ISS Astrobee Facility

Sponsoring Org/Office Code: *ISS Program, OZ3*
Name of Forum: *Astrobee TIM November 2023*
Date: *November 15th, 2023*

Jose V. Benavides
NASA Ames Research Center
Intelligent Systems Division (Code TI)
Henry Orosco
ISS Research Portfolio Manager

Purpose

- **Purpose:** Provide Astrobee Facility overview, status and near-term plan

- **Select the appropriate box below:**
  - □ Request for Technical Concurrence
  - ☑ Information Only
  - □ Management Direction
  - □ Response to an Action Item

- **Agenda:**
  - **Overview (Henry)**
  - **Facility Status Engineering (Jonathan)**
  - **Operations (Aric)**

Astrobee Technology Interchange Meeting (TIM)			Join by Teams Link: https://teams.microsoft.com/l/meetup-join/19%3ameeting_MjJmZjliZGUtYzg0YS00NmIwLTg4ZD			
Draft, Subject to change			Location: Phone, MS Teams, and NASA Ames Research Center, N269 Room R200			
Date:	Wednesday, November 15th, 2023, 10am PST					
Agenda	Group	Sponsor	Project	Name	Time	duration (min)
0	Badging			n/a	9:00 AM	1:00
0	NASA ISS		Introductions/Welcome	Henry Orosco	10:00 AM	0:05
1	NASA Astrobee	NASA TDO	NASA ISS Program TDO/OZ overview	Henry Orosco	10:05 AM	0:10
2	NASA ISS		Astrobee Facility Status	Jose Benavides & Jonathan Barlow	10:15 AM	0:20
3	NASA ISS TDO		Astrobee PIM Status	Cristian Garcia	10:35 AM	0:10
4	National Lab	Nat Lab	National Lab overview	Robbie Hampton/Hana	10:45 AM	0:05
5	NASA Ames	NASA STMD	ISAAC	Trey Smith	10:50 AM	0:15
6	Stanford	NASA STMD	Gecko	Somrita Banerjee	11:05 AM	0:15
7					11:20 AM	0:15
8	Questions/Discussion/Break		Questions/Discussion/Break		11:35 AM	0:25
9	Lunch		Lunch (Ames Space Bar)		12:00 PM	1:45
10	JPL/USC	Nat Lab	Clingers	Dave Barnhart	1:45 PM	0:15
11	Zero G Horizons	Nat Lab	SOARS	Deepak	2:00 PM	0:15
12					2:15 PM	0:15
13	ILC Inc./STEMX365/MIT	Nat Lab	Zero Robotics	Katie/Danielle/Mizan	2:30 PM	0:15
14	Obruta	Nat Lab	AstroSee	Kirk Hovell	2:45 PM	0:15
15	Questions/Discussion/Break		Questions/Discussion/Break		3:00 PM	1:00
16					4:00 PM	0:00
17					4:00 PM	0:00
18	JAXA	JAXA	The 4th Kibo Robot Programming Challenge	Nakata Yui	4:00 PM	0:15
19	CSIRO/Boeing	Nat Lab	Multi-resolution Scanning	Marc Elmouttie	4:15 PM	0:15
20	Travel				4:30 PM	1:30
21	Group Dinner		Group Dinner		6:00 PM	1:00
Date:	Thursday, November 16th, 2023, 9am PST					
Agenda	Group	Sponsor	Project	Name	Time	duration (min)
21	NASA ISS		Introductions/Welcome	Henry Orosco	9:00 AM	0:05
22	NPS	DOD	Astrobatics	Jennifer/Marcello	9:05 AM	0:15
23	Metis	NASA SBIR	CoSLAM	Tom Zurales	9:20 AM	0:15
24	Picknik	NASA SBIR	Perception Framework	Sean	9:35 AM	0:15
25	Makel Engineering	NASA SBIR	EMMA	Darby Makel	9:50 AM	0:15
26	Questions/Discussion/Break		Questions/Discussion/Break		10:05 AM	0:30
27	TRACLabs, Inc.	NASA SBIR	PLUMMRS: A collection of Plan Ledgers and Unified Maps for Multi-Robot S	Ana Quispe	10:35 AM	0:15
28	Orbit Fab	N/A	Docking-Refueling	Connor Geiman	10:50 AM	0:15
29	Kall Morris Inc. (KMI)	Nat Lab	REACCH	Austin Morris	11:05 AM	0:15
30	Lab Tours		Lab Tours		11:20 AM	0:45
31	Lunch/Farewell/Discussion		Lunch/Farewell/Discussion		12:05 PM	1:45

