

Astrobee



2022

Evergreen Valley High School Robotics Club

"Astrobee, A free flying robot on ISS"

Jose Benavides, Astrobee Facility PM



Jose Benavides Background

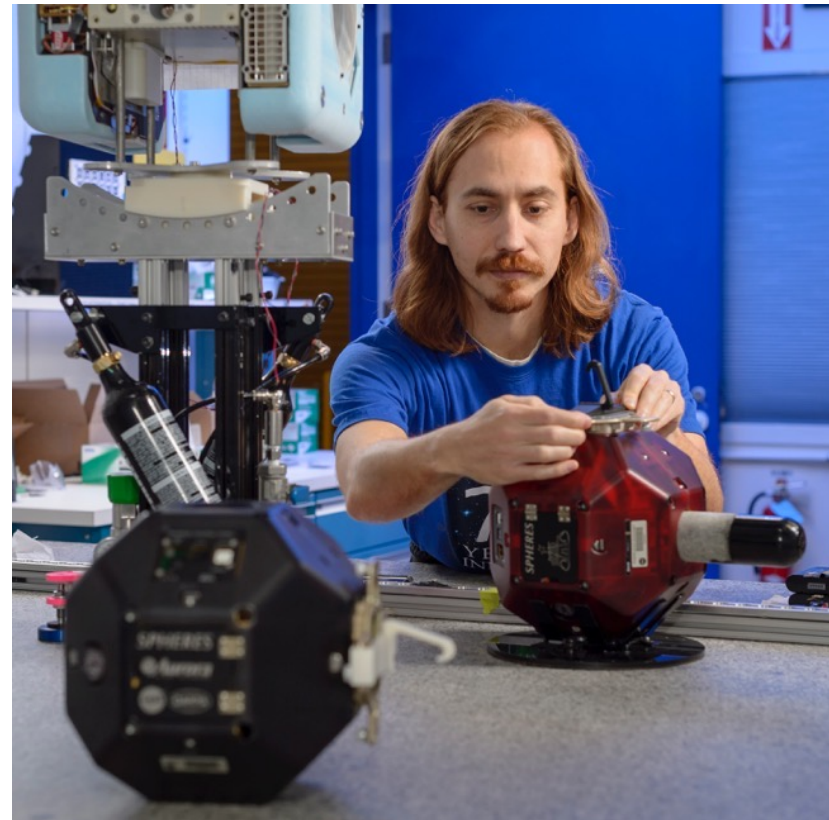
- Grew up in Chandler, AZ. My parents were raised as migrant farm workers and were the first to get college degree's
- Jose started employment as a contractor at NASA's Ames Research Center California's Silicon Valley in 2008 as a member of the Advanced Control and Evolvable Systems (ACES) Group in the Intelligent Systems Division.
- Jose is currently the Project Manager of the NASA International Space Station (ISS) [Astrobee Facility](#) project. In conjunction with the prior platform, [SPHERES](#), the [Astrobee Facility is one of the most used and popular ISS National Lab Facilities with over 80 on-board test sessions and 400+ hours of Facility Console activities involving crew.





Background Cont.

- His past projects include rapid prototyping of controls systems using FPGAs, controls-oriented vehicle design of air-breathing hypersonic aircraft, trajectory generation and optimization for tactical flight management systems, pilot-in-the-loop high fidelity 6-dof flight simulation, and small satellite software. His research interests include embedded systems, rapid prototyping of control systems, spacecraft, small satellites, robotics, and human-machine interaction (HMI).
- He has a bachelors and masters degree from Arizona State University in Electrical Engineering, with specialization in control systems. His hobbies include reading, hiking, dancing, and computer networking.





