

Astrobee

Space Station Robotic Free Flyer



ISS Research & Development Conference 2016

July 14, 2016

Chris Provencher

SGT at NASA Ames Research Center

Intelligent Robotics Group



Outline

- Overview
- High level design
- Status
 - Development
 - Testing

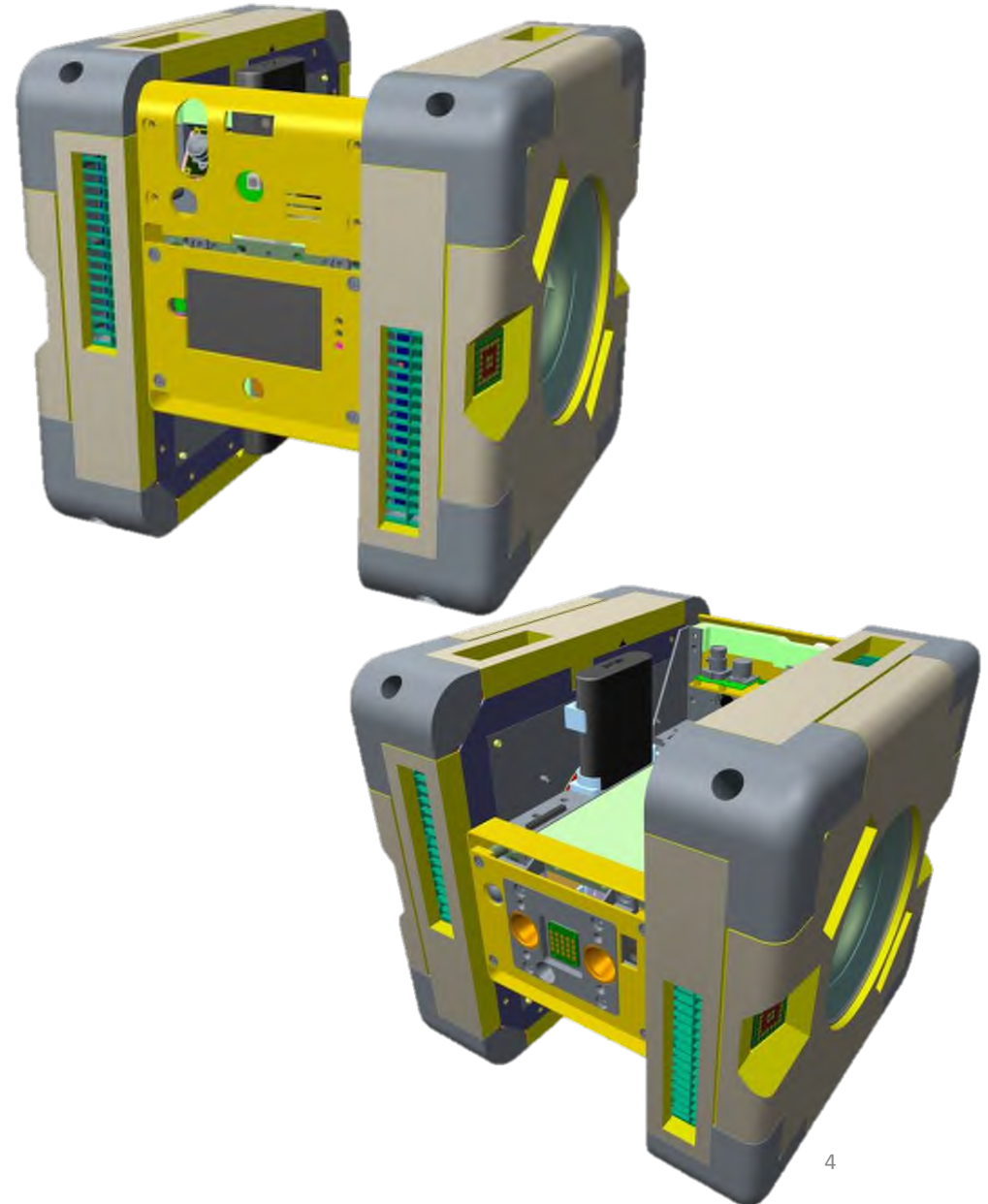


Overview



Project Summary

- Develop, test, deliver 2 free flying robots for ISS IVA use
- 3 year project (FY15-FY17) under Human Exploration Telerobotics 2 (HET2)
- 1 year (FY18) extension for on-orbit commissioning (proposed)
- Sponsor: Space Technology Mission Directorate, Game Changing Development Program
- Technology infusion to ISS payloads & operations





