



ASTROBEE'S MULTI-YEAR ACTIVITIES AT THE INTERNATIONAL SPACE STATION'S JAPANESE EXPERIMENTAL MODULE

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2022-09-21

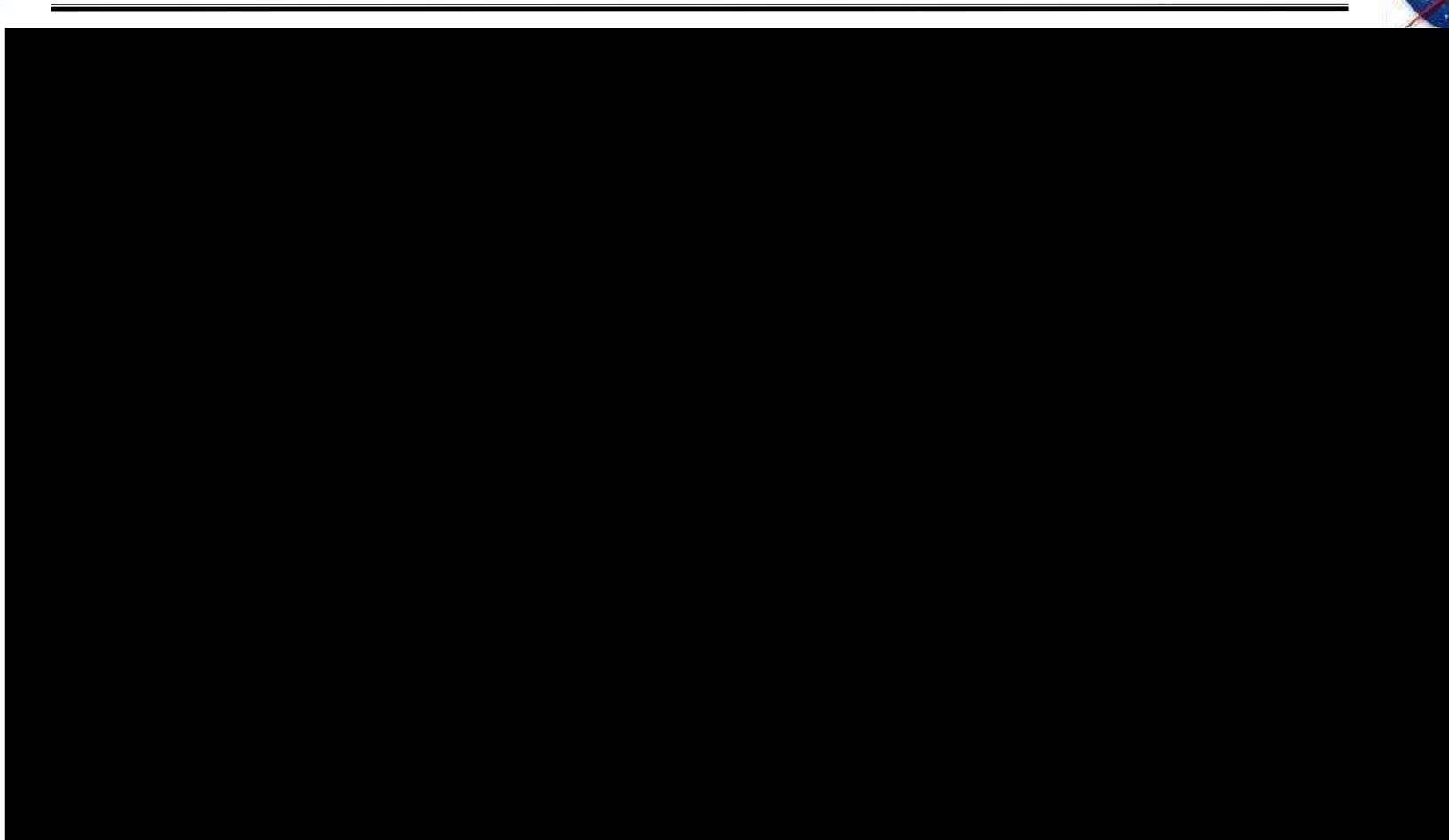
Room S03, 10.25am

IAC-22,B3,6-A5.3,2,x70755

73rd International Astronautical Congress, Paris, France



¹NASA Ames Research Center, Moffett Field, CA / ² Japan Aerospace Agency (JAXA)