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





Overview Video

ASTRBEE



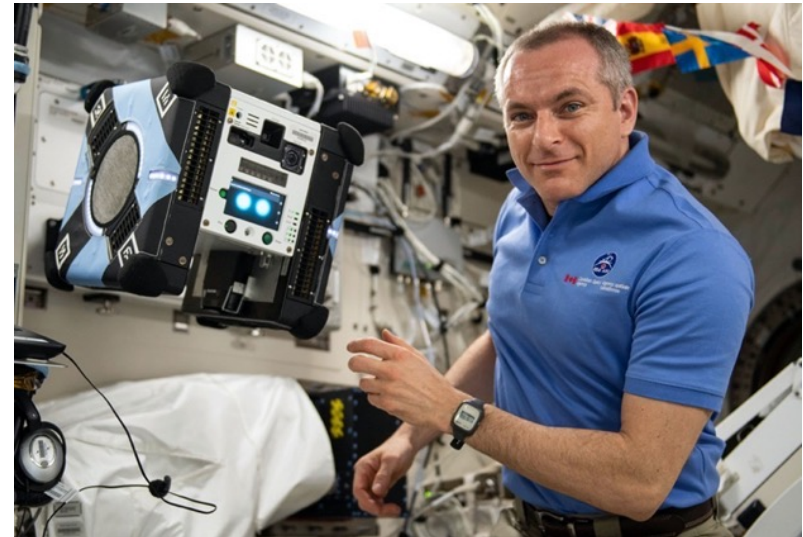
Astrobee meets Chris Cassidy





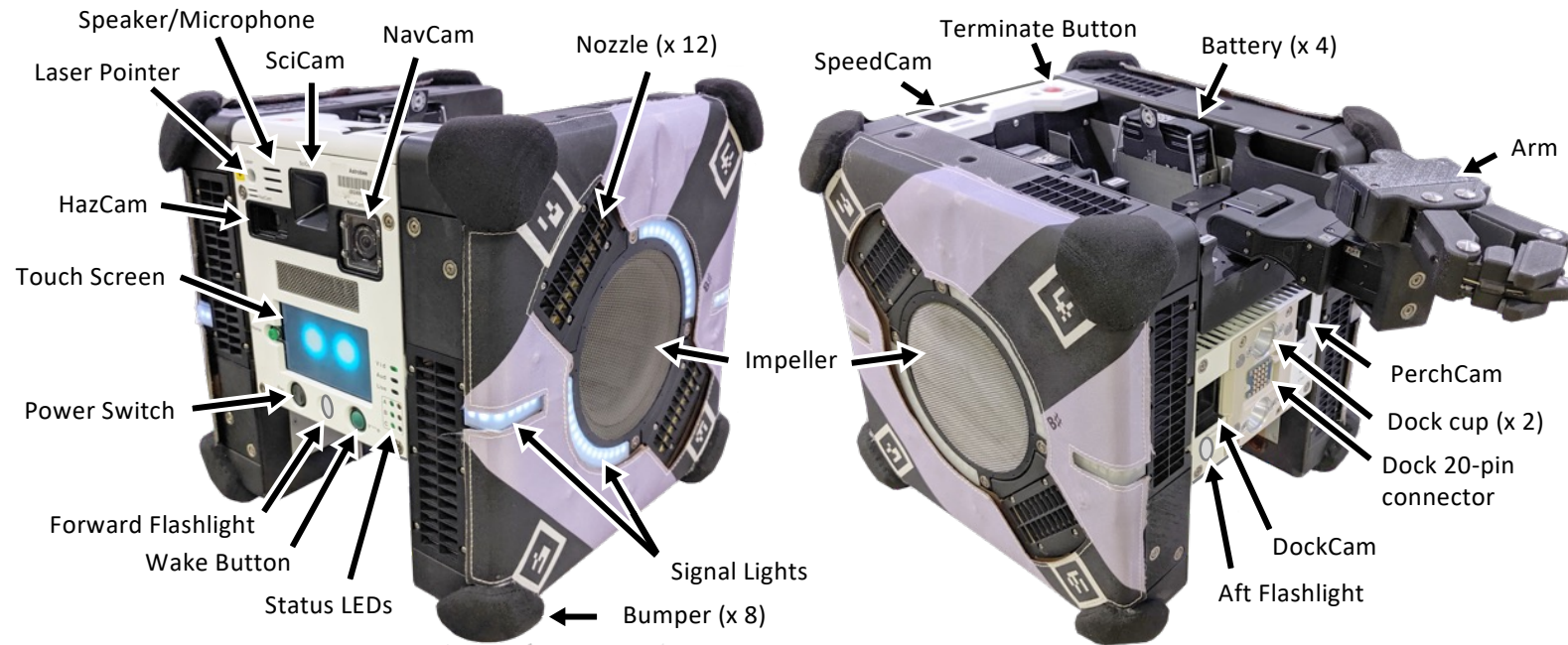
Astrobee Purpose

- Objectives
 - Provide a microgravity robotic research facility inside the ISS US Orbital Segment (USOS), which has replaced the existing SPHERES facility
 - Demonstrate feasibility of intra-vehicular robot caretaking for future human exploration vehicles
 - Provide an opportunity for future automation of certain ISS operations
- Driving use cases
 - Guest science experiments