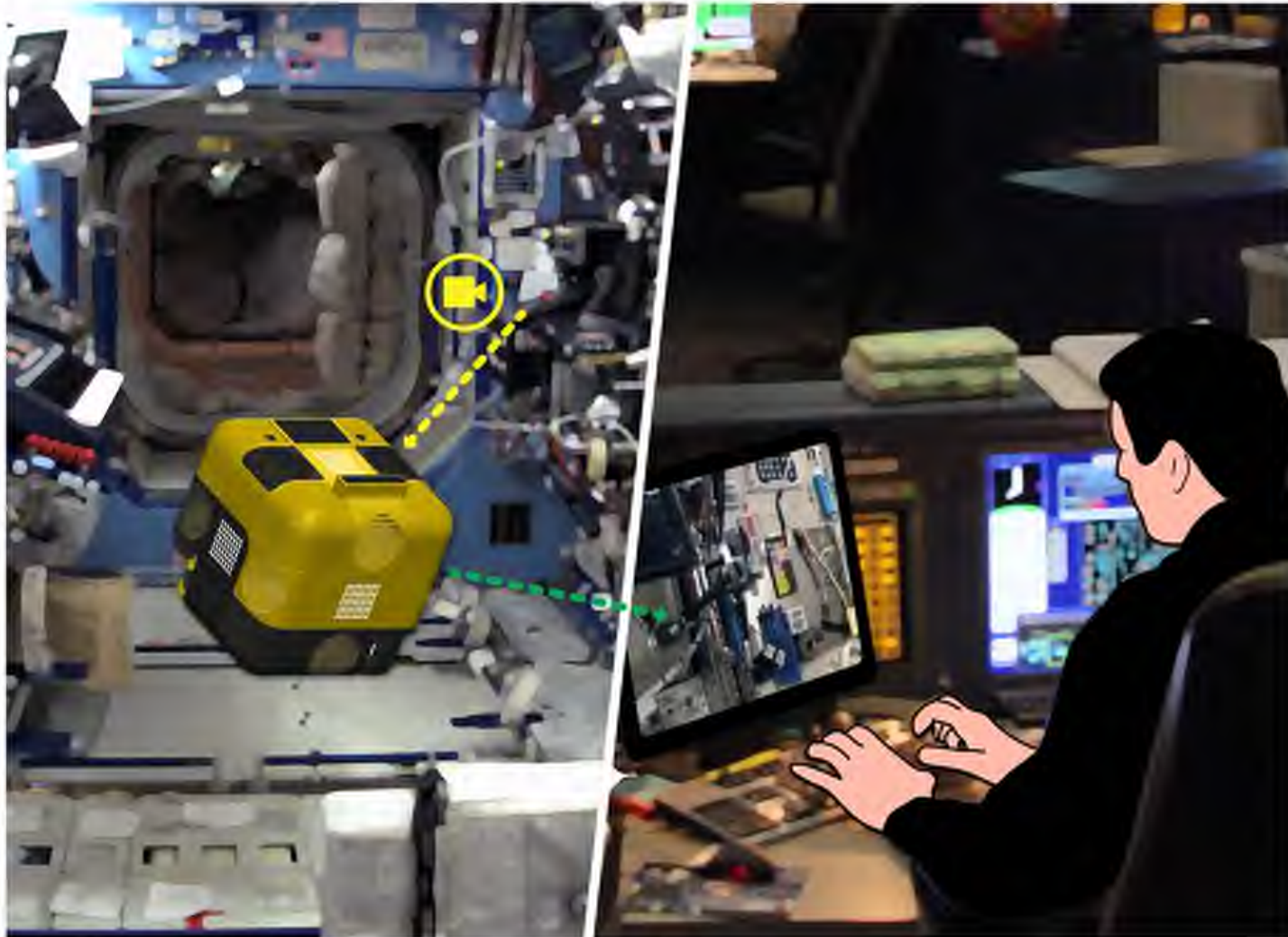
0g Robotics Research Facility



AES, SPHERES Program, SPHERES users



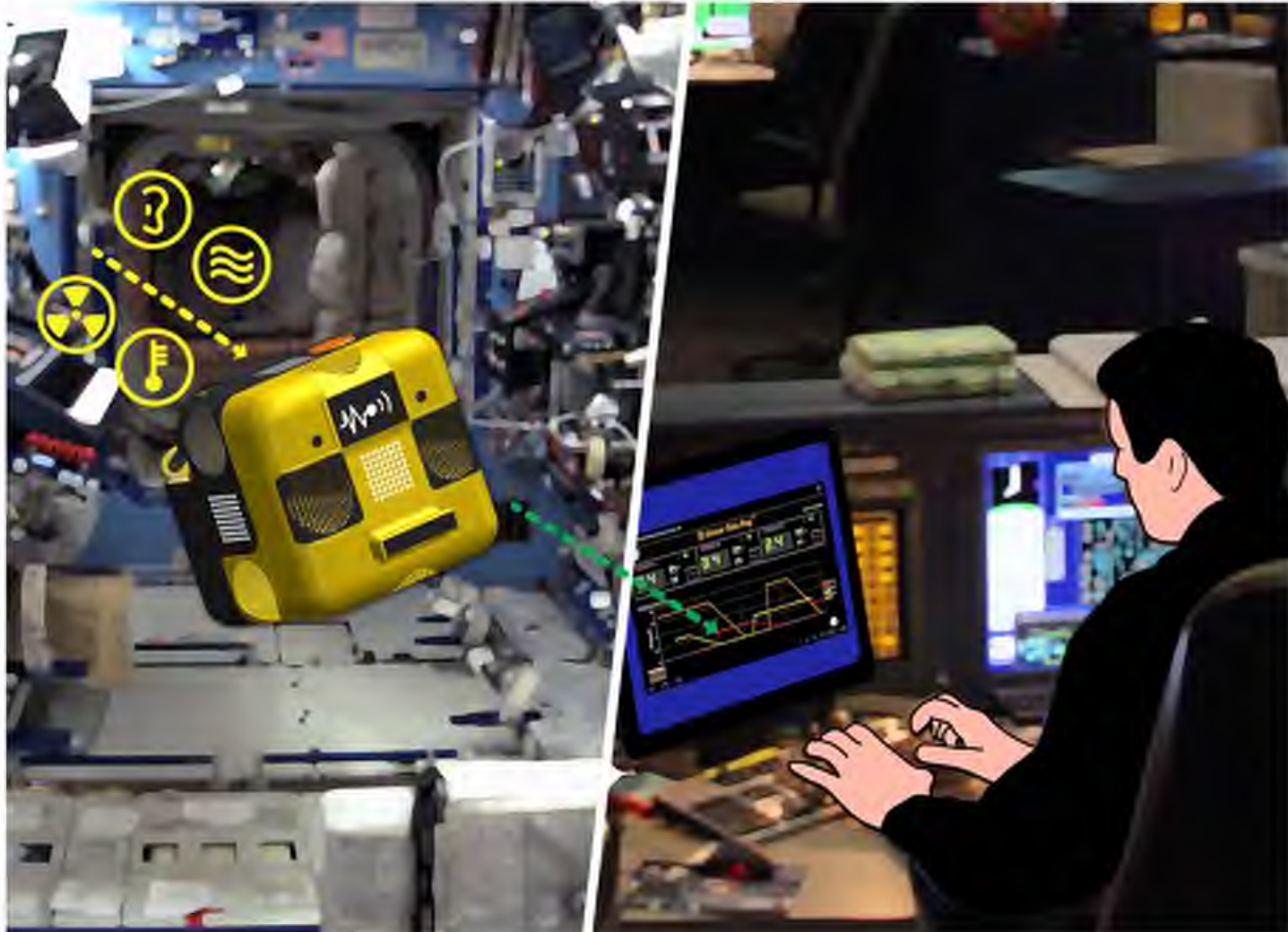
Mobile Camera Tasks



ISS Program, FOD, POIC



Mobile Sensor Tasks



ISS Program, FOD, POIC



Dock & Resupply

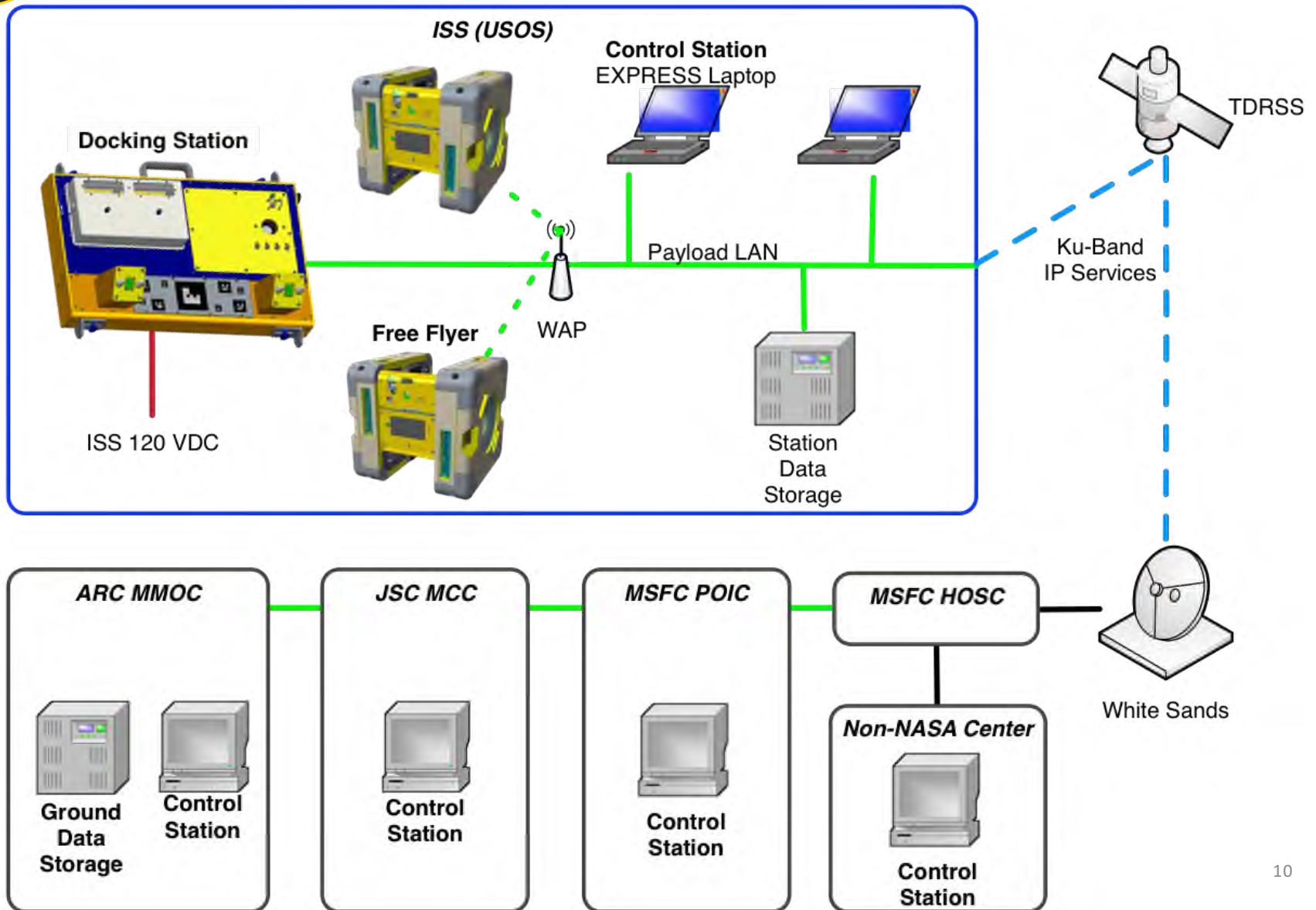




Design



System Architecture





