ASTROBEE: CURRENT STATUS AND FUTURE USE AS AN INTERNATIONAL RESEARCH PLATFORM



Andres Mora Vargas

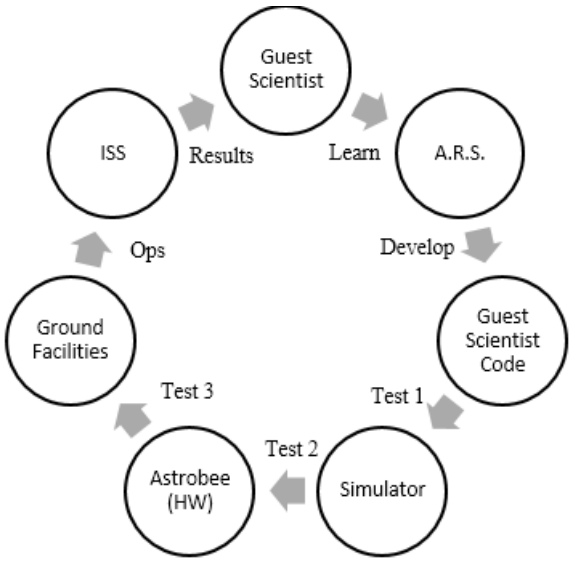
Appropriate Technologies Guest Lecture

Swansea, Wales, UK

April 26th, 2021

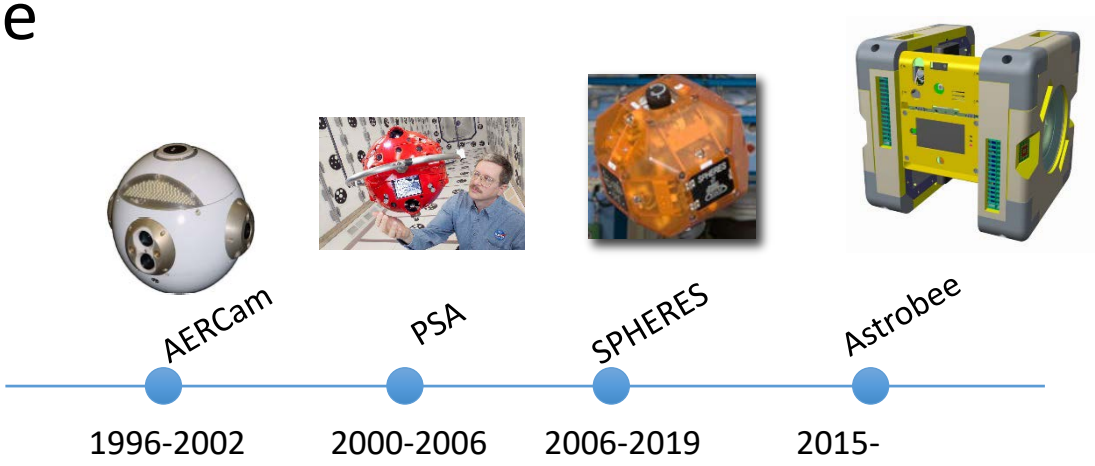
Introduction

- Astrobee research platform ecosystem
  - Astrobee hardware: Ground and flight units
  - Ames Research Center Experimental Facilities
  - Astrobee Robot Software
  - Access to the International Space Station
- Support different research: AI, manipulation, computer vision, HRI, many, many other fields!



Introduction

- AERCam Mini: Autonomous Extravehicular Robotic Camera
- PSA: Personal Satellite Assistant
- SPHERES: Synchronized Position Hold, Engage, Reorient, Experimental Satellites
- Astrobee



Related Work

Other free-flyers

- JAXA JEM Internal Ball Camera (Int-Ball)
  - Developed during 2016 and launched in 2017
  - Autonomous, fan-propelled
  - 1kg, 15 cm in diameter
- DLR, Airbus, IBM's Crew Interactive Mobile Companion (CIMON)
  - AI-based assistant, fan-propelled
  - 5kg, 32 cm diameter