 - Remotely operated mobile camera
 - Sensor surveys





System Description - Hardware



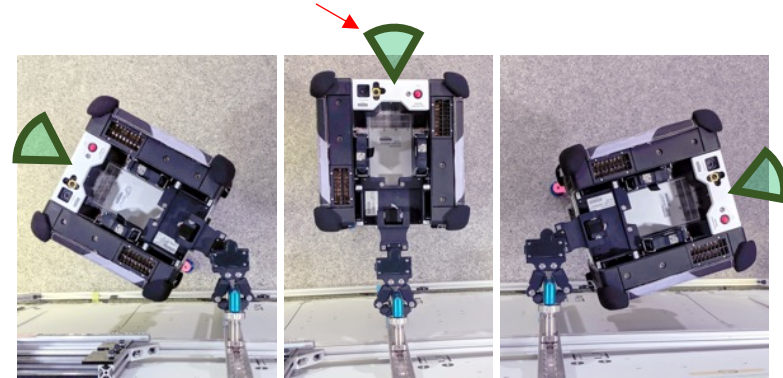
- Free flying robot inside the ISS
- 32 cm wide, ~9.1kg (2 batt., no arm)
- All electric + fan-based propulsion
- Robot arm for “perching”, ~1kg
- Three smartphone computers
- Three payload bays for expansion
- Microphone not currently enabled



System Description - Perching Arm

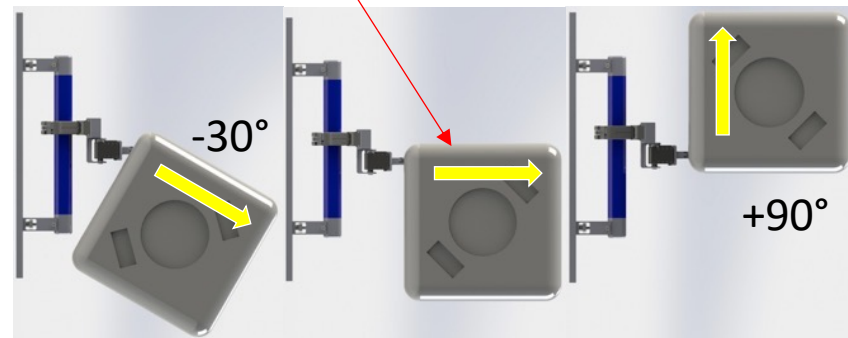
- Designed to grasp handrails
- Stows completely in payload bay
- Acts as a pan-tilt unit while perched
- Flexible and back-drivable
- May be perched manually