Astrobee Overview



SPHERES

- SPHERES: Synchronized Position Hold, Engage, Reorient, Experimental Satellites
- Installed on ISS in 2006, managed by ARC since Fall 2010
- Formation flight, Docking, Proximity Operations
- Required supervision, CO2 tanks

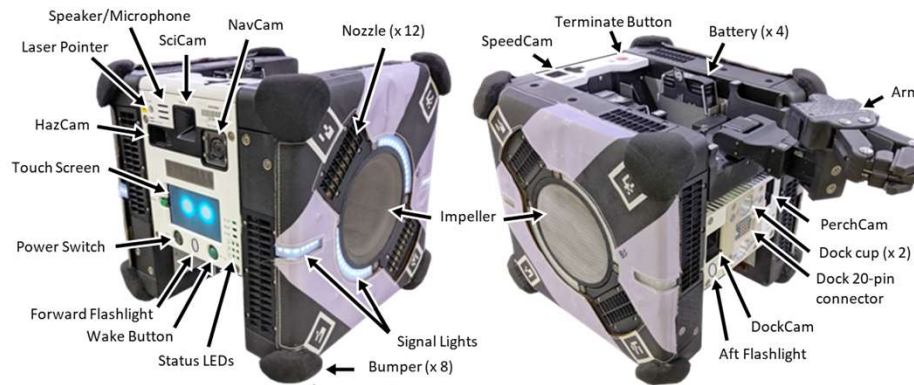
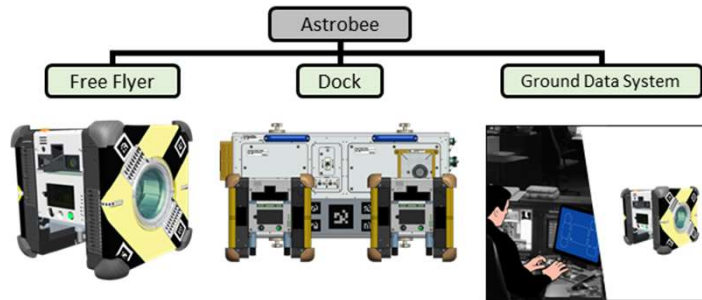


Scott Kelly working with SPHERES at the ISS' JEM.





Astrobee Overview





Astrobee Guest Scientists

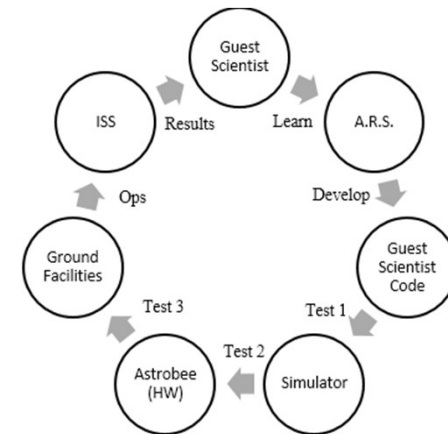
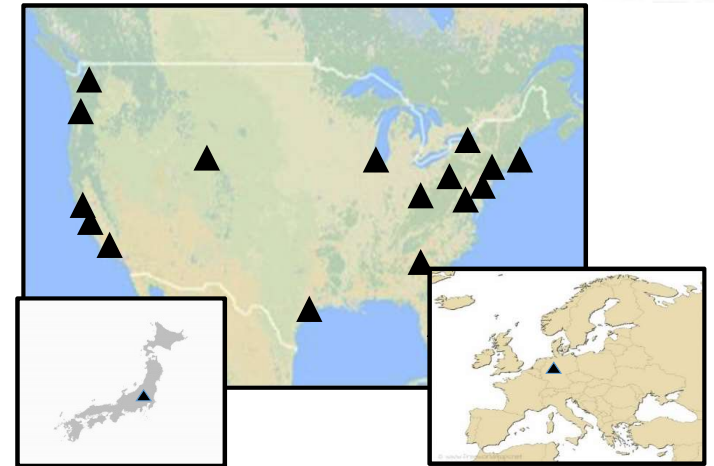


