Environmental Monitoring Microsensor Array (EMMA) for Free Flying Robots

Phase II SBIR

Contract: 80NSSC21C0621

Astrobee Working Group June 1, 2023

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EMMA Payload Motivation and Objectives

- **Objective:** Provide mobile smart sensing capability to support autonomous habitat monitoring
- **Sensors:**
  - Chemical: O_2, CO_2 ,CO, H_2, NH_3, VOCs
  - Environmental: Pressure, Humidity, Temperature
  - IR and Visual Cameras and Sound
- **Data Analysis:**
  - Integrated machine learning capability interprets sensor data and sends alerts autonomously
- **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**
  - Overheating of electronics
  - Outgassing
  - Potential classification of materials
- **Flexible Platform for 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	VOC 0 - 10 ppm	VOC 0 - 10 ppm
Environmental Sensors	Pressure 0.5 to 16 psia Humidity 0-95 RH (-40 to 30 °C DP) Temperature -20 to 50 °C	Pressure 0.5 to 16 psia Humidity 0-95 RH (-40 to 50 °C DP) Temperature -20 to 50 °C
IR Camera	FLIR Lepton	FLIR Lepton
Imaging Sensor	720p Visible Camera	1080p or higher res Camera
Audio	Microphone (60 to 15 kHz)	Microphone (60 to 15 kHz)
External Connectivity	Communications to Astrobee HLP	Communications to Astrobee HLP Bluetooth hub for 3rd party device connection to Astrobee
Other Specifications		
Power	14.4VDC, 0.90 A	14.4 VDC, 0.40 A
Envelope	5.9 in x 4 in x 1.8 in	5.9 in x 4 in x 1.8 in
Mass	520 grams	Under 400 grams

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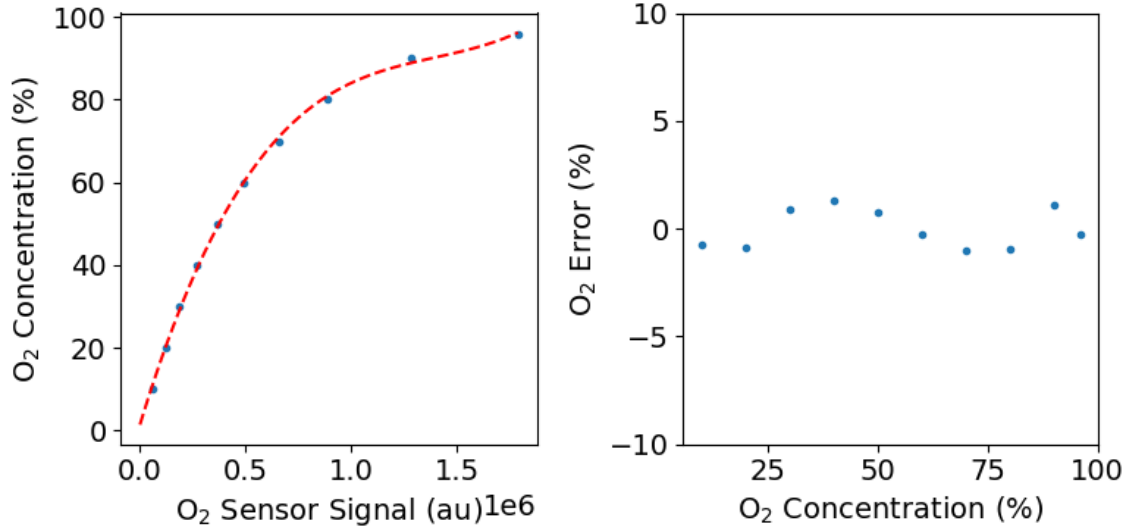
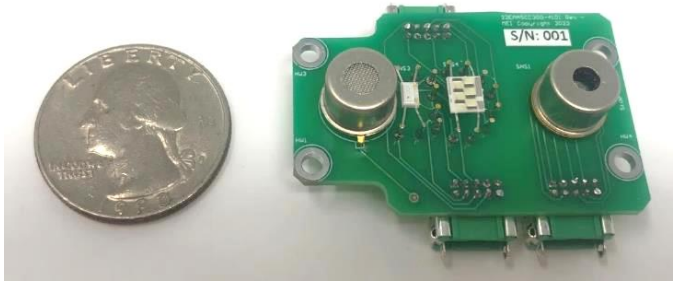
Sensing Technology: Electrochemical and Optical