Camera View Direction



Astrobee Perching Arm pan motion

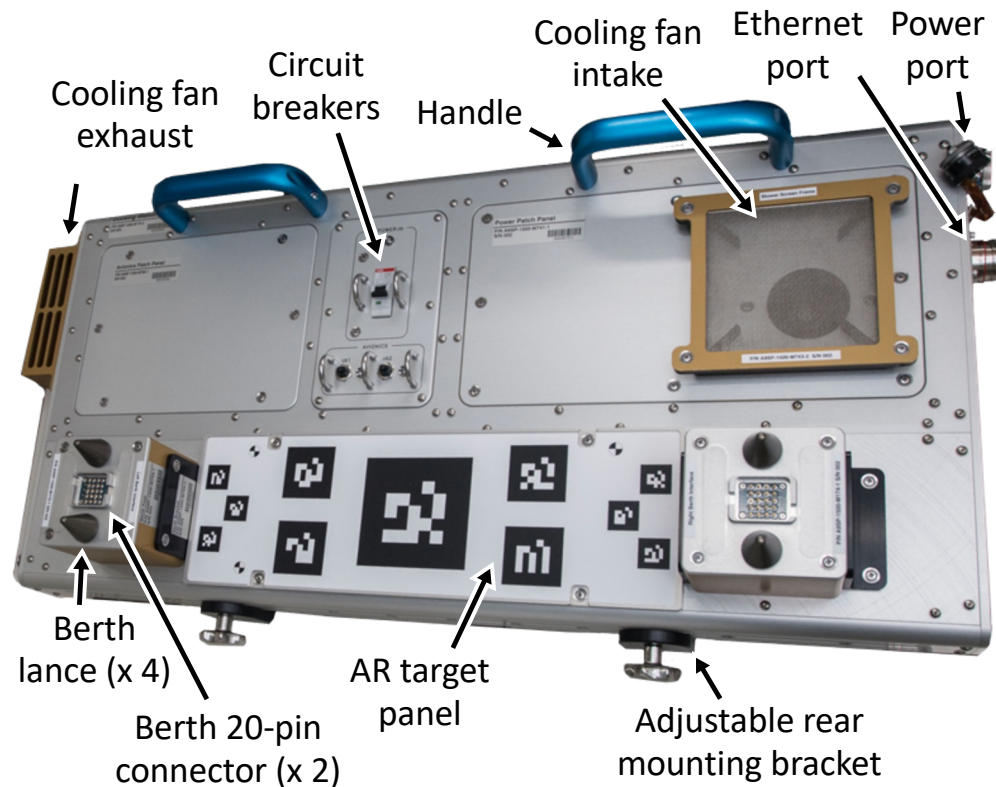
Camera View Direction



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



ISS Crew helpers





Astrobee Control Station

Crew Control Station

File View Help

Run Plan Teleoperation Guest Science

FreeFlyerA Comm ● Control DW@DW-Windows7-32 Est. Batt 2:39 Docking Station ● GPS 18Mar17 17:38:44

Health and Status

Operating State	Plan Execution
Mobility State	Flying
Operating Limits	Default_Safeguard
Plan	Survey1
Plan Status	Executing

Robot Commanding

File ... C:\Users\DW\Desktop\FPlans\Survey1.fplan

Plan Valid

Grab Control Load Run Pause Skip Step

Description
Survey European Lab and US Lab

Plan

Total Elapsed Time 00:00:35

Plan Step	Duration	Success
Survey1		
0 Station		Complete
0-1 Segment	00:01:48	Complete
1 Station		Complete
1.0 PowerOnIten		Complete
1.1 Wait	00:00:25	Complete
1.2 PowerOffIten		Complete
1-2 Segment		
2 Station		
2.0 Wait		
2-3 Segment		
3 Station		
3-4 Segment		
4 Station		
4-5 Segment		
5 Station		
5-6 Segment		
6 Station		

Live Telemetry Live Images Live Video

17:38:09 FreeFlyerA: Run Plan Pending ...