Astrobee Free Flyer



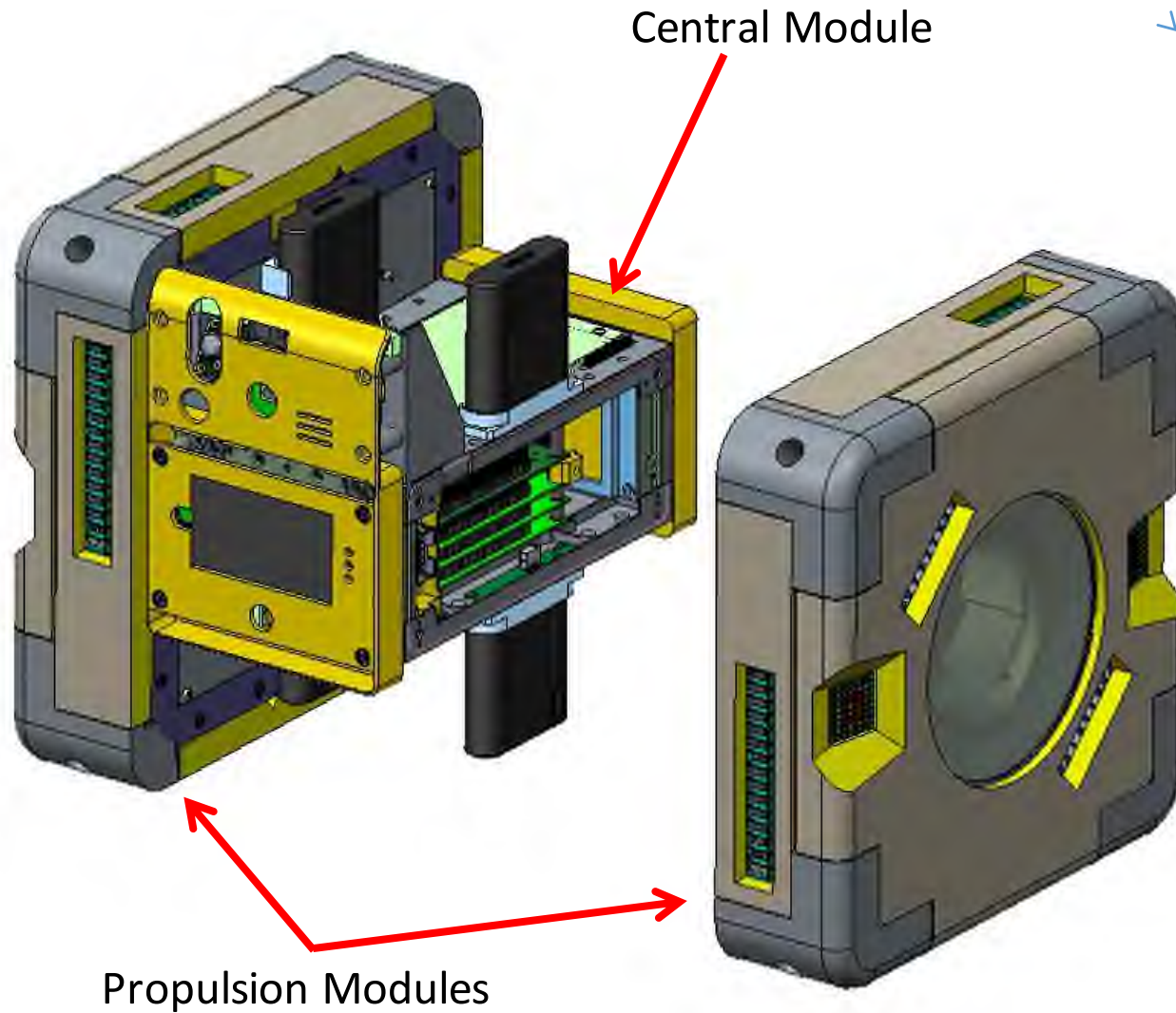
Forward Top



Aft Top



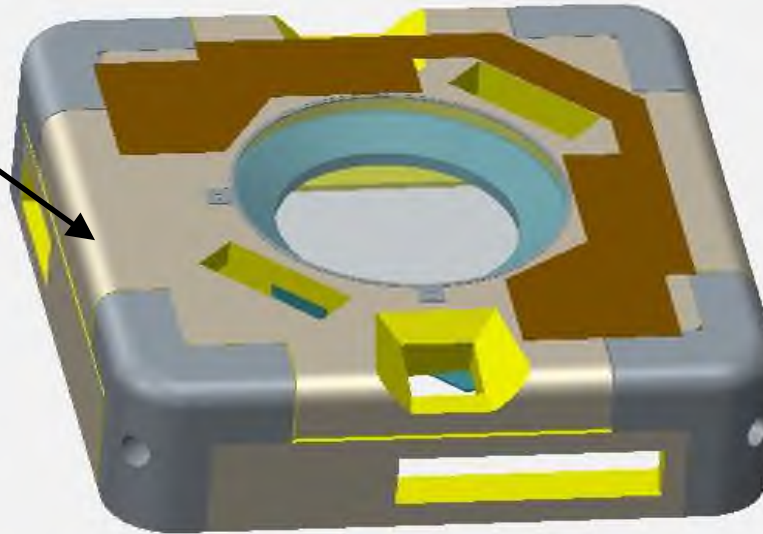
Astrobee Modules





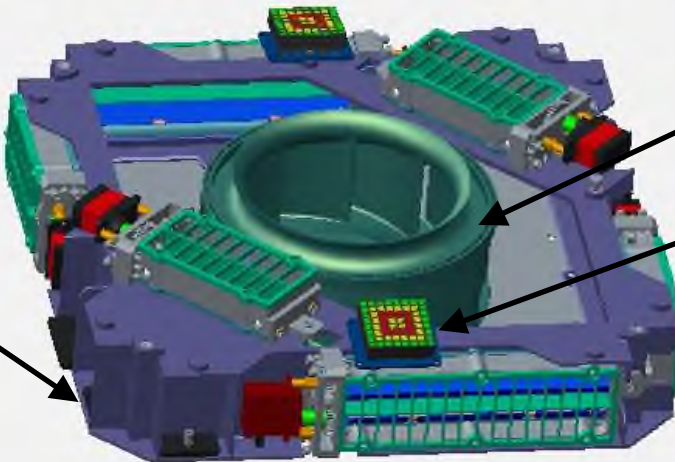
Prop Module Assembly

Impact Mitigation
(TBD)



Nozzles

Plenum



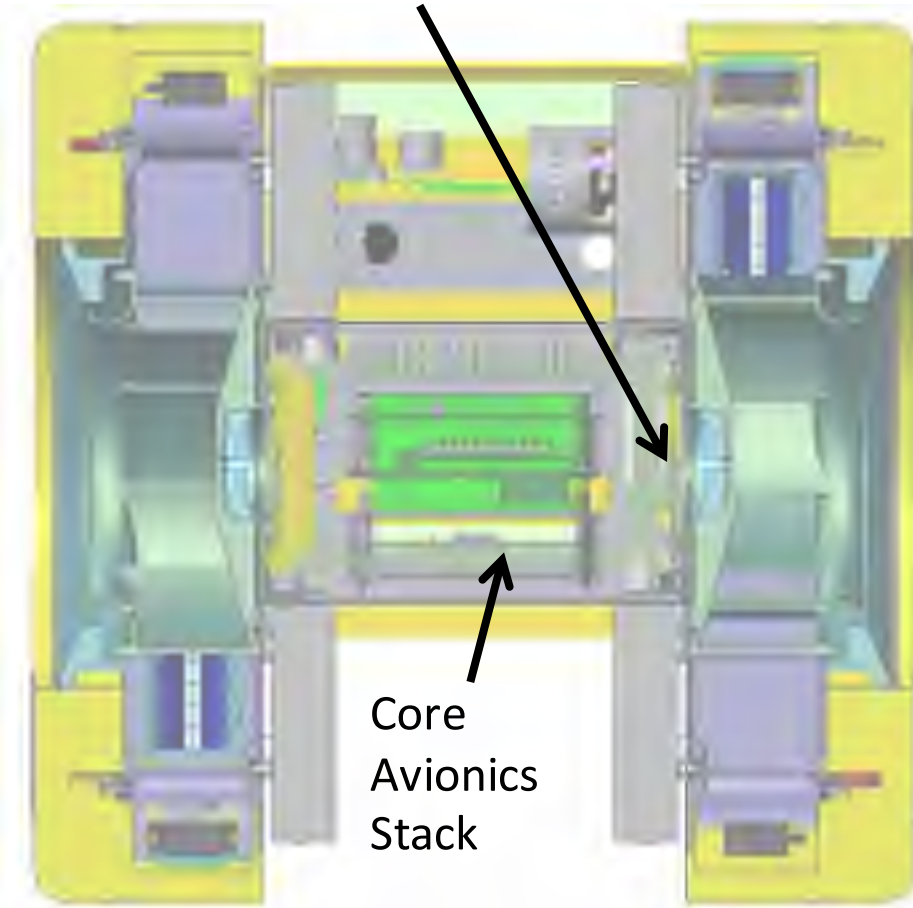
Impeller
Rotational
Assembly

Directional Signals
(TBD)