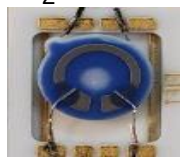


Miniaturized Solid-State Chemical Sensors

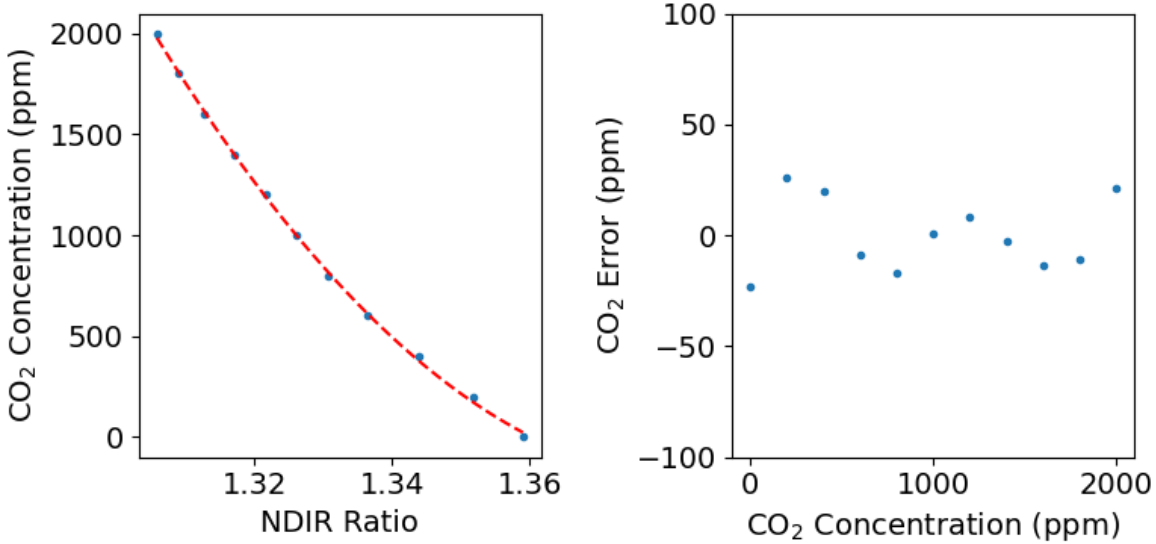


CO Sensor

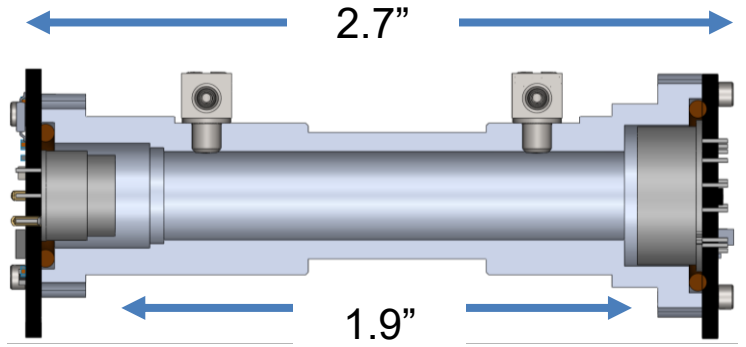
O_2 Sensor



H_2 Sensor