- Payloads in ISS Integration or Operational

- Astrobatics (NASA-DoD/Naval Postgraduate School)
- RFID Recon (NASA AES/REALM-2)
- JAXA Kibo-RPC (JAXA)
- ISAAC (NASA STMD-GCD/ARC)
- SVGS (NASA STMD/FIT)
- SOARS (ISS NL/Zero-g Horizons)
- CLINGERS (ISS NL/JPL-USC)
- Zero Robotics (ISS NL/MIT)

- Completed Investigations:

- Astroporter (NASA-STMD/Tethers Unlimited)
- REGGAE (ISS NL/NanoRacks-Braunschweig)
- ROAM (ISS NL/MIT-DLR)
- ReSWARM (ISS NL/MIT)
- Gecko (NASA STMD/Stanford)
- SoundSee (ISS NL/Astrobotic-Bosch)





Outline



- What's Astrobees?
- KIBO-RPC competition
- Mapping & localization
- Map coverage
- ISS Ops Summary
- Conclusions





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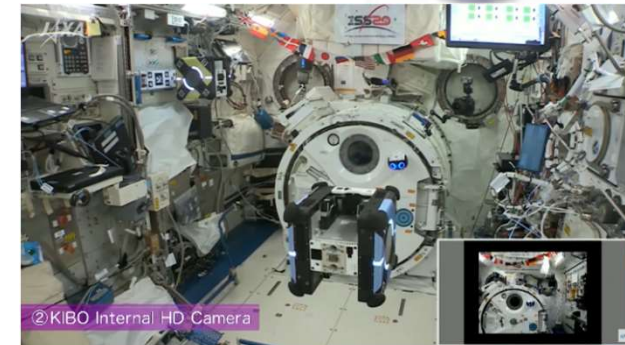




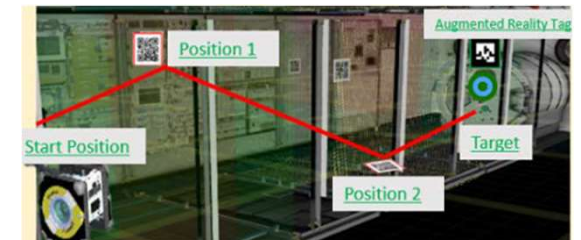
KIBO-RPC Competition



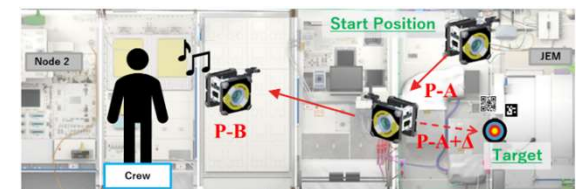
- NASA/JAXA collaboration 2018
- Educational outreach using NASA' Astrobee & JAXA's Int- Ball
- Kibo Robot Programming Challenge (Kibo-RPC): students solve various problems by programming Astrobee.
- For 1st Kibo-RPC (2020):
 - 1,168 students participated
 - 313 teams
 - 7 countries
- For 2nd Kibo-RPC (2021):
 - 905 students participated
 - 286 teams
 - 11 count



Snapshot of 1st Kibo-RPC Final event (JAXA)