Computing Systems

Propulsion Module Controller



Core
Avionics
Stack

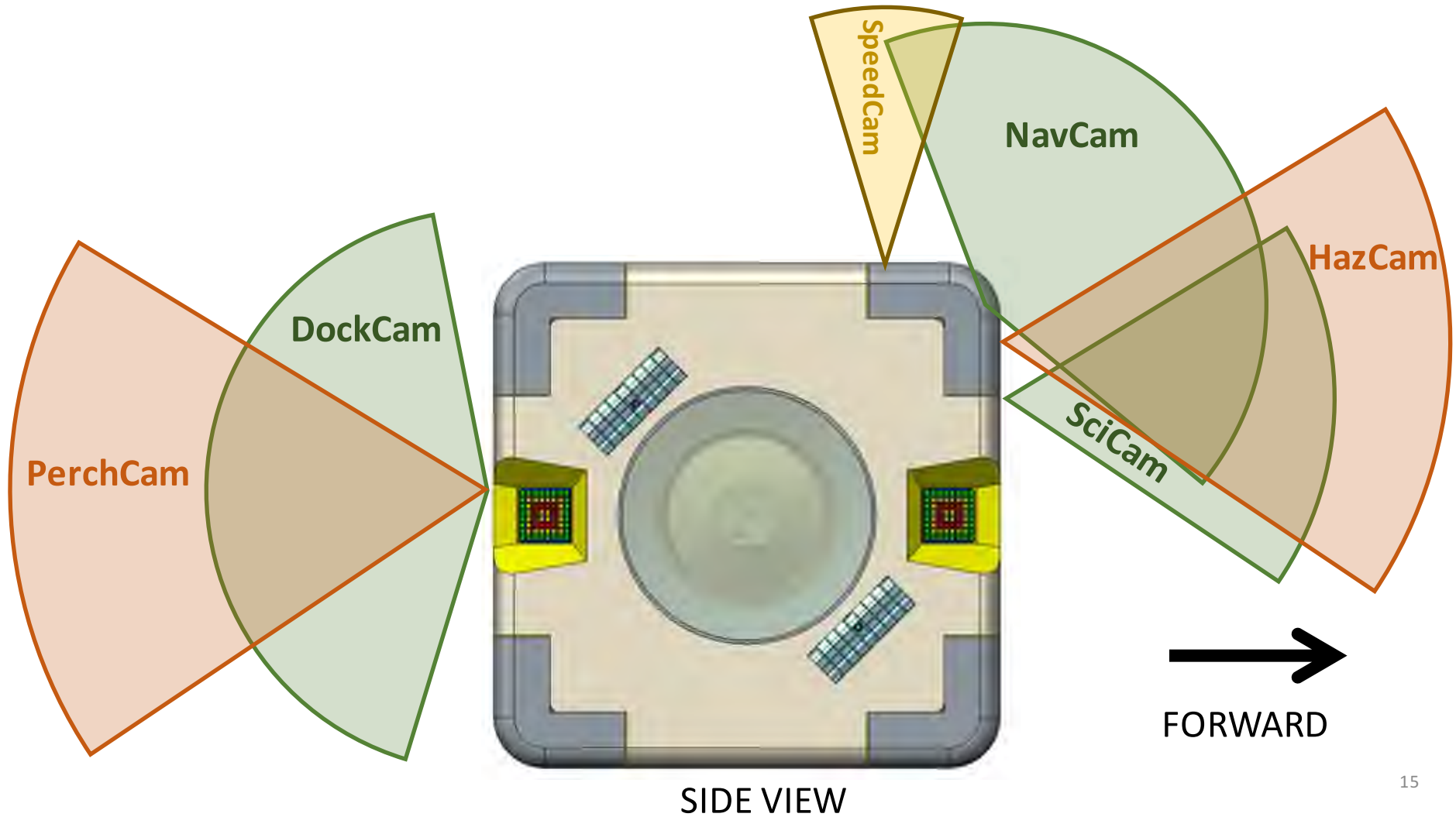
AFT/CUTAWAY VIEW



Perching Arm
Controller

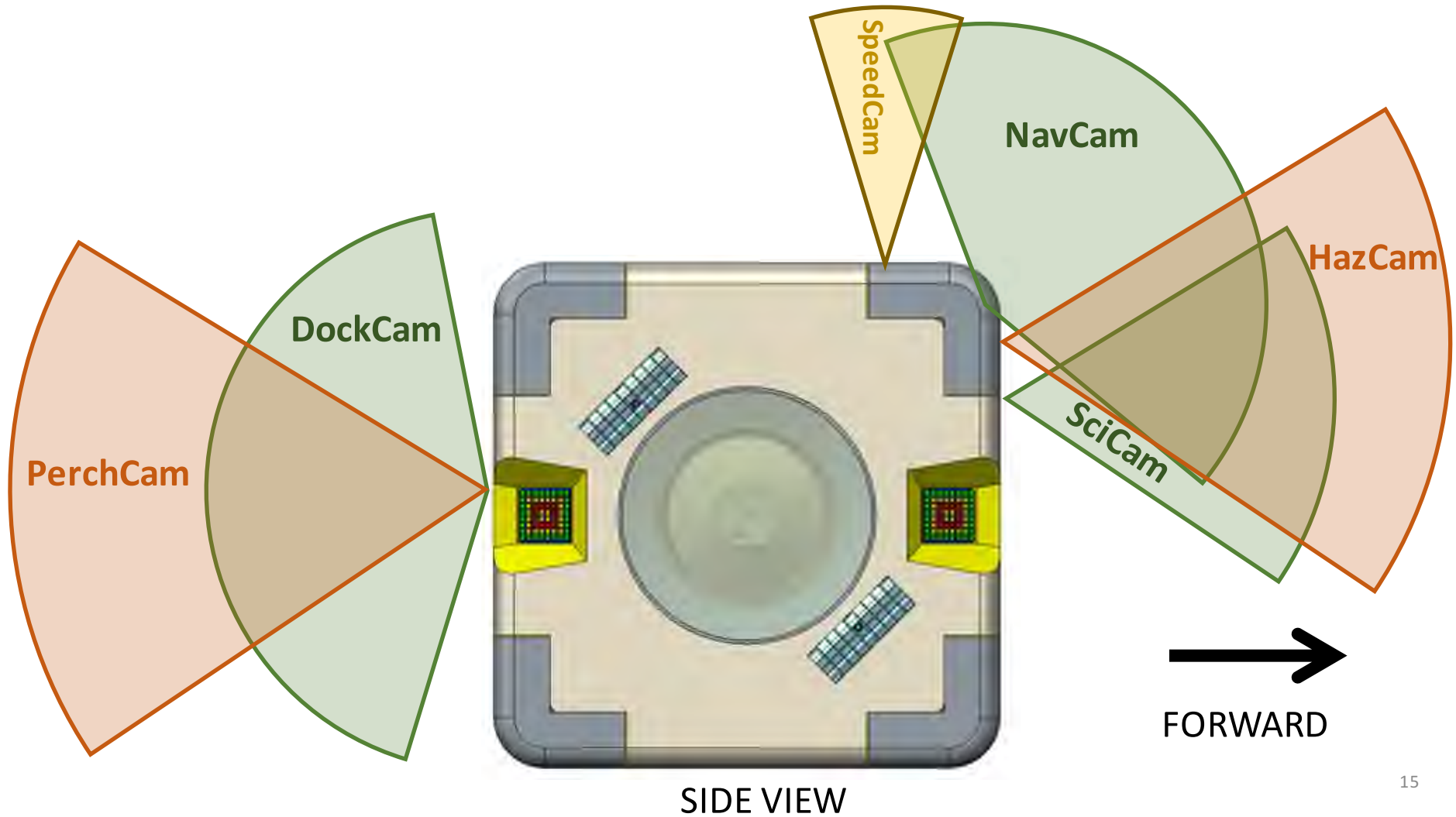


External Sensors



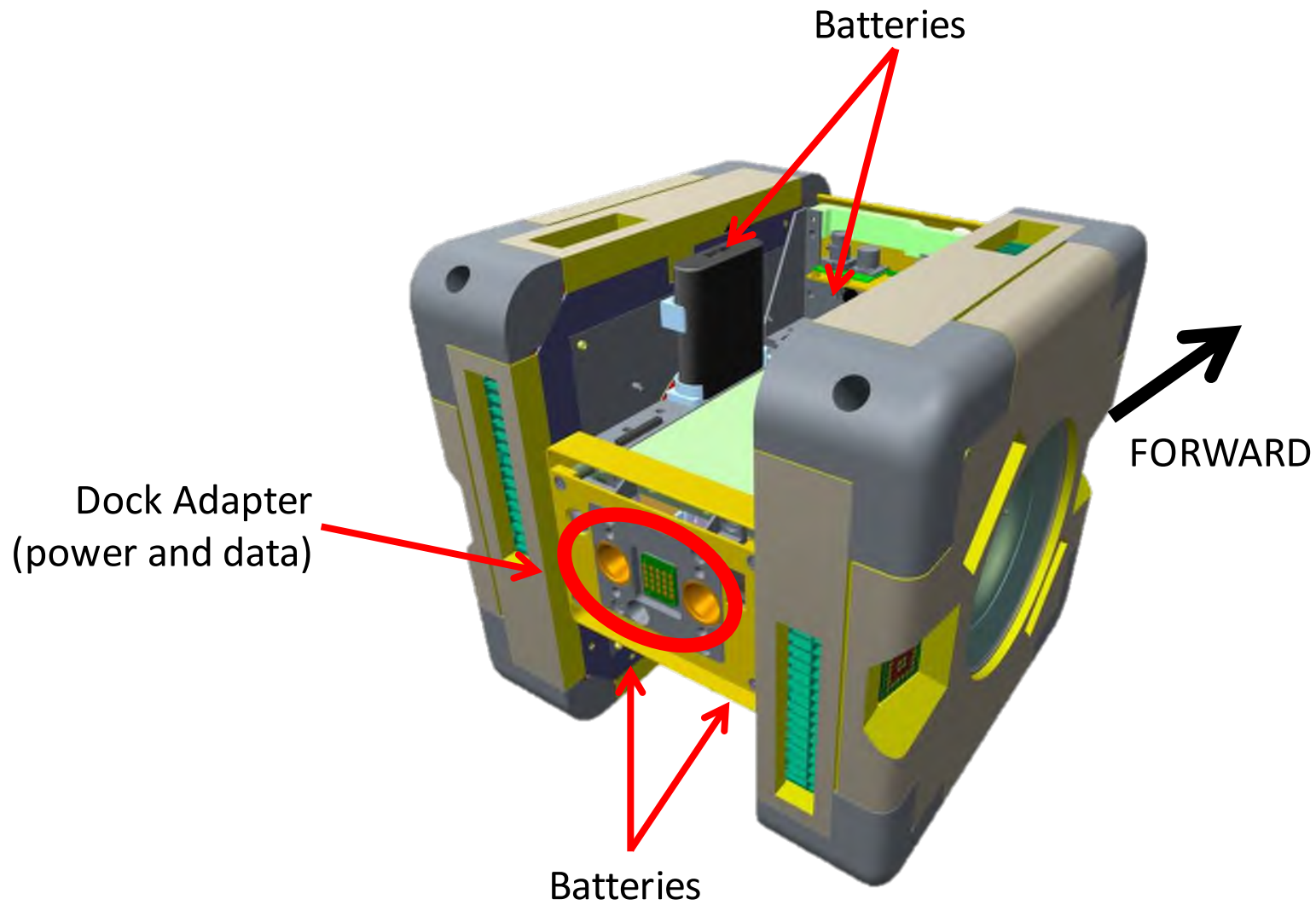


External Sensors



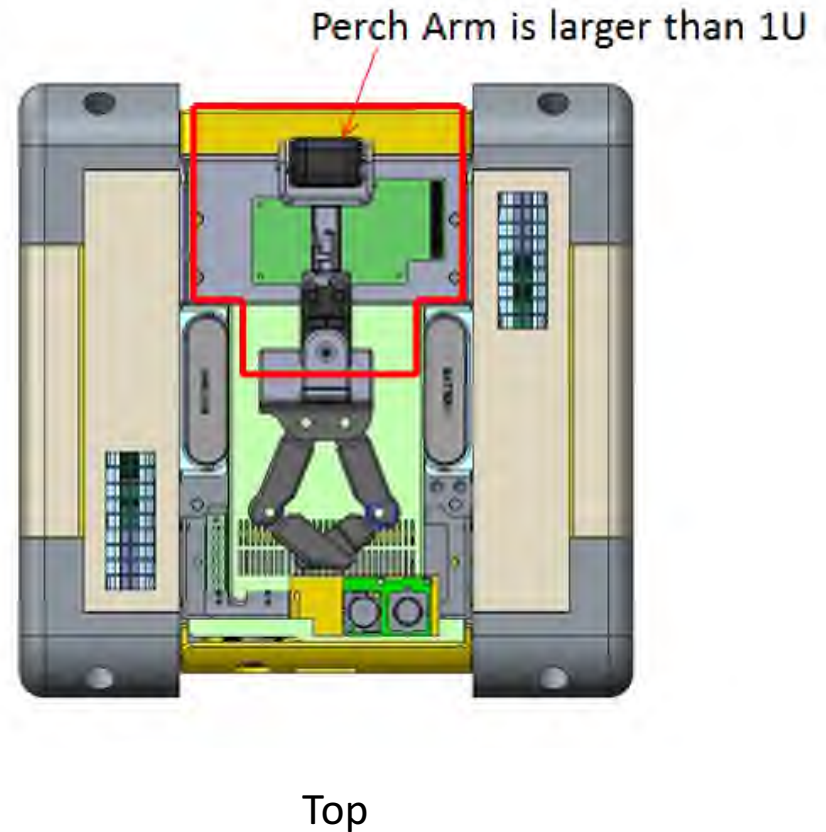
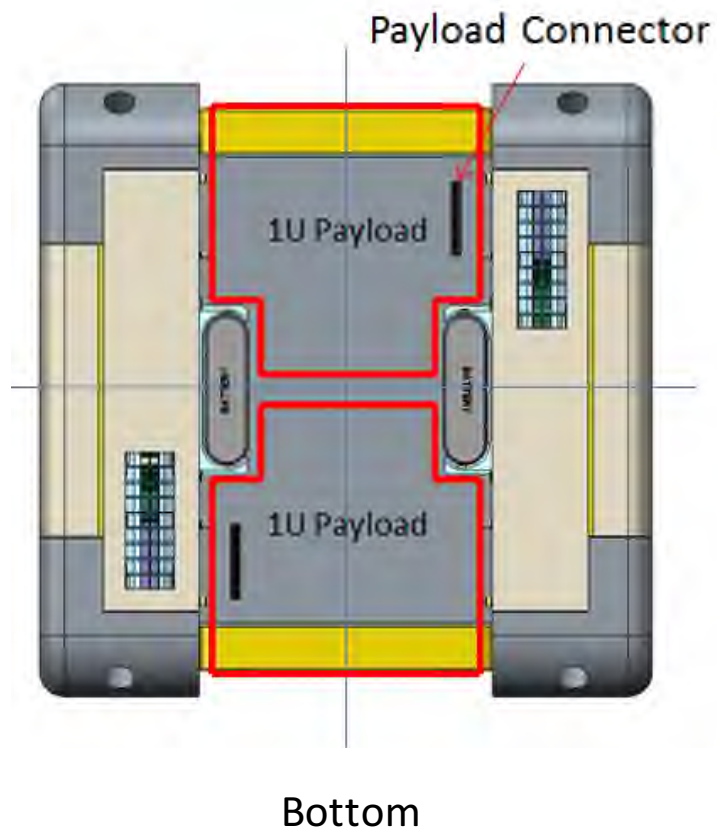