Multi-Species NDIR



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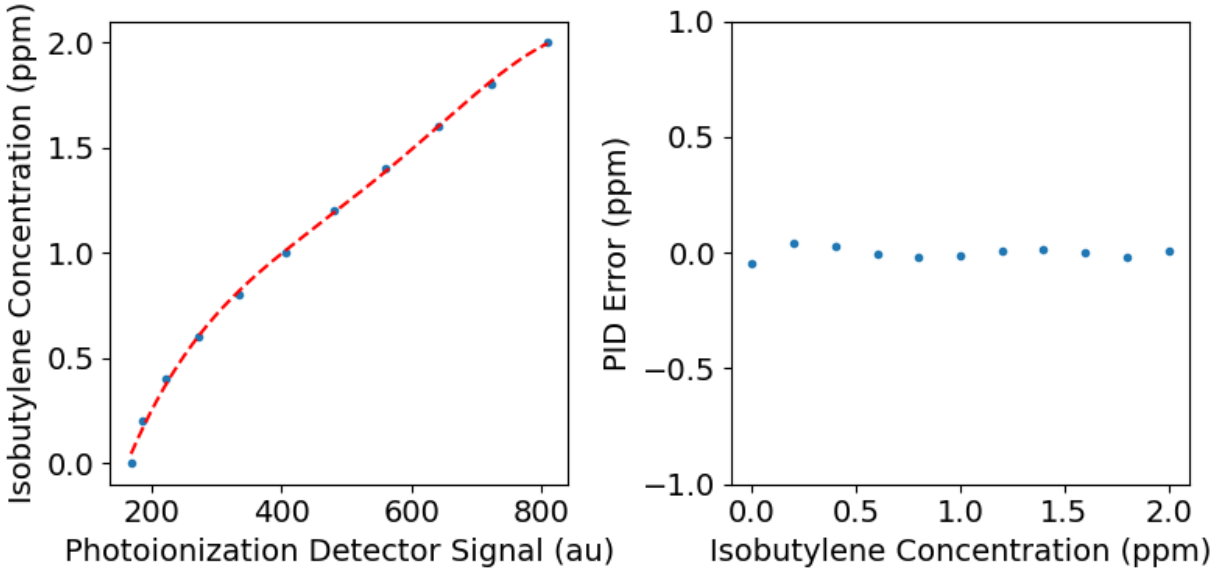
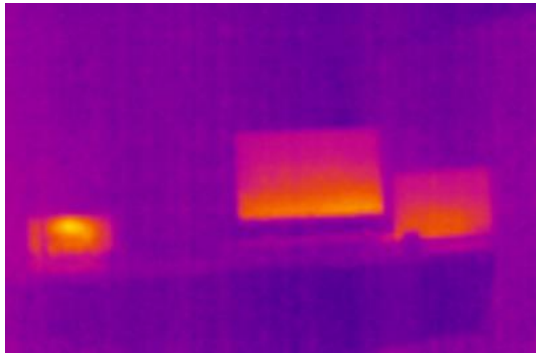
Sensing Technology: Photoionization and Camera



