Integrated System for Autonomous and Adaptive Caretaking (ISAAC) Update

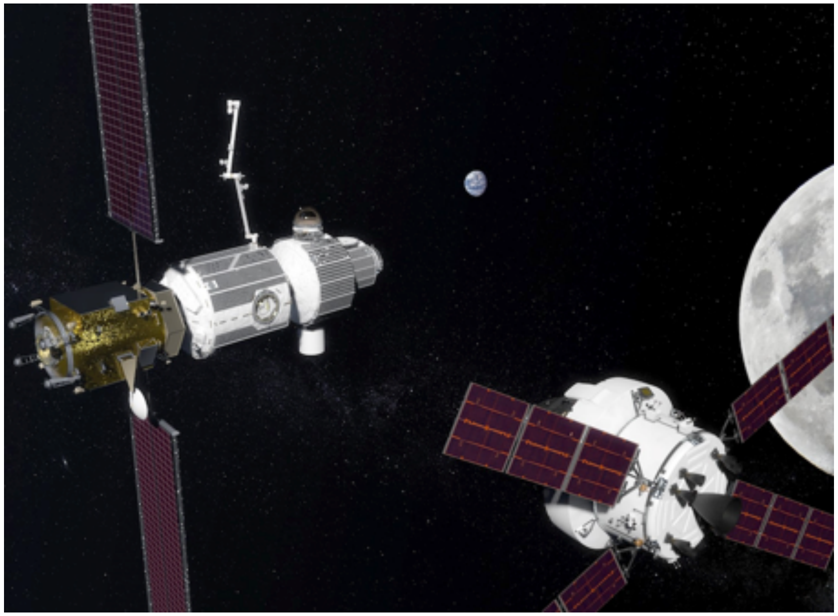
Astrobee Working Group
2020/10/29

Agenda

- **ISAAC overview**
- **Phase 1**

ISAAC overview

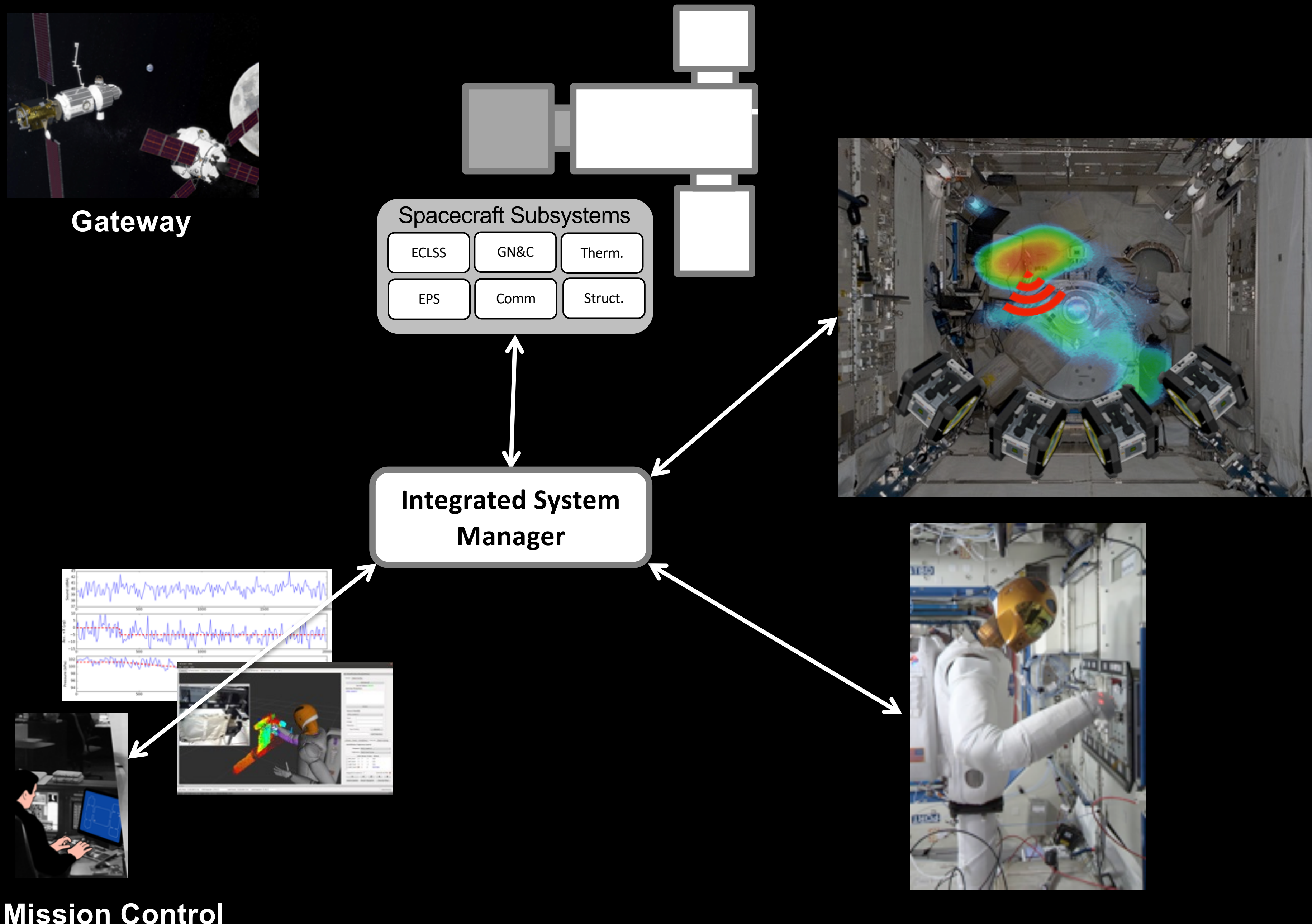
- Research project, FY20-22, to develop technology for **autonomous caretaking** of spacecraft primarily during **uncrewed** mission phases
- Led by NASA Ames Research Center with collaboration from Johnson Space Center
- Integrate **autonomous intra-vehicular robots** (IVR) with **spacecraft infrastructure** (power, life support, etc.) and **ground control**
- Focus on capabilities required for the **Gateway** that also apply to human missions to Mars and beyond
- Test with **existing IVR on the ISS** (Astrobee, Robonaut) as an analog for **future IVR on Gateway**
- Do not:
  - Develop the IVR needed for Gateway
  - Develop Gateway flight software
  - (These tasks are vital but not part of ISAAC.)



Why ISAAC?