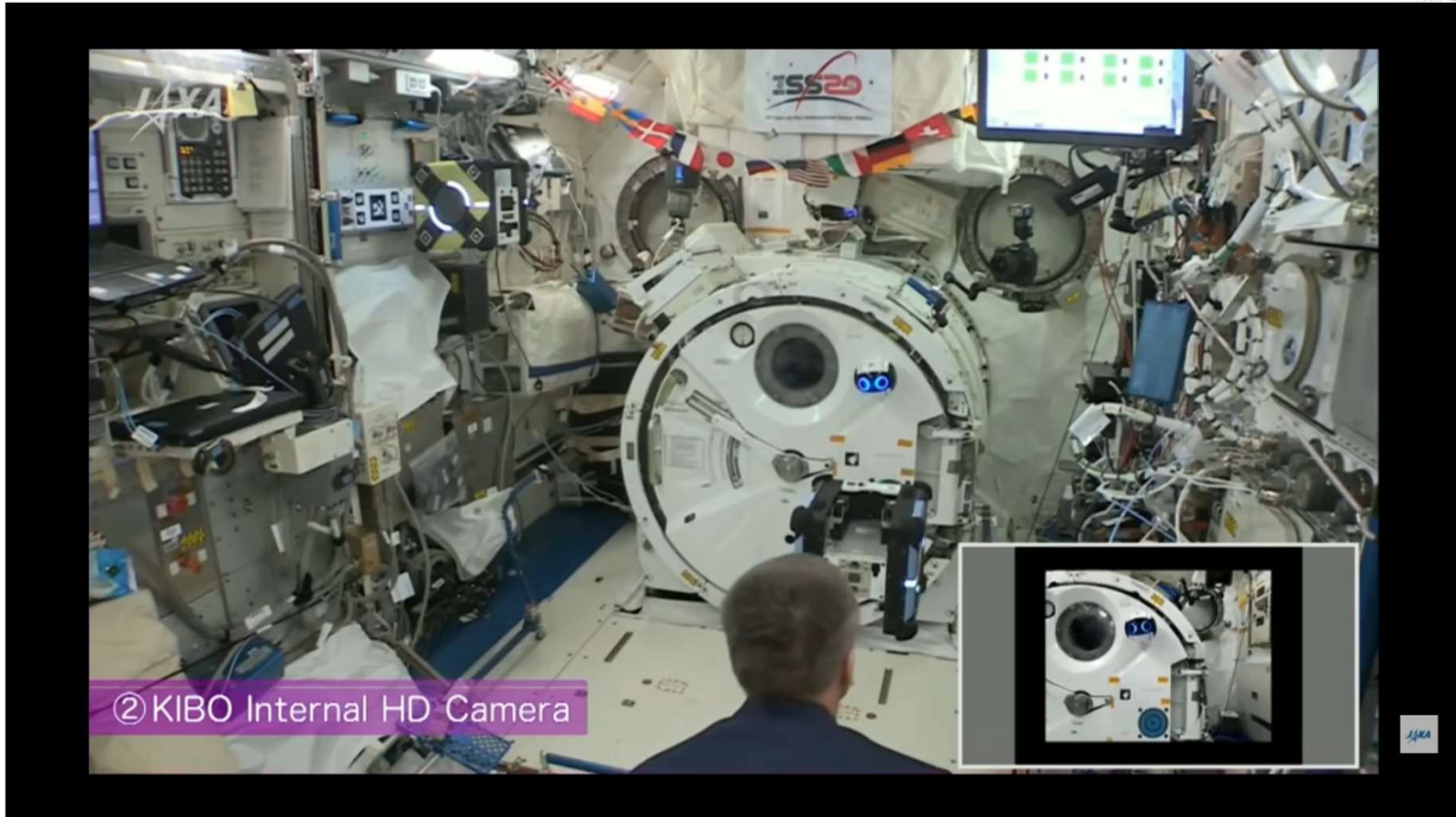
1st Kibo-RPC (JAXA)



2nd Kibo-RPC (JAXA)



KIBO-RPC Competition





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Mapping and Localization



- Mapping

- Astrobbee uses natural landmarks to generate an off-line map for use in localization
- Astrobbee needs to detect landmarks to get a position estimate, the more the better
- Once map is build, its performance only verifiable at during ISS ops
- Needed pre-assessment tool