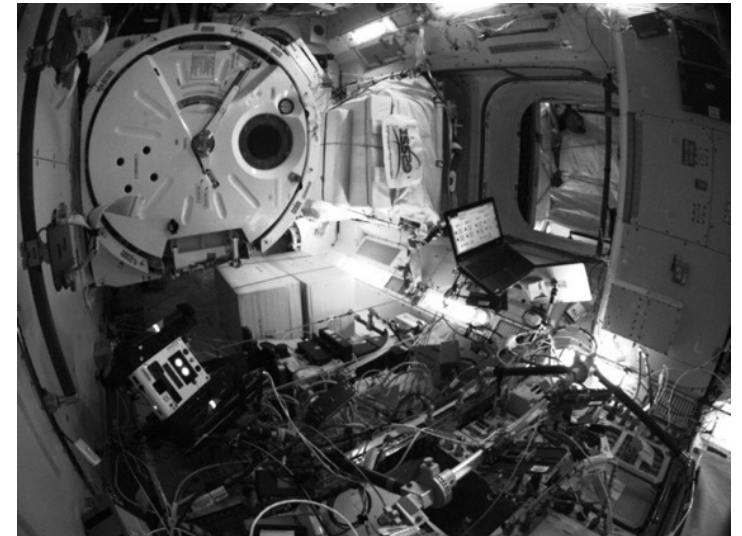
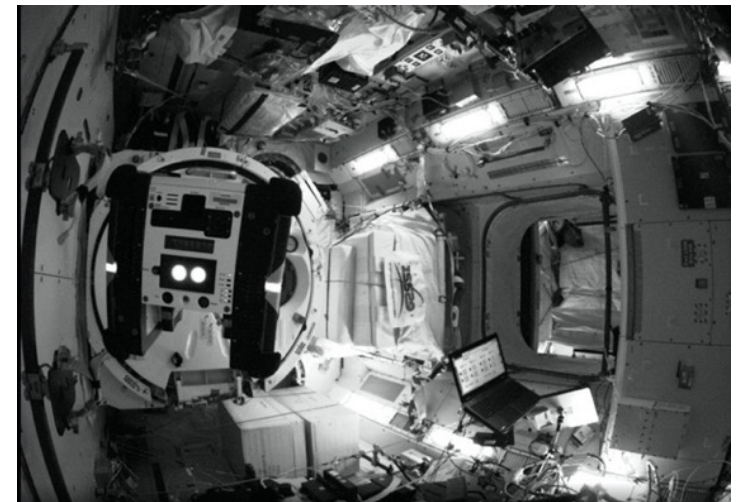
Basic Conops

- 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 occurrence (minimize crew time)



Perching Demonstration

- Honey perched autonomously on 07/26/2021
- Perch location was also useful to see how Bumble had become entangled.
- Operator was able to use the view from Honey to free Bumble.





Completed Investigations

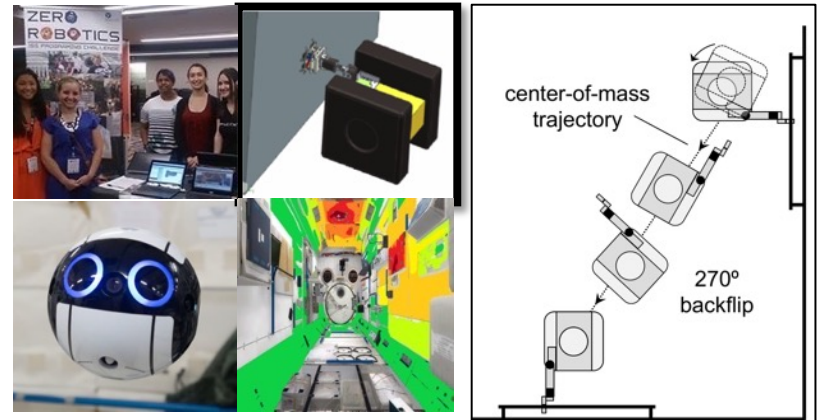
- Kibo Robotic Programming Competition – Year 1 – Completed 10/2020
- The REduced Gravity Gecko Adhesion docking Experiments (REGGAE) – Completed 01/2021
- Stanford Gecko – Phase 1 – Completed 04/2021





Ongoing Investigations

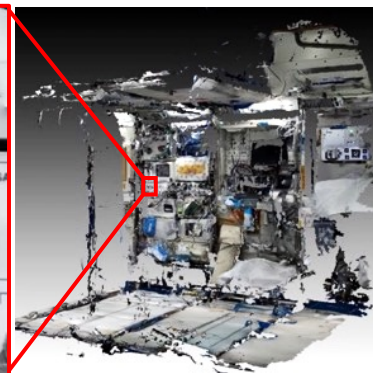
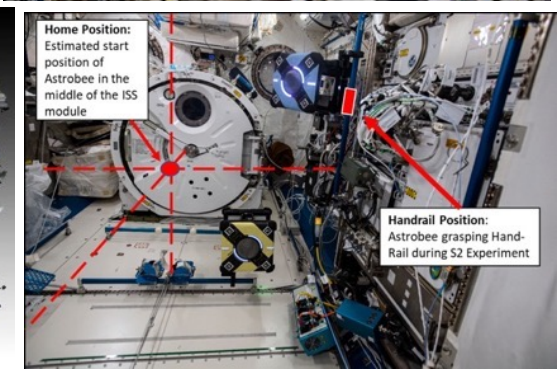
- Astrobatics (Naval Postgraduate School)
- SoundSee (Astrobotic/Bosch)
- Gecko (Stanford)
- RFID Recon (NASA AES/REALM-2)
- JAXA Kibo-RPC
- Astroporter (Tethers Unlimited)
- ISAAC (NASA STMD/GCD)
- ROAM (MIT/DLR)
- ReSWARM
- SVGS (FIT)
- SOARS (Zero-g Horizons)