Power Systems





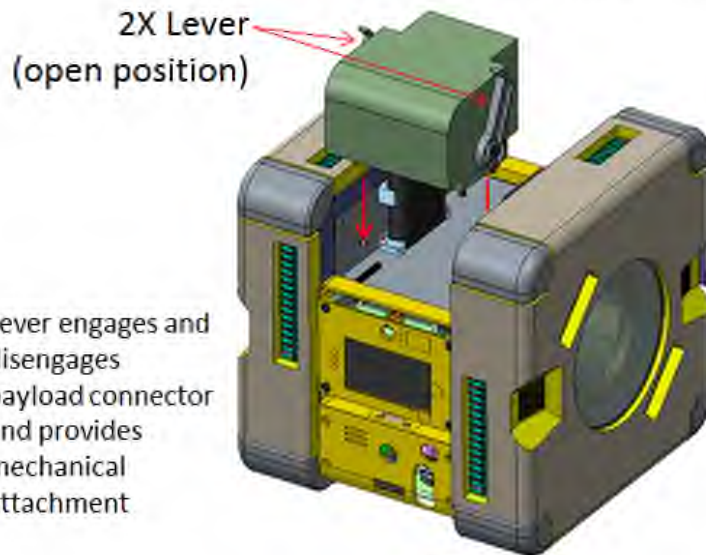
Payload Layout



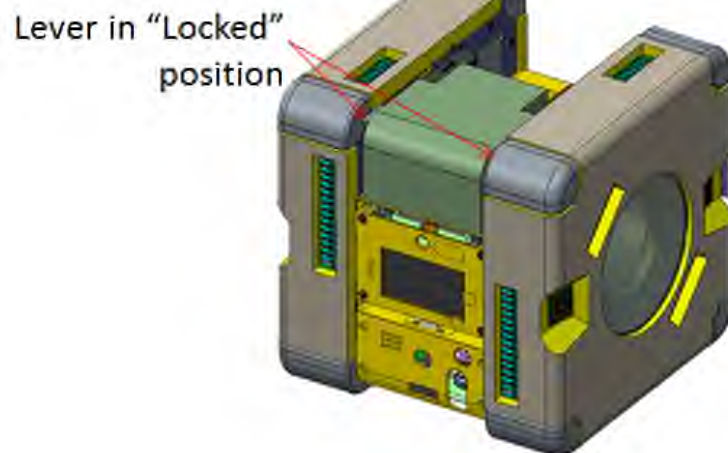
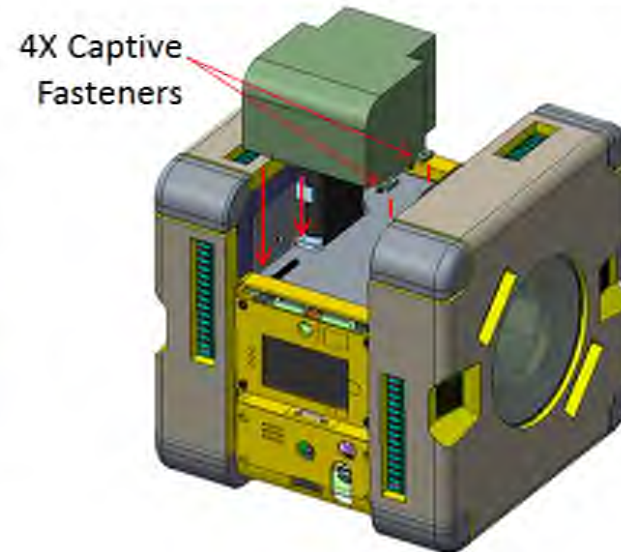


Payload Mechanical Attachment Options

Quick "No Tool" Payload Attachment

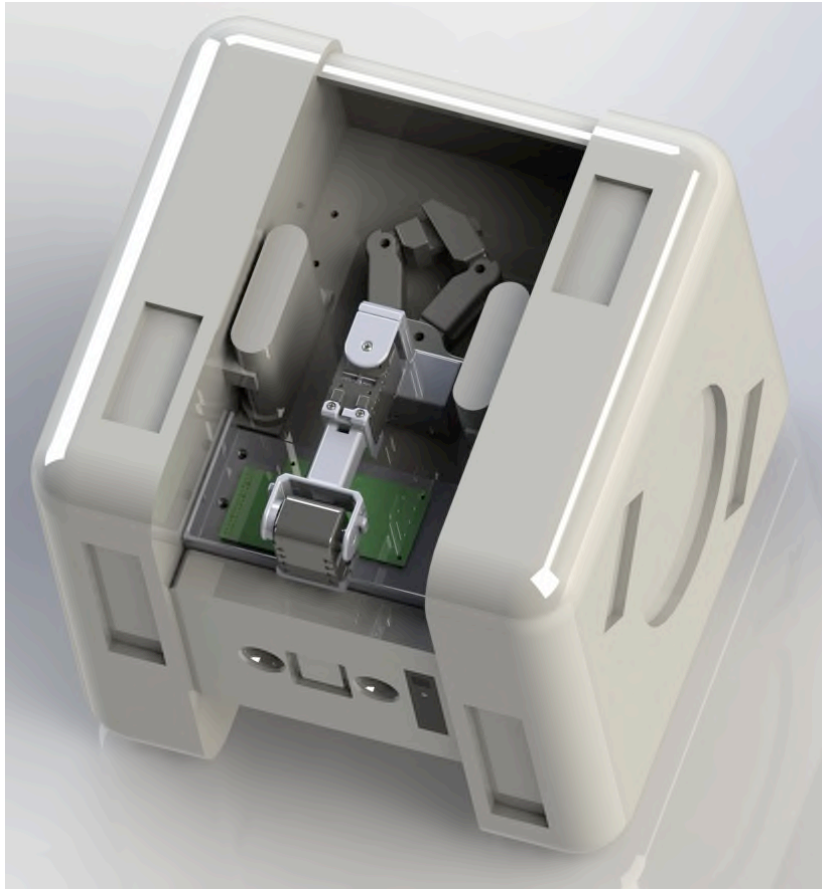


4X Fastener Payload Attachment

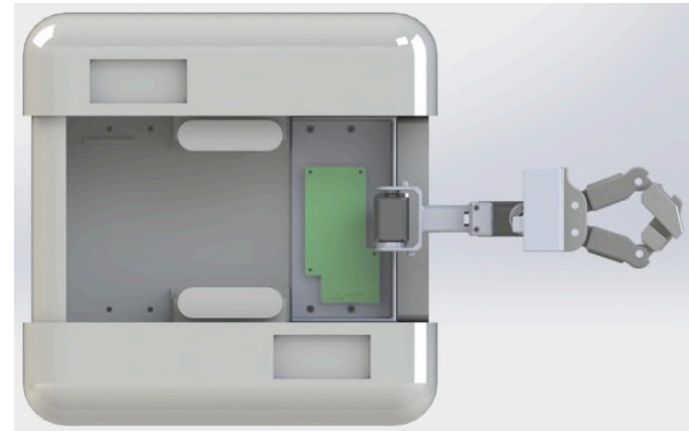
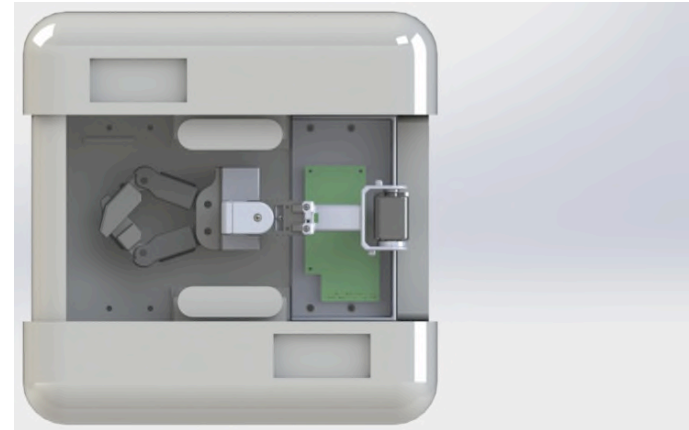