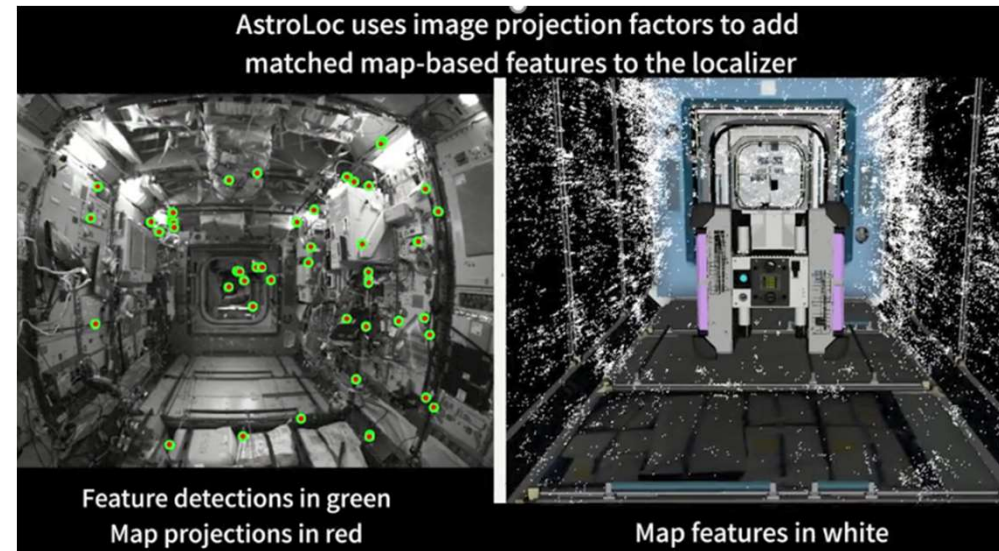


Mapping and Localization



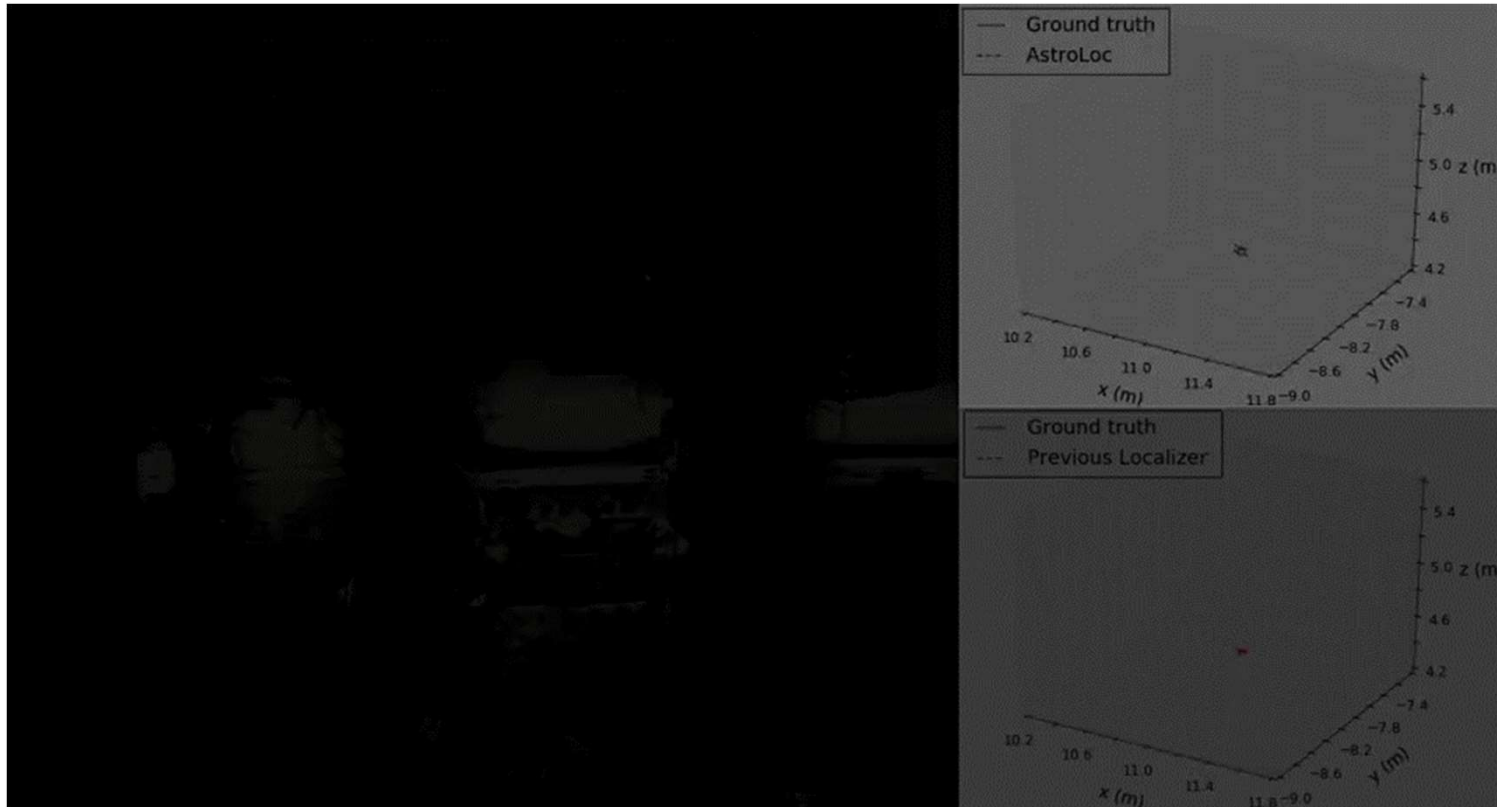
Localization

- Extended Kalman Filter (EKF) upgraded to graph-based localizer
 - Reduced number of “astronaut recoveries” events
 - Graph localizer had 54% smaller position error on average
 - Since deployment, multiple Astrobees ISS activities have logged hours of free flying with no crew intervention





Mapping and Localization



R. Soussan, V. Kumar, B. Coltin y T. Smith, «AstroLoc: An Efficient and Robust Localizer for a Free-flying Robot,»