Photoionization Detector for Volatile Organic Carbon (VOC) Detection

Photoionization Detector

Thermal and Visible Imaging



Thermal Image

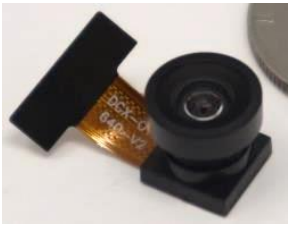
+

Visible Light Image

=

Image Overlay

FLIR Camera



Visual Camera

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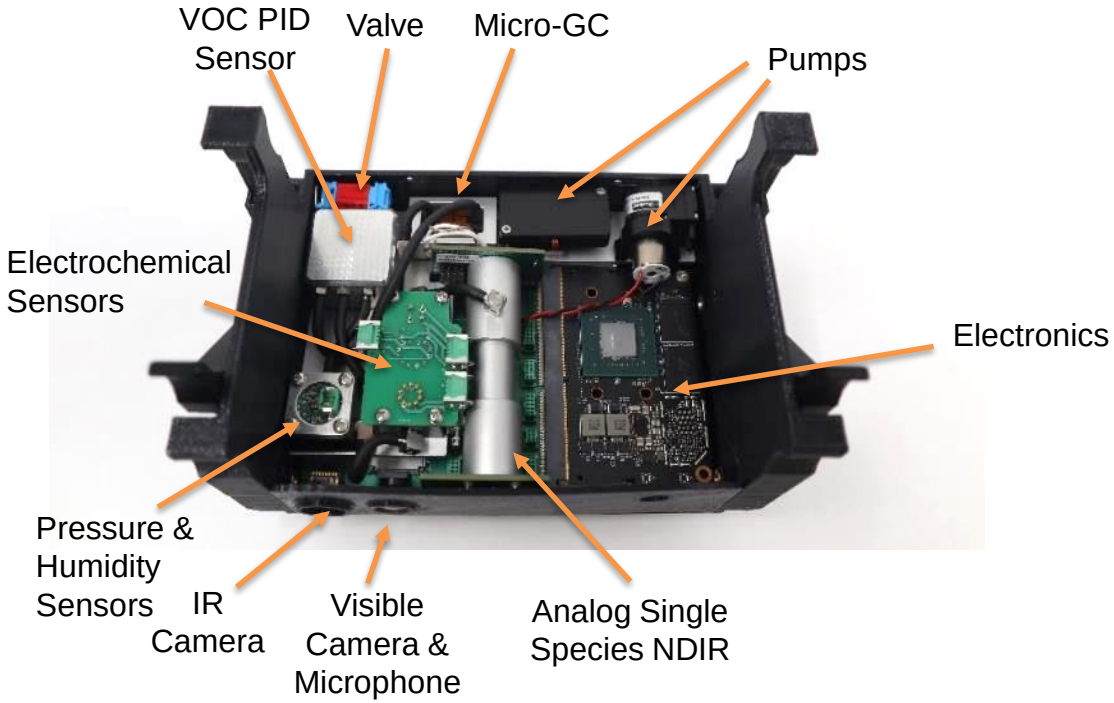
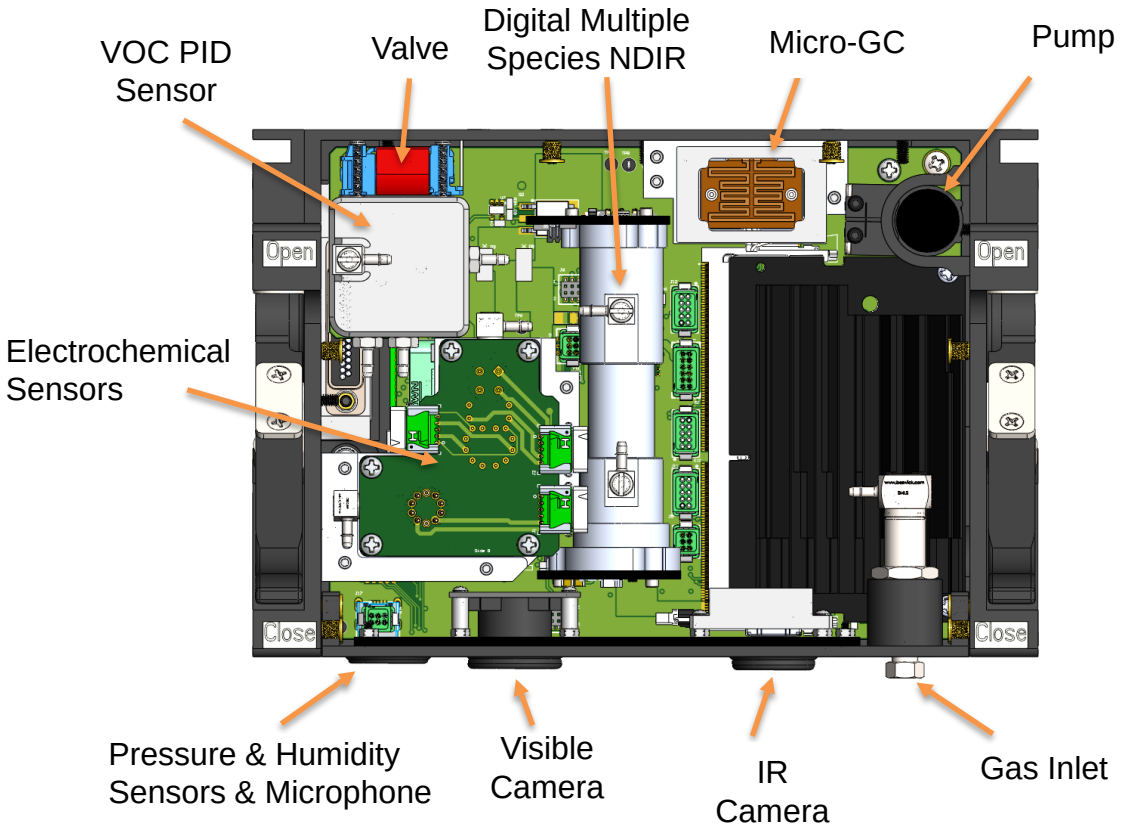
EMMA GEN-1 to GEN-2 Evolution

