Astrobee Overview

2021

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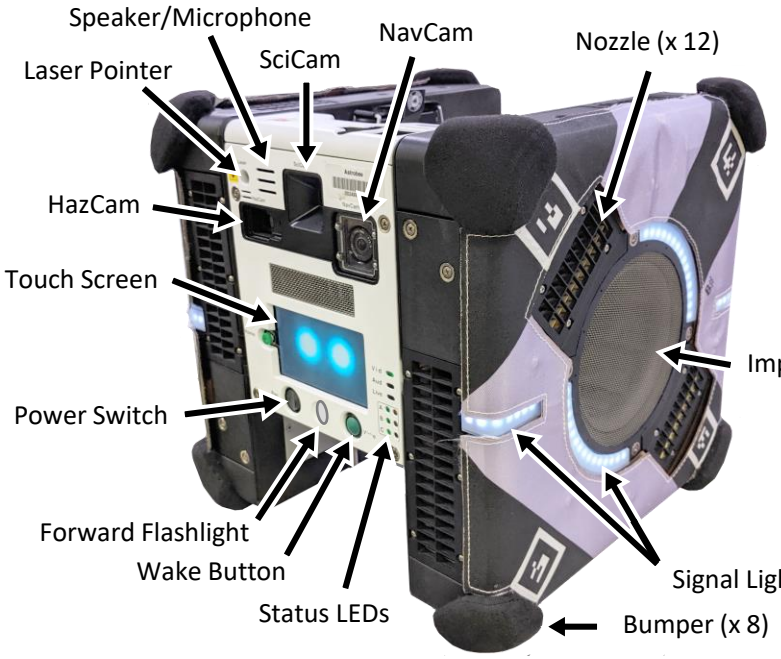
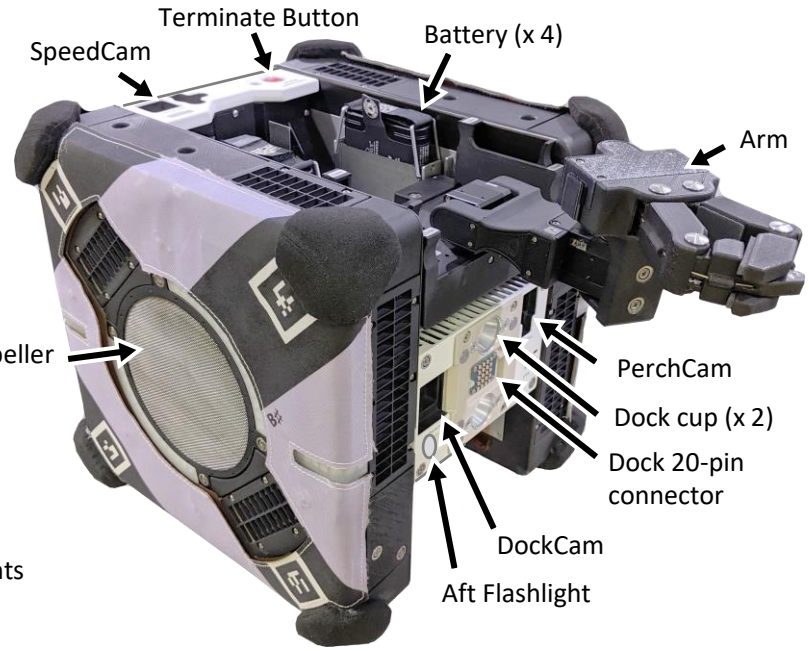
Astrobee Objectives

- Provide a microgravity robotic research facility in the ISS US Orbital Segment (USOS), which will replace the existing SPHERES facility
- Provide remotely operated mobile camera views of the ISS USOS to enhance the situation awareness of mission control
- Perform mobile sensor tasks in the ISS USOS

