



Astrobee Facility

***Sponsoring Org/Office Code: ISS Program, OZ3
Name of Forum: Astrobee Working Group
Date: October 28th, 2021***



***Jose V. Benavides
NASA Ames Research Center
Intelligent Systems Division (Code TI)
Henry Orosco
ISS NASA Tech Demo Sphere Lead***



Event Agenda



Astrobee Working Group			Join by Teams Link:			
Draft, Subject to change			Location: Phone/ MS Teams			
Date:	Thursday, October 28th, 2021, 8am PST					
Agenda	Group	Sponsor	Project	Name	Time	duration (min)
0	NASA ISS		Introductions/Welcome	Henry Orosco	8:00 AM	0:05
1	NASA Astrobee	NASA TDO	NASA ISS Program TDO overview	Henry Orosco	8:05 AM	0:10
2	NASA ISS		Astrobee Facility Status	Jose Benavides	8:15 AM	0:30
3	NASA ISS TDO		Astrobee PIM Status	Tyler Dorval/Melissa Boyer	8:45 AM	0:10
4	National Lab	Nat Lab	National Lab overview	John Trzinski	8:55 AM	0:05
5	NASA Ames	NASA STMD	ISAAC	Trey Smith	9:00 AM	0:15
6	NASA JSC	NASA AES	RFID-Recon	Andrew Chu	9:15 AM	0:15
7	Break				9:30 AM	0:15
8	Astrobotic/Bosch	Nat Lab	Sound See	Charles	9:45 AM	0:15
9	University of Nevada	Nat Lab	Cubee/Cling	Adarsh Rajguru/Ke-Xun Sun	10:00 AM	0:20
10	MIT/DLR	Nat Lab	ReSwarm, Astrobee-ROAM	Keenan/Dr. Richard Linares	10:20 AM	0:15
11	SPEC Sensors	Nat Lab/STMD	SMELS	David Peaslee	10:35 AM	0:15
12	Zero G Horizons	Nat Lab/STMD	SOARS	Deepak Sathyanarayan	10:50 AM	0:15
13					11:05 AM	0:15
14					11:20 AM	0:15
15	Break/Lunch				11:35 AM	1:30
16	FIT	NASA STMD	SVGS	Hector Gutierrez	1:05 PM	0:15
17	NPS	DOD	Astrobatics	Stephen/Jennifer/Marcello	1:20 PM	0:15
18	ILC Inc./MIT	Nat Lab	Zero Robotics	Kathleen Magrane/Danielle Wood	1:35 PM	0:15
19	Kall Morris Inc.	Nat Lab	REACCH	Austin Morris	1:50 PM	0:15
20	CSIRO/Boeing	Nat Lab	Multi-resolution Scanning	Marc	2:05 PM	0:15
21	Makel Engineering Inc.	NASA STMD	SBIR Phase 2, EMMA	Darby Makel	2:20 PM	0:15
22					2:35 PM	0:15
23	Metis	NASA STMD	SBIR Phase 1, Colaborative SLAM	Walter	2:50 PM	0:15
24	Kibo-RPC	JAXA	Kibo-RPC-2	Arakane-san	3:05 PM	0:15
25	NASA Ames		Wrapup, Action Items	Jose Benavides & Henry Orosco	3:20 PM	0:15



Purpose



- **Purpose:** provide an Astrobe Facility overview and update
- **Select the appropriate box below:**
 - ☐ Request for Technical Concurrence
 - ☒ Information Only
 - ☐ Management Direction
 - ☐ Response to an Action Item
- **Agenda:**
 - Overview
 - Engineering
 - Operations



Overview



Project Description



Based at Nasa Ames Research Center, the ISS Astrobee Facility provides a free-flying robotic system for ISS research and ISS STEM outreach. The Astrobee free-flying robotic system consists of three cubed-shaped robots, software, and a docking station used for recharging. The project provides sustaining engineering tasks for ensuring the facility operational readiness on ISS. The project provides payload support to users from academia, private industry, NASA, and other government agencies in the execution of ISS approved research and STEM objectives.



Chris Cassidy, GMT 248 2020



Overview



Why Free Flyers on ISS? Provide a risk-tolerant testbed to:

- Enhance & Enable Human Exploration (e.g. Gateway)
 - Astrobees can potentially perform a range of Intra-Vehicular Robotics (IVR) caretaking tasks to help maintain and protect the Gateway, particularly during uncrewed mission phases.
- Perform Fundamental Research

Objectives

- Ensures the facility readiness for ISS Astrobees test sessions
- Provides real-time ISS test session Ops support, and Increment Planning
- Supports a diverse user community of government, commercial, and academic investigators to enable Free-Flyer research

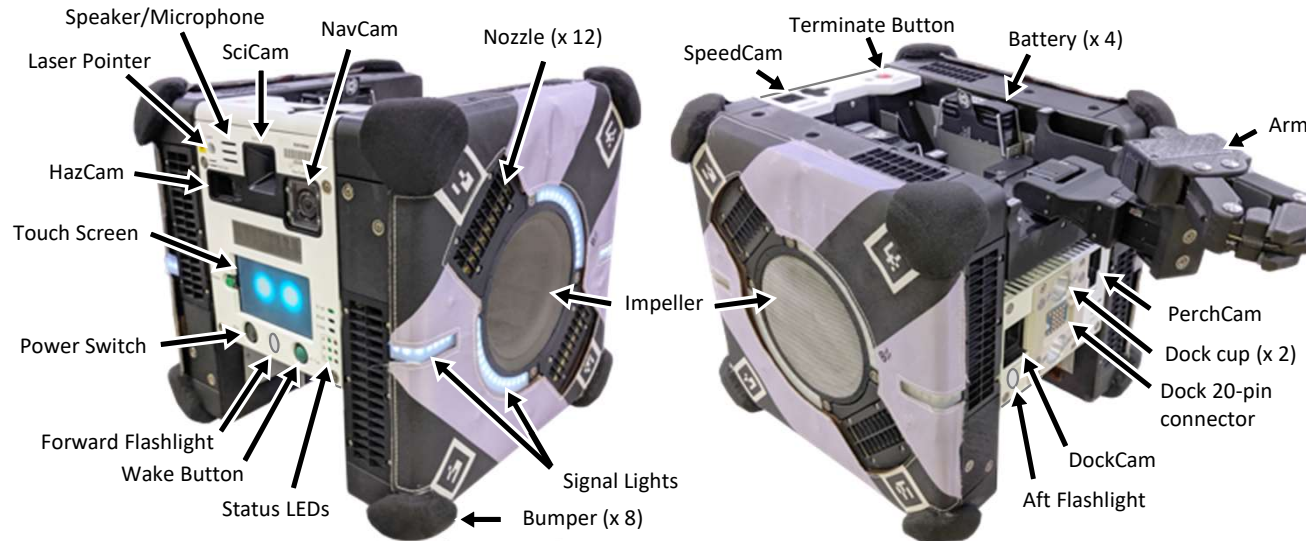
Current activities

- Completing Astrobees commissioning activities
- Maintaining & Operating Astrobees
- Facilitating Free Flyer user community
 - Periodic Astrobees Working Group (AWG)
 - International Partners: JAXA (Int-Ball) and DLR/Airbus (CIMON)
- Supporting over 6 Astrobees users in various stages of integration