Perching Arm



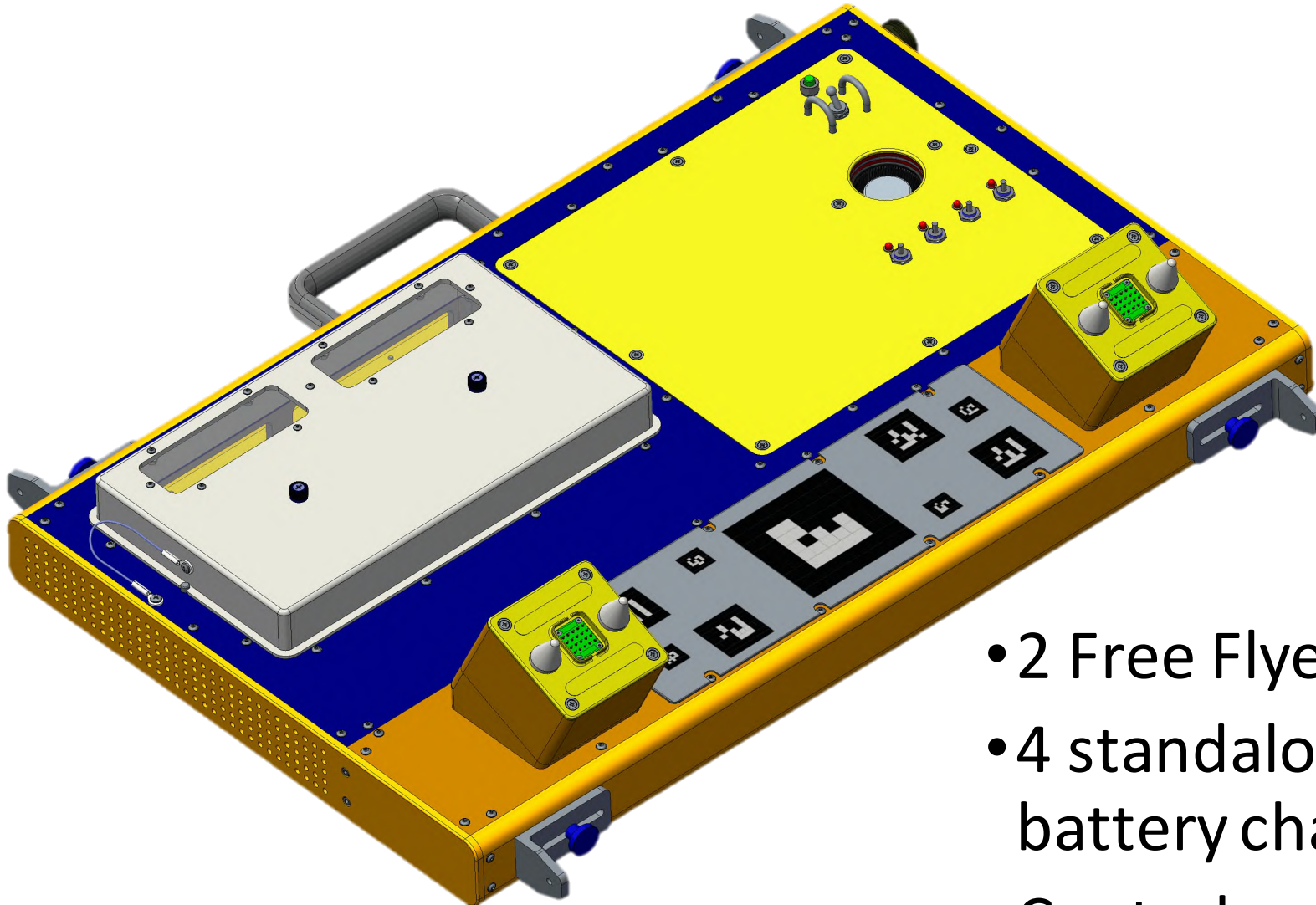
Stowed



Stowed/Deployed



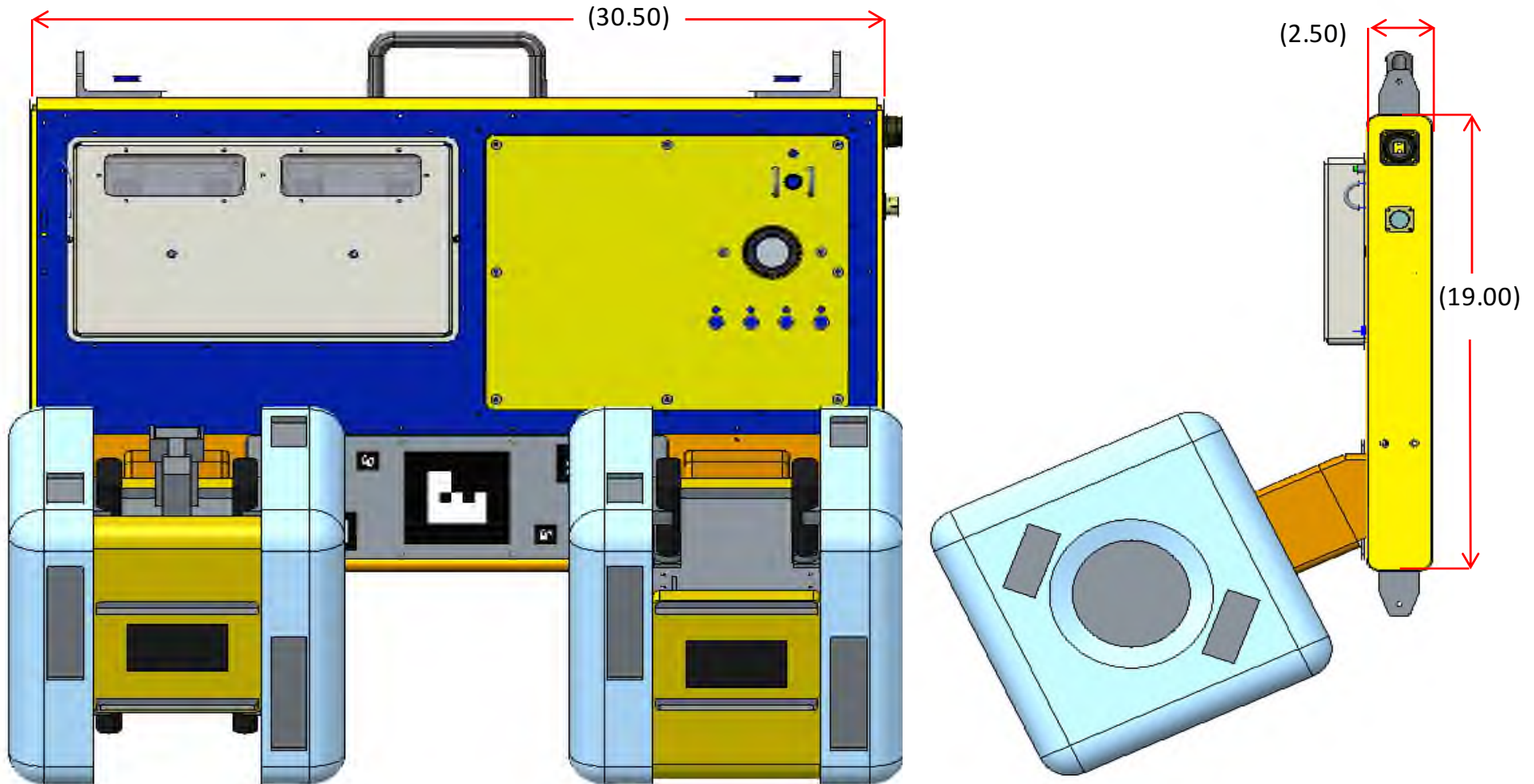
Docking Station



- 2 Free Flyer berths
- 4 standalone battery chargers
- Control panel



Docking Station Front and Side View



NOTE: Dimensions are in inches

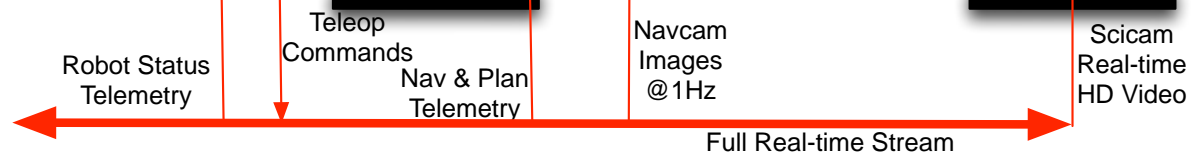
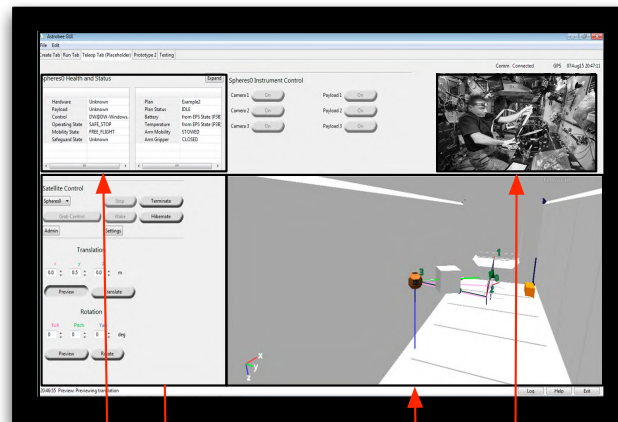


Control Station

- Eclipse based GUI
- Create, run, tele-op plans
- Run guest science
- Administration
- Separate ground UI for file transfer, software updates and diagnostics



Distributed Video





Plan Validation

Plan Editor Run Plan Teleoperation Guest Science Advanced

Comm **Not Connected** GPS 01Jun16 23:00:39

Plan Editor

Plan Name AADemo
Estimated Duration 00:11:02
Validation Not Validated **Validate**

Plan Step	Duration
▼ AADemo	
0 Station	
0-1 Segment	00:01:23
1 Station	
1-2 Segment	00:01:44
2 Station	
2-3 Segment	00:01:41
3 Station	
3-4 Segment	00:02:41
4 Station	
4-5 Segment	00:02:20
5 Station	
5-6 Segment	00:01:13
6 Station	

3 Station

Location Based Coordinate Based Bookmarks Commands

X 5.78 Y -0.19 Z -0 m
Roll 0 Pitch 0 Yaw 0 deg

Ignore Orientation
Tolerance 0.1 m
 Drag to Translate Drag to Rotate

Interactive Plan Viewer **Reset View**

Validation Failed
Potential collision in Segment 2-3. Please move Station 2 or Station 3.
OK

00:00:00 Message goes here **Log Help Exit**



Run Plan Tab

File Edit View Help

Plan Editor Run Plan Teleoperation

Comm Connected GPS 16May16 19:18:58

FreeFlyerA Health and Status Fault Details

Hardware	Nominal
Payload	Nominal
Software	Nominal
Control	Dw@dw-windows7-32
Operating State	Safe Stop
Mobility State	Docked
Safeguard State	-
Plan	Bb