System Description - Hardware



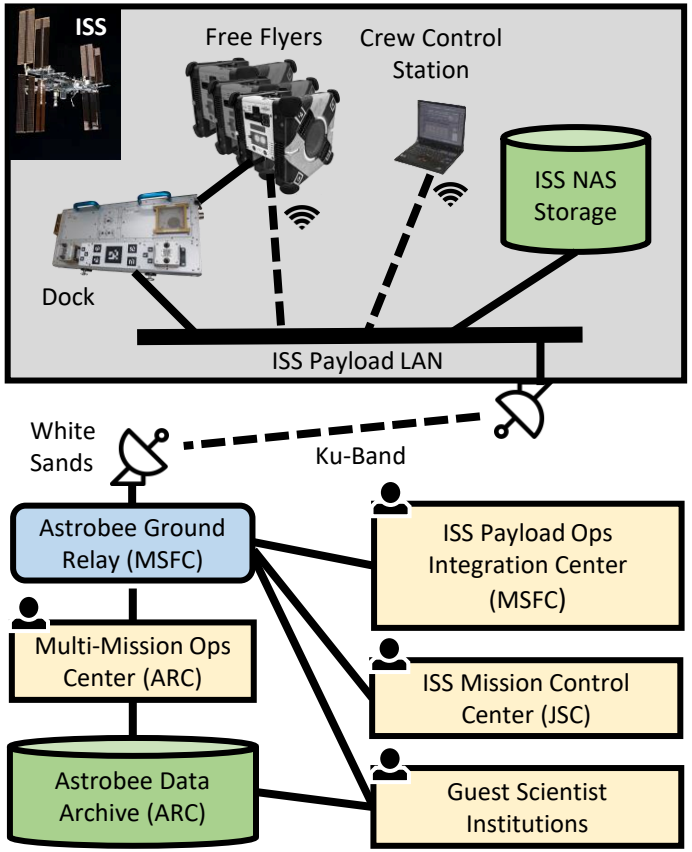


- Free flying robot inside the ISS
- 32 cm wide, ~9.1kg (2 batt., no arm)
- All electric + fan-based propulsion
- Robot arm for “perching”, ~1kg

- Three smartphone computers
- Three payload bays for expansion
- Microphone not currently enabled

System Description - Communications

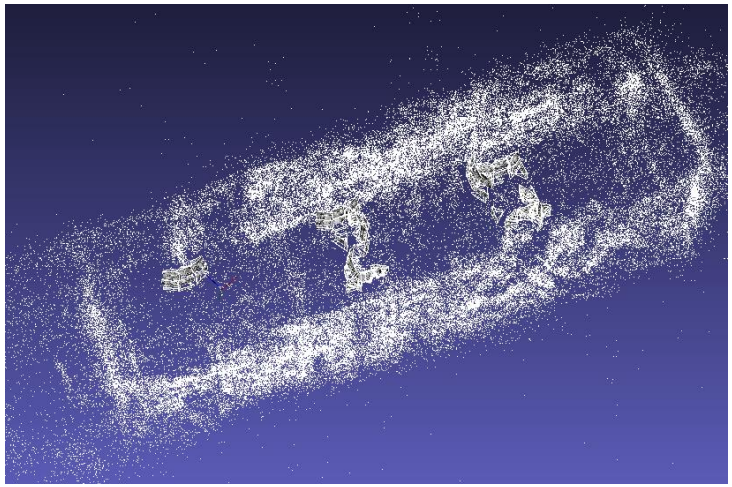
- Communicates through ISS WiFi when flying
- Single telemetry/video stream to ground
- Multiple ground stations can connect through server
- Large file transfers and software updates through Ethernet on the dock



Astrobee communications path

System Description - Navigation

- Vision-based navigation
  - Compares features with on-board a priori map
  - Incorporates inertial measurements
- Fiducials used for autonomous docking
  - Requires approximately 1 cm position accuracy
- Visual odometry
  - Robot can continue to navigate where no map features are recognized

