

# Astrobee On-Orbit Commissioning

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The Astrobee free flying robots operate in the interior of the International Space Station (ISS) under supervisory control of a ground operator or ISS crew. They replace the Synchronized Position Hold Engage and Reorient Experimental Satellites (SPHERES) as research platforms for zero-g free-flying robotics. Astrobee also provides a tool for improving the efficiency of ISS operations as a mobile camera/sensor platform available to flight and payload controllers.<sup>1</sup>

The Astrobee system consists of three robots with perching arms, a docking station, and a ground data system. Development began in late-2014, and flight hardware has been deployed to ISS on several launches starting in November 2018 and concluding in October 2019. Shortly after the first two robots arrived on ISS in April, we began a series of “commissioning” activities to validate both space and ground segments. We plan to complete commissioning and become an operational facility available to guest scientists by the end of 2019.

This paper provides an overview of the Astrobee system, a description of the on-orbit activities, and commissioning results.

**System Description:** An Astrobee robot is a 32 cm-on-a-side cube with a mass of approximately 10 kg. 2 fan-based propulsion modules on opposite sides of a central avionics core provide holonomic motion in six degrees of freedom, meaning it has the ability to move instantaneously in any direction and rotate about any axis. This all-electric system requires no consumables except for battery charge; it is able to replenish its charge by autonomously connecting to its docking station.<sup>2</sup>

The robot will be able to traverse the majority of the US Orbital Segment (USOS) by using a vision-based navigation system that compares existing features of the ISS interior with an on-board a priori map combined with inertial measurements.<sup>3</sup>

Astrobee has 3 available bays for perching arm, guest science payload, or new sensor integration. Each bay supplies battery power and a USB connection to the robot’s main processors.

**Commissioning Activities:** Astrobee on-orbit commissioning takes an incremental approach, gradually demonstrating increasing capability, with planned repeat activities to account for the inevitable problems that will be exposed when any robotic system is tested in a new environment. Commissioning consists of the following types of activities: hardware checkout and calibration, ISS interior mapping, performance tuning and characterization, and operational demonstration.

Hardware checkout and calibration of each free flyer is independent of the others, however improvements to software performance (for example, on the localization subsystem) on one robot improves all. Thus the commissioning schedule concentrated first on one robot, before moving on to the others.

The activities rely on astronaut support, especially in the beginning, before Astrobee is flying on its own. The final activity is a ceremonial passing of the torch between SPHERES and Astrobee.

**Results:** We began commissioning activities on our first free flyer, Bumble, on April 30, 2019. The hardware checkouts and calibration activities showed that the robot survived launch well with all sensors retaining their pre-flight calibration. Initial mobility testing proved that the propulsion system and rate control is responsive and capable of maneuvering in the ISS environment.

Challenges were tuning of the localization system, primarily optimization of the a priori map, and operational constraints. Due to concerns about crew privacy with regard to imagery acquired by Astrobee, the ISS program levied a

constraint that all commissioning activities involving cameras required the presence of crew. Because of the limited availability of crew time, this slowed the pace of commissioning.

As of this writing, Bumble has demonstrated basic mobility capabilities, including disturbance rejection, and autonomous docking and undocking.

**References:**

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