IEEE International Conference on Robotics and Automation (ICRA), Philadelphia, USA, 2022.





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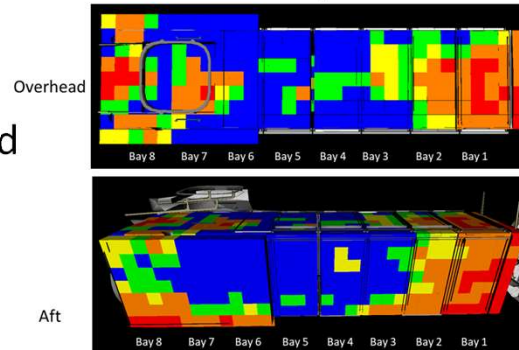


Coverage Analysis

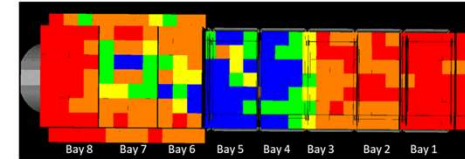


- Visualizes coverage of a given map or Astrobeer trajectory
- Map pre-assessment for Astrobeer team and Guest scientists
- Trajectory post-assessment
- The more features, the more stable Astrobeer localization will be.
- Analysis produces:
 - 3D JEM heat map
 - 3D Astrobeer trajectory heat map
 - PDF report