Astrobee Working Group Community

- Astrobee Working Group (AWG) meeting
  - Meet twice a year (ideally in-person)
  - Timed similarly to the POIWG conference
  - Next: Spring 2024,
- Purpose:
  - Information sharing across the Astrobee community
  - Astrobee Facility shares status, updates, overall calendar
  - Discuss proposed changes/updates

Pictures from last AWG

June 1st, 2023, Astrobee Working Group

Updates

- New Project Manager: Jonathan Barlow
  - Jonathan Barlow is a senior aerospace research engineer at NASA Ames Research Center. With 10+ years working experience in aerospace, he has been the Astrobee Engineering Lead, Astrobee Integration and Test Lead, SPHERES Engineering Lead, and a Task Lead and manager for SGT and KBR. He holds a Ph.D in Engineering from Dartmouth College. He is the father of four future engineers.
- New Integration Check-in's
  - Recommended monthly
  - Open to in-person trips

Overview

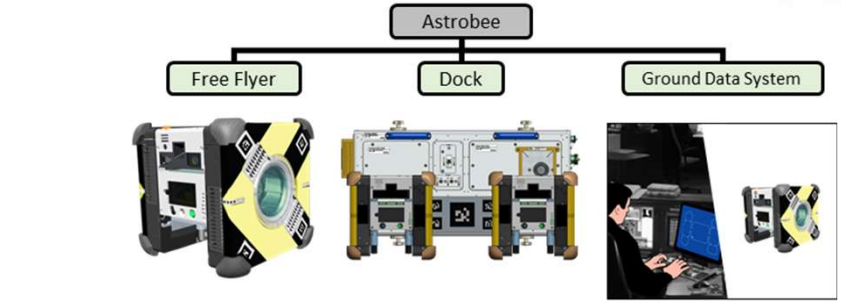
Project Description

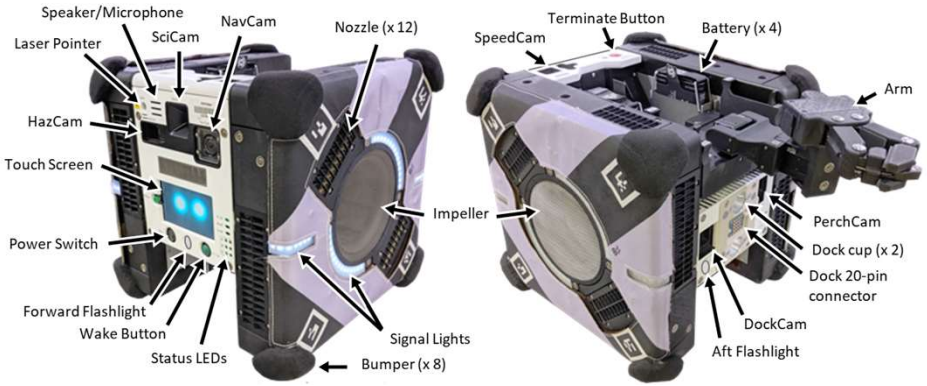
Based at Nasa Ames Research Center, the ISS Astrobee Facility provides a free-flying robotic system for ISS research and ISS STEM outreach. The Astrobee free-flying robotic system consists of three cubed-shaped robots, software, and a docking station used for recharging. The project provides sustaining 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

ISS Astrobee Facility Overview

- 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: Artificial Intelligence, manipulation, computer vision, Human Robotic Interactions, many, many other fields!
- Concept of ops summary
  - Dock battery recharging when idle
  - Autonomously undock, survey multiple modules, return to dock, and no crew supervision
- Overview Video: https://youtu.be/IEuAVK1nNp0
- Project Website: www.nasa.gov/astrobee
- **Guest Science Resources:** www.nasa.gov/general/guest-science-resources/



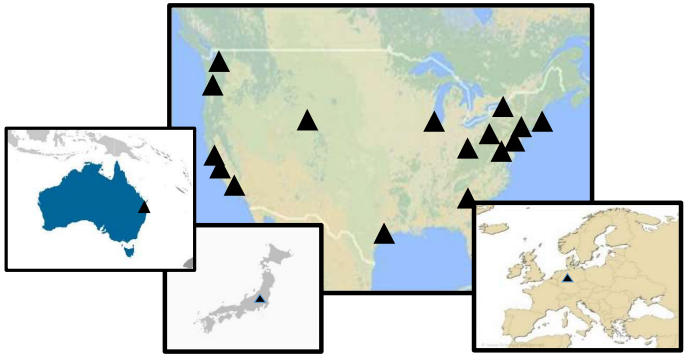


- Free flying robot inside the ISS
- 32 cm wide, ~9.1kg (2 batt., no arm)
- All electric + fan-based propulsion
- Robot arm for “perching”, ~1kg
- Three smartphone computers
- Three payload bays for expansion
- Microphone not currently enabled