Achievements

- 3 hours of continuous operation without crew intervention
- One Astrobee unit used to rescue a second
- 20 user sessions
- On-orbit repair of dock
- Autonomous Perching



(a)



(b)



(c)



(d)



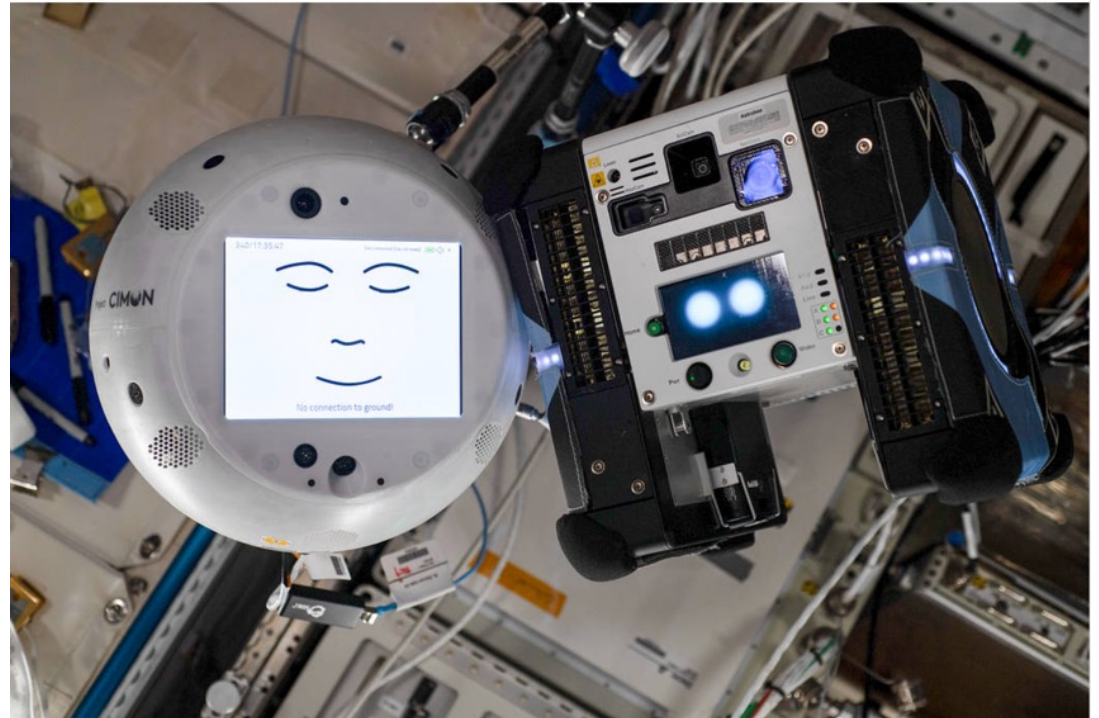
Robot Colleagues

JAXA's Int-Ball



Mar 22, 2022

Robot Colleagues Meet Aboard the International Space Station





Kibo-RPC Finals, 2020



- <https://youtu.be/B0-ZJaAdNDw> (2 min trailer)
- <https://jaxa.krpc.jp>



Join Kibo-RPC!

KIBO Robot Programming Challenge 3rd Mission

Code and Compete Internationally to BEE Programming Champions!



<https://nasacentral.force.com/s/course-offering/a0Bt00000004lQww/2022-kiborpc>



Zero Robotics (2018)





Astrobee Game Prototype

- Prototype game created at Academy of Art University (AAU)
 - GAM498 CoLAB class over two semesters Spring 2021 and Fall 2021.
- <https://www.youtube.com/watch?v=WIPn54KHhhE>

ASTROBEE
FIRST FLIGHT





Backup