Astrobee HW Overview



- 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
- More: www.nasa.gov/astrobee



AWG Community



- Astrobee Working Group (AWG) meeting
 - Meet twice a year (ideally in-person)
 - Timed similarly to the POIWG conference
 - Next: April 2022
- Purpose:
 - Information sharing across the Astrobee community
 - Astrobee Facility shares status, updates, overall calendar
 - Discuss proposed changes/updates



Astrobee Users

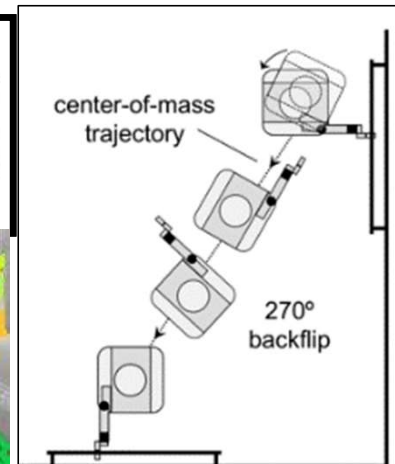


- 11 Projects actively working towards ISS payloads

- Astrobatics (Naval Postgraduate School)
- SoundSee (Astrobotic/Bosch)
- Gecko (Stanford)
- RFID Recon (NASA AES/REALM-2)
- JAXA Kibo-RPC
- ISAAC (NASA STMD/GCD)
- ROAM (MIT/DLR)
- ReSWARM
- SVGS (FIT)
- SOARS (Zero-g Horizons)
- Cubee/CLING

- Complete:

- Astoportor (Tethers Unlimited)
- REGGAE (NanoRacks/Braunschweig)





Astrobee ops from home



Day 584 of WFH



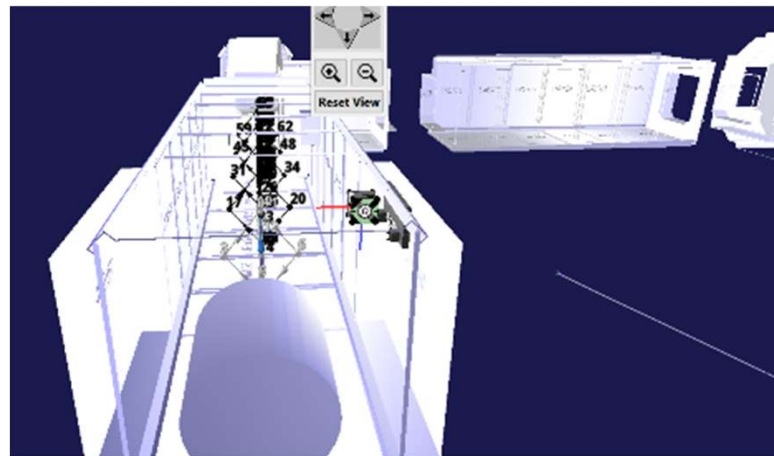
July 8th, 2021, Astrobee Working Group



Highlights



- Maintained a high operating tempo
 - 15 Activities since the last AWG
- Dozens of successful research activities executed successfully and looking forward to dozens more in 2021 and beyond



Bumble Shooting Star, Oct. 26, 2021



Highlights



- Continued lab and integration testing activities at NASA Ames Astrobee Lab under Covid-19 restrictions
- Astroporter Investigation complete in August
- First autonomous Perching demonstrated in September



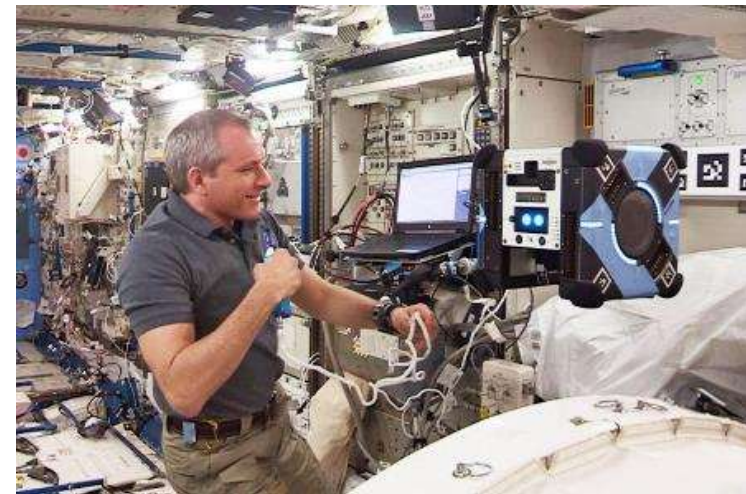
Three-fingered Hand Integration, Columbia University



Aki Hoshida
Kibo-RPC, May 26th 2021



Highlights



CSA astronaut David Saint-Jacques supporting
Astrobee commissioning



Astrobee Summary since last AWG



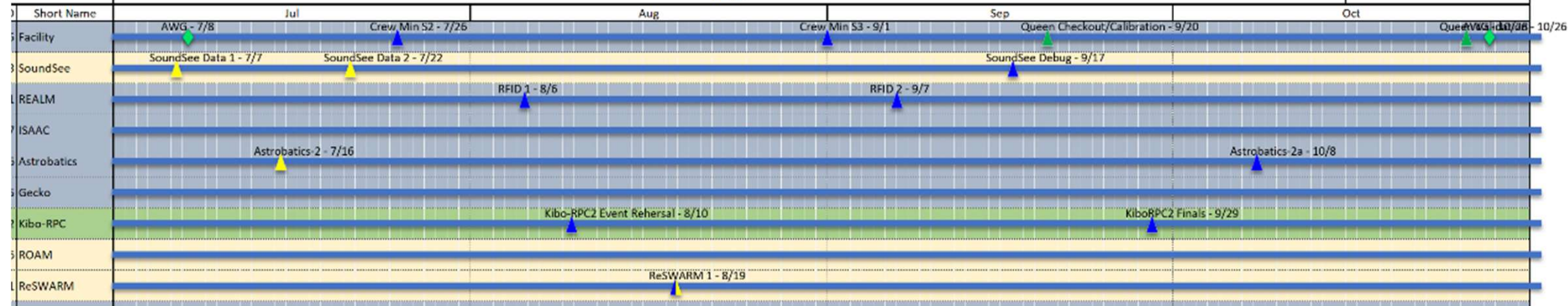
By Months
7/1/2021
4

- Start Date
- Number of Months



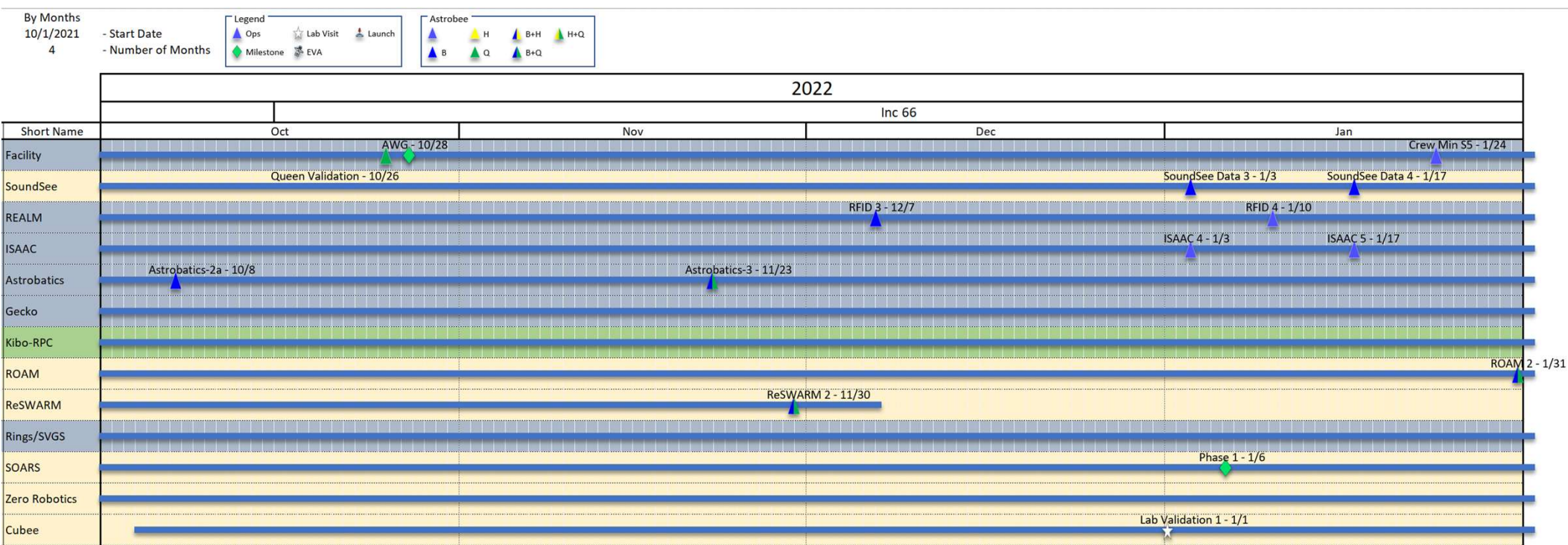
2021

Inc 65





Astrobee Calendar





Astrobee Calendar (planning)



By Months
10/1/2021
18

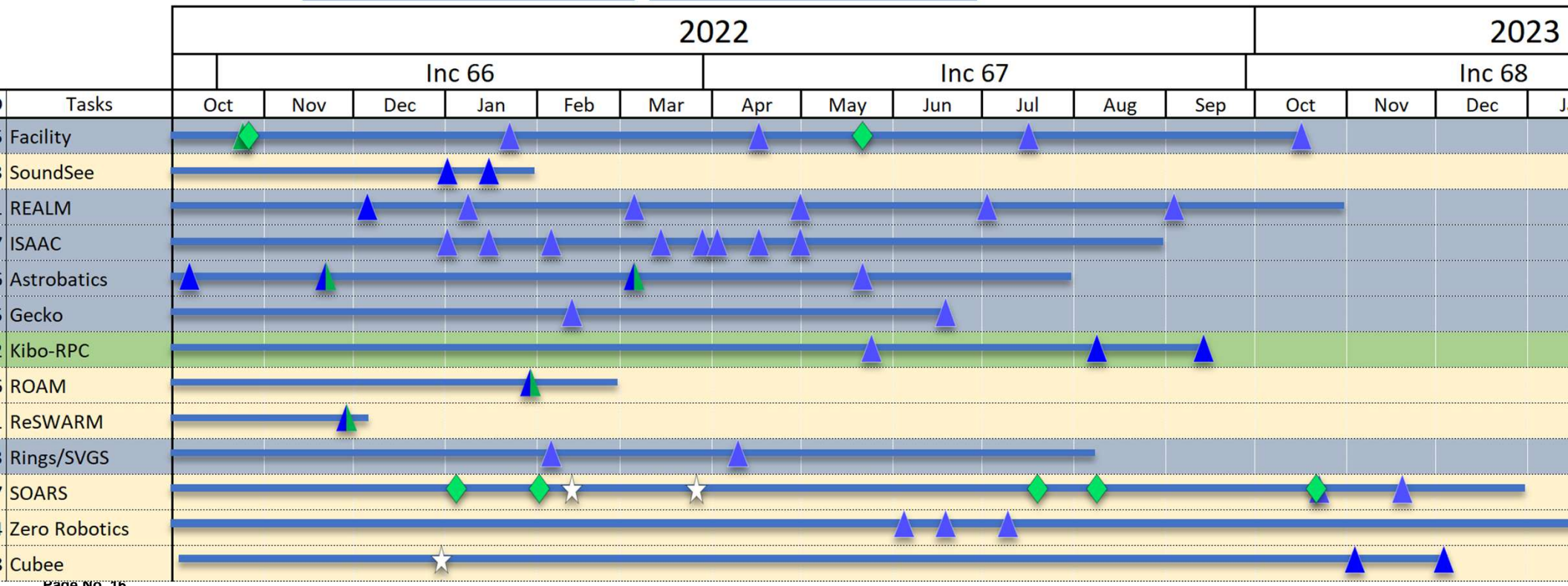
- Start Date
- Number of Months

Legend

- ▲ Ops
- ★ Lab Visit
- 🚀 Launch
- ◆ Milestone
- 👤 EVA

Astrobee

- ▲ B
- ▲ H
- ▲ B+H
- ▲ H+Q
- ▲ Q
- ▲ B+Q





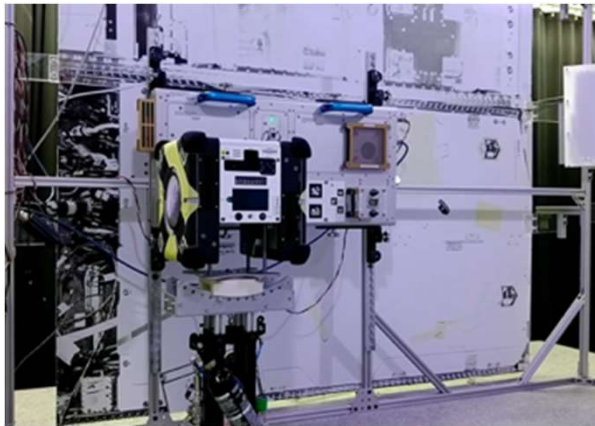
Engineering



Hardware and Lab Status



- Granite Lab: Online



- Flight Lab: Online



- Engineering Evaluation Lab (EEL): Available upon request

Name	Status
Flat Sat A	Operational
Flight 1,3	In Space, Operational
Flight 2	Returning
Flight Spare	Operational
Cert (B#)	Operational
Ground (Wannabee)	Operational



Commissioning Status 2021



Crew Activity	Robot	Date
Localization & Mobility 5	Honey	4/30/20
Localization & Mobility 6	Bumble	5/13/20
Crew-Minimal 1-5	Bumble	7/2-8/19/20
Localization & Mobility 7	Bumble	9/4/20
Crew-Minimal 6-8	Bumble	9/10-10/01/20
Crew-Minimal 9-11	Bumble + Honey	12/07-3/10/21
Dock Repair	N/A	02/02/21
Arm Installation	Bumble + Honey	02/04/21
Arm Demo	Bumble + Queen	09/01/21
SPHERES/Astrobee Hand-off	TBD	TBD

Completion of Phase 1 enables support of initial Guest Scientists

- RFID Recon, JSC
- SoundSee, Astrobotic / Bosch
- Gecko Gripper, Stanford
- Kibo-RPC, JAXA



User Integration Status

overall assessment



User Support: (by user, percent complete)

- User community support (Comm)
 - System documentation, working group meetings, conferences, public outreach
- Assessment and technology demonstration (Assess)
 - initial payload assessments,
 - ground-only/non-IPL technology demonstration support (e.g. NASA-STMD funded SBIR's and Grants)
- Integration, safety, and verification (Integration)
- Interface and user training (Interface)
- Lab testing (Lab)
 - Hardware/Software/Network interface testing
 - Operational Readiness Testing (ORT)
- Ops planning (Planning)
 - procedures, crew training, increment scheduling
- Ops activates (Ops)
- Data distribution

User	Percent Complete
Astrobotics (Naval Postgraduate School)	100
SoundSee (Astrobotic/Bosch)	100
Gecko (Stanford) – Phase 2	20
RFID Recon (NASA AES/REALM-2)	100
ISAAC (NASA AES)	100
SVGS (FIT)	60
SOARS	15
ROAM (MIT)	100
ReSWARM (MIT)	80
Zero Robotics	05
Cubee/CLING	05

Finished Investigations

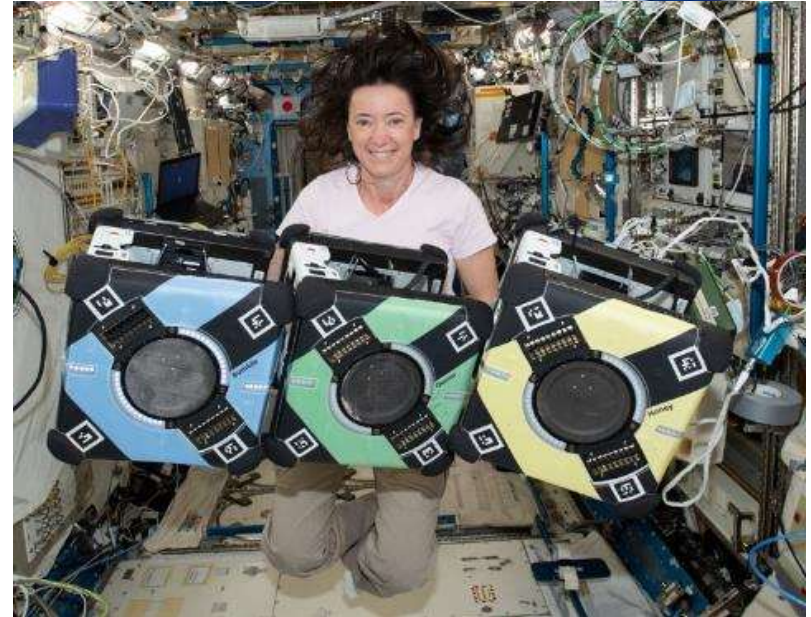
Astroporter (Tethers Unlimited)
JAXA Kibo-RPC - Year 2



Honey Debug



- Issue: LLP CPU not booting (during ReSWARM-1 on Aug. 19th)
- Honey packed on 09/20
- It was returned on returned on SpX-23
- It will be returned to Ames for repair and testing
- This is our first opportunity to see first hand how space affects the robots





Queen Checkout

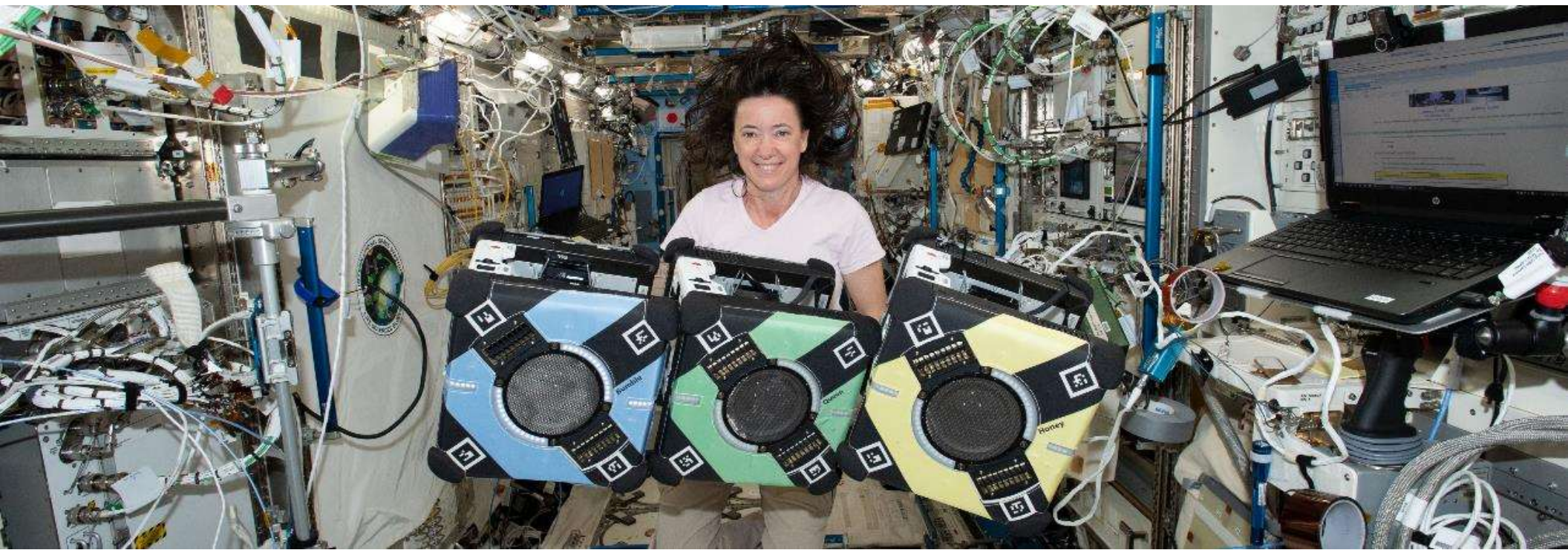


- Unpacked and all systems checked on 09/20
- First test session used on 10/08
 - (Asrobatics 2a)
- Localization validation on 10/26





Astrobee Family

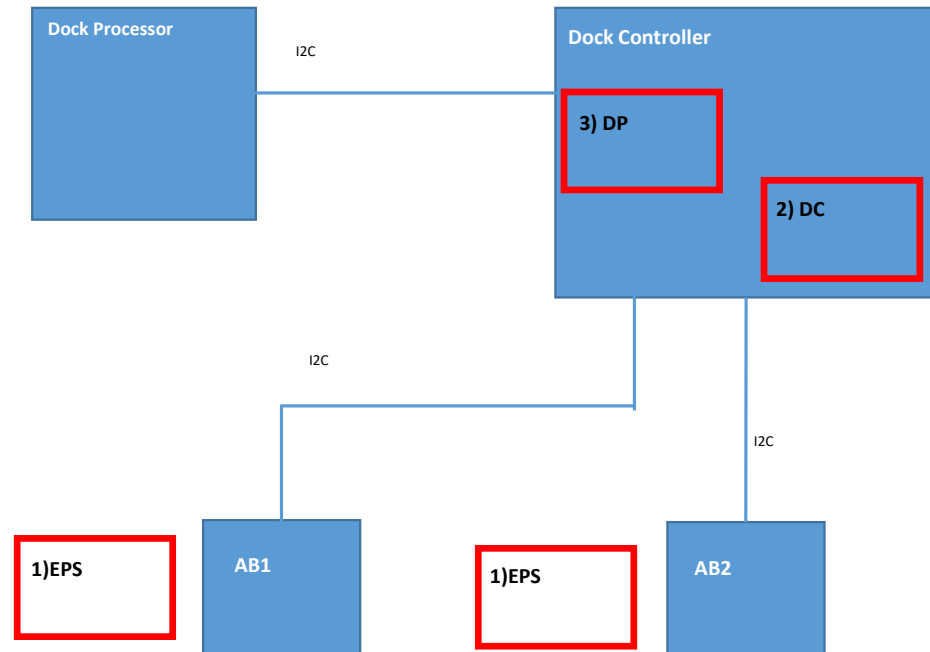




Dock Software Update



- Includes watchdog timers and recovery mode ssh
- Pending lab dry run and verification completion





JEM Coverage Analysis



- Software tool helps visualize the coverage of a given map or Astrobees trajectory
- Coverage of a map: the number of Map Landmark (ML) features in a volume of $30cm^3$ along an imaginary grid on the overhead, aft, forward, deck walls and the front of the airlock throughout the JEM
- Coverage of an Astrobees trajectory: the number of ML features the robot registered at a given pose of the trajectory.
- The more ML features, the more stable Astrobees localization will be.
- Three possible outputs:
 - 3D JEM heat map
 - 3D Astrobees trajectory heat map
 - PDF report

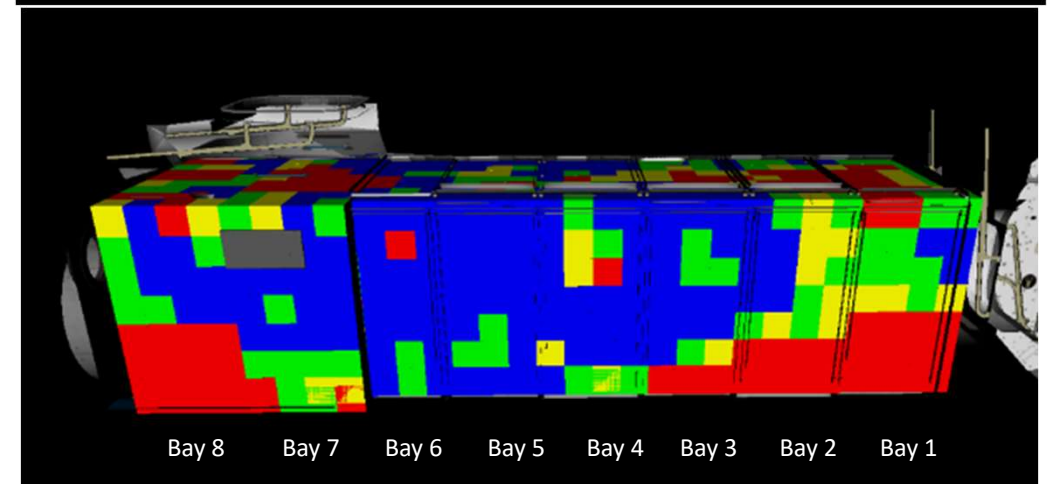
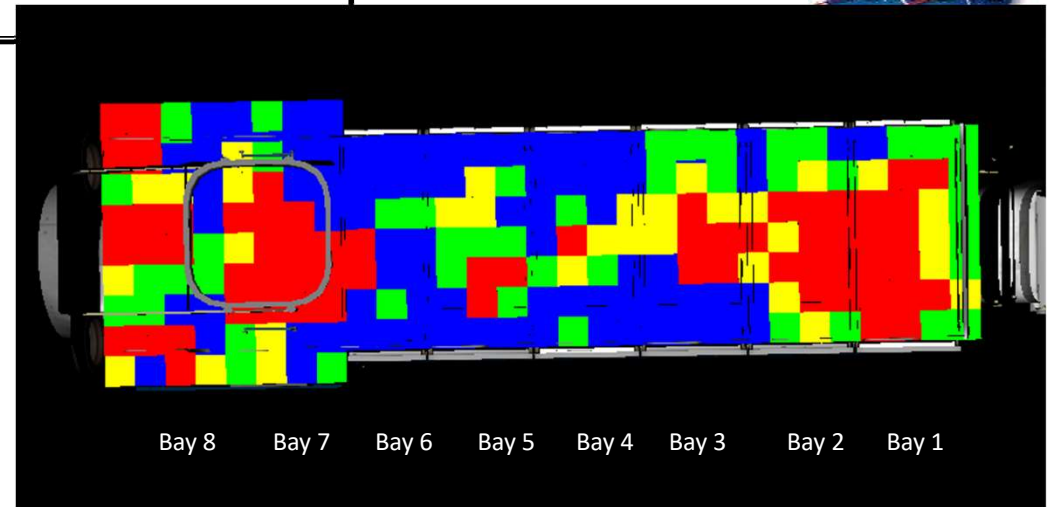
Color	ML features
Red	0
Orange	1-10
Yellow	11-20
Green	21-40
Blue	40+



3D JEM Heat Map



Color		ML features
Red		0
Orange		1-10
Yellow		11-20
Green		21-40
Blue		40+

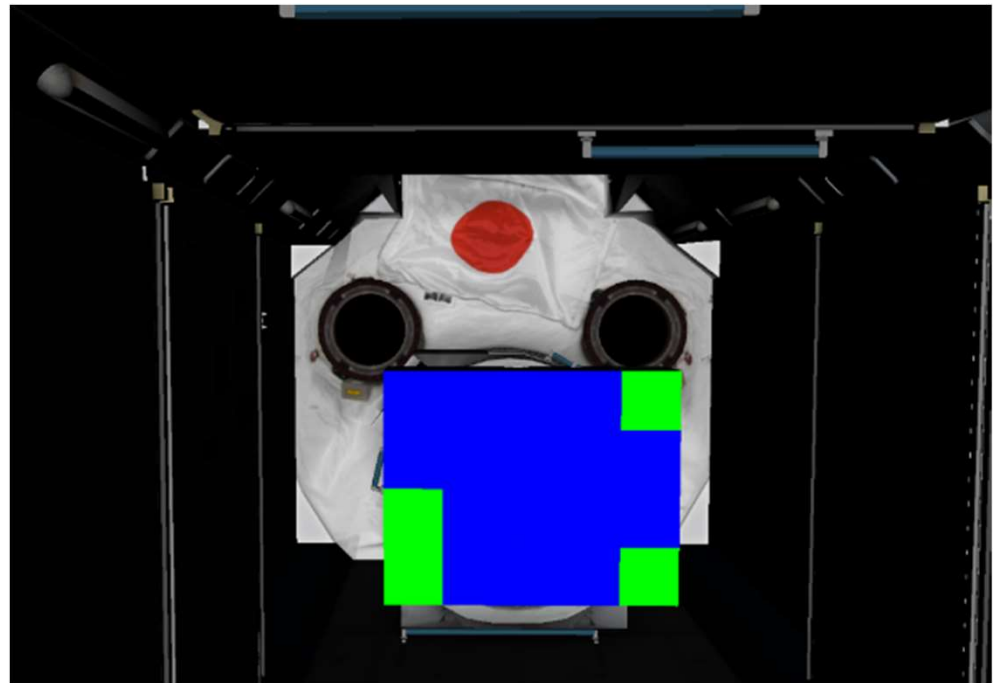




Airlock



Color		ML features
Red		0
Orange		1-10
Yellow		11-20
Green		21-40
Blue		40+

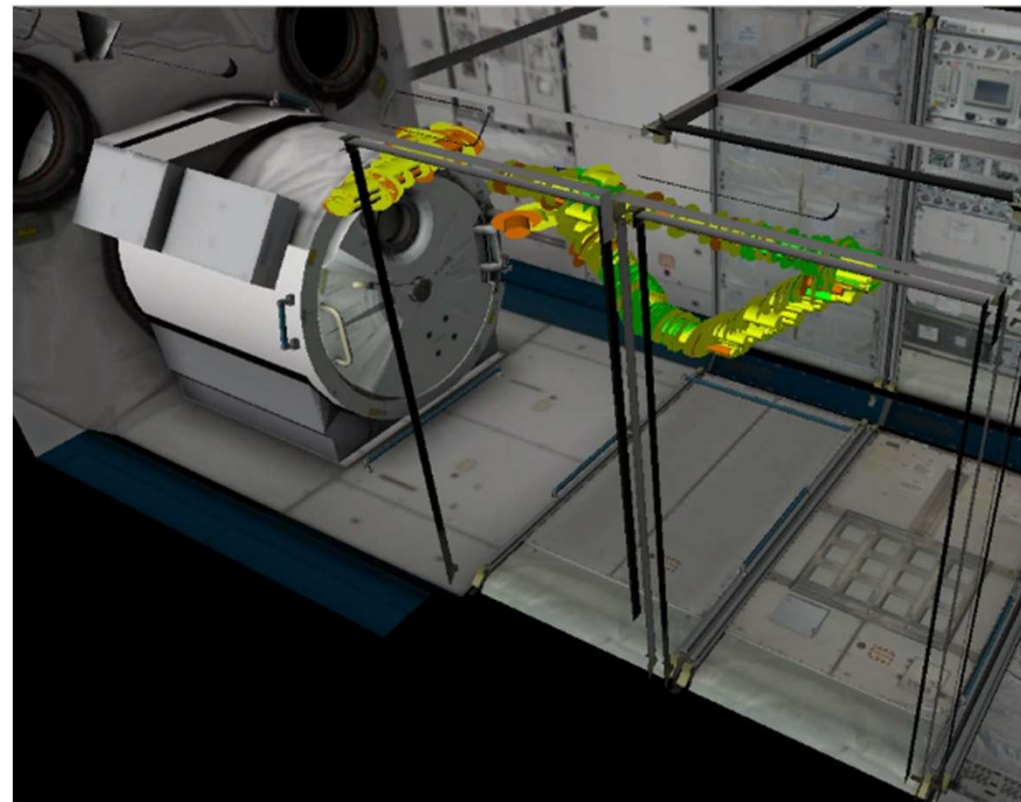




3D Astrobeer Trajectory Heat Map



Color		ML features
Red		0
Orange		1-10
Yellow		11-20
Green		21-40
Blue		40+

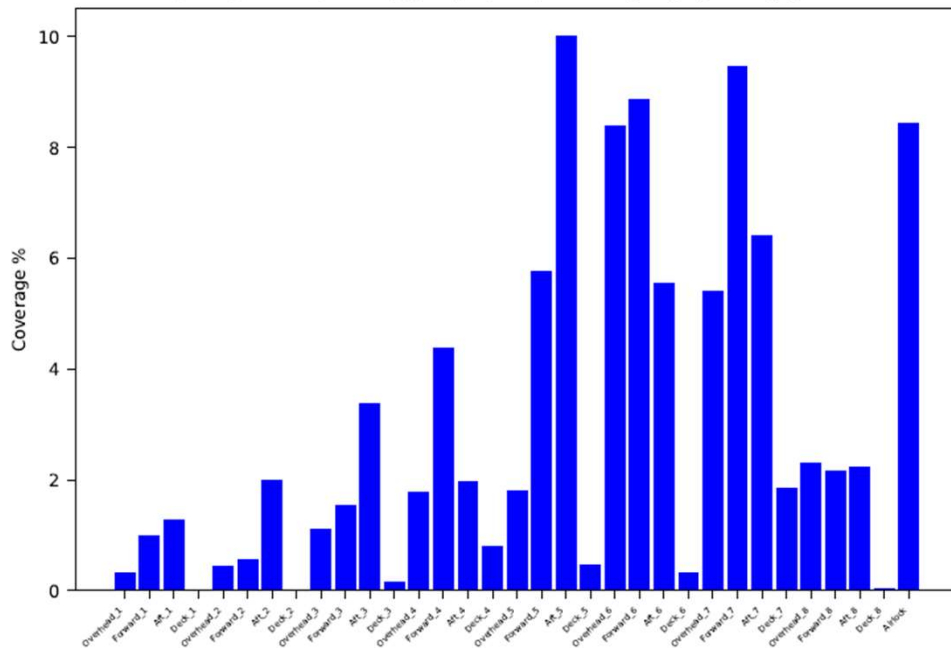




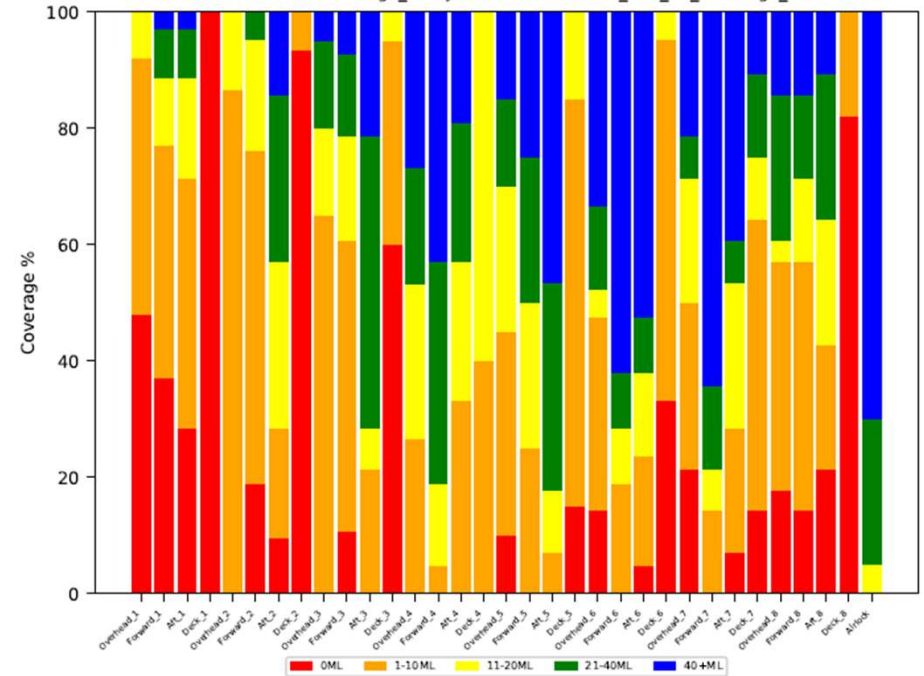
PDF Report



General Coverage Distribution per Wall
/home/amoravar/coverage_analysis/tests/20210707_dali_db_coverage_db.csv



Detailed Coverage Distribution per Wall
/home/amoravar/coverage_analysis/tests/20210707_dali_db_coverage_db.csv





Flight Software



- Astrobeer Robot Software release 0.15.2 is out on Github





Operations



Astrobee Utilization Stats to date



Utilization Stats to date	
Number of on orbit test sessions:	59 (27 science, 31 commanding, 1 other)
Number of crew hours:	48
Unique Crew Members trained:	6
Number of on-console hours:	316
Number of Astrobee Users:	12



Operations: Functions



- Ensure Facility Readiness for ISS Test Sessions
 - All crew training is handled via Onboard Training (OBT).
 - Manage crew procedure and all planning products updates via OCR/ECR system
 - Coordinate crew time with ISS Lead Increment Scientist and POIC Cadre
 - Assist Astrobees team & PDs in acquiring proper access to ops systems as required for real-time ops support
 - Coordinate with investigators for product development and delivery
 - Help investigators set up remote communication capabilities as needed
- Real-Time ISS Test Session support
 - Coordinate with MSFC and POIS (POIC Specialist) all deltas to real-time ops and products
 - Support crew & POIC cadre with real-time ops – plan and conduct crew conferences as needed
 - Coordinate commanding and data download window requirements and planning
 - Test session data and video management
- Public Relations
 - Maintain website, work with ARC PAO office to publish material on site



Operations: Functions



- Increment Planning
 - 2-pager development and submittal, updates as needed throughout increment
 - Assist PIM (Payload Integration Manager) with CEF inputs as needed
 - Regular timeline planning with Lead PPM (Payload Planning Manager), PPM planning team and MSFC POIS/PARC team
- Safety and Verification Assessments
 - Integrated Safety & Verification Assessments as needed for Astrobees Facility and Guest Science Payload Developers (PDs)
 - Continued SPHERES Safety & Verification focuses on return of hardware.
 - Complete CoFR (Certification of Flight Readiness) for ground systems and on-orbit hardware and operations products
- Astrobees Ground Ops Development
 - Coordinate ground Engineering and Operations Readiness Tests (ERTs/ORTs) in preparation for real-time ops
 - Work with Astrobees team and PDs to develop flight procedures, coordinate reviews with MSFC for final delivery and formal ECR review



Increments 64-65 Test Sessions (since last AWG 7.8.21)



- | | |
|-------------------------------------|-------------|
| • AB082: Astrobatics Science 2 | July 16 |
| • AB083: SoundSee Data Collection 2 | July 22 |
| • AB084: Astrobeer Crew Minimal S2 | July 26 |
| • AB085: REALM 2 Science 1 | August 6 |
| • AB086: Kibo RPC-2 Rehearsal | August 10 |
| • AB087: ReSWARM Science 1 | August 19 |
| • AB088: Astroporter Science 1 | August 26 |
| • AB089: Crew Minimal S3 | September 1 |



Increments 64-65 Test Sessions (since last AWG 7.8.21)

- | | |
|---|--------------|
| • AB090: REALM 2 Science 2 | September 7 |
| • AB091: Kibo-RPC2 Finals (attempt 1) | September 15 |
| • AB092: SoundSee Troubleshooting | September 17 |
| • AB093: Queen Bee Checkout & Calibration | September 20 |
| • AB094: Kibo-RPC2 Finals (attempt 2) | September 29 |
| • AB095: Astrobatics Science 2 Redo | October 8 |
| • AB096: Astrobee Crew Minimal S4 | October 26 |

= 15 Test Sessions over 16 weeks since last AWG

= 55 total remote Test Sessions since 4.30.20 (1.4 weeks/session)



Increment 66-67 Forward Plan



• Astrobratics 3	November	(11/23)
• ReSwarm 2	Nov./Dec.	(11/30-12/1)
• REALM 2 Science 3	December	(12/7-12-8)
• SoundSee Data 3	January	(1/1-1/2)
• Crew Minimal S5	January	(1/23-1/24)
• ISAAC 4	January	
• SVGS Science 1	January/February	
• ROAM 2	February	
• SoundSee Data 4	February/March	
• ISAAC 5	February/March	
• REALM 2 Science 3	March/April	
• Gecko 3	April/May	
• ISAAC 6	April/May	
• Crew Minimal S5	April/May	



Crew Procedures (1 of 2)



- Baselined
 - REALM-2 RFID Recon Science 2 – 9/26
 - Queen Checkout and Calibration - 9/27
- Under ECR – To be baselined soon
 - Astrobatics Science 3 - 11/1
 - SoundSee Data Collection 3 - 12/6
 - Smartphone Video Guidance System (SVGS) - 12/6



Crew Procedures (2 of 2)



- Upcoming procedures in development
 - ISAAC 4 (mapping of Node 2 for localization)
 - SoundSee Data Collection 4
 - Astrobatics Science 4
 - REALM-2 RFID Recon Science 3
 - Astrobee Perching Arm Demo
 - Astroporter



Astrobee Outreach



What is Astrobee?

NASA has developed three new robotic teammates to work alongside astronauts on the International Space Station as they help to advance research.

It turns out that astronauts could use some help with their chores, just like many of us on Earth. Juggling priorities and schedules plays a big part in an astronaut's life aboard the International Space Station, and teams of flight controllers on the ground are constantly working to optimize the precious human work hours in space. Getting some assistance from robots that can take on some tasks will make work on the station more efficient.

Astrobee, NASA's new free-flying robotic system, will help astronauts reduce time they spend on routine duties, leaving them to focus more on the things that only humans can do. Working autonomously or via remote control by astronauts, flight controllers or researchers on the ground, the robots are designed to complete tasks such as taking inventory, documenting experiments conducted by astronauts with their built-in cameras or working together to move cargo throughout the station. In addition, the system serves as a research platform that can be outfitted and programmed to carry out experiments in microgravity - helping us to learn more about how robotics can benefit astronauts in space.

The Astrobee system consists of three cubed-shaped robots, software and a docking station used for recharging. The robots use electric fans as a propulsion system that allows them to fly freely through the microgravity environment of the station. Cameras and sensors help them to "see" and navigate their surroundings. The robots also carry a perching arm that allows them to grasp station handrails in order to conserve energy or to grab and hold items.

Website

<http://www.nasa.gov/spheres>

<http://www.nasa.gov/astrobee>



QUESTIONS?



Back-up Slides



Topic	Slide





EPO Activities



- Summary of Education and Public Outreach
- Significant Media Coverage

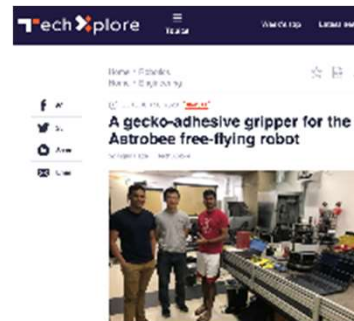


Web Features



www.nasa.gov/Astrobees

[Hi Honey! NASA's Second Astrobees Wakes Up in Space](http://www.nasa.gov/Astrobees)



[A gecko-adhesive gripper for the Astrobees free-flying robot](http://www.nasa.gov/Astrobees)



www.nasa.gov/astrobee