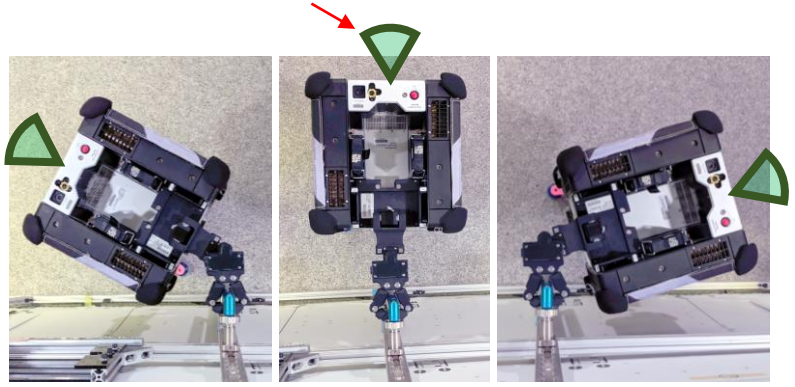


Feature map of the JEM-PM

System Description - Perching Arm

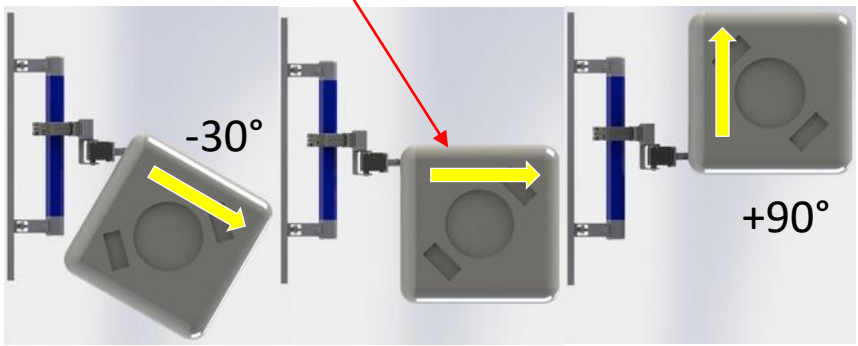
- Designed to grasp handrails
- Stows completely in payload bay
- Acts as a pan-tilt unit while perched
- Flexible and back-drivable
- May be perched manually