GEN-1 Prototype



GEN-2 Prototype



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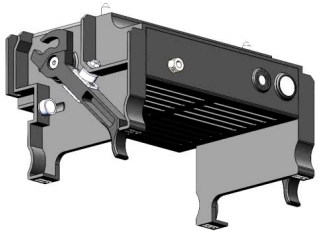
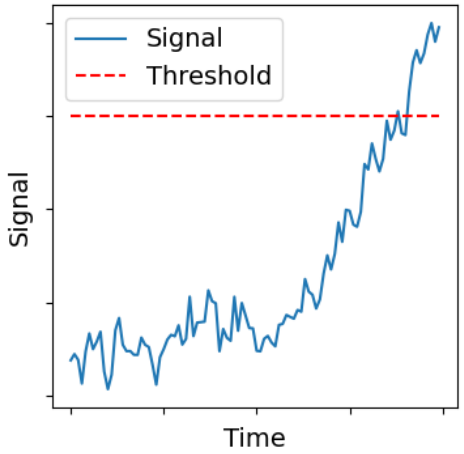
Integration with Astrobee





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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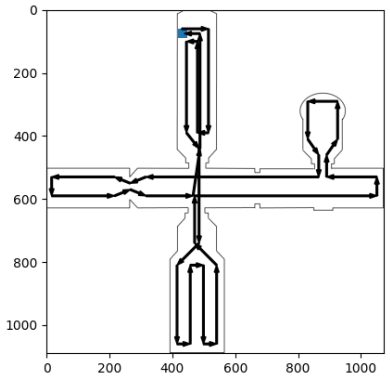
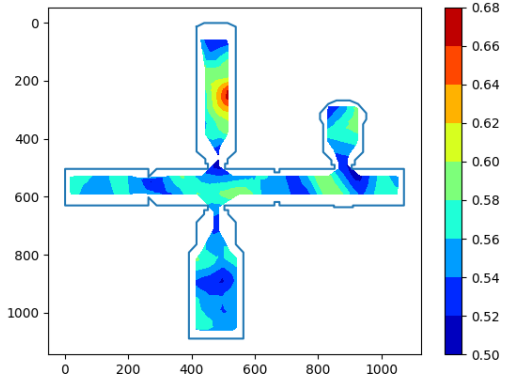
Flight Mission Types

- **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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Sample Concept of Operations Leveraging Machine Learning

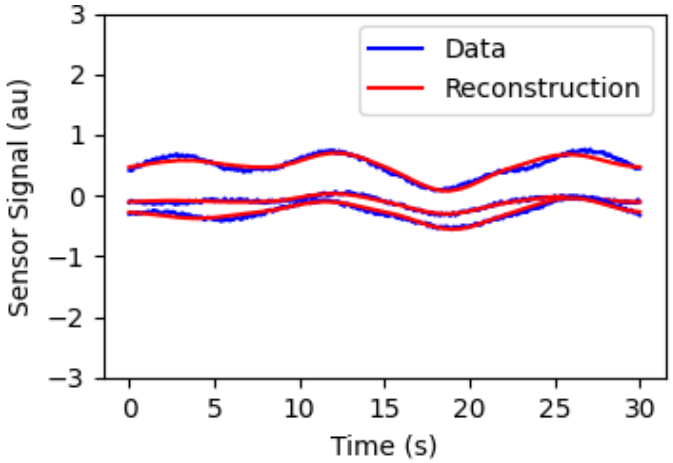
Normal Habitat Conditions

- Analyze chemical measurements on patrol
- Learn to recognize typical normal chemical signatures
- Unrecognized chemical signatures are flagged as anomalous

Local Anomaly