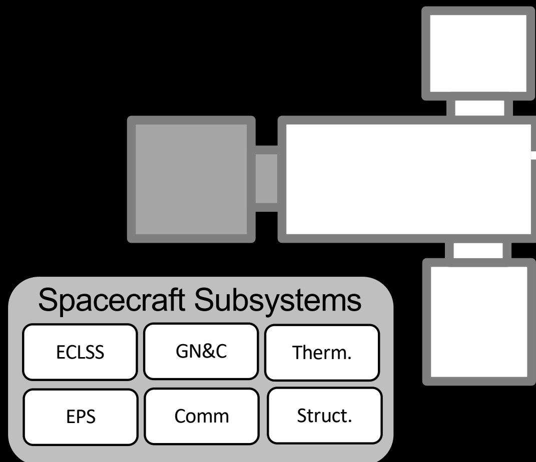
- **Gateway will be uncrewed for extended periods. During these periods NASA needs autonomous systems that can perform:**
  - Fault Detection, Isolation, and Recovery (FDIR)
  - Routine maintenance
  - Logistics operations
  - All through high latency communication to ground controllers
- **Autonomous systems can free crew from routine maintenance and logistics tasks**
  - Gateway Ground Rules & Assumptions has crew spending 3.5 hrs per day working non-utilization/non-exercise tasks
- **ISAAC provides the glue between Intra-Vehicular Robotics (IVR) and vehicle systems (power, life support, etc.) through**
  - Integrated data
  - Coordinated execution
  - Integrated control interface
- **Infusion into Gateway:**
  - Interaction with IVR Working Group
  - ISAAC MOU with Gateway