Camera View Direction



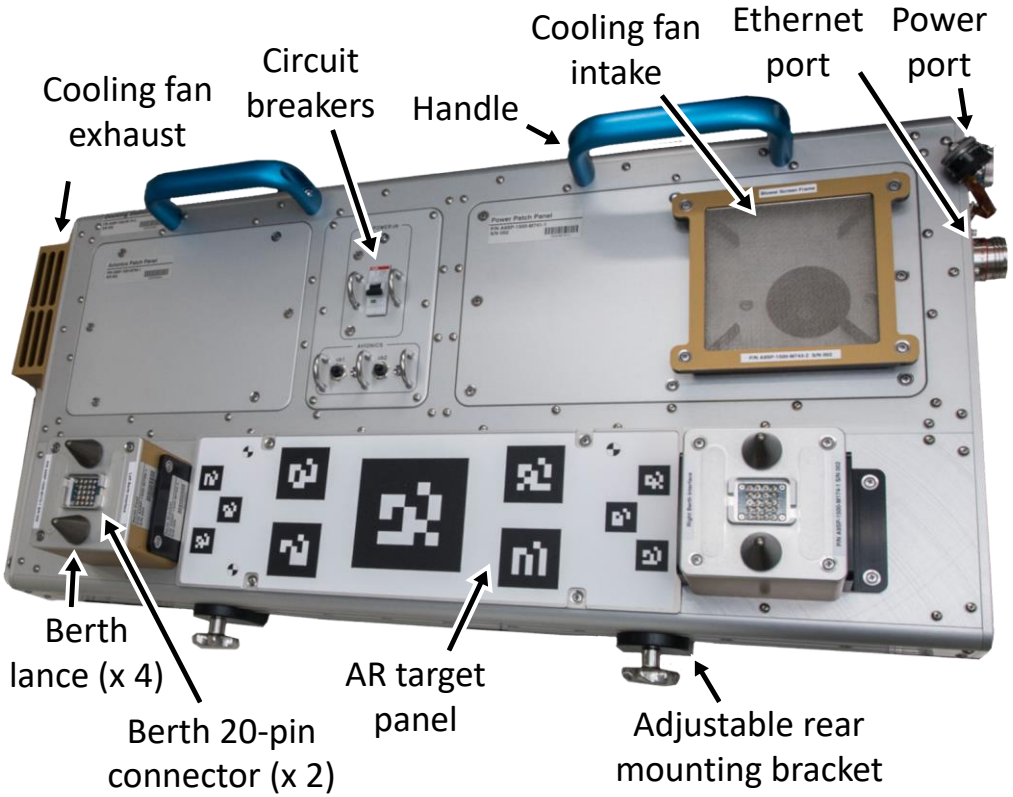
Astrobee Perching Arm pan motion

Camera View Direction



Astrobee Perching Arm tilt motion

System Description - Docking Station

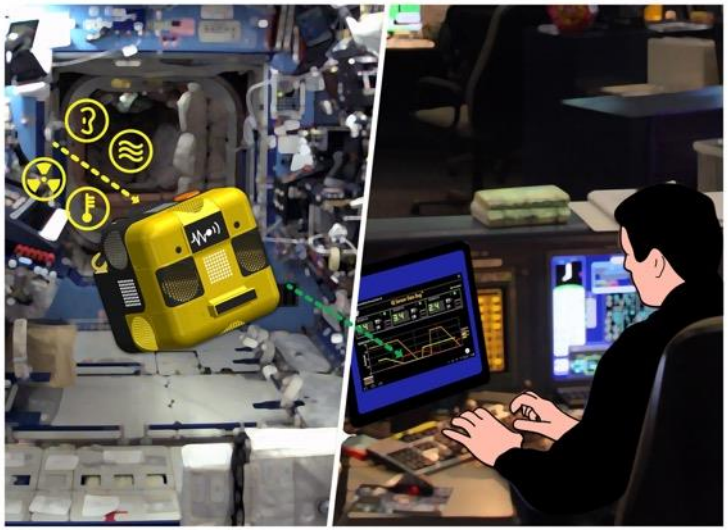


- 85 cm x 38 cm x 28 cm
- Berths for 2 free flyers
- Provides power and Ethernet

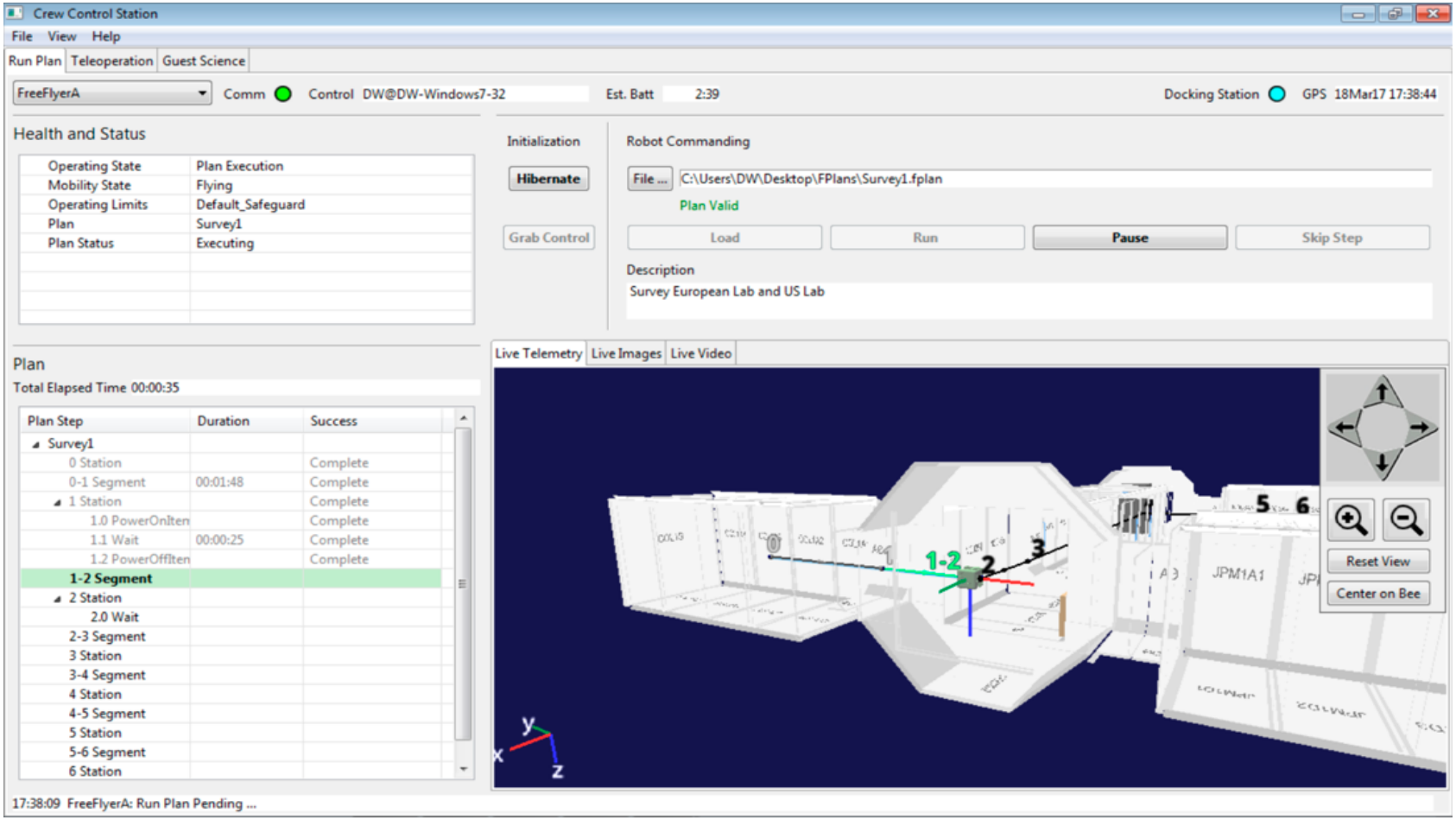
- Fiducials used for visual servoing to autonomously dock
- Magnets provide retention force