Astrobee Guest Scientists

Payloads in ISS Integration or Operational

- Astrobatics (NASA-DoD/Naval Postgraduate School) TX04.2
  - Advanced Free-Flyer Maneuvers for self-toss and retrieval of cargo with inaccurate inertia estimates
- RFID Recon (NASA AES/REALM-2) TX07.2
  - Autonomous Logistics Management with Radio Frequency Identification (RFID) Reconnaissance (Recon)
- JAXA Kibo-RPC (JAXA) N/A
  - Kibo Robot Programming Challenge for STEM Education
- ISAAC (NASA STMD-GCD/ARC) TX04.6
  - Technology for autonomous caretaking of spacecraft primarily during uncrewed mission phases
- SOARS (ISS NL/Zero-g Horizons) TX03.2
  - Spacecraft On-Orbit Refueling and Storage
- CLINGERS (ISS NL/JPL-USC) TX04.5
  - Docking for Rendezvous Proximity Operations
- Zero Robotics (ISS NL/MIT) N/A
  - ISS Programing Challenge for students using Astrobee
- Gecko (NASA STMD/Stanford) TX04.5
  - Gecko material grasping and safe trajectory optimization
- Multi-Resolution Scanner (MRS) (ISS NL/CSIRO) TX04.1
  - Sensor payload to support multi-resolution 3D scanning