Technical thrusts

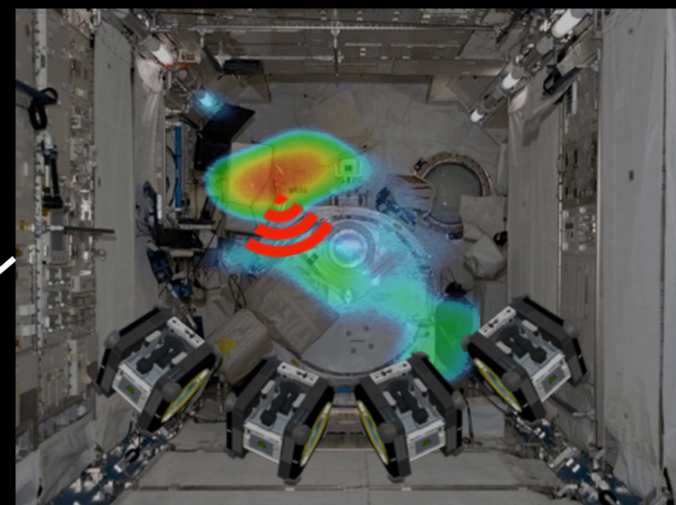


Technology: Integrated Data

Gateway



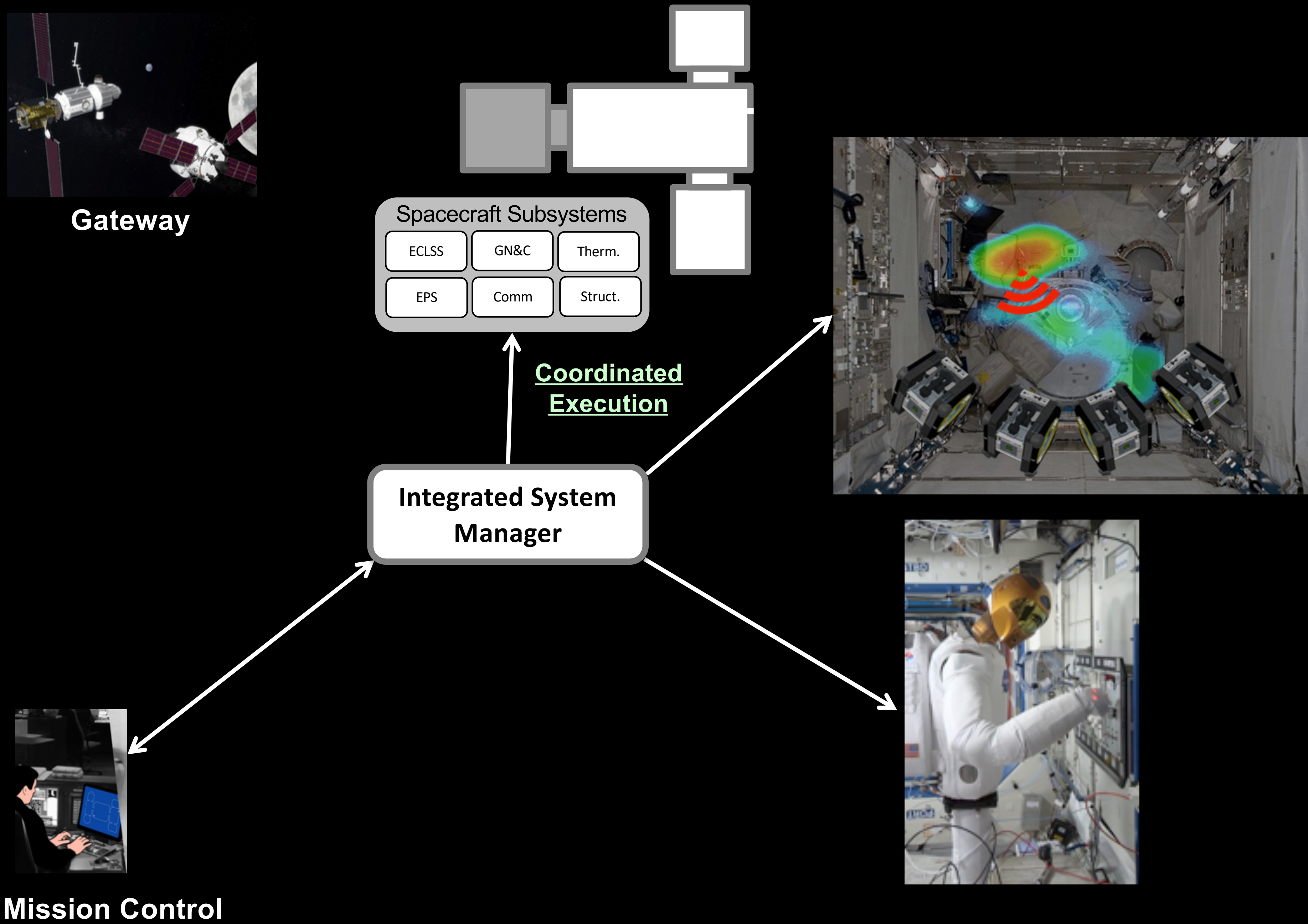
Integrated Data



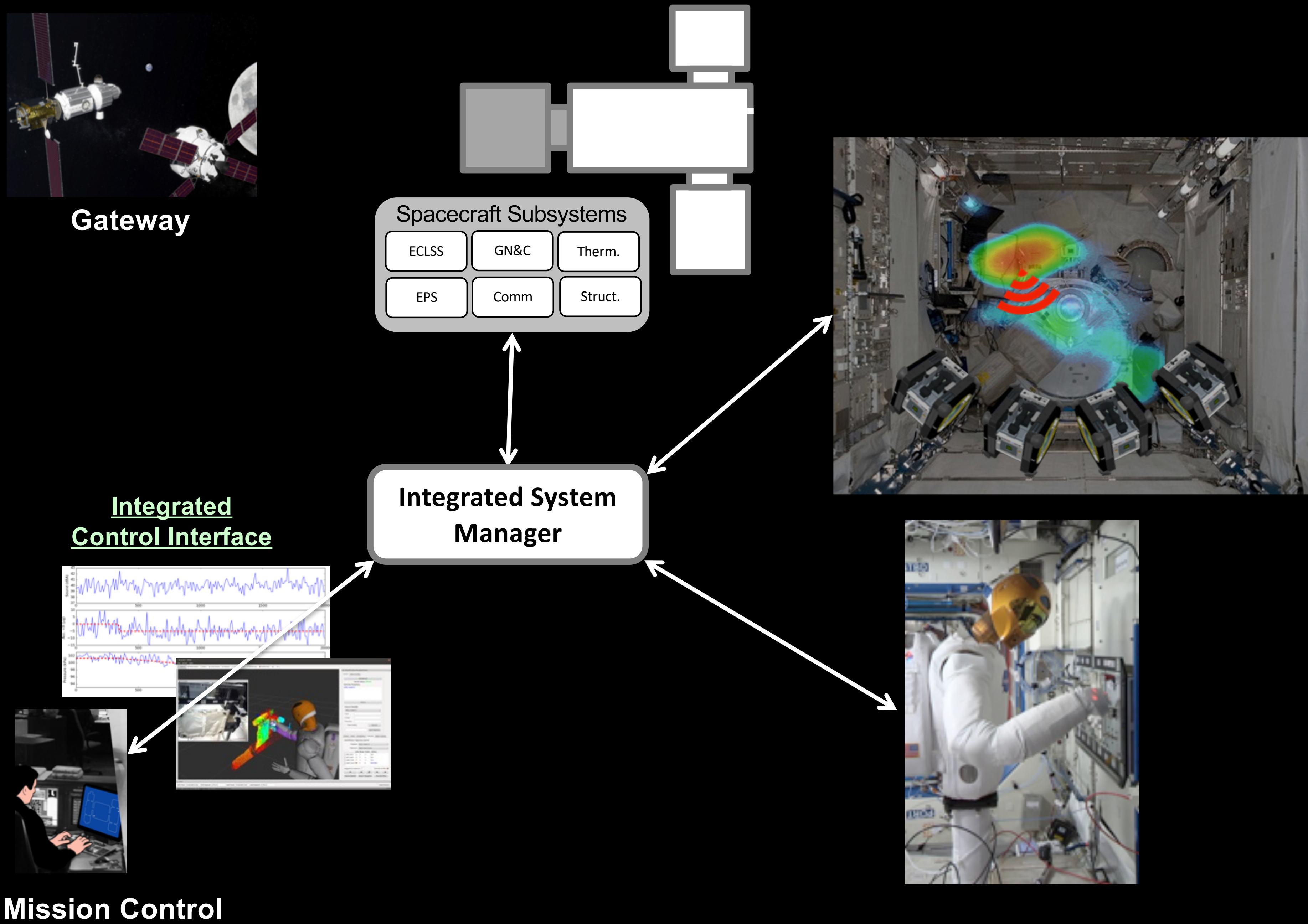
Integrated System Manager

Mission Control

Technology: Coordinated Execution

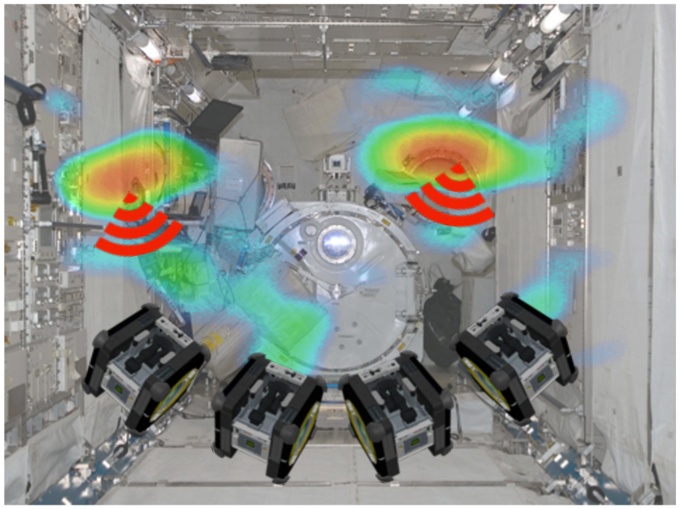


Technology: Integrated Control Interface

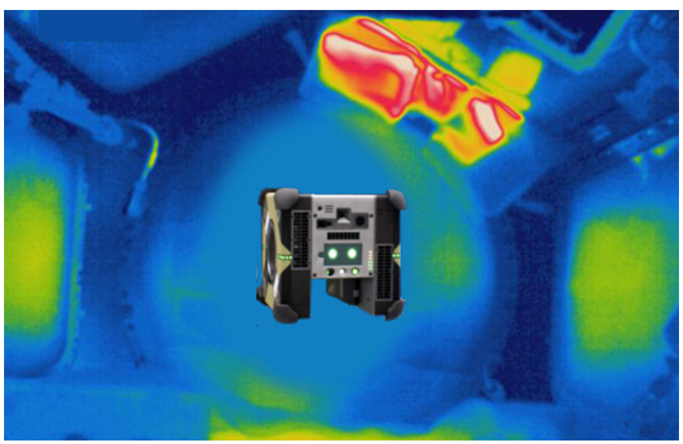


Capability areas

Autonomous State Assessment

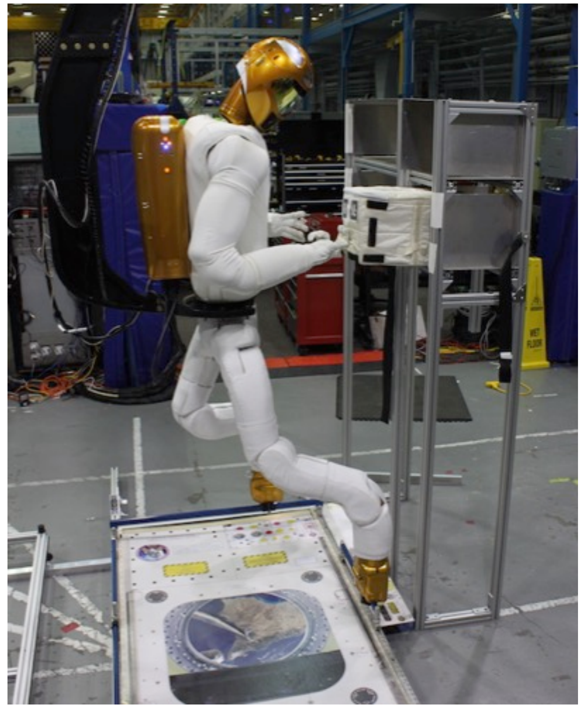


Localizing signal sources by analyzing signal strength variation



