



## Astrobee Guest Science Interface

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**ABSTRACT** At the end of 2018, Astrobee will launch three free-flying robots that will navigate the entire US segment of the ISS and serve as a payload facility. The mechanical and electrical interfaces are now established and several payloads are being developed.

### **Payload Interface**

Astrobee is designed to host third party guest science program payloads (GSP payloads). Some GSP payloads may be software only, such as the Zero Robotics Finals Competition, which is currently hosted on SPHERES, and which will transition to Astrobee in 2019. Several GSP payloads with custom hardware, such as the Advanced Exploration Systems (AES) Logistics Reduction and Repurposing (LRR) Project RFID reader, are already under development. These payloads will attach in the Astrobee payload bay.

**Volume:** Astrobee is designed to accommodate payloads in ~12 x 15 x 10 cm bays. There are three payload bays on each robot, two on the bottom, and one on the top. The two on the bottom may be used together for larger GSP payloads. A 3D CAD model of the maximum size payload within one GSP payload bay is available.

**Mass:** Astrobee is designed to operate normally with up to 1 kg of GSP payload mass. Increasing payload mass gradually degrades acceleration performance. Payloads greater than 1 kg will be evaluated case-by-case to characterize performance and ensure the motion controller stability. Large payloads have less performance impact if they are balanced to maintain Astrobee's center of mass.

**Quick Attachment:** A quick attachment mechanism designed to reduce installation time and therefore reduce crew setup time is also provided as a 3D CAD model. The quick attachment can be achieved without tools and even one handed.

**Rigid Attachment:** Large GSP payloads and those with large expected forces may need a stronger attachment. A bolt pattern is provided for each payload bay using #8-32 hardware. Payloads should use captive fasteners to avoid the need for a glove box.

**Outside the Box:** GSP payloads that remain physically within the robot volume will benefit from safety features of the robot, but since the bays are on the exterior of the robot, larger GSP payloads can easily be accommodated. Very large payloads analogous to SPHERES SLOSH may connect to the aft face of an Astrobee in a "tractor-trailer" configuration, and possibly employ two Astrobees on opposite sides of the payload.

**Electrical Interface:** Each Astrobee payload bay has a 31-pin D-sub connector that provides  $V_{batt}$  (14.4V DC nominal at 3A), and three USB 2.0 compatible data pinouts (USB 5V DC power is not provided). The USB pins communicate with the internal Astrobee processors.

**Communication Interface:** Astrobee is WiFi-enabled and can communicate with other Astrobees via the ISS LAN. Astrobee can communicate with the ground operator and relay information from the GSP payloads for real-time viewing of health, status and data. The robot will also log additional data onboard for later downlink.

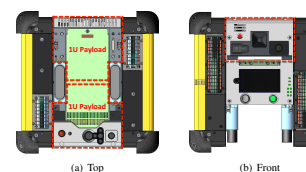
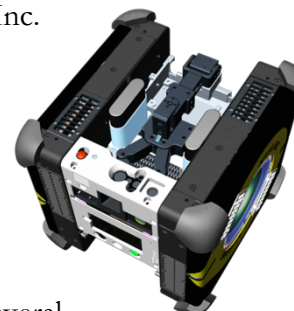
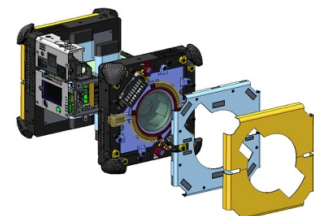
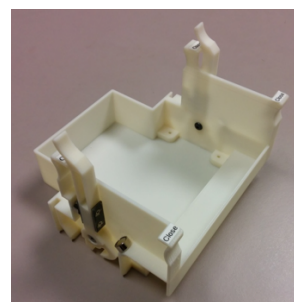
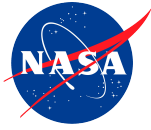


Fig. 2. Snapshot of the Astrobee payload bay.



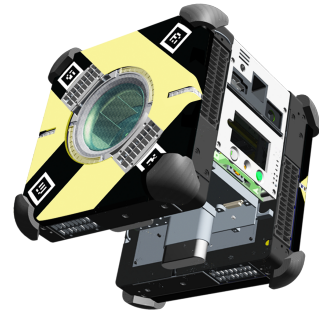


## Payloads

Several payloads are being developed, both with and without hardware. More than 40 research groups have already expressed interest in using the Astrobee facility. A few examples are included to illustrate how the Astrobee platform can be utilized.

**Zero Robotics:** Zero Robotics is a competition run by the Massachusetts Institute of Technology (MIT) that enables thousands of students ages 12-18 from more than 18 countries to write code that controls robots on the ISS. Zero Robotics is implemented using a software only payload that has been operating on SPHERES and will transition to utilize Astrobee in the summer of 2019. The first rounds of competition are held via simulation, and the finals are held on the ISS. During the finals, the student code will be executed onboard Astrobee on orbit.

**REALM-2:** The AES LRR project at Johnson Space Center aims to save crew time by automating inventory tracking on the ISS. Part of the project is the REALM-2 RFID reader Astrobee payload, which can leverage Astrobee's motion capability to pinpoint the location of lost items by monitoring RFID signal strength variations. REALM-2 includes both hardware and software. REALM-2 hardware consists of a main module that occupies one Astrobee payload bay, and two flexible antenna skins that mount on the flat faces of Astrobee's propulsion modules using snaps and hook-and-loop, replacing fabric skins that are part of Astrobee's baseline configuration. This mounting configuration allows larger antennas to improve coverage and gain. Since REALM-2 is a sensor, it can be operated either as a "primary payload" that controls Astrobee (e.g. surveying a module or searching for a lost item), or as a "secondary payload" that collects data opportunistically during other activities.



**Payload Tester:** Ames Research Center is developing a payload tester for Astrobee to test the payload power and data connections on orbit. It will demonstrate the development path for payloads and will provide a processor that interfaces with the Astrobee. It will run Linux alone and is also designed to be able to run Core Flight Software. It will provide a standard seat-track interface as an additional attachment option for payload hardware and a standard USB pass-through connector to allow COTS devices to be interfaced with Astrobee.

**COBRA-Bee:** Tethers Unlimited, Inc. (TUI) has developed a prototype payload based on TUI's high-TRL, 3-DOF COBRA gimbal. This payload uses the quick-release mechanism, and has additional degrees of freedom compared to the baseline perching arm. Their prototype, developed with NASA Small Business Innovative Research (SBIR) funding, was successfully mounted in the payload bay of the current Astrobee prototype.

**Gecko Gripper:** The Stanford Biomimetics and Dexterous Manipulation Lab (BDML) is maturing grippers based on gecko-like adhesives for use in spaceflight. Applications include grappling satellites for on-orbit servicing or collecting space debris for disposal. Funded by the NASA Early Stage Innovations (ESI) program, BDML is developing an Astrobee gripper payload that will be able to controllably grasp and release flat objects such as ISS walls. Their gripper will mount on the end of the baseline Astrobee perching arm, which provides a crew-swappable end-effector interface—one more way that Astrobee can accommodate payloads.

## Conclusion

The Astrobee robots will provide a unique opportunity to develop mobile sensors and payloads for the ISS. Now that the mechanical, electrical, and software interfaces are defined, payloads are being developed by NASA, academia, and commercial companies to utilize this unique platform.