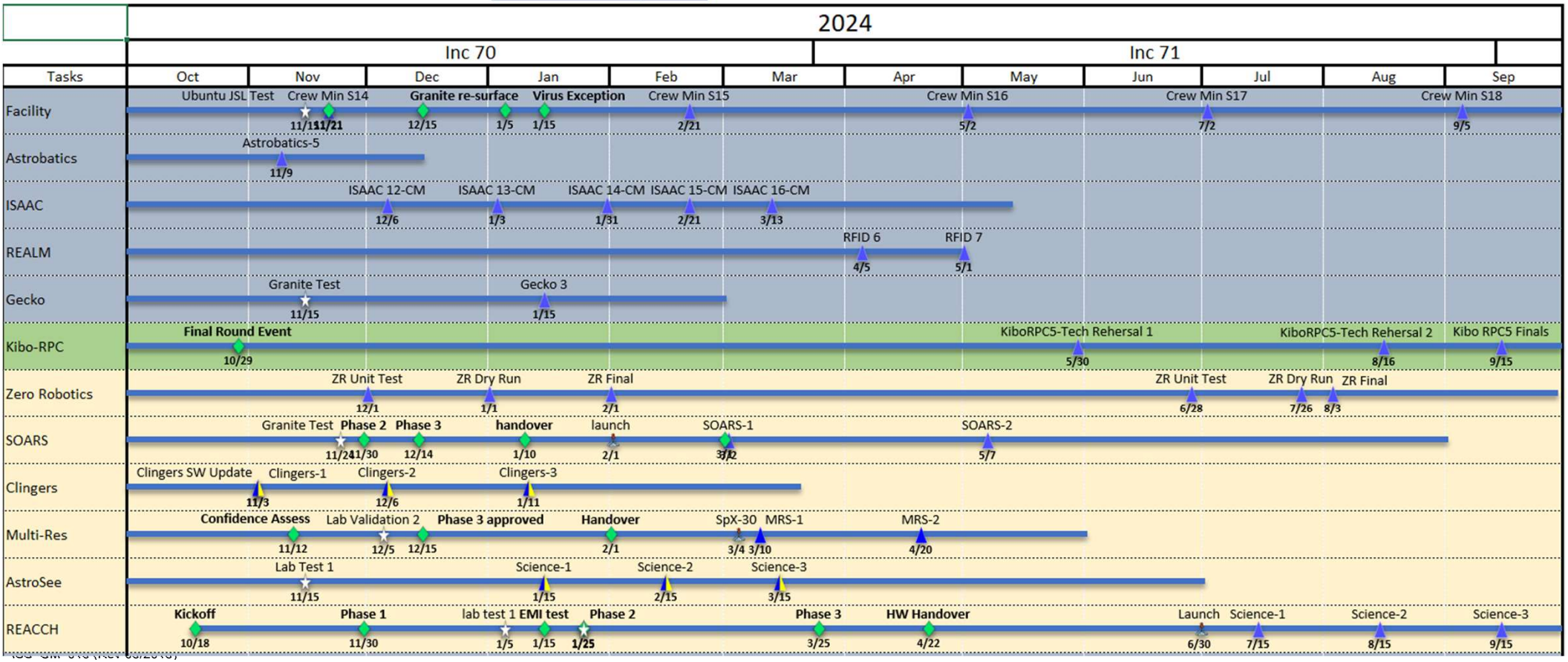
Completed Investigations

- Astroporter (NASA-STMD/Tethers Unlimited) TX04
  - Algorithms for collaborative behavior between multiple robots in space including cargo transfer
- REGGAE (ISS NL/NanoRacks-Braunschweig) TX04
  - Gecko material grasping
- ROAM (ISS NL/MIT-DLR) TX04
  - Autonomous rendezvous with non-cooperative tumbling targets
- ReSWARM (ISS NL/MIT) TX04
  - Algorithms for safe on-orbit assembly, logistics, and cooperative control
- SVGS (NASA STMD/FIT) TX04
  - Beacon-assisted vision-based navigation for formation flight
- SoundSee (ISS NL/Astrobotic-Bosch) TX04
  - 3D Acoustic Monitoring

Astrobee 12-month forward plan

By Months
10/1/2023 - Start Date
12 - Number of Months

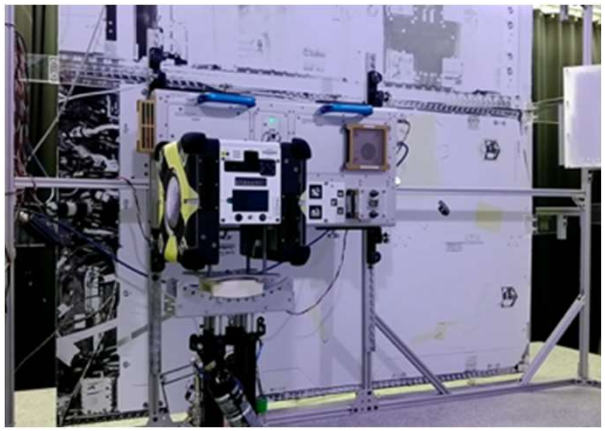
Legend: Ops, Lab Visit, H+Q, Milestone, Launch



Facility Status

Hardware and Lab Status

- Granite Lab: Online



- Flight Lab: Online

Name	Status
Flat Sat A	Operational
Flight 1,2 (Bumble, Honey)	In Space, Operational
Flight 3 (Queen)	On Ground, repair TBD
Flight Spare	Operational
Cert (B#)	Operational
Ground (Wannabee)	Operational

- Engineering Evaluation Lab (EEL): Available upon request

Repair Status Update

- Queen experienced a suspected power system failure on June 7th
  - It's been down-massed and repair is TBD
- Honey was repaired, launched, and checked-out
- Dock has been repaired, now fully operational
- Both Honey and the Dock now have new, more robust SD cards

Ubuntu 20.04 Transition

- Linux Operating System (OS) Upgrade underway
  - Verifications using JSL/SDIL testing in planning, targeting November
  - On-orbit install planned for late 2023
  - First user to utilize update is ISAAC
- Rational
  - OS is beyond end-of-life, currently in extended security maintenance
  - User software dependance on latest OS environments
    - OS libraries
    - Development environments

Lessons Learned / Future Work

- PD one-on-one Check-In's
  - Additional tags are scheduled with each PD to ensure success for ISS integration
- Software Maintenance
  - Ubuntu OS upgrade
  - Ground Control Station improvements
- Re-route Astrobee video to utilize ISS video down-links
  - Could minimize dependance on additional Bldg-8 Video Control Center (VCC) oversight needed during Astrobee un-crewed activities
- Queen Repair (completion date TBD)

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 Astrobee 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
  - Real-time commanding support
- 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 Astrobee 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
- Astrobee Ground Ops Development
  - Coordinate ground Engineering and Operations Readiness Tests (ERTs/ORTs) in preparation for real-time ops
  - Work with Astrobee team and PDs to develop flight procedures, coordinate reviews with MSFC for final delivery and formal ECR review