Plan Step	Duration	Success
BB		
0 Station		
0-1 Segment		
1 Station		
1-2 Segment		
2 Station		
2-3 Segment		
3 Station		
3-4 Segment		

rapid_imagesensor_sample-science

Image #114

Commands for: FreeFlyerA

Grab Control Terminate

Wake Hibernate

Plan Name Plan Valid

File ... C:\Users\DW\Document Upload

Run Stop

Pause Skip Step

Live Telemetry Reset View

19:18:15 FreeFlyerA: Sending plan

Log Help Exit



Run Plan Tab

File Edit View Help

Plan Editor Run Plan Teleoperation

FreeFlyerA Health and Status Fault Details

Hardware	Nominal
Payload	Nominal
Software	Nominal
Control	Dw@dw-windows7-32
Operating State	Plan Execution
Mobility State	Free Flight
Safeguard State	-
Plan	Bb

Comm Connected GPS 16Mav16 19:19:24

Plan Step	Duration	Success
BB		
0 Station		Complete
0-1 Segment	00:01:14	Complete
1 Station		Complete
1-2 Segment		
2 Station		
2-3 Segment		
3 Station		
3-4 Segment		

rapid_imagesensor_sample-science

Image #164

Reset View

Live Telemetry

Plan Name Plan Valid

File ... C:\Users\DW\Document Upload

Run Stop

Pause Skip Step

19:19:02 FreeFlyerA: Pending ...

Loa Help Exit



Teleoperation Tab

File Edit View Modeling Help

Plan Editor Run Plan Teleoperation

Comm Connected GPS 22Apr16 20:30:52


FreeFlyerA Health and Status Fault Details

Hardware	Nominal
Payload	Nominal
Software	Nominal
Control	Dw@dw-windows7-32
Operating State	Safe Stop
Mobility State	Docked
Safeguard State	-
Plan	-

Instrument Control for: FreeFlyerA

Camera 1 <input type="button" value="On"/>	Payload 1 <input type="button" value="On"/>
Camera 2 <input type="button" value="On"/>	Payload 2 <input type="button" value="On"/>
Camera 3 <input type="button" value="On"/>	Payload 3 <input type="button" value="On"/>

Info Label



Commands for: FreeFlyerA

<input type="button" value="Grab Control"/>	<input type="button" value="Terminate"/>
<input type="button" value="Wake"/>	<input type="button" value="Hibernate"/>
<input type="button" value="Stop"/>	<input type="button" value="Undock"/>

Translation Rotation Arm Commands

AFT	<input type="text" value="1.0"/>	FWD
PORT	<input type="text" value="0.0"/>	STBD
OVHD	<input type="text" value="0.0"/>	DECK

m

Show Preview

Teleop Command Log

Live Telemetry Reset View



26

20:30:11 FreeFlyerA: Completed

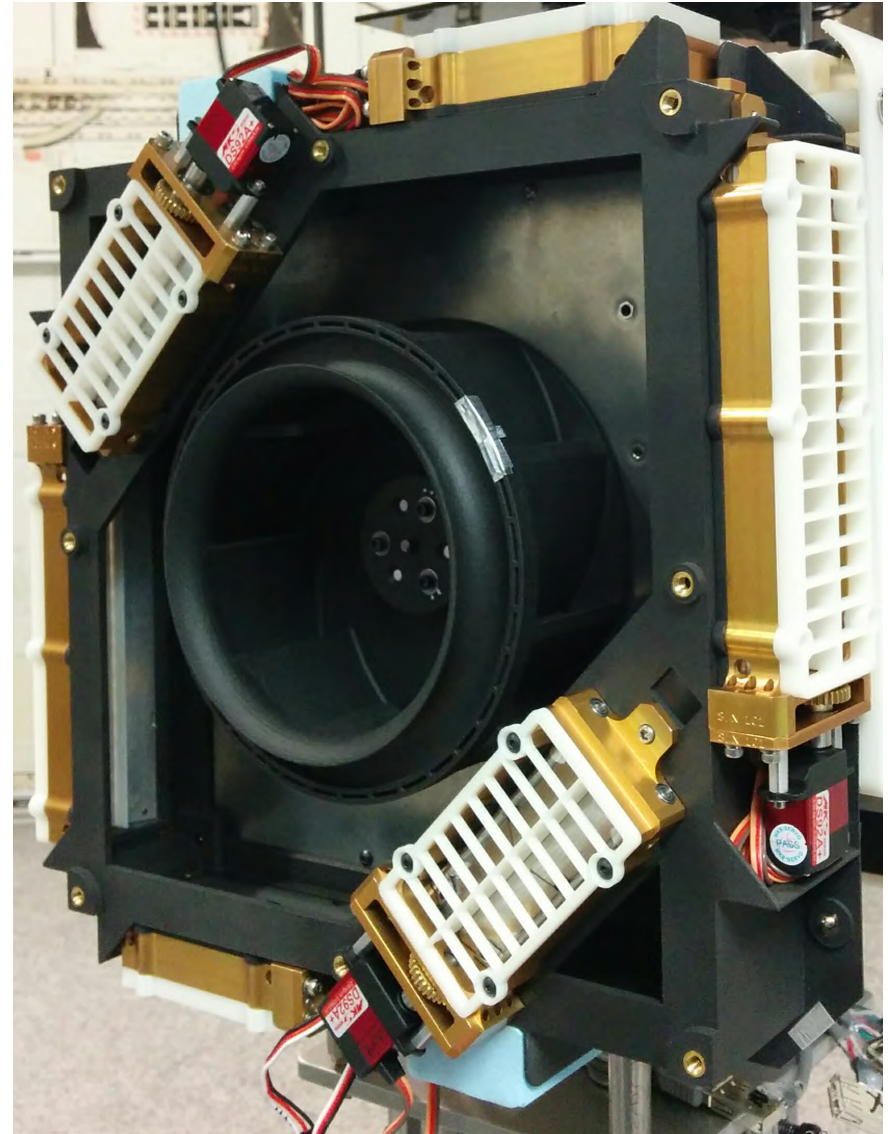


Status



Propulsion

- Propulsion modules were lagging the rest of the hardware development due to a major design shift
- During FY16, went from drawing board to flight-like prototype
- Every major part (plenum, nozzle, impeller, controller board) is the result of multiple iterations of prototyping and rework
- Besides better compatibility with overall flight design, new propulsion modules on P4 already show better stability and motion accuracy than P3

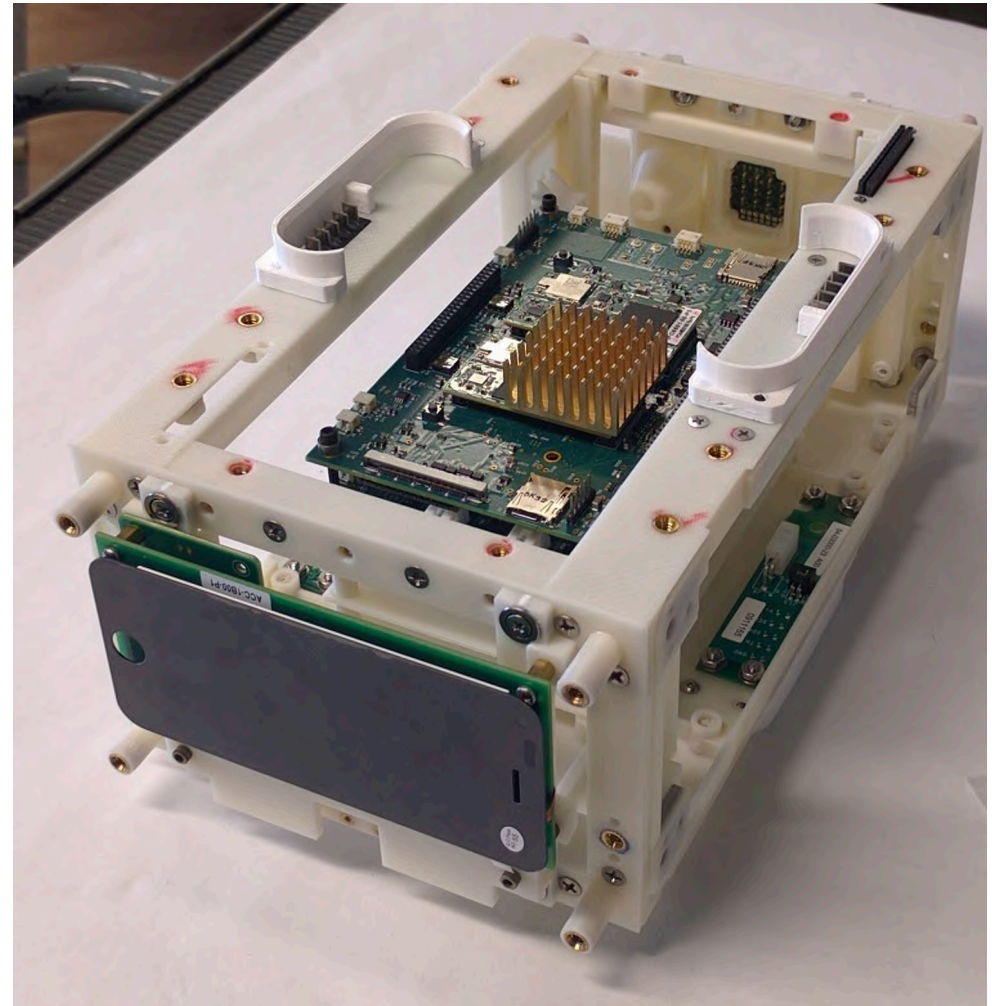


Propulsion module without cover



Avionics

- Stack of five custom boards connecting two propulsion modules, six external sensors, three payloads, and a variety of other hardware
- With P4, now working reliably in constrained volume of core module
- As expected, power system can support multiple hours of autonomous flight between charges