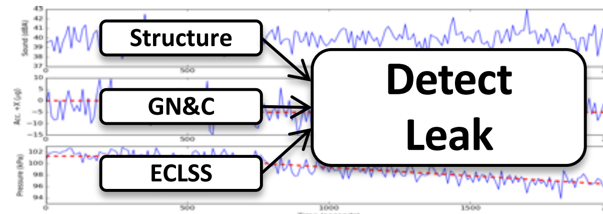
Habitat thermal mapping

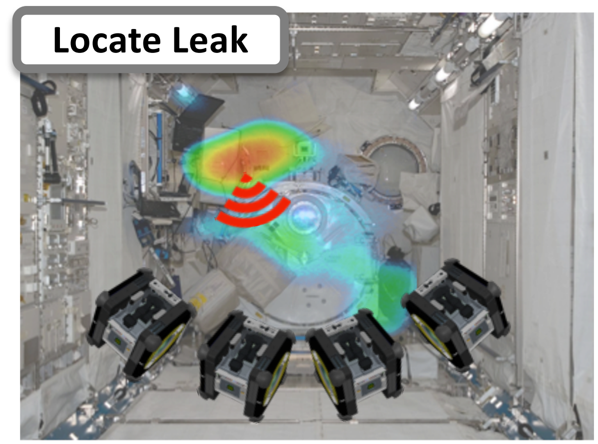
Autonomous Logistics Management



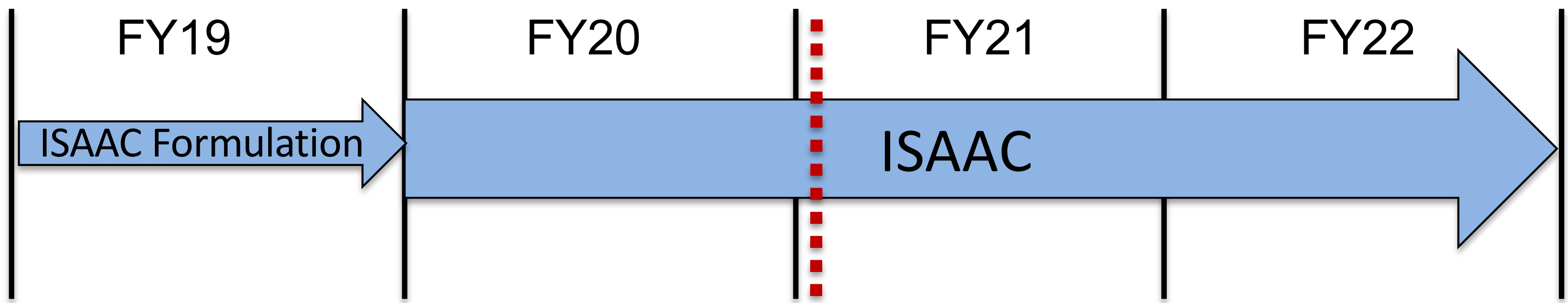
Robotic cargo transfer

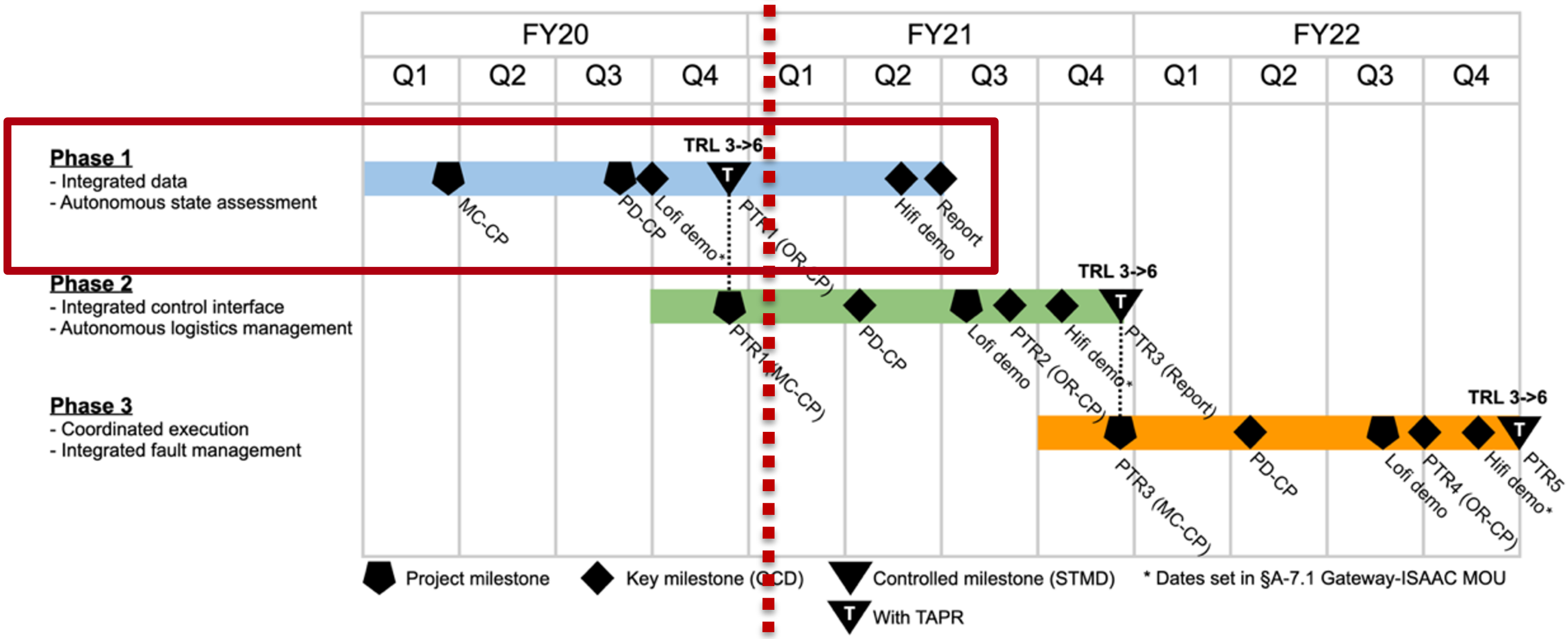
Integrated Fault Management





ISAAC schedule





We are here

PHASE 1

ISAAC Phase 1 Demo Activities

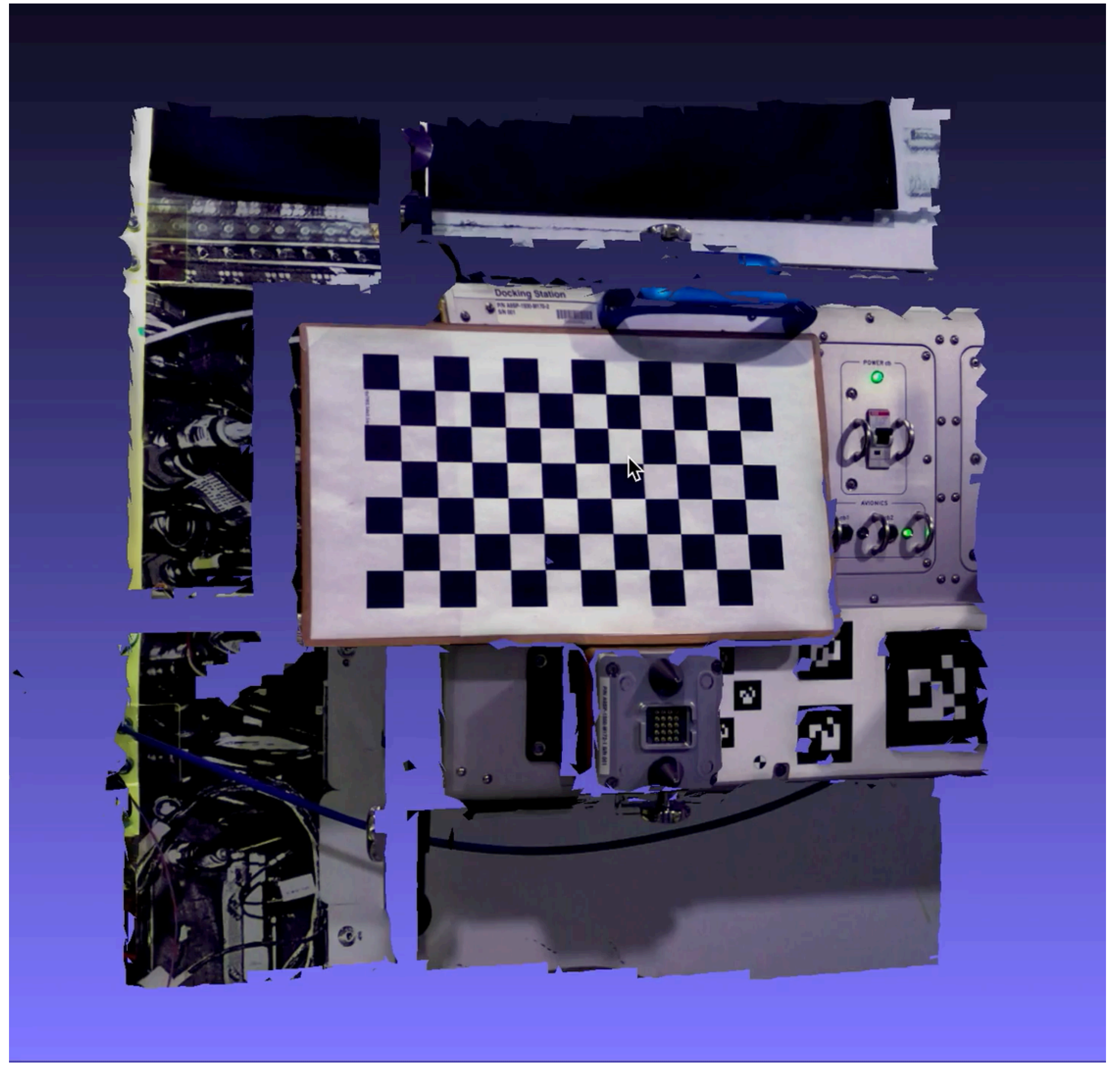
3 on-orbit activities

		Environment	
Activity	**Objective**	**Low-fidelity**	**High-fidelity**
Calibration and mapping checkout	Calibrate sensors and validate mapping approach with a small survey	Lab demo	ISS session 1
Baseline survey	Cover full survey area, build baseline 3D geometry and high-res surface texture	N/A	ISS session 2
Follow-up survey	Cover full survey area again, stream live updates to multiple sensor layers. (Checking for changes and anomalies not implemented yet.)	Software sim	ISS session 3
Fault management	Respond to a simulated high-CO_2 anomaly in the JEM by sending Astrobee to autonomously check whether a vent is blocked	Software sim	ISS session 3