Astrobee Utilization Stats

Since 2019, Astrobee has built a four-year track record of supported operations

Utilization Stats to date	
Number of on orbit operations:	148
Unique Crew Members trained and who have operated Astrobee on the ISS:	31
Number of on-console hours:	1090+
Crew hours	~270
Number of past/present users	15

On-Orbit Activities
(since April 2023)

AB137: ZR Tech Demo 2	May 02	AB147: ZR Finals	Aug. 03
AB138: UAE ZR Dry Run	May 16	AB148: Kibo RPC Tech Rehearsal 2	Aug. 16
AB139: Kibo RPC Tech Rehearsal 1	May 30	AB149: Honey Checkout	Aug. 30
AB140: ZR Tech Demo 3	June 07	AB150: Crew Minimal S13	Sept. 07
AB141: UAE ZR Finals	June 23	AB151: Kibo RPC Finals	Sept. 13
AB142: Kibo RPC Tech Rehearsal 1.5	June 27	AB152: Dock Station Repair	Sept. 28
AB143: ZR Unit Test	June 28	AB155: Astrobatics-5	Nov. 09
AB144: Crew Minimal S11	July 03		
AB145: Crew Minimal S12	July 21		
AB146: ZR Dry Run	July 26		

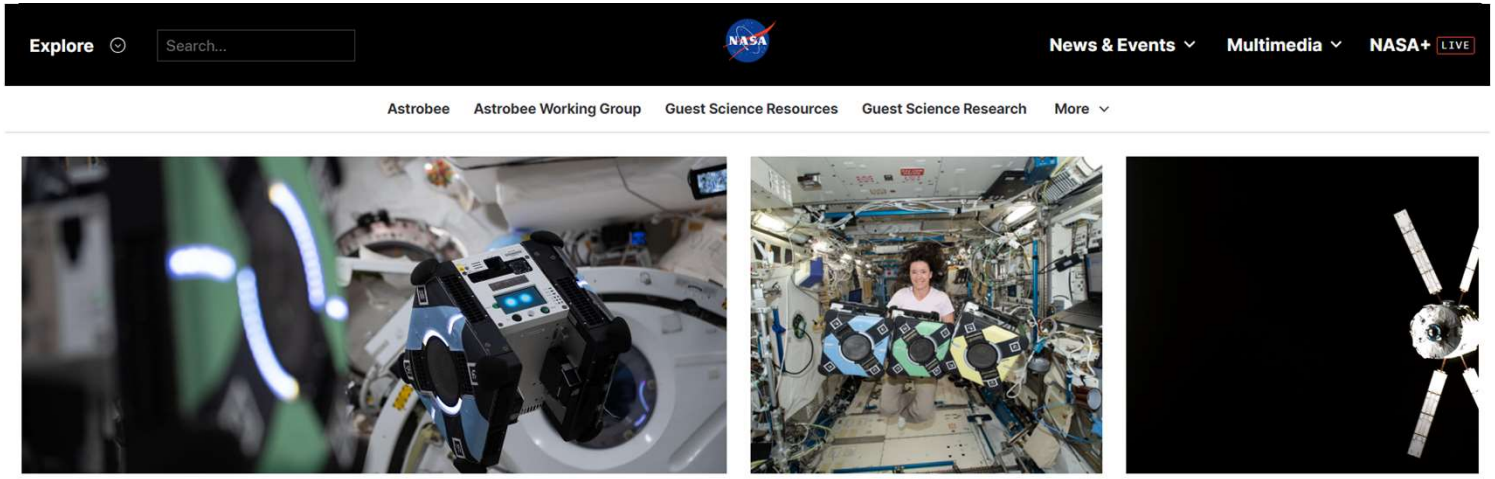
Ops Deliverables/Planning – MSFC

Milestone	Deadline
PD inputs (procedures, planning products, Flight Rules, PL Regs)	L-12 weeks Launch Date/Vehicle (T)
Pre-ECR Submit	Count back from ECR submittal, depending on 1 or 2 week ECR review
ECR Submit	L-6 weeks (for 2-week Impact review) L-5 weeks (for 1-week review)
Team ECR Review	L-4 weeks (week prior to IMEP with at least 2 days for comment verification)
Board at IMEP (Mondays)	L-3 weeks (or Ops-3 weeks)
PL Reg/Flight Rule/OBT/Phase III Self Study Baseline	Ops-1 week Note: more commonly, Self Study is baselined same time as crew procedures