System Description - Ground Data System

- Astrobee Control Station
  - Sortie planning tool
  - Execution monitoring
    - Live telemetry
    - Image and video streams
    - 3D virtual display
  - Supervisory control (run plans or single commands)
  - Typically used by ground operators
- Crew Control Station runs on an EXPRESS Laptop Computer (ELC)
- Server for archiving and distributing Astrobee data
- Suite of engineering tools to support maintenance and software upgrades



Astrobee Control Station



Basic Conops

- When an Astrobee is idle, it charges in its dock
- Astrobees can execute complex plans with full autonomy and no astronauts present
  - Including undock, traverse multiple modules, return to dock
- However, Astrobees run with ground operator oversight
  - When an anomaly occurs, an Astrobee generally stops and waits for operator intervention
  - It can continue operating during communication outages until it encounters an anomaly
- The operator can always take over and teleoperate
- Astronauts can also be operators, but this is will likely be a rare occurance (minimize crew time)

Hardware Status

- Docking Station
  - Launched on NG-10 – 11/17/18
  - Installed on 2/15/19
- 2 Astrobees (Bumble & Honey) and Dock Spares Kit
  - Launched on NG-11 – 4/17/19
  - Checkout of Bumble began 4/30/19
  - Checkout of Honey began 10/30/19
- 1 Astrobee (Queen) and 3 Perching Arms
  - Launched on SpX-18 – 7/21/19

Astrobee Commissioning Activities

1. Checkout
   - Crew inspects the robot
   - Functional tests of all hardware
2. Calibration & Mapping
   - Crew collects camera and IMU calibration data
   - Crew collects mapping data of Kibo
3. Localization & Mobility
   - Verify robot localization within Kibo
   - Robot performs increasingly complex motions to test mobility system
4. Checkout & Calibration
   - Combination of 1 & 2 without mapping