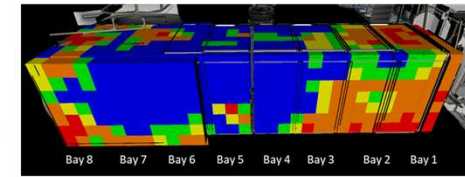
3D JEM Heat Map



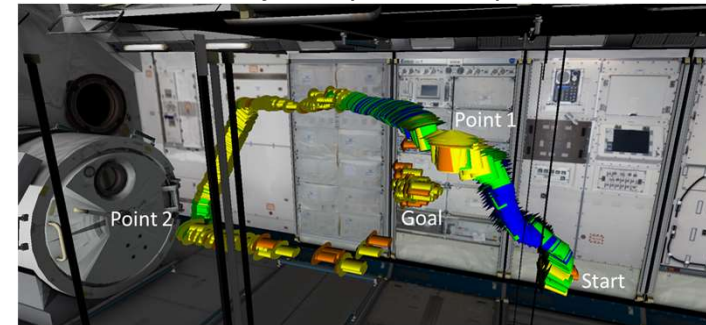
Deck



Forward



3D Astrobeer Trajectory Heat Map



Color	# Features
Red	0
Orange	1-10
Yellow	11-20
Green	21-40
Blue	40+





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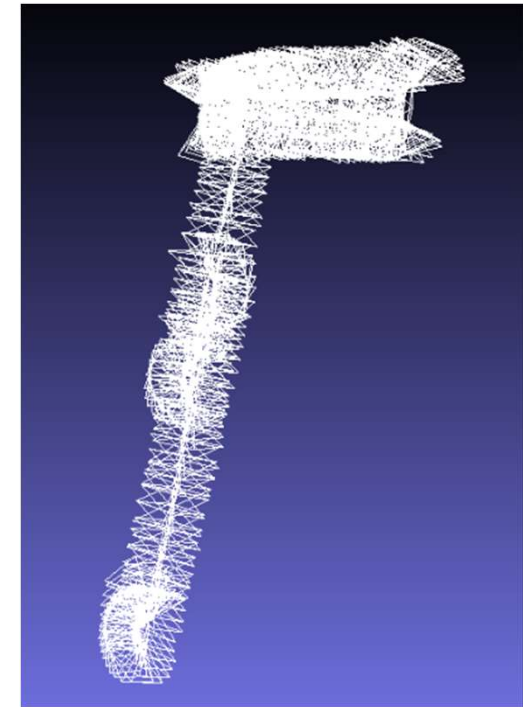


ISS Ops Summary



- Mapping & Localization

- The ISS is a dynamically changing environment.
- A localizer without mapped landmarks, the longer the better.
- Maneuvers need to point periodically to areas with good features.



3D view of JEM, NOD2, USL camera poses





ISS Ops Summary



Utilization Statistics To Date

Number of on-orbit operations:	123
Number of on-orbit REMOTE* Test Sessions	82 (66% of total operations)
Unique Crew Members trained and who have operated Astrobee on the ISS:	25
Number of on-console hours:	900+
Crew hours	~200
Astronaut recoveries per ISS ops (Prior/After to new localization)	2 (average) / 0

* REMOTE ops are ISS Ops that were run offsite from Ames Research Center (ARC) from April 2020 to present. All other ops were run onsite at ARC.





Conclusions



- Many firsts in Astrobees' history:
 - Operation of an Astrobees free-flying robot without crew supervision
 - Autonomous image acquisition
 - Non-NASA code running on the robot
 - Multiple free-flying robots working together
 - 1st payload using Astrobees controlled from a non-NASA location (Tsukuba Space Center).
- Mapping and localization have been improved
 - Map performance verification tools: coverage analysis
 - Localization algorithm increased ISS activity's reliability
- JAXA/NASA's collaborative effort shows international partnerships effectively and positively engage students to remain in STEM





Astrobee & JAXA Teams



Astrobee

- Jose Benavides – Project Manager
- Jonathan Barlow – Engineer Lead
- Aric Katterhagen – Operations Lead
- Roberto Carlino – Engineer
- Andres Mora Vargas – Engineer
- Simeon Kanis – Operations Support Engineer
- Jose Cortez – Engineer
- Maria Bualat
- Trey Smith
- Marina Gouveia Moreira
- Kathryn Hamilton
- Brian Coltin
- All Ames Research Center who helped develop, test, and build Astrobee
- Henry Orosco – ISS Research Integration Manager (RIM)
- Cristian Garcia – ISS Payload Integration Manager (PIM)

MSFC Support

- Stormi Denton POI Specialist
- Andrew Howard POI Specialist
- Sharon Manley POI Specialist
- Michael Cluxton - PARC
- Tameka Stewart - PIE

JAXA Team Members

- Doi Shinobu
- Yuta Kawai
- Ryo Uchida
- Kyouichi Arakane
- Yayoi Miyagawa
- The Int-Ball team at Tsukuba Space Center





QUESTIONS?