-tended LoMo's: 3
 - Number of Not-crew tended (Crew Minimal) activities: 8
 - All 15 done within 23 weeks and done with Ames' personnel working from home
 - Note: Many activities considered part of Astrobee's commissioning



Summary

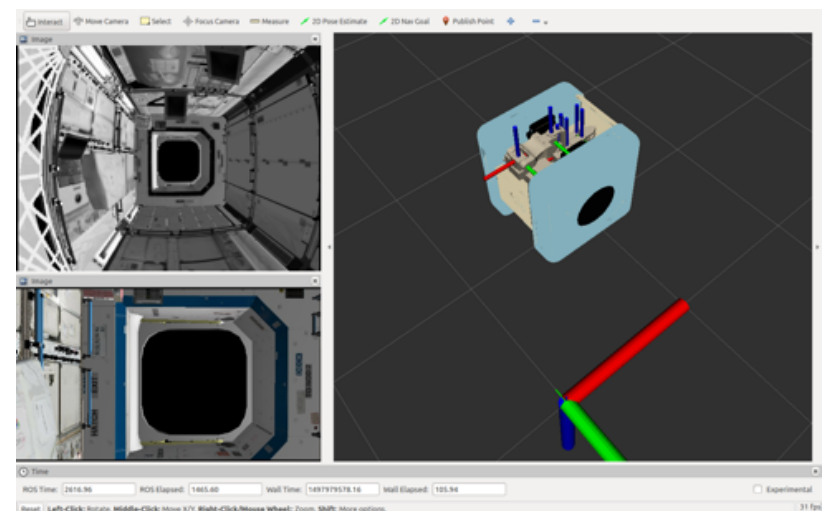
- Multiple “firsts”:
 - Astrobee robot operation without crew
 - autonomous image acquisition towards mapping
 - non-NASA code run on robots (JAXA and students)
 - heterogeneous free-flying robots from 2 different space agencies working together (Int-Ball & Astrobee) during finals
 - student competition using Astrobee
 - Astrobee controlled from non-NASA location (Tsukuba)





Summary

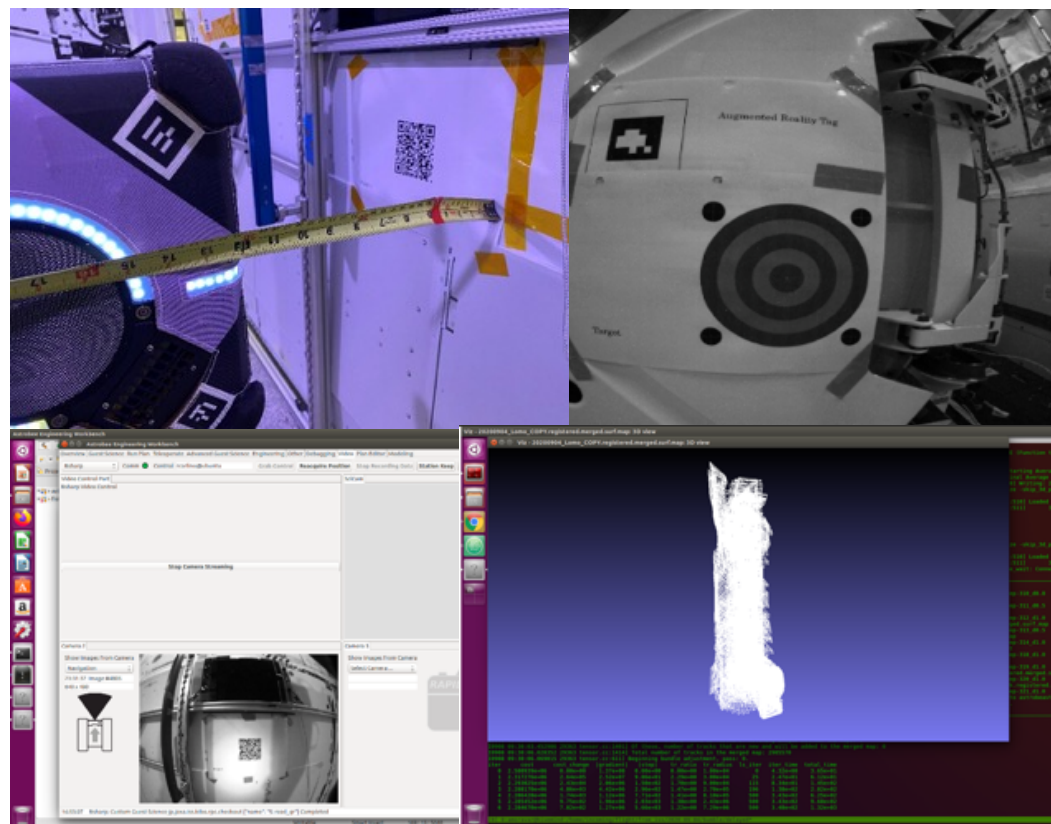
- Coordination between several locations: JAXA, NASA - Ames, JSC, & Marshall
- Almost 300GB of data acquired during activities related to Kibo-RPC
- Standard software verification and evaluation procedures created
- Operations performed in coordination with multiple actors, in real-time (Astrobee operators, JSC Video Control Center, ISS POIC, ISS Mission Control, JAXA, crew members)
- Environment (CTB bags, lighting, new payloads installation) controlled for final non-crew and crew tended activities
- Autonomous trajectories successfully performed
- Map creating/updating turn around as well as localization analysis performed on a weekly basis
- Improvements to localization and mapping systems performed
- Tools to monitor localization performance created





Astrobee matured as a facility

- Many software and operation workflows were tested, improved, and validated
 - Software testing and preparation
 - Flight Software operation
 - Operation Planning
 - Real-time communication and support
 - Remote, work-from-home support





Astrobee in the year ahead

- The Astrobee facility is implementing improved localization software and completing the commissioning of its perching arms
- Looking forward to supporting nine different users with on-orbit operation goals in 2021
- Work has already started for supporting Kibo-RPC 2 in 2021