Ops Deliverables/Planning – Astrobee Internal

Milestone	Nominal
ISS OPS (ERD+>1week) Estimated Readiness Date (ERD)	ERD = MSFC Baseline of Ops/Flight Products Launch Date/Vehicle (T)
Paper SIM (pre-ECR)	ERD - 7 weeks
Paper SIM if needed (pre-OCR)	ISS OPS - 3 week
PD connectivity test complete	ISS OPS - 2 weeks
PD software delivery (APK, Debian(s), etc.)	ISS OPS - 2 weeks
Ground procedure complete	ISS OPS - 2 weeks
Rehearsal ORT (Operations Readiness Test)	ISS OPS - 1 week
TRR (Test Readiness Review)	ISS OPS - 1-4 days
ARC completes working draft of Ops Products	ERD - 6 weeks
PD submission of planning inputs	ERD - 10 weeks
OPS Products Updates	ISS OPS - 2 weeks
Software (list needed for OCR)	ISS OPS - 2 weeks

Astrobee
on Social Media



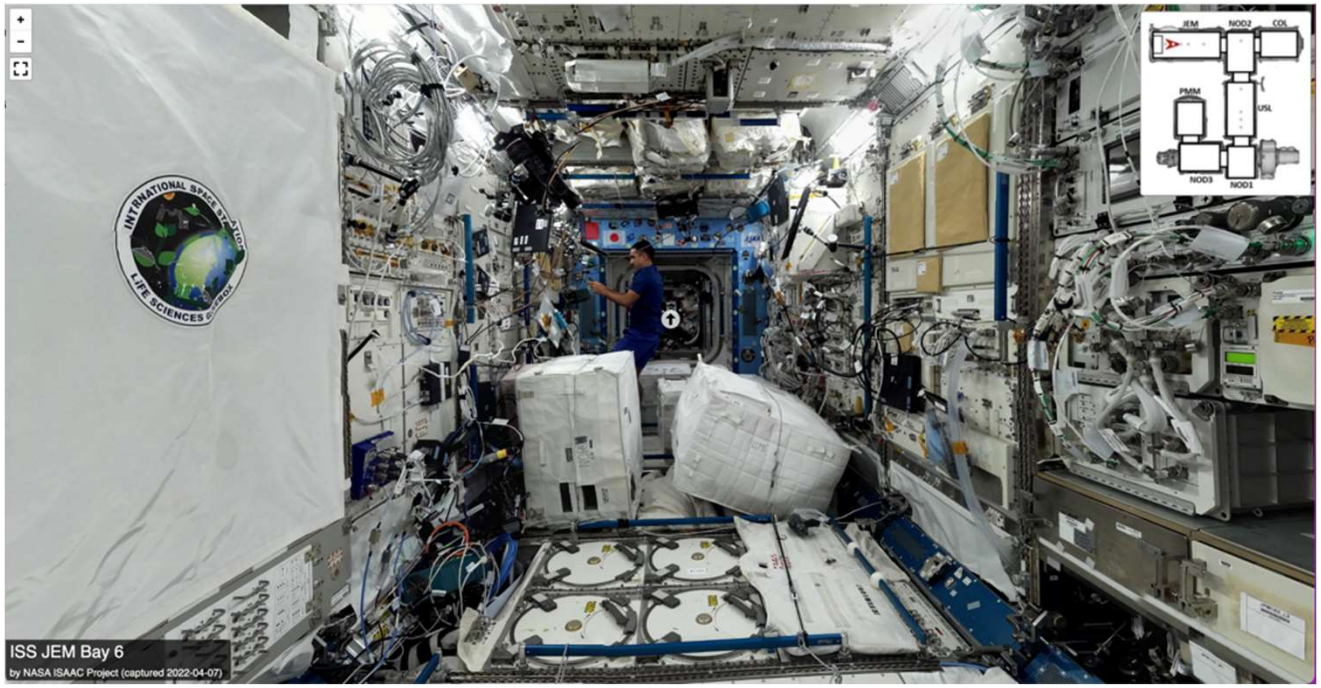
We are in the process of transitioning to a new Content Management System which will result to new Astrobee webpage layouts by the end of 2023.

Website

http://www.nasa.gov/astrobee


QUESTIONS?

What is a panorama image?



https://www-stage.nasa.gov/specials/pano/pannellum.htm?config=tour.json

This interactive google-street-view like interface for ISS 360-degree panoramas can significantly enhance vehicle caretaking and ground operator situational awareness

On Break, back at 01:45pm CST