Core module

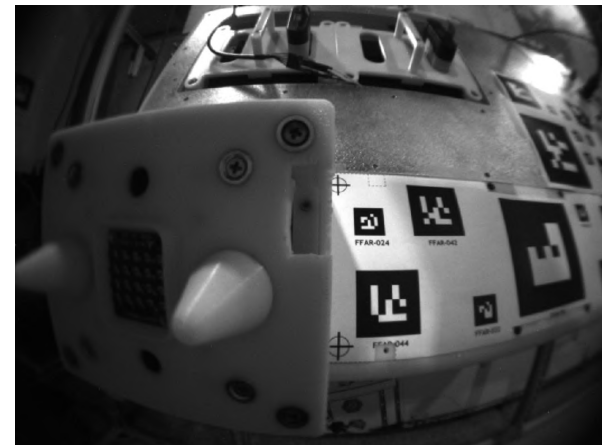


Mobility Software

- Demonstrated reliable localization based on fusing sparse map, optical flow, and IMU
- Mapping scaled up; demonstrated mapping an entire floor of our building
- Control approach ported to new propulsion system



ISS map built from Smart SPHERES data

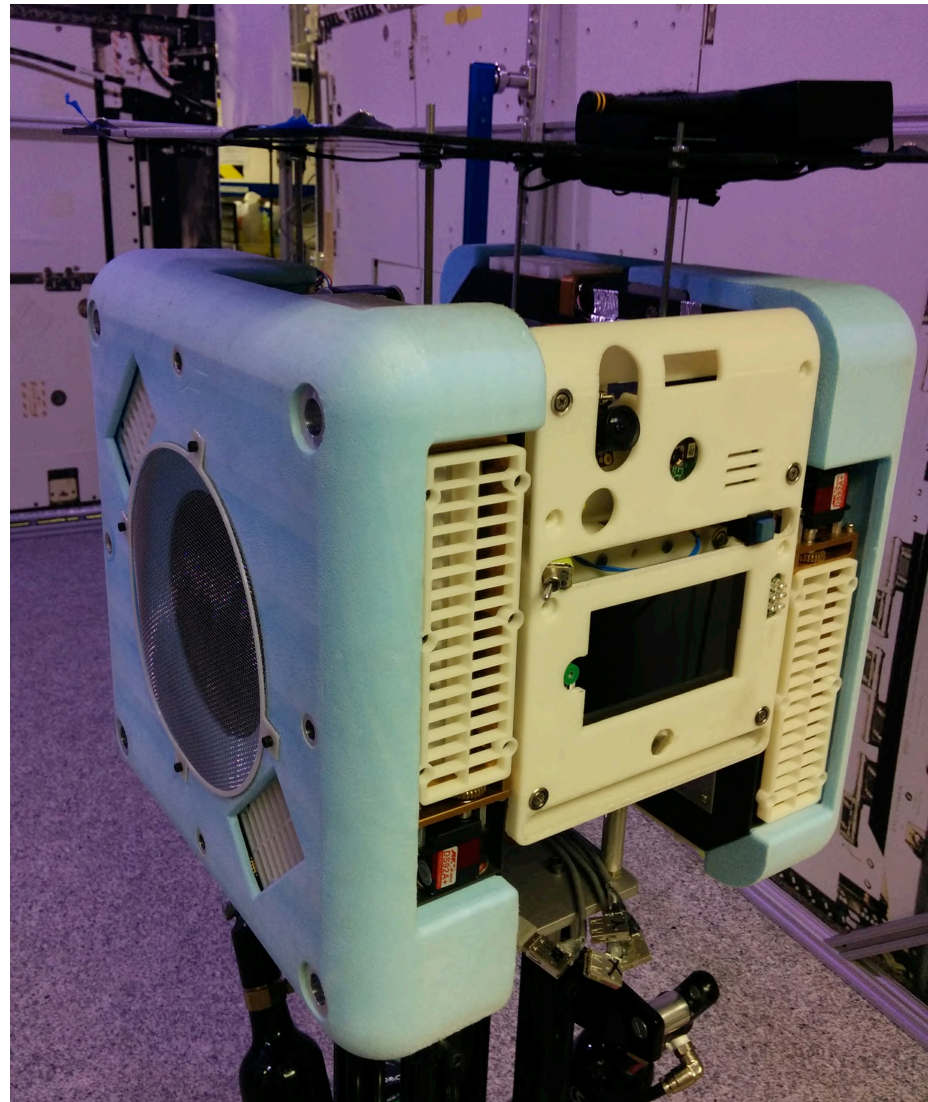


DockCam imagery during approach



Integrated Prototype 4

- First flight-like prototype
- Reduced risk for cert unit and practiced I&T procedures
- Matured details like wiring, sensor mounting brackets, design for crew servicing
- Uncovered avionics and thermal issues during integration
- Many lessons learned during testing
- More details in I&T discussion

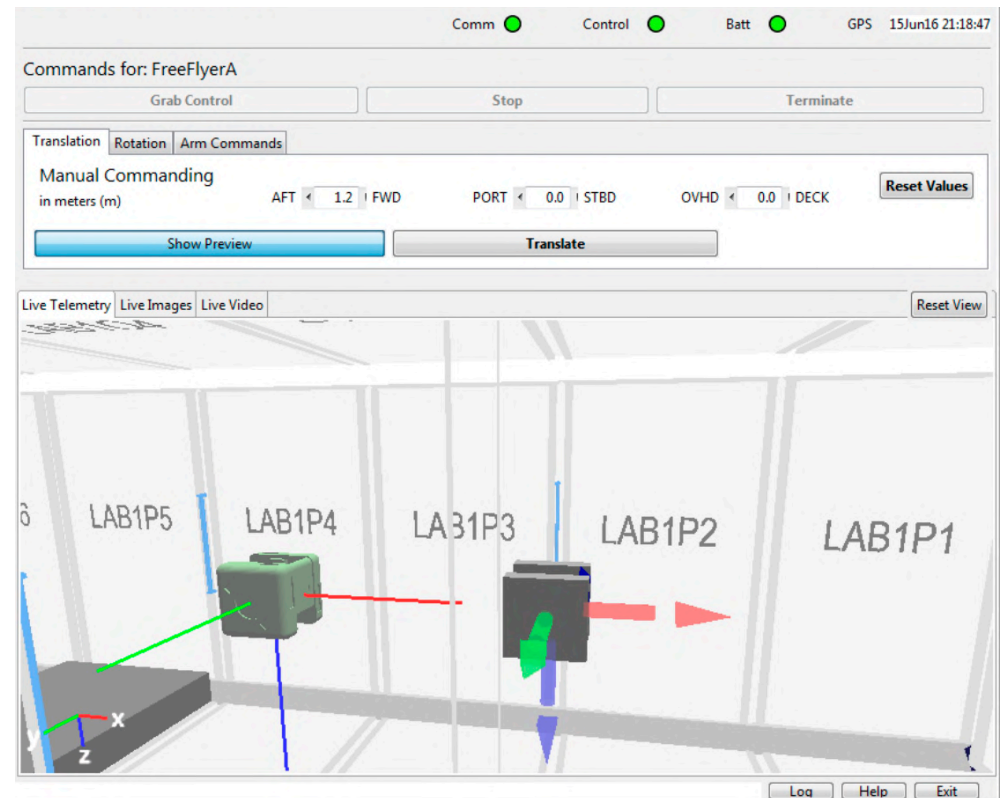


Prototype 4



Control Station

- Control Station now used to author and run plans
- Conducted usability tests (with varying ISS & Astrobee experience) to obtain user feedback and update design
- Integrated with Free Flyer simulator and Prototype 4



Free Flyer control GUI



Prototype 4 Testing

- Near flight-like form
- Verify requirements related to h/w design
- Reduce risk for Cert Unit
- Practice I&T procedures



Prototype 4 free flyer & dock



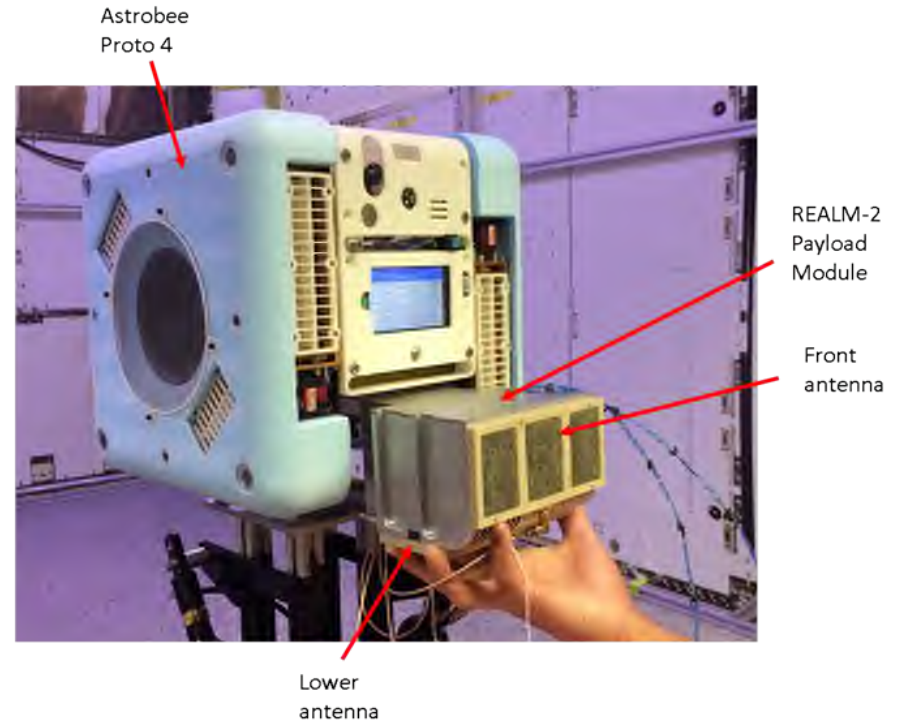
Payload Interoperability Test

- REALM payload (RFID reader)
- Verified power/data interface
- Read RFID tags
- Displayed tag info on touchscreen display



Electrical integration test

- R2P1 on pink bubble wrap
- Blue LED is RF indicator





Navigation Demonstration