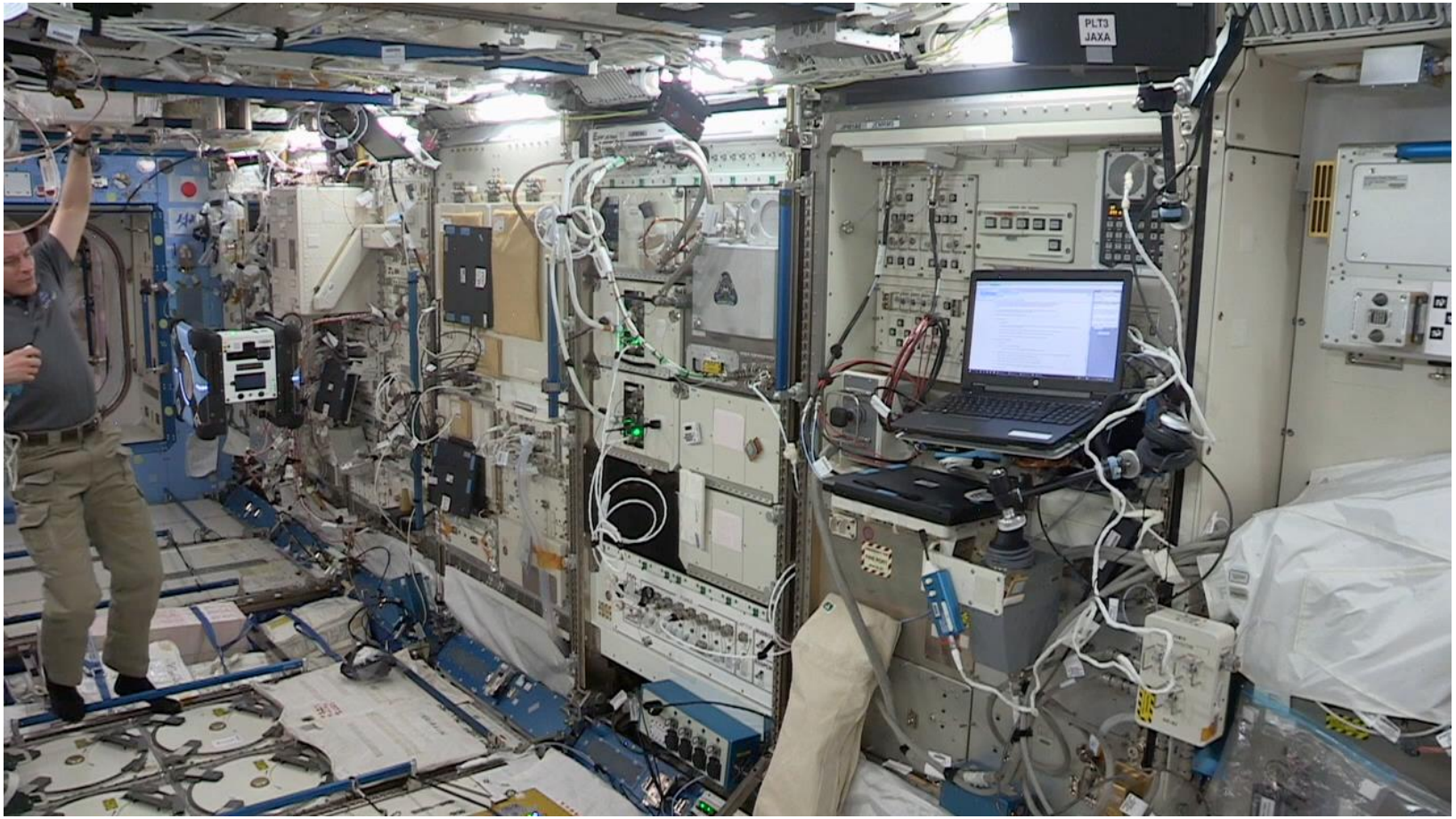
Astrobee Commissioning Activities

6. Ops Demo
   - Demonstrate an operational mission scenario
7. Payload Installation
   - Crew installs payload (perching arm)
   - Functional tests of payload
8. Payload Demo
   - Operational demonstration of payload (perching arm)
9. Performance Characterization
   - TBD tests to further characterize Astrobee performance
10. SPHERES/Astrobee Hand-off
    - Symbolic passing of the torch from SPHERES to Astrobee
    - Completion of commissioning

Bumble Checkout

IMU Calibration

1st Flight



Stopping Ability

1st Autonomous Undocking

1st Autonomous Docking

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
- **JAXA Kibo-Robotic Programing Challenge (RPC)**
  - **STEM robotics competition**
- Astrobatics (Naval Post-graduate School)
  - Software-only payload investigating propellant-less propulsion using a manipulator

Fun with Robots

Questions?