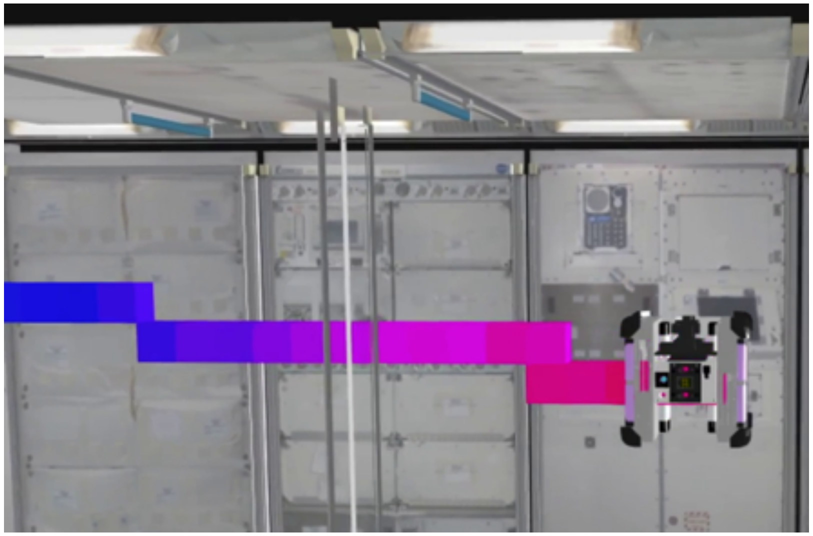
Tentatively scheduled for Jan/Feb

3D Mapping Demo Result

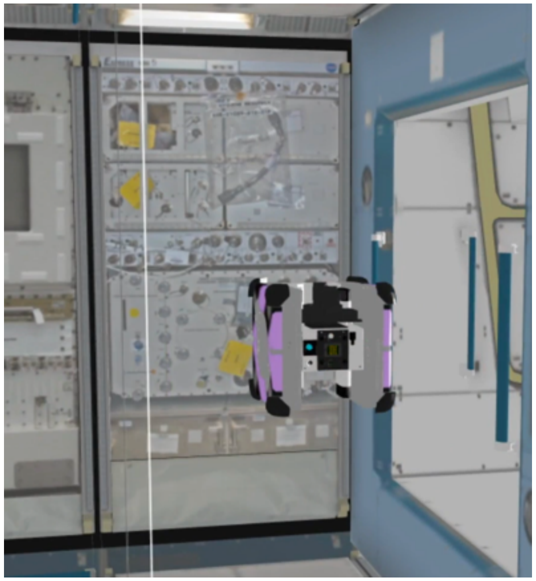
- Gross geometry is accurate
- Effective surface texture resolution ~0.6 mm (enough to read 14-pt font labels)
- Alignment between HazCam geometry and SciCam texture is accurate
- No obvious stitching artifacts between multiple SciCam frames in this small example



Survey demo video preview



Colored trail is WAP signal strength map (because samples are collected in situ, this is a "volumetric" map layer, as opposed to a surface texture layer)

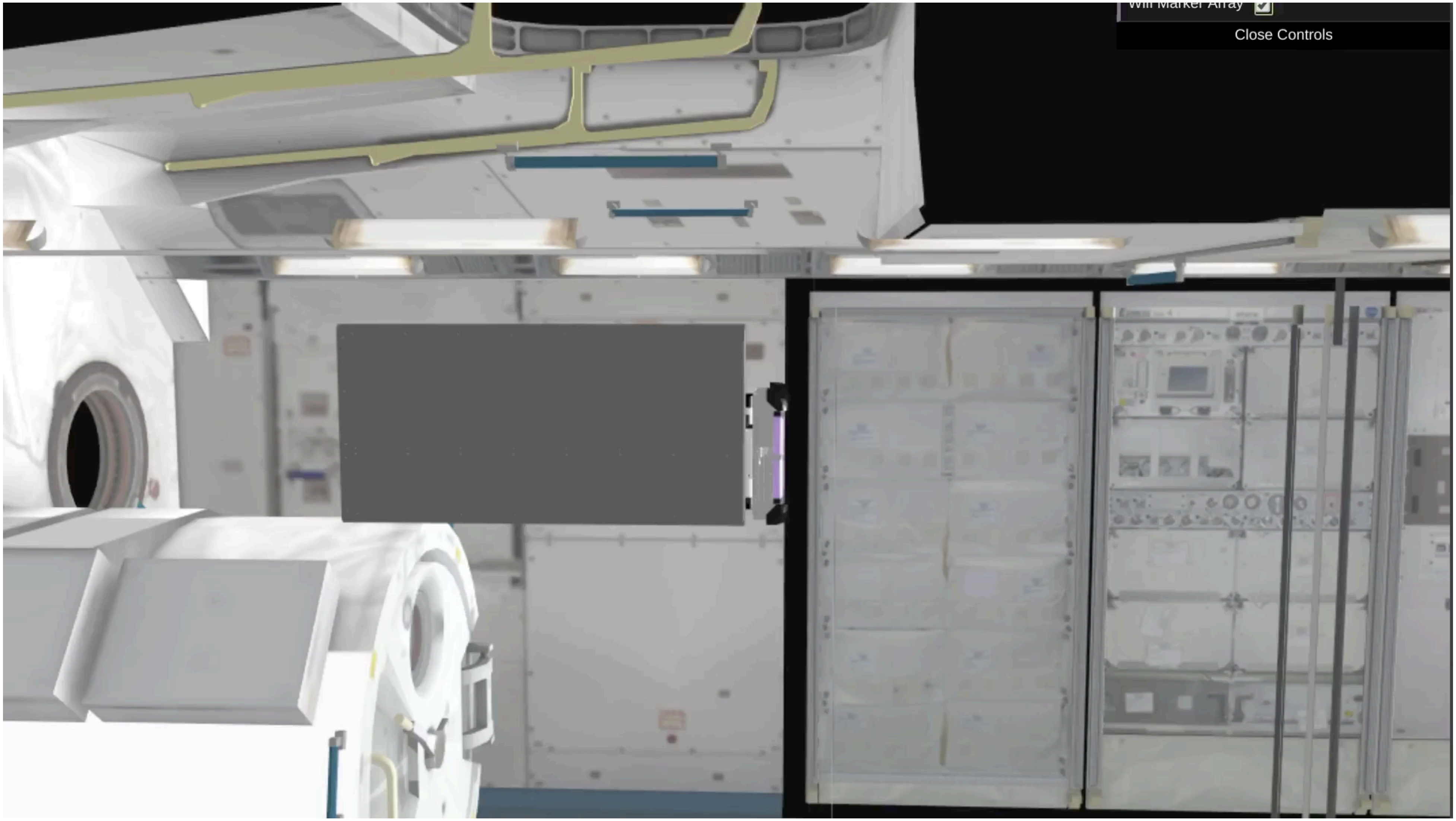


Prior visual texture layer (displayed with reduced contrast)

Red flash indicates extent of incoming map update

New SciCam imagery replaces prior imagery

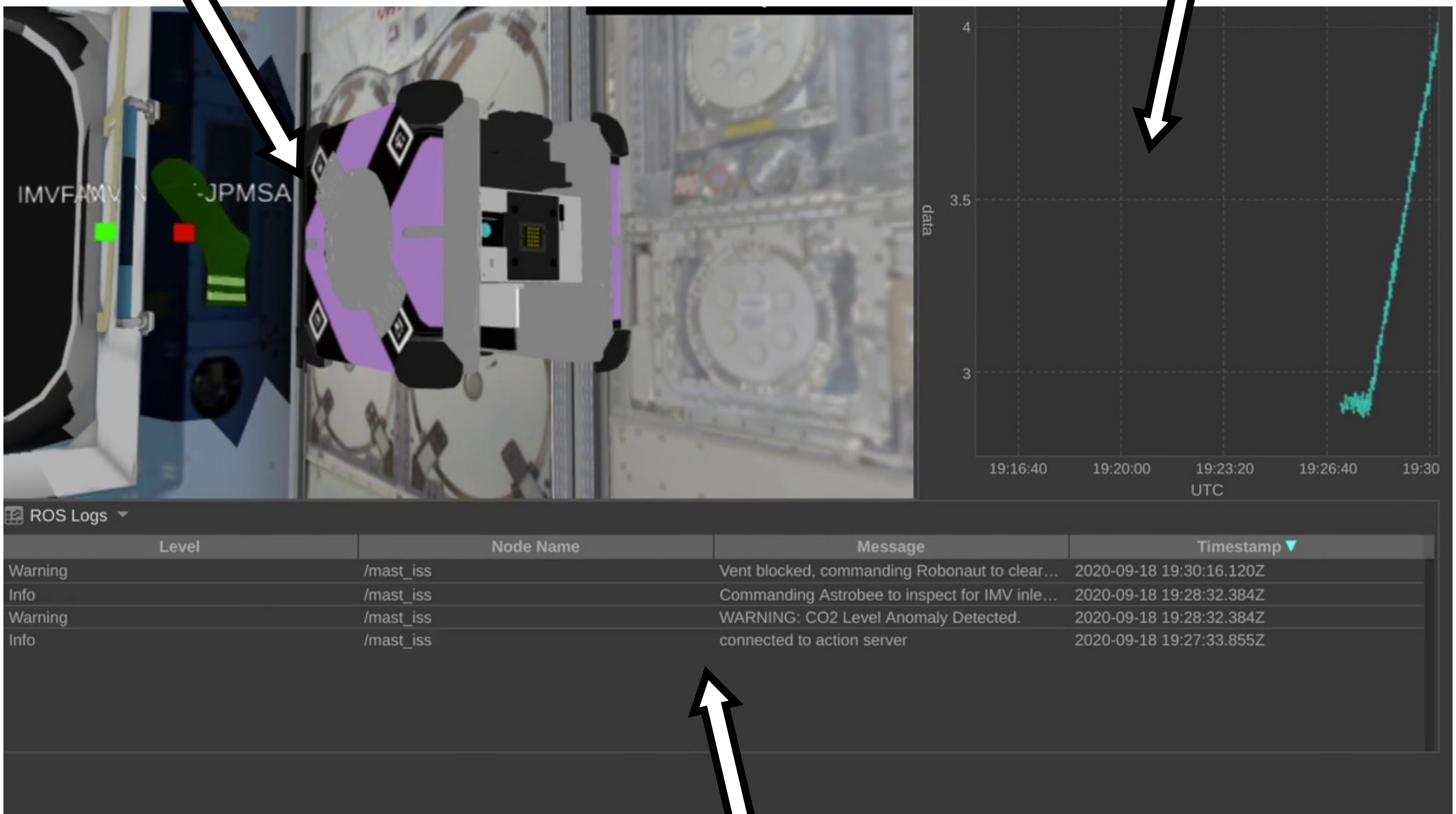
Survey demo video



Fault management video preview

3D view of module and robot

Time series view. Shows CO_2 spike that triggers Astrobee targeted inspection



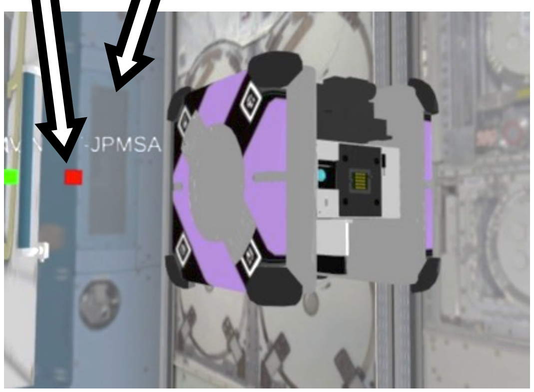
Event log (reverse chronological order)

Fault management video preview

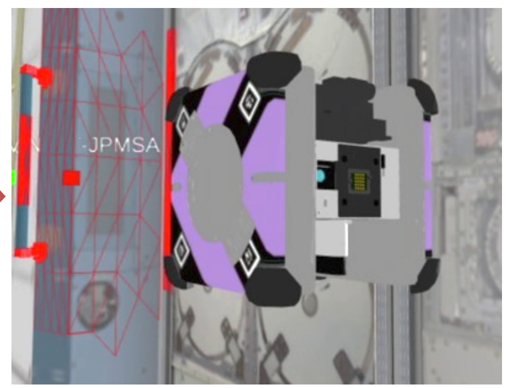
Spatially linked model: Marker turned red to show location of a component linked to the detected fault (triggering robotic inspection)

IMV Inlet (inspection target)

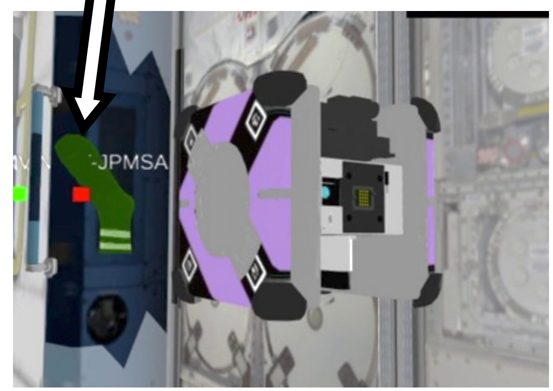
Robot detects object (crew sock) is blocking inlet



Prior visual texture layer

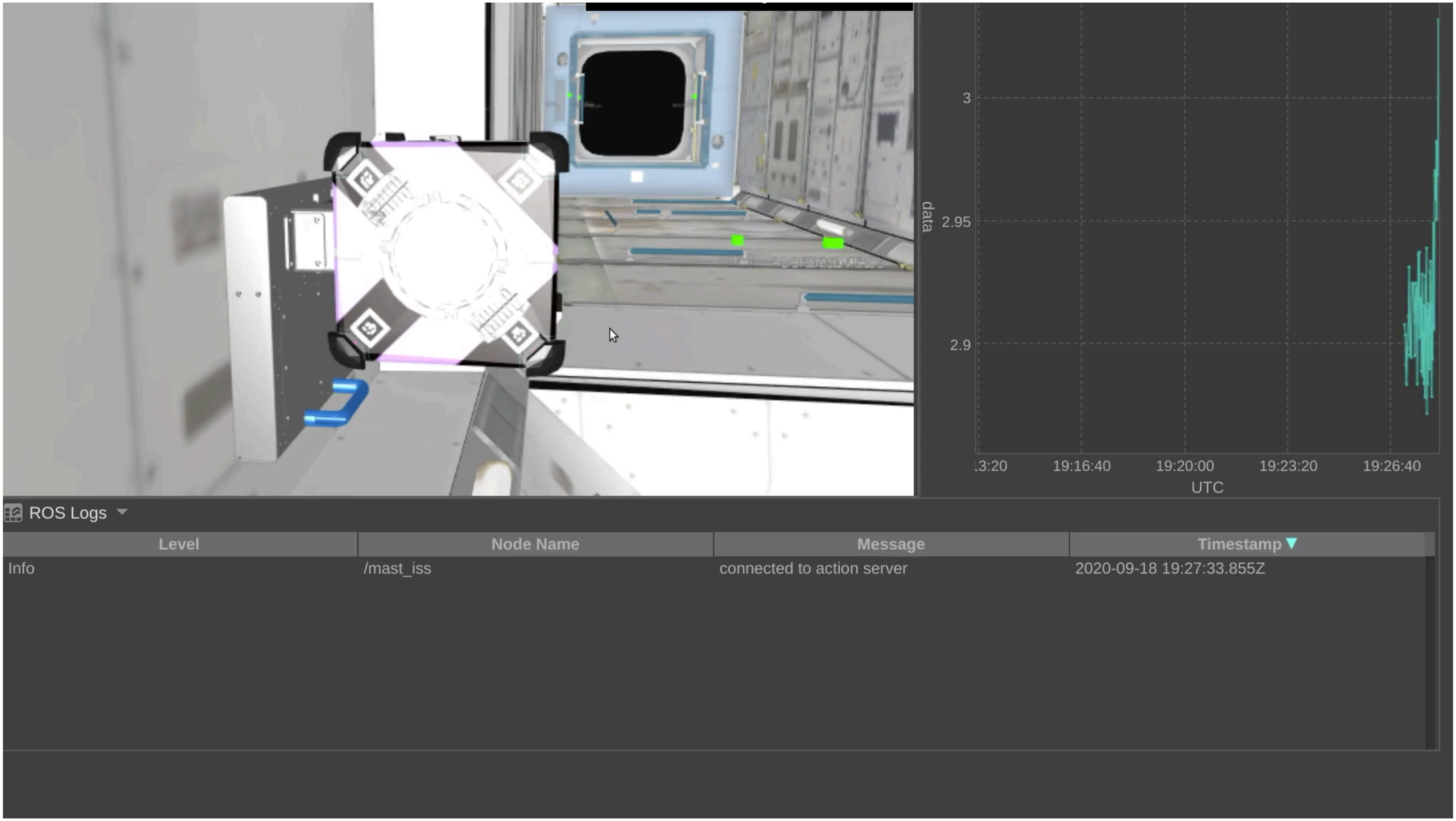


Red flash indicates extent of incoming map update



New SciCam imagery shows anomaly

Fault management demo video



QUESTIONS?

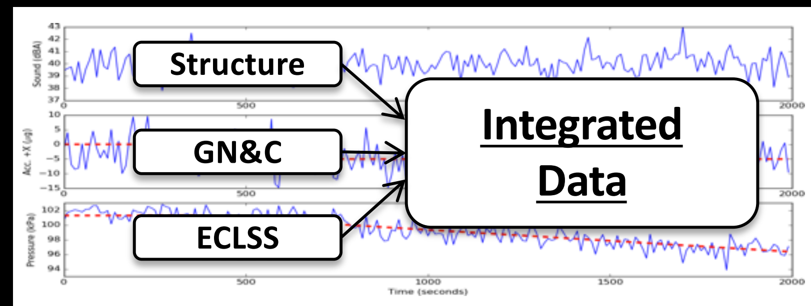
BACKUP SLIDES

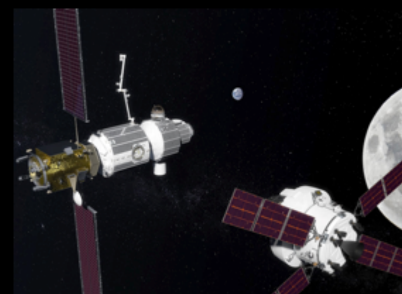
Integrated System for Autonomous and Adaptive Caretaking (ISAAC)

PT: Terry Fong (Autonomous Systems)
Thrust Area: ST5
PM: Trey Smith (ARC)
Deputy PM: Julia Badger (JSC)
Centers: ARC + JSC

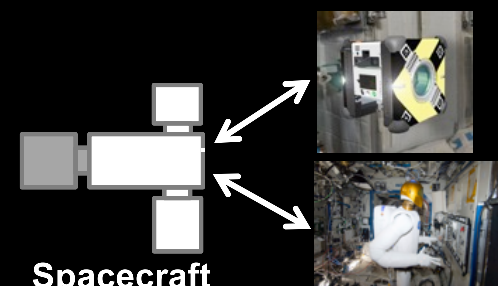
Description and Objectives

- Develop a **critical capability to support autonomous caretaking of exploration spacecraft while uncrewed**
- Integrate autonomous robots, spacecraft infrastructure (avionics, sensors, network), and ground control
- Enhance **autonomous state assessment**, **autonomous logistics management**, and **integrated fault management**
- Focus on **capabilities required for the Gateway** (Human Exploration Requirements HEOMD-004: GTW-L2-0044, 0047, 0050, 0142, 0143, 0145) and applicable beyond the Earth-Moon system.
- Enable **important assessments of feasibility and relevance** for the design of future deep space spacecraft.
- Extend **autonomous system manager architecture** to enhance integrated analysis of data, operator productivity, and reliable coordinated execution of system-level tasks.





Gateway



Spacecraft Subsystems

Autonomous Robots

Customers

- **Gateway.** ISAAC-developed capabilities directly relevant to HEOMD-004 and other requirements for Gateway.

Partners

- **AES Autonomous Systems and Operations.** Support fault diagnosis and planning+execution technologies used by ISAAC architecture.
- **AES Astrobee Facility.** Support Astrobee testbeds and ops.
- **AES Logistics Reduction.** Support Robonaut2 testbeds and operations. Collaborate on logistics demonstration.
- **Gateway Intra-Vehicular Robotics (IVR) and Vehicle System Manager (VSM) Working Groups.** Provide Gateway guidance.

Leverage

- **GCD/HET2.** Developed analog robot platforms for Gateway IVR.
- **MAST.** Developed system architecture that ISAAC will extend.

Technical Approach

- Focus on three technical thrusts:
  - Integrated Data: Link models and telemetry across multiple spacecraft subsystems and robots
  - Coordinated Execution: Enable higher-level commanding and effective collaboration
  - Integrated Control Interface: Enable mission control to understand and control integrated autonomous systems
- Perform tests with the iPAS facility (JSC) and on ISS
  - Leverage existing testbeds and robots developed with STMD support
  - Capstone demo on ISS: Link embedded sensors and multiple robots to detect, isolate, and patch a simulated leak
- Proposing ISAAC development in **FY20-22**
  - Deliverables staged to respond to relevant Gateway milestones
- **Investment is needed now in order to meet Gateway needs**