Environmental Monitoring Microsensor Array (EMMA) for Free Flying Robots

Phase II SBIR

Contract: 80NSSC21C0621

Astrobee Working Group November 16, 2023

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EMMA Payload Motivation and Objectives

- **Objective:** Provide mobile smart sensing capability to support autonomous habitat monitoring
- **Sensors:**
  - Chemicals: O_2, CO_2 ,CO, H_2, NH_3, VOCs
  - Environmental: Pressure, Humidity, Temperature
  - IR and Visual Cameras and Sound
  - Particulates
- **Data Analysis:**
  - Automated alarm thresholds and alerts
  - Integrated machine learning capability interprets sensor data
- **Development Work:**
  - Targeting development work toward important use cases on Gateway and ISS
  - Developing and delivering prototypes to NASA for testing
  - Transitioning to an ISS Flight Demonstration as EMMA matures

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Key EMMA Use Cases

- **Air Quality and Revitalization Monitoring**
  - CO_2 and O_2 monitoring
- **Chemical Leak Detection**
  - Thermal management/cooling systems using working fluids such as ammonia
  - Hydrogen release from batteries, fuel cells, water processing systems such as electrolysis
  - CO, H_2, or CO_2 from water recovery Sabatier reactors
- **Precombustion/Early Fire Detection**
  - Fixed smoke detector alarm verification
  - Overheating or outgassing of electronics and wiring
  - Potential classification of materials
- **Flexible Platform for Additional Sensor Integration**

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EMMA Prototype Specifications

Feature	GEN-1 EMMA	GEN-2 EMMA
Measurements and Ranges		
Solid State Chemical Sensors	O_2 0-96% CO 0-10 ppm H_2 0-5% NO_2 0-5 ppm	O_2 0-96% CO 0-10 ppm H_2 0-5% NO_2 0-5 ppm
NDIR Chemical Sensors	CO_2 0-3000 ppm	CO_2 0-3000 ppm NH_3 0-200 ppm CO 0-2000 ppm
VOC Sensors	PID 0 - 10 ppm	PID 0 – 10 ppm
VOC Speciation	None	Preconcentrator & Micro-GC Column for VOC classification
Particulate Sensor	None	Mass concentration Number concentration Size Distribution
Environmental Sensors	Pressure 0 to 16 psia Humidity 0-95 RH (-40 to 65 C DP) Temperature -20 to 50 C	Pressure 0 to 16 psia Humidity 0-95 RH (-40 to 65 C DP) Temperature -20 to 50 C
IR Sensors	FLIR Lepton 3	FLIR Lepton 3
Imaging Sensor	Visible Imager	1080p Camera
Audio	None	Microphone (60-15 kHz)
External Connectivity	USB	Communications to Astrobee HLP and LLP/MLP Bluetooth hub for 3rd party device connection to Astrobee USB
Other Specifications		
Power	14.4VDC, 0.9 A	14.4 VDC, 0.4 A
Envelope	5.9 in x 4 in x 3.125 in	5.9 in x 4 in x 1.85 in
Mass	520 grams	Under 400 grams

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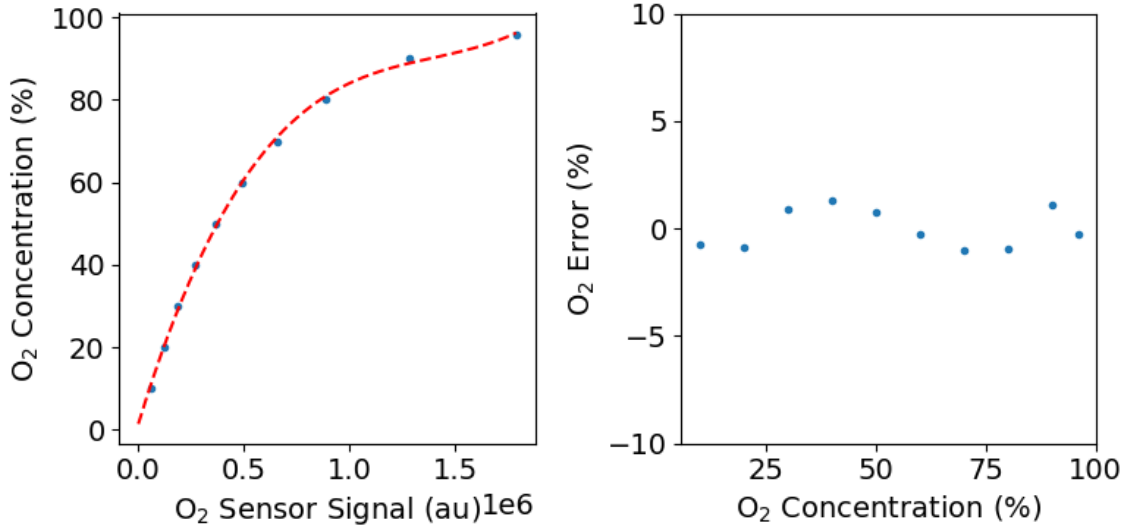
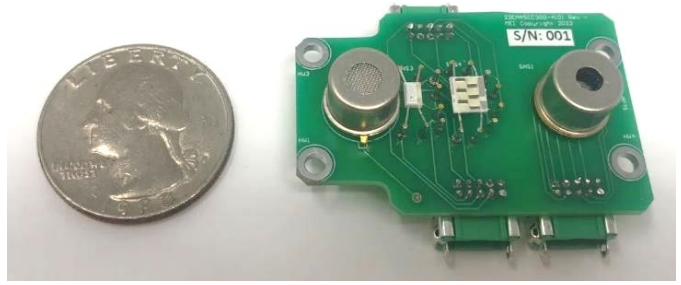
Sensing Technology: Electrochemical and Optical

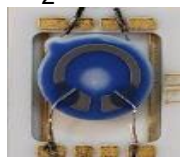


Miniaturized Solid-State Chemical Sensors

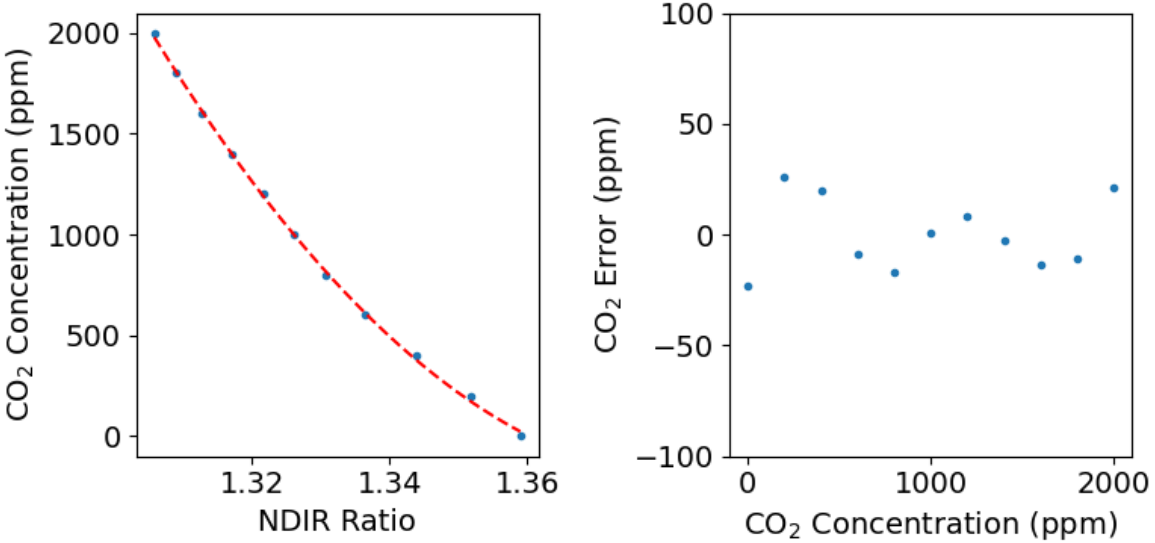


CO Sensor

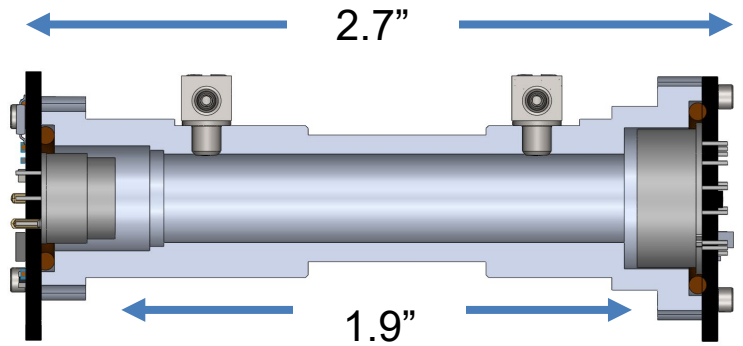
O_2 Sensor



H_2 Sensor



Multi-Species NDIR



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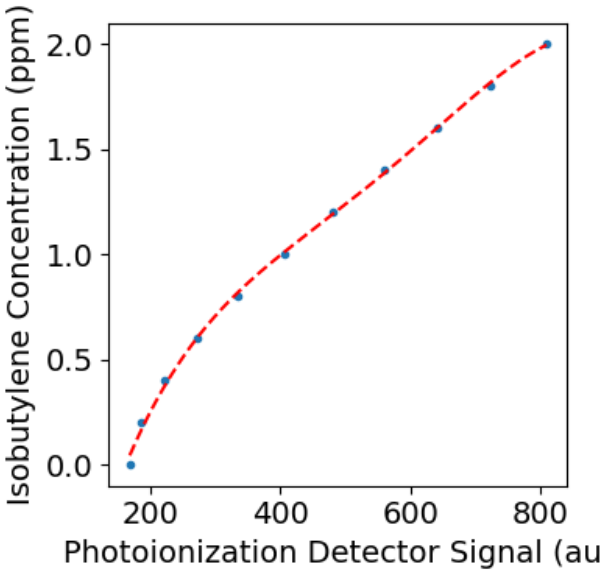
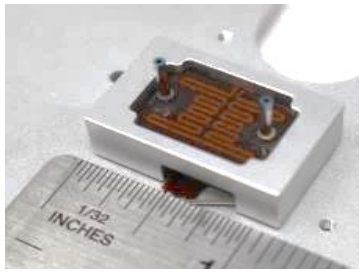
Sensing Technology: Photoionization and Camera

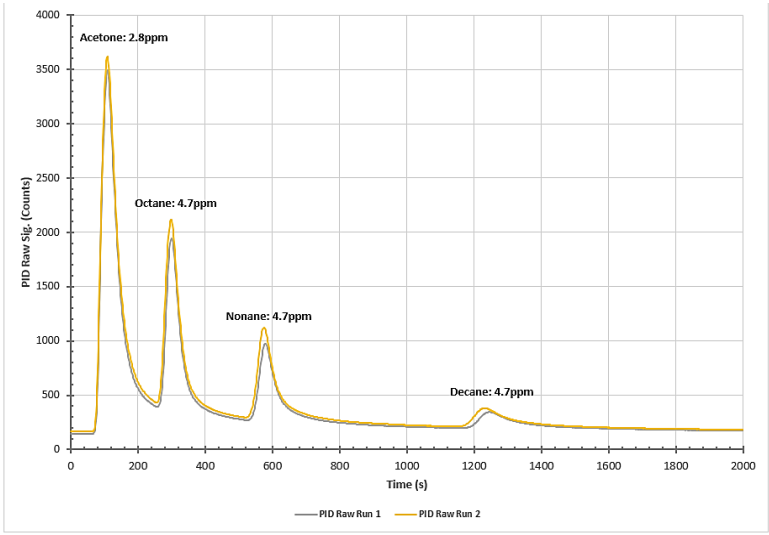


Photoionization Detector for Volatile Organic Compound (VOC) Detection

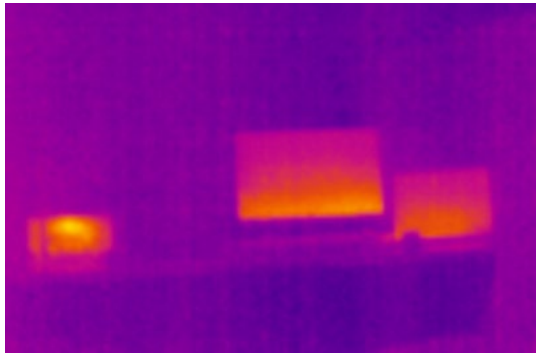
Photoionization Detector

Preconcentrator and Micro GC Column for VOC Separation





Thermal and Visible Imaging



Thermal Image

+

Visible Light Image

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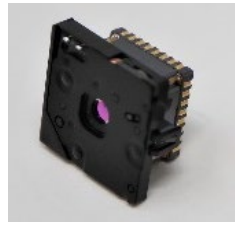
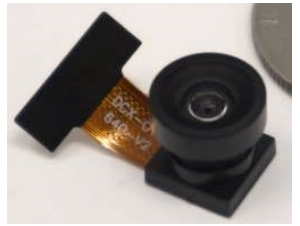
Image Overlay



FLIR Camera



Visual Camera

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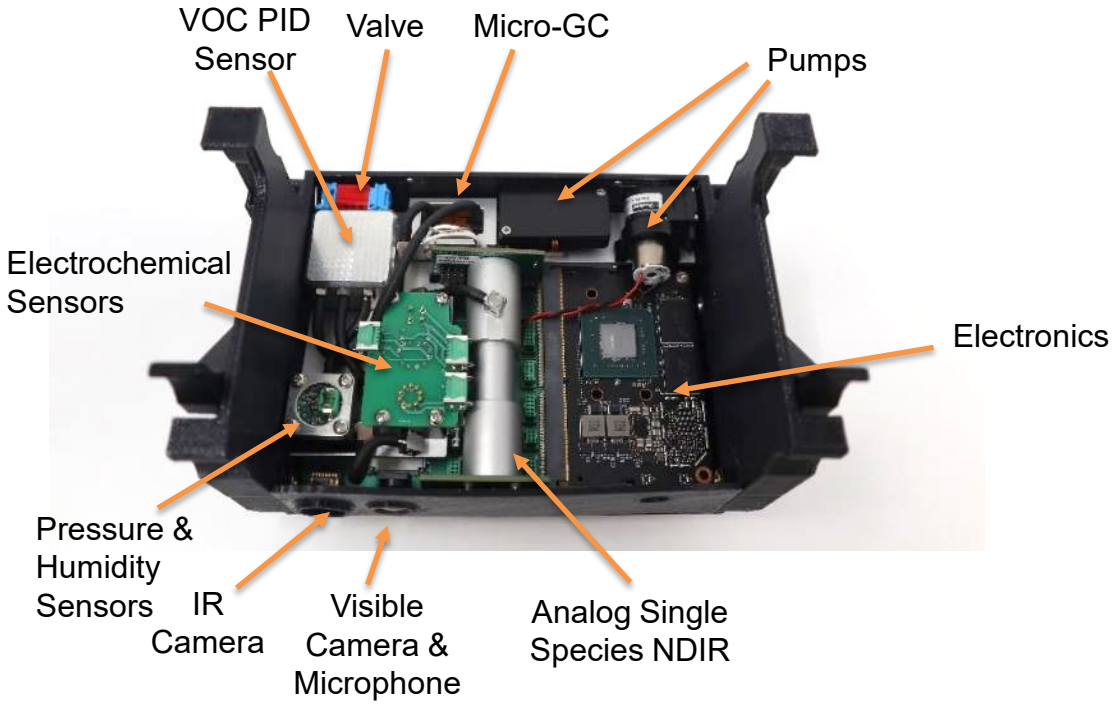
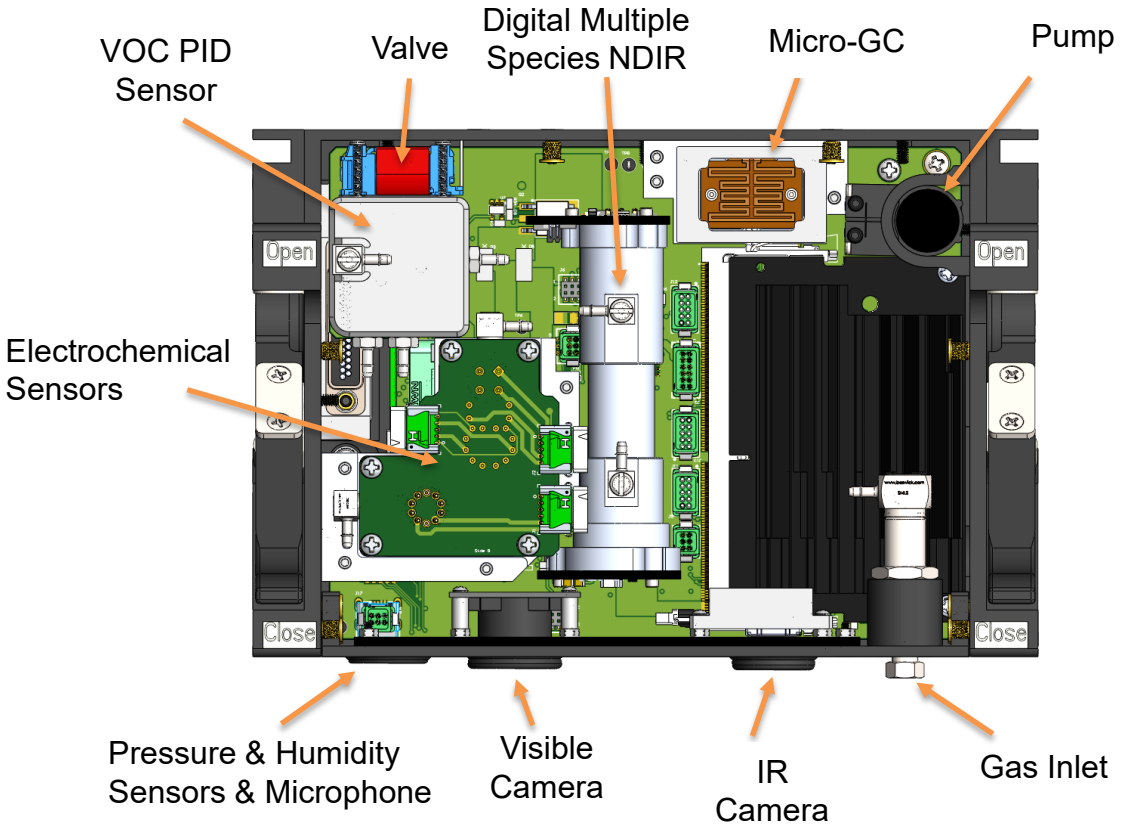
EMMA GEN-1 to GEN-2 Evolution

GEN-1 Prototype



GEN-2 Prototype



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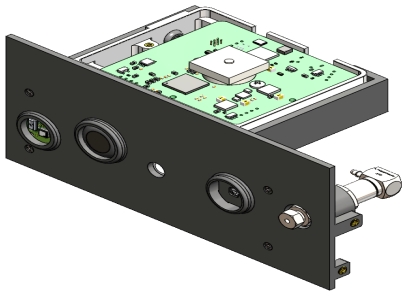
New Capability – Particulate Sensing

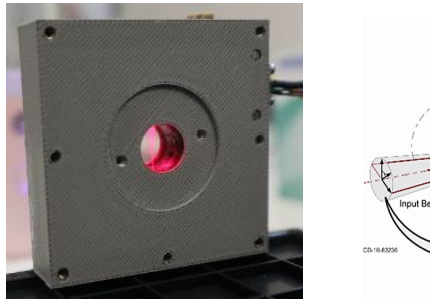
- Evaluating multiple COTs and custom particulate sensors
  - Mass concentration
  - Number concentration
  - Particulate size distribution
- COTs Sensirion SP30
- NASA Multi-Parameter Aerosol Scattering Sensor (MPASS)
  - Evaluation License and Space Act Agreement with NASA GRC
  - MPASS has been used in previous reduced gravity combustion experiments
- Modifying EMMA front panel design and integrating with electronics and machine learning models

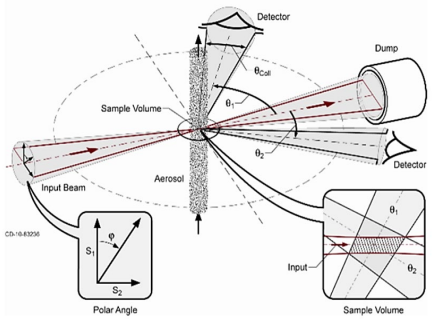
NASA MPASS

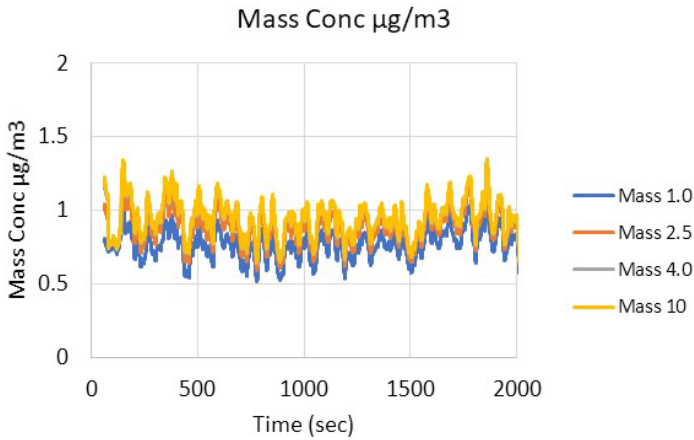
Sensirion SPS30

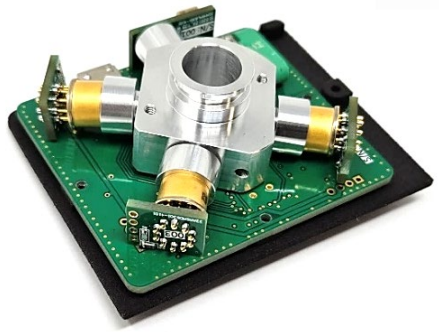


EMMA Front Pane Integration of MPASS









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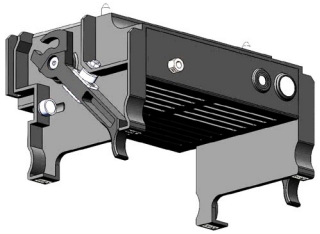
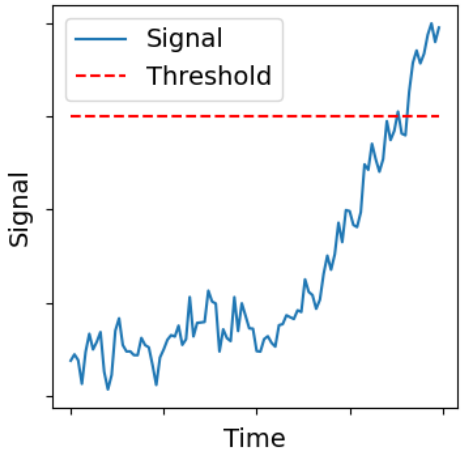
Integration with Astrobee





EMMA Payload Analyzes Data

Threshold and Anomaly Alert Messages Sent

Astrobee Coordinates and Payload Configuration Sent

EMMA Android Application Manages Payload

Habitat State Reported

Manual Control

Autonomous Habitat Monitoring Systems/Ground Control

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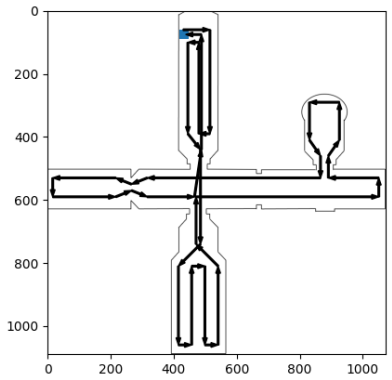
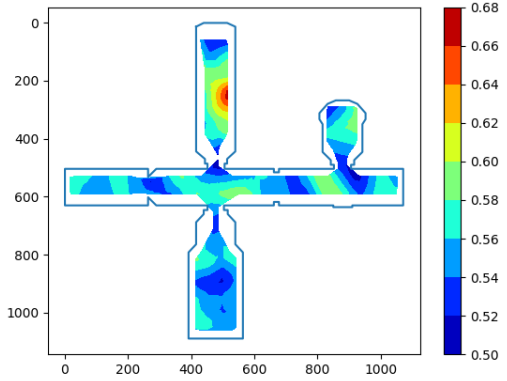
Flight Mission Types

- **Ride-along Mission**
  - Collect useful data while Astrobee performs other tasks

- **Patrol Mission**
  - Patrol entire habitat to learn normal conditions and locate anomalies





- **Loiter Mission**
  - Monitor fixed location or small area of interest over time

- **Response Mission**
  - Investigate area in response to detection and commands from other autonomous systems

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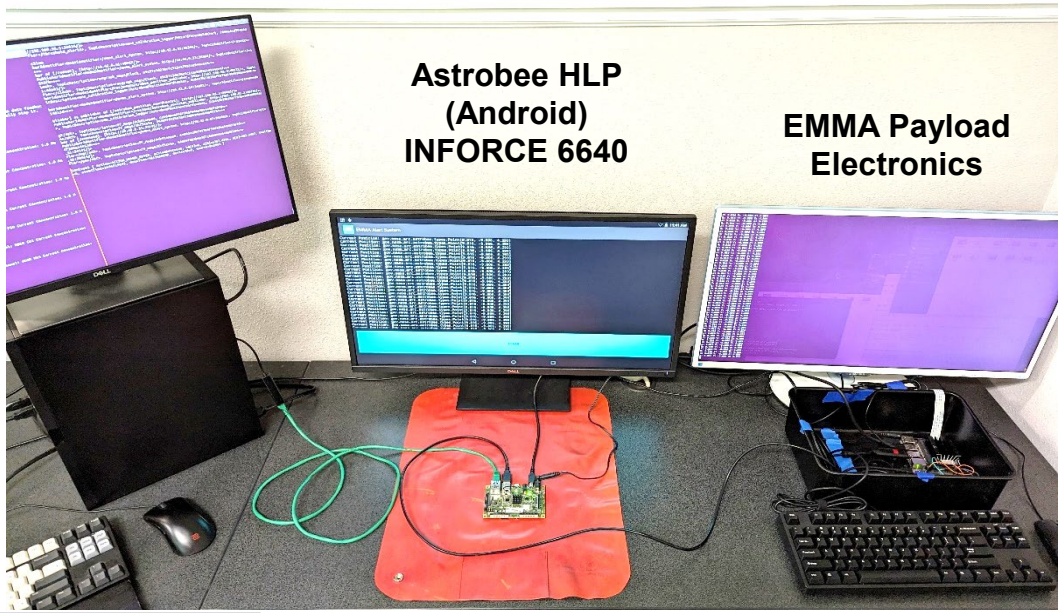
Development EMMA Alert System App for HLP



Astrobee
LLP/MLP

Ground/User
Send Command

Astrobee High-Level Processor

Guest Science Manager
Forward commands
Launch APK
Payload ON/OFF

EMMA APK

Guest Science Service
Get Location
Process commands

EMMA Service
Publish Location
Report Alerts

Astrobee MLP/LLP
Robot software
Telemetry data

EMMA Sensors

EMMA Payload

Main Node
Log SD
Report Alerts
Send File

Machine Learning Node
Neural Network Config
Report Alerts

Astrobee

High-Level Processor

Guest-Science Manager App
Manage Guest Science Apps

EMMA Alert System App

EMMA Start Service
GS Commands
GS Start/Stop

EMMA Service

ROS Node Executor
Hazard Subscriber
AI Commands
EMMA Commands
Location Publisher

Main Activity (GUI)
Display Information
Controls for Payload

Mid- and Low-Level Processors
Motor Control and Low-Level Functions

EMMA (payload)

Anomaly Detection Package
Anomaly Alert Publisher
AI Commands (Pub/Sub)

Chemical Logging Package
Threshold Alert Publisher
Location Subscriber
Sensor Commands (Pub/Sub)

Sensor Control Board
Chemical Sensing Data
Sensor Heater Control

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EMMA Development Progress and Plans

- GEN 2 Prototype Development
  - Reducing power consumption by adding capability to switch off peripherals and optimizing solid-state sensor packaging
  - Adding particulate sensing capability
  - Developing EMMA Android app to run on Astrobee High Level Processor (HLP)
  - Maturing data storage and processing procedures for machine learning algorithm training
  - Verifingy SSP 57000 Pressurized Payloads Interface Design Requirements
  - EMI per DSG-RQMT-007
  - Delivery of GEN 2 Prototypes planned June 2024

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