

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

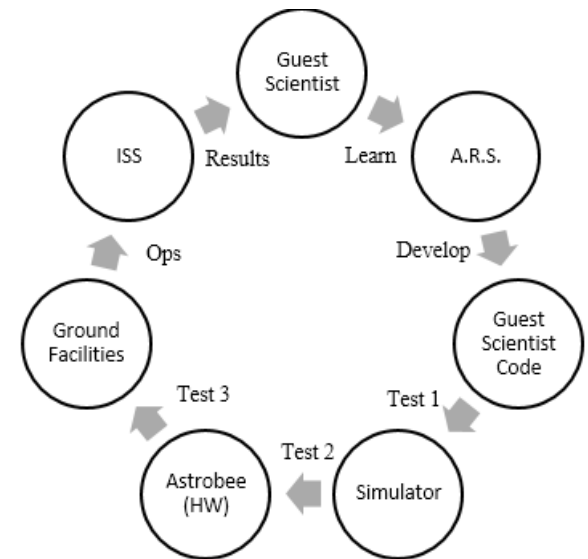


Andres Mora Vargas
Ad Astra High School
Hawthorne, CA
28.02.2020



Introduction

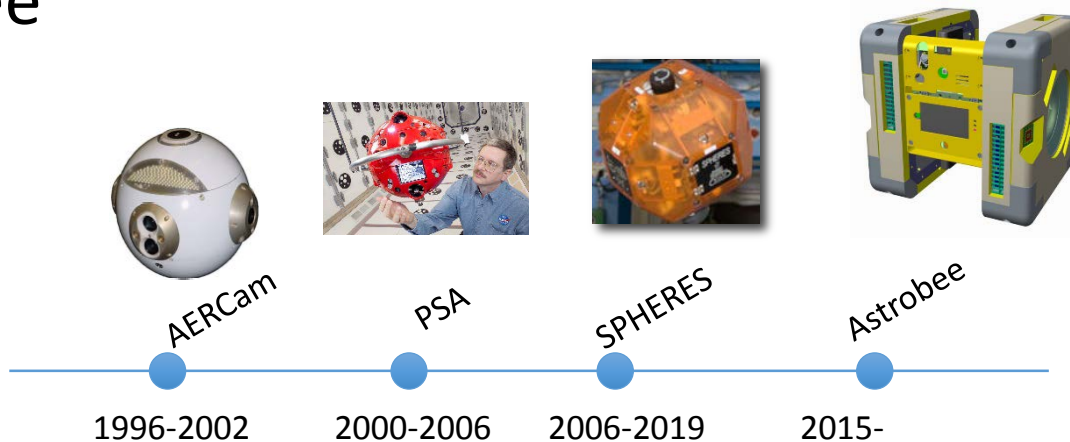
- Astrobee research platform ecosystem
 - Astrobee hardware: Ground and flight units
 - Ames Research Center Experimental Facilities
 - Astrobee Robot Software
 - Access to the International Space Station
- Support different research: HRI, manipulation, computer vision





Introduction

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





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



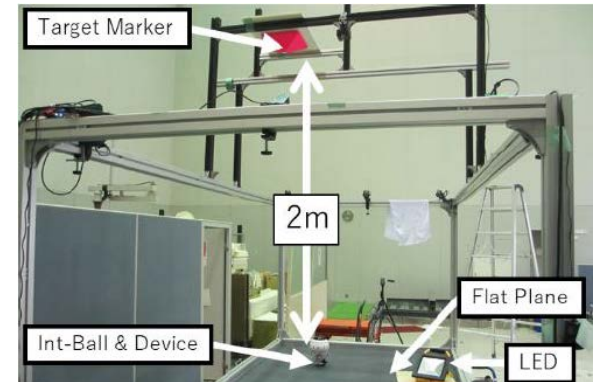
DLR, Airbus, IBM's CIMON



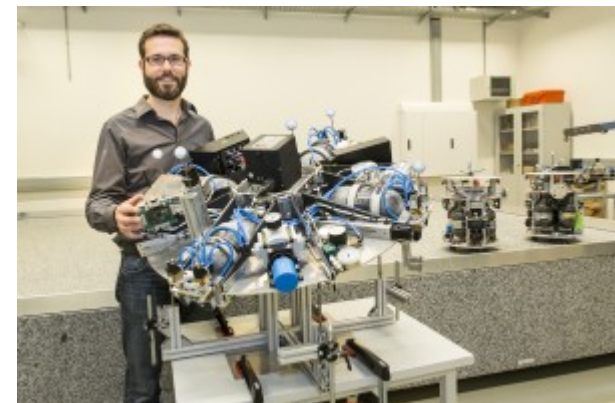
Related Work

Ground facilities for Microgravity Research

- JAXA
 - Granite, 2x1x1 m, Optitrack ground truth system
- DLR (TEAMS)
 - Two granite, 4x2.5m, AR Tracking ground truth system
- Stanford
 - Granite, 2x2x2m, Vicon ground truth system



From N. Tanishima, S. Mitani, S. Shigeto, Y. Matsumoto, Y. Arai, M. Goto and S. Suzuki, "Effective and Accurate Method for Ground and On-Orbit Verification of Control Systems for Free-Flying Robot With Low Thrust Force," in *International Symposium on Artificial Intelligence, Robotics and Automation in Space (i-SAIRAS)*, Madrid, Spain, 2018.



From <https://www.dlr.de/irs/desktopdefault.aspx/tabid-11360/>



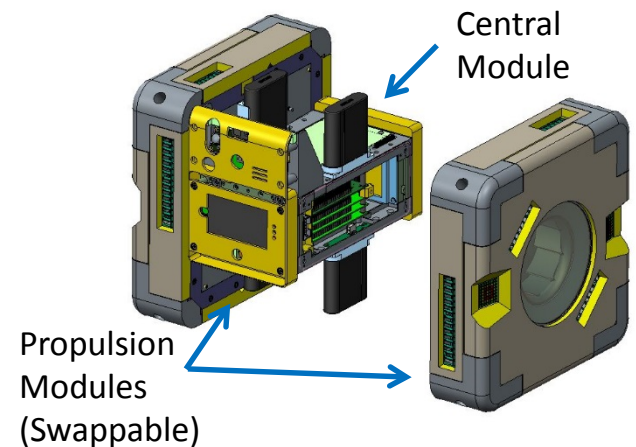
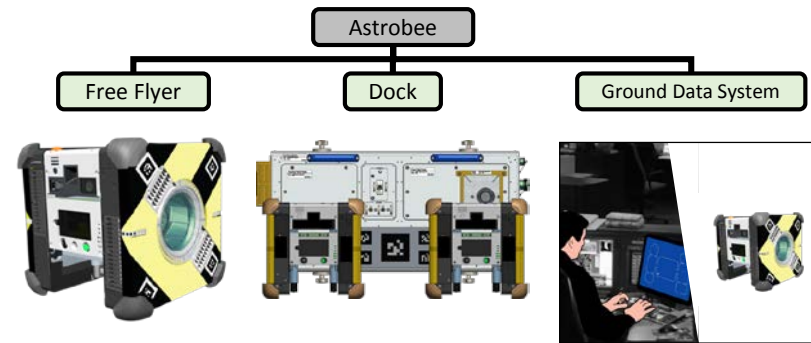
Astrobee Platform & Simulator

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

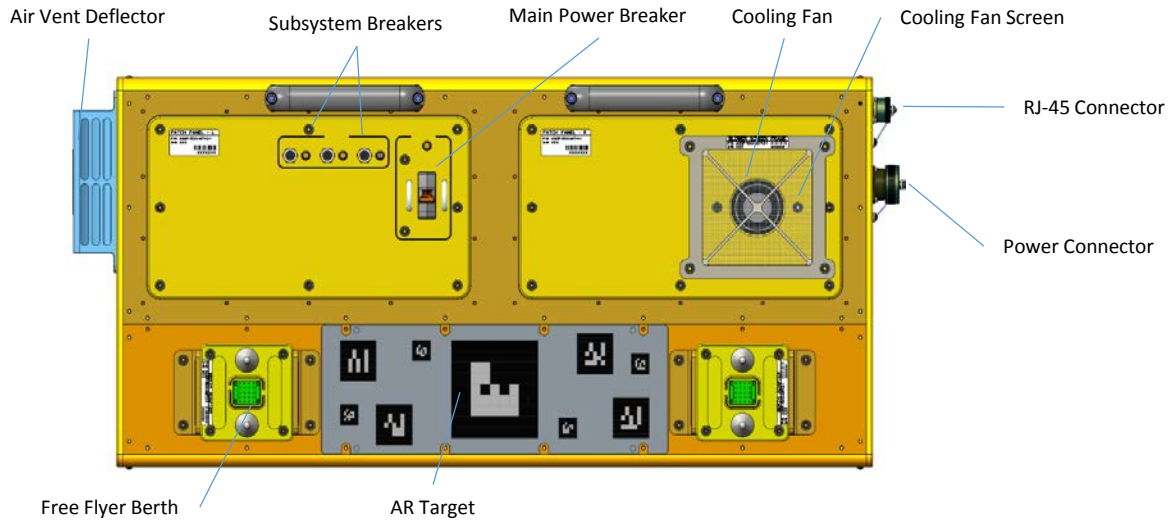
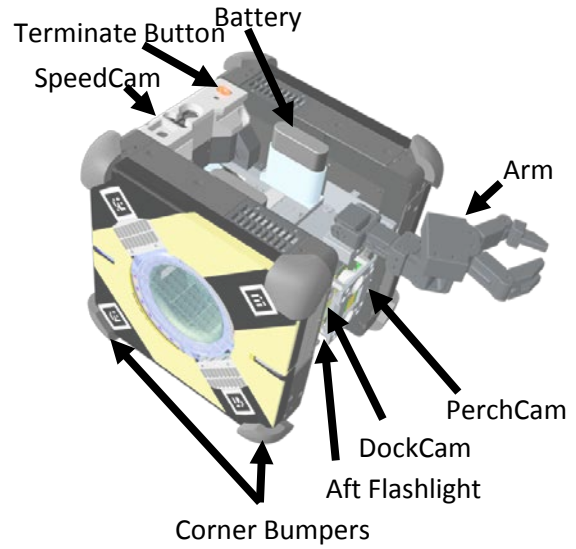
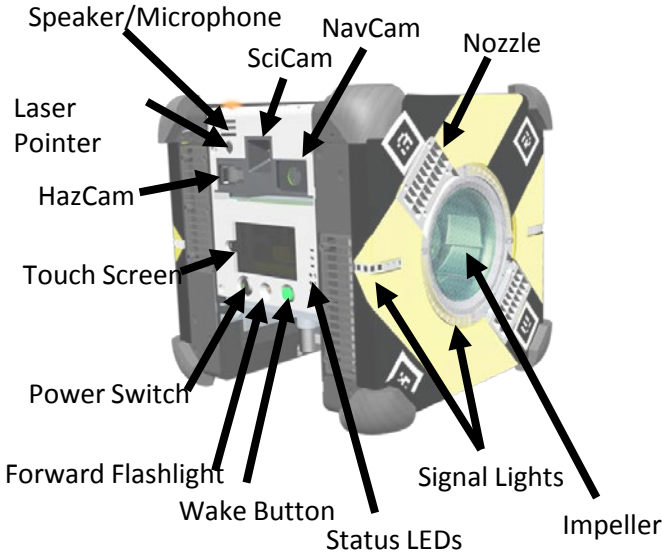
<https://www.nasa.gov/astrobee/videos>



FORWARD



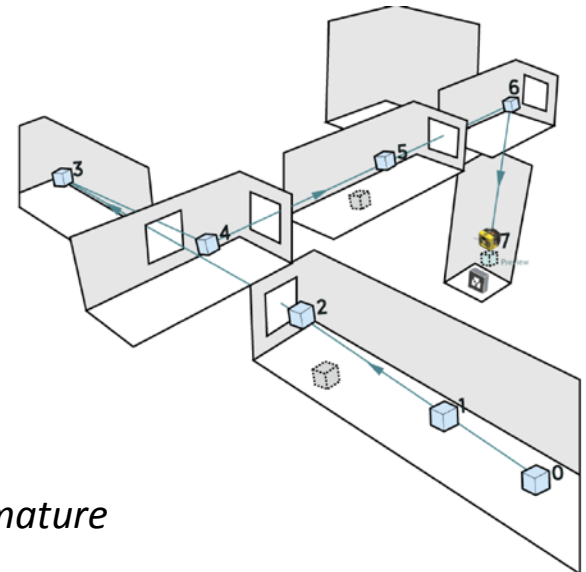
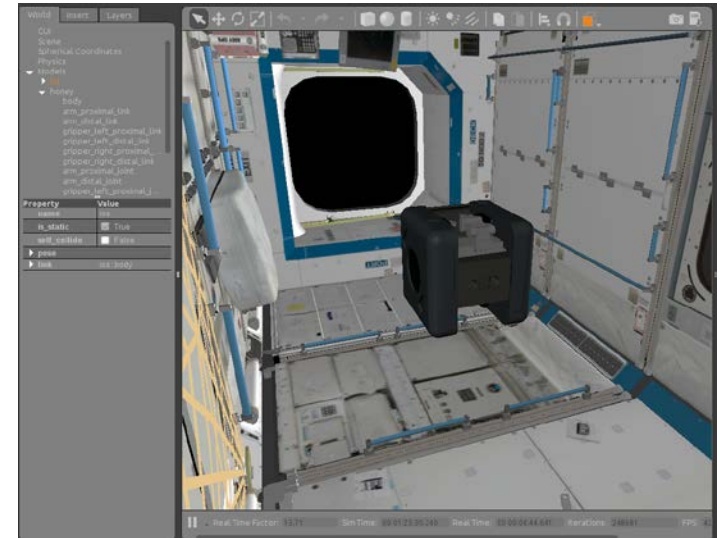
Astrobee Platform & Simulator





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 introspection 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*



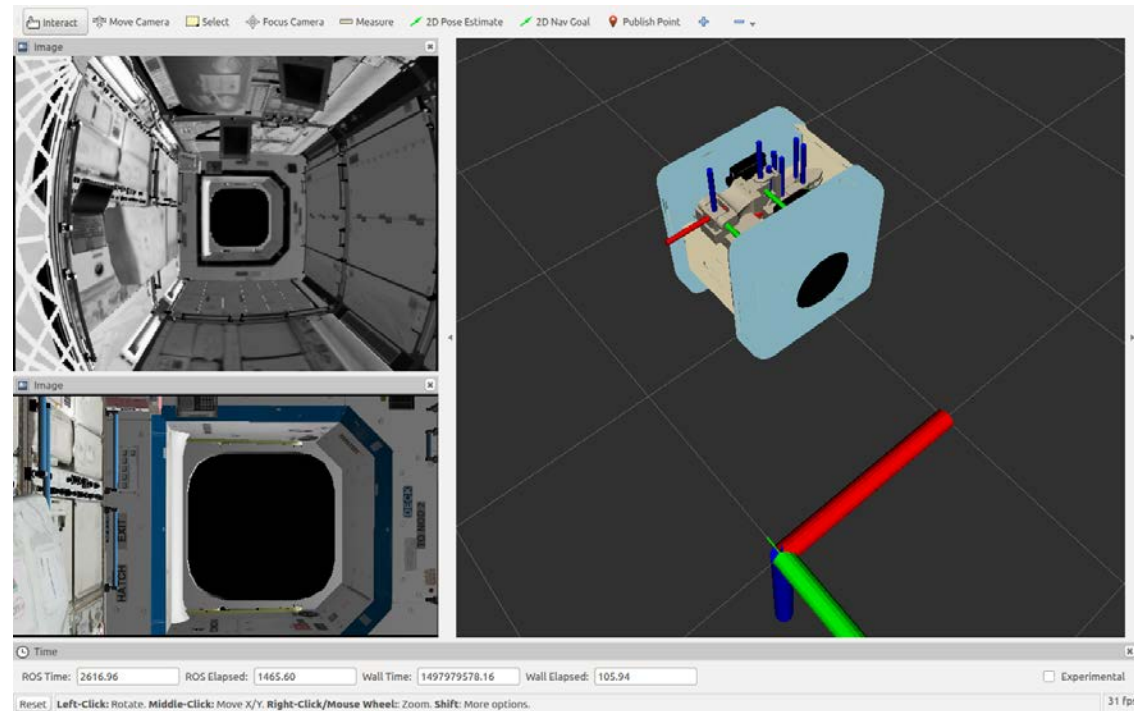
} *less mature*



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

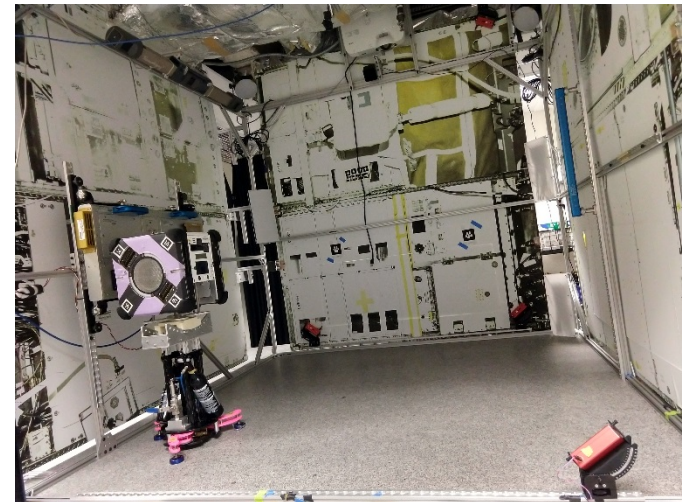
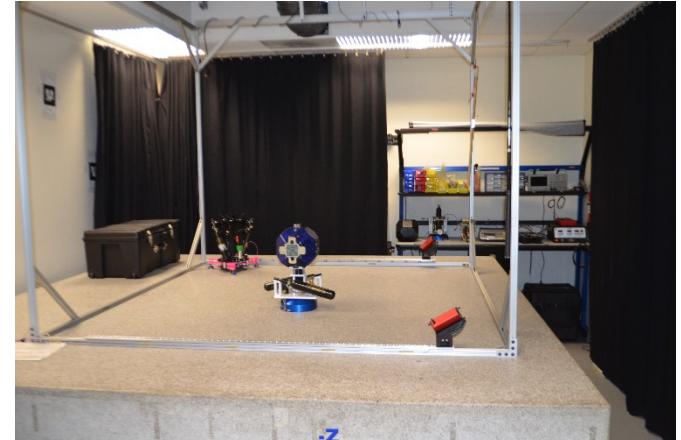




Ground Facilities

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).

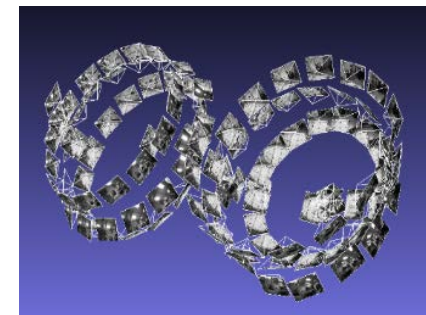




Ground Facilities

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

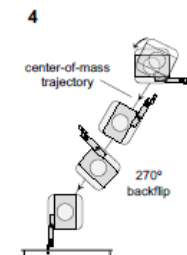
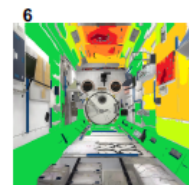
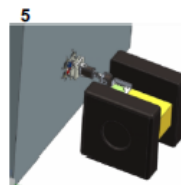
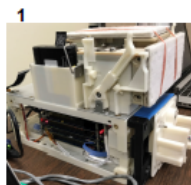
Guest Science Program

- 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	Astrobotics
5	Stanford	STMD-STRG	Gecko Gripper
6	Astrobotic/Bosch	CASIS	SoundSee

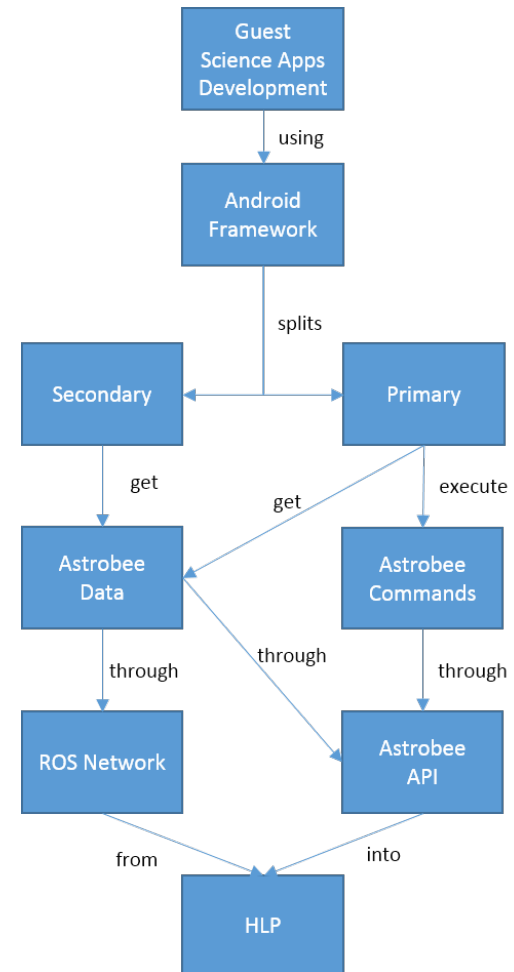




Guest Scientist

Application Development

- Guest scientist interfaces w/Astrobee via HLP by creating an APK called Guest Science Applications.
- GS applications should execute in background mode only. GS apps only take commands and retrieve data thru Astrobee Ground Data System not thru touchscreen.
- Two types of GS applications:
 - Primary: allowed to command & get data from the robot.
 - Secondary: allowed only to get data from the robot.

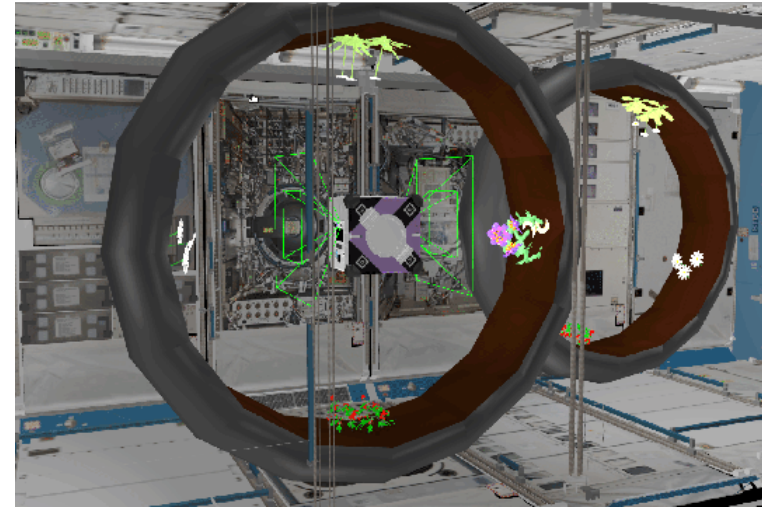




Guest Scientist

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.





Conclusion & Future Work

- Components of the Astrobee research platform, the interaction between them, and how guest scientists are involved in that ecosystem.
- Current status of the Astrobee robot, its software including its simulator as well as the micro-gravity simulating research facilities at Ames Research Center.
- Overview of how guest scientists develop hardware and software payloads and the processes required to use these facilities.
- Successful commissioning of the Astrobee platform on the ISS in 2019.
- Integration of Astrobee's first users, and continued sustaining support of the overall Astrobee facility.
- Multi-robot framework supporting JAXA's Int-Ball, ESA's CIMON, and NASA's Astrobee to enable guest scientists to expand the range of experiments that can be carried out.
- Improvement of capability and performance of Intra Vehicular Activity (IVA) robots to perform payload operations and spacecraft caretaking in preparation for human exploration beyond Earth orbit.