JAXA's Int-Ball

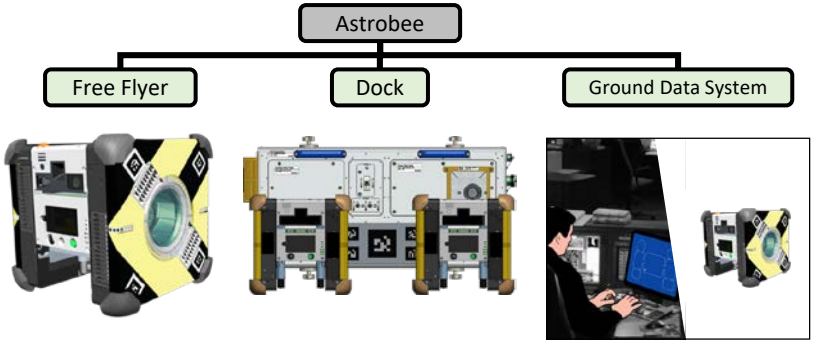


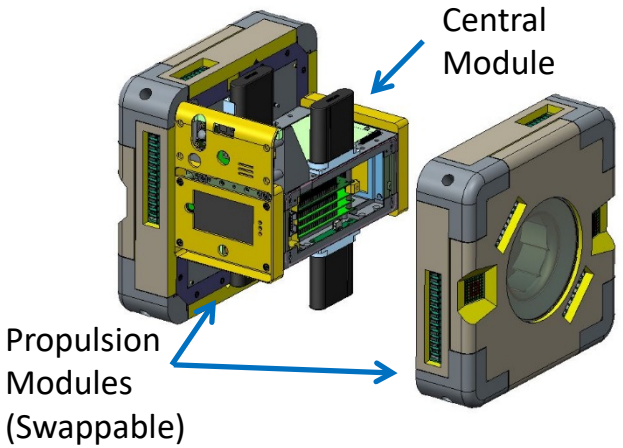
DLR, Airbus, IBM's CIMON

Astrobee Platform & Simulator

Astrobee Free-Flyer

- Operates in Intravehicular (IV) environment
- Cube: 30.5cm per side
- Approximately 8kg
- Forward motion, top side aligned with ISS' ceiling
- Touch screen
- Sensors (range, cameras)
- Dock adapter & perching arm
- Simple setup
- Easily battery replacement
- Propelled by air
- No continuous supervision required

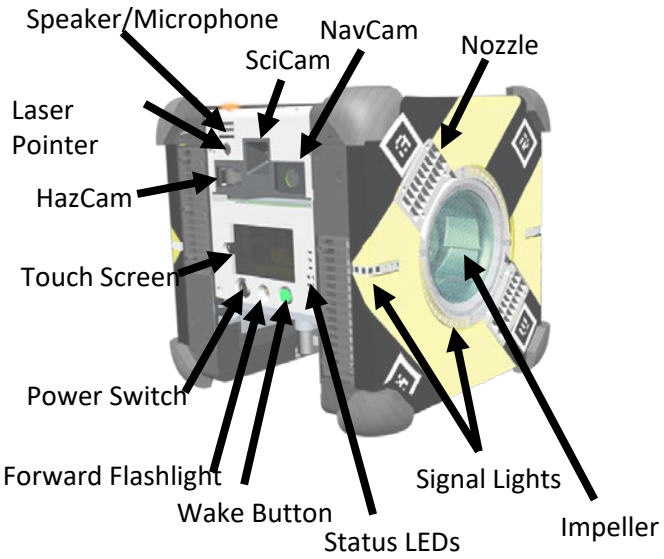


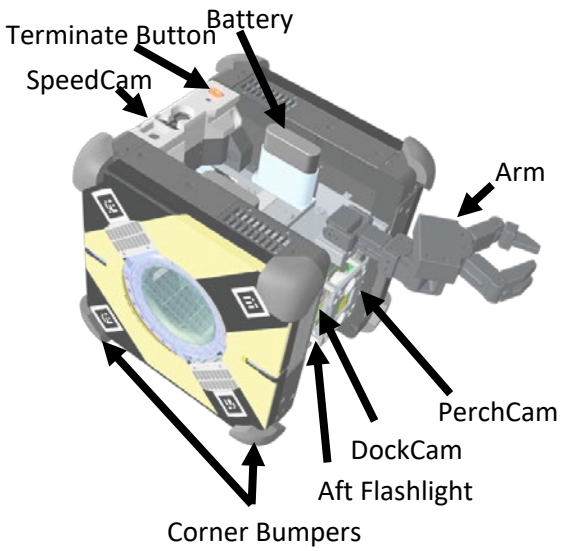


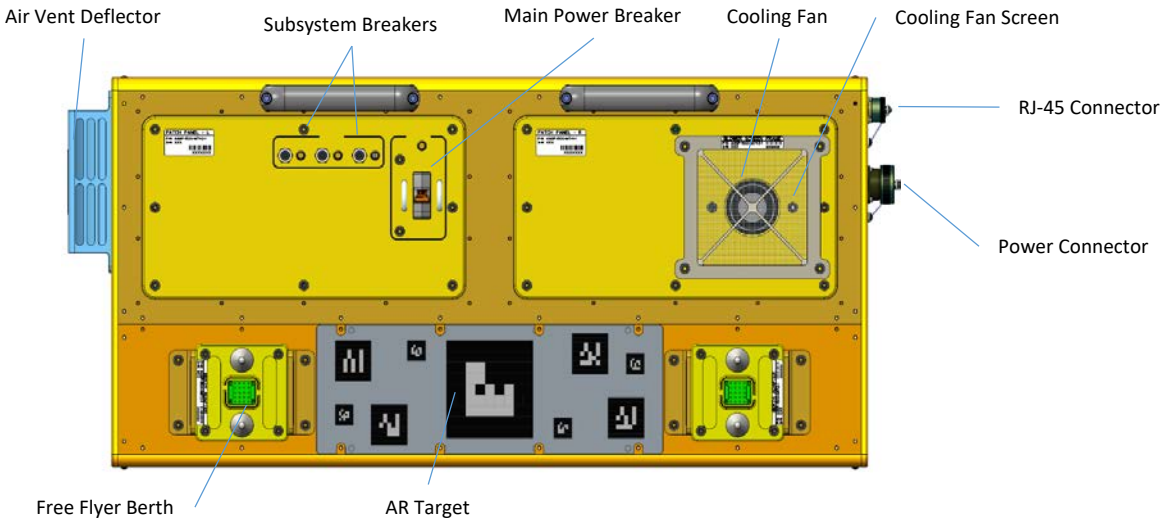


Astrobee Homepage
https://www.nasa.gov/astrobee/videos

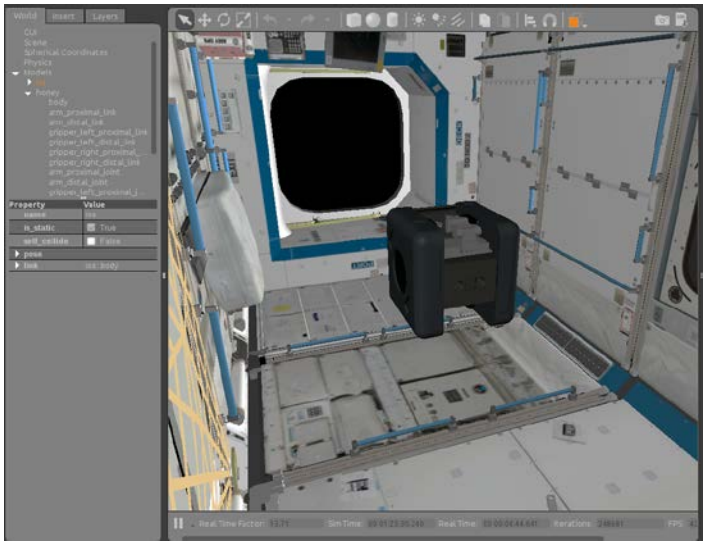
Astrobee Platform & Simulator





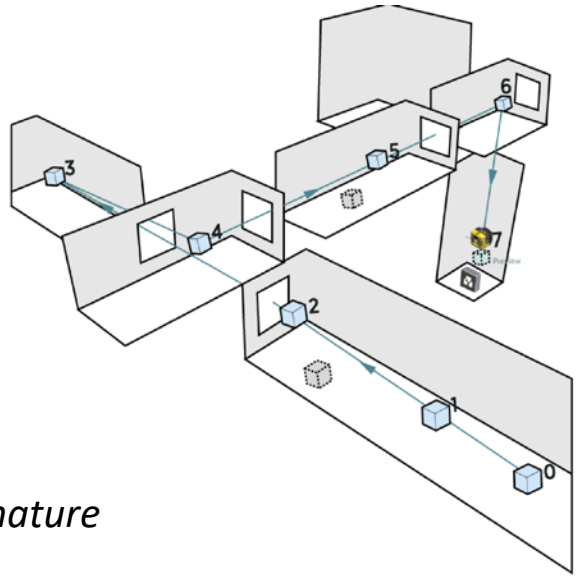


Astrobee Platform & Simulator



- Astrobee Robot Software (A.R.S.) makes extensive use of the open-source Robot Operating System (ROS):
  - Communication framework linking all “nodes” running on the target platform
  - Try to maximize the re-use of existing ROS messages benefit from existing ROS packages
  - Use ROS introspections tools to rapid debugging
  - Use ROS facilities to record/replay/analyze data
  - Use some ROS/Gazebo components for the simulator
- A.R.S. Features:
  - Manage Astrobee sensing and actuation
  - Localize and Navigate within the ISS
  - Perform autonomous docking (+ return to dock)
  - Perform autonomous perching
  - Support teleoperation from ground
  - Support plan based automated tasks
  - Support “Guest Science” operations
  - *Support multi Astrobees communication*
  - *Support hardware for multisensory human interaction*

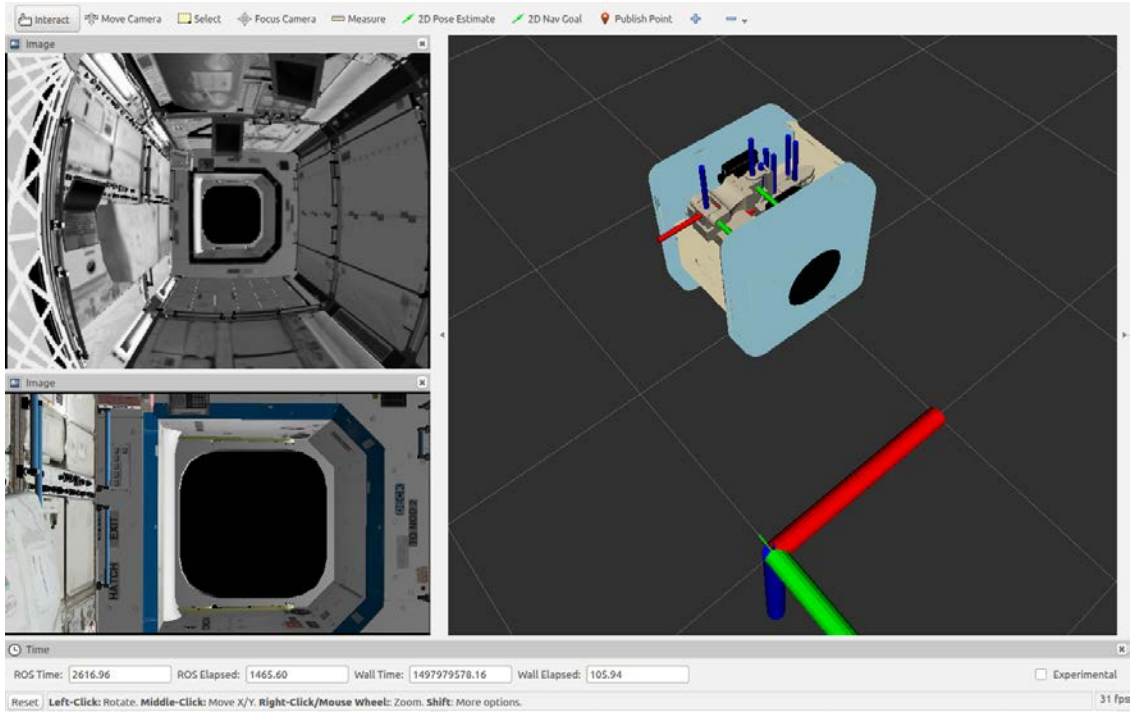
} *less mature*



Astrobee Platform & Simulator

Astrobee Simulator

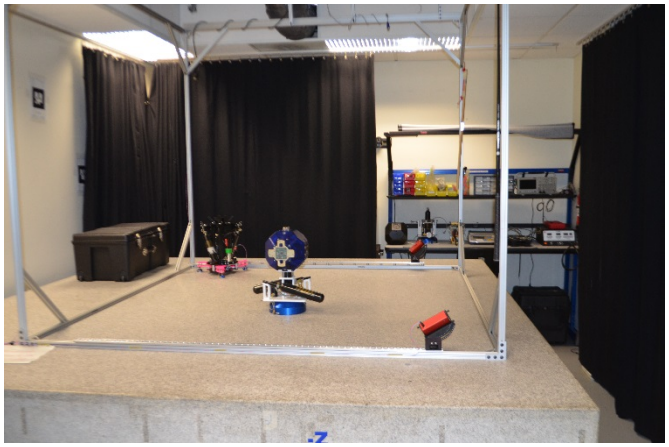
- Custom propulsion system and some localization sensors
- Gazebo based dynamics model, imagers, arm, lights and ISS model
- Can run all nodes on desktop or some nodes on target development board

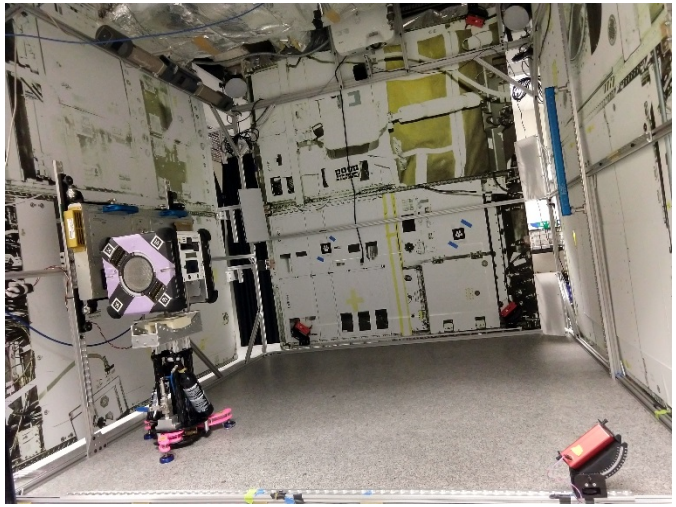


Ground Facilities

Granite Laboratory

- 2m x 2m granite table complying with ISO 10012, ANSI/NCSL Z540-1, ISO/IEC 17025.
- Certified with a surface accuracy of 0.0004 inches.
- Mimics microgravity conditions in three axes (x/y/yaw) by mounting one or multiple Astrobees on mobile air bearings bases to eliminate friction.
- Bases use CO2 tanks providing an experimental continuous time of up to 15 minutes.
- Lighting control (intensity, colorimetry, and shape of lighting source) enabling a multitude of experiments such as mapping an environment with changing light conditions.
- Ground truth localization system provides sub-millimetric precision when tracker is static.
- Granite Lab is a smaller environment and restricts Astrobee to movement on x, y, and yaw.
- Restricted mobility to a smaller area but improves research focused on fine-tuned movement control (handrails grasping/perching, docking maneuver validation, mapping and localization experiments).

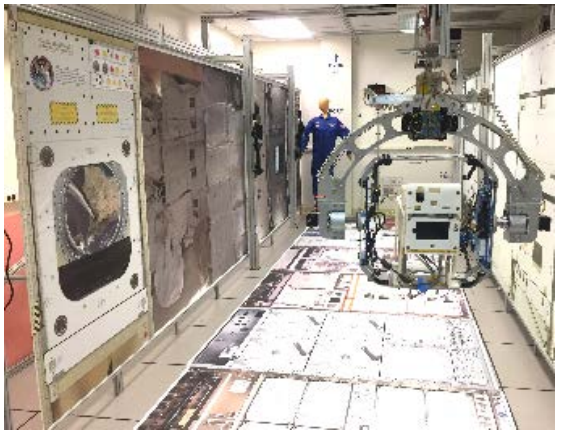




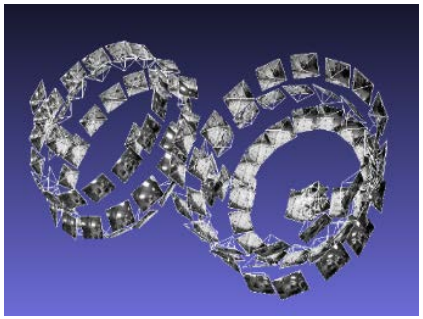
Ground Facilities

Micro-Gravity Test Facility (MGTF)

- Gantry and gimbal structure that provides Astrobee with 6 DOF movement capabilities.
- Gantry that achieves linear displacement in x-y-z, and a gimbal performs rotations about those axes.
- Motion driven by physics controller that responds to simulated thrust commands from Astrobee.
- At the Granite lab, Astrobee propels itself using its propulsion module. At the MGTF, Astrobee is mounted inside the MGTF's gimbal structure without its propulsion module.
- MGTF is larger allowing experiments to have a longer range of motion, to reach Astrobee's maximum accelerations and velocities, and to be only time-limited by the free-flyer's batteries charge.







Guest Scientist

Guest Science Program

- Guest scientists (GS) can become part of this program following the Guest Science Lifecycle (GSL).

  Steps:

  1. GS contacts the Astrobee Facility
  2. Strategic phase: defines high-level who, what, where, and how the GS research will be done
  3. Tactical phase: technical planning, development, and evaluations.
  4. Operations phase: GS science using the HW/SW developed during Tactical phase is run on the ground (at the MGTF or at the Granite laboratory) or on the ISS.
  5. Post-Operations phase: GS receives experimental data and reports from Operations phase

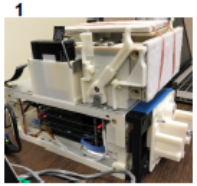
- SPHERES/Astrobee Working Group (SAWG) quarterly meeting provides an opportunity for information sharing across the SPHERES/Astrobee user community.

	Institution/Project	Sponsor	Payload
1	REALM (JSC)	HEO/AES-Logistics	RFID Recon
2	MIT	CASIS	Zero Robotics
3	JAXA	ISS Program Office/JAXA OP3	Robotics competition
4	Naval Postgraduate School	DoD	Astrobatics
5	Stanford	STMD-STRG	Gecko Gripper
6	Astrobotic/Bosch	CASIS	SoundSee

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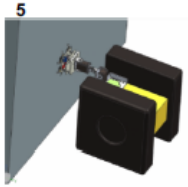
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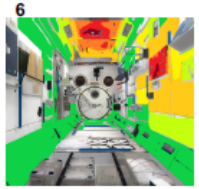
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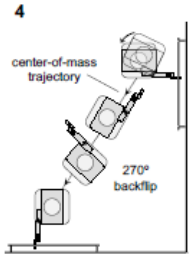
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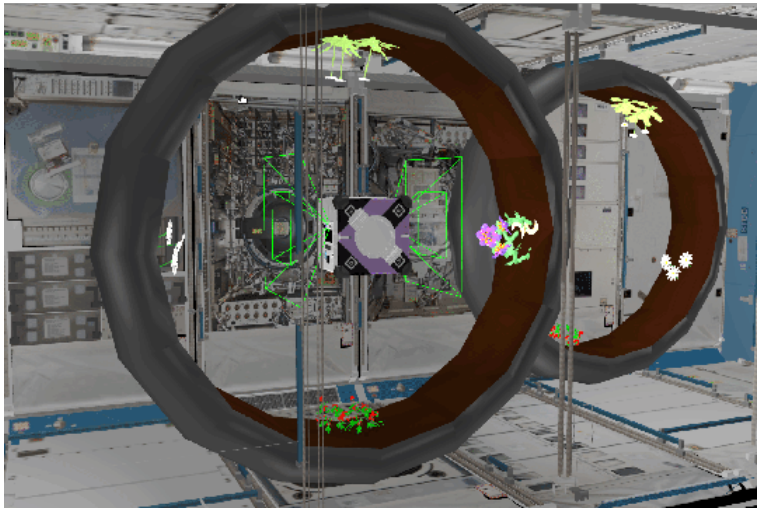
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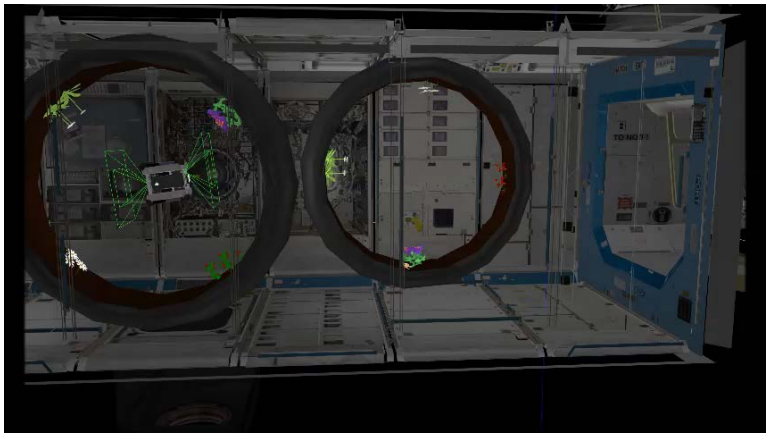


Guest Scientist

MIT Zero Robotics (ZR) Competition

- Aims at inspiring middle/high school students solve code challenges using SPHERES in order to win a game and starting from 2020, using Astrobee.
- MIT works on new Astrobee-based game
- A proof-of-concept game called Astrobotany has been developed based on a customized version of the Astrobee Simulator.
- One key challenge of this transition for MIT is to use a version of the Astrobee Simulator that can be deployed in the cloud, scale to thousands of students, and incorporate student submitted code.

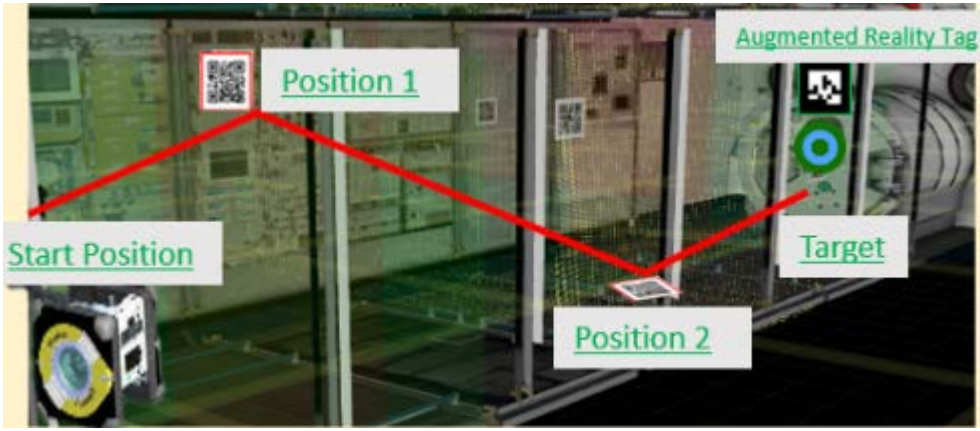




Guest Scientist

JAXA Kibo-Robot Program Challenge

- Aims at inspiring middle/high school and university students solve code challenges using Astrobee to win a game
- https://jaxa.krpc.jp/
- Hundreds of students already signed up
- Astrobee will have to visit different locations, take pictures, even point the laser to a target!
- Chris Cassidy meets Astrobee



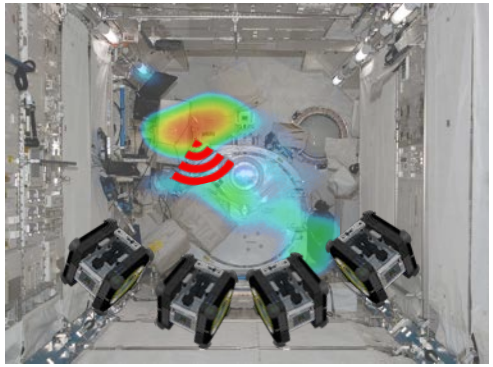


Near-Term Guest Science Payloads

- NASA JSC's RFID-Recon (REALM-2)
  - RFID reader allows inventory and searches for logistics reduction
  - Launch on NG-12
- CASIS's SoundSee (Astrobotic/Bosch)
  - Microphone array that creates a sound map used to monitor health of on-board systems
  - Launch on NG-12
- Gecko Gripper (Stanford)
  - Gecko-inspired end-effector for gripping of smooth surfaces
  - Launch on SpX-18
- Zero Robotics (MIT)
  - Middle school and high school STEM robotics competition
- JAXA Astrobee-IntBall Joint activity
  - Asia-region STEM robotics competition similar to Zero Robotics
- Astrobatics (Naval Post-graduate School)
  - Software-only payload investigating propellant-less propulsion using a manipulator

Future Applications

- Astrobee will help prove out the concept of “Caretaker Robots” for future exploration architectures
- Allows monitoring, maintenance and repair of a facility before and between crews
  - Gateway may be crewed just six weeks per year
  - Critical need to care for spacecraft when crew are not present
- Inspection functions can include:
  - Spot checks
  - Surveys
  - Automated change detection and trending
  - Localizing problems
- With dexterous robotic manipulation capabilities, future tasks could include:
  - Maintenance
  - Repair
  - Cargo transfer



Isolating faults: Ultrasonic leak detection



Off-load routine astronaut tasks: Robotic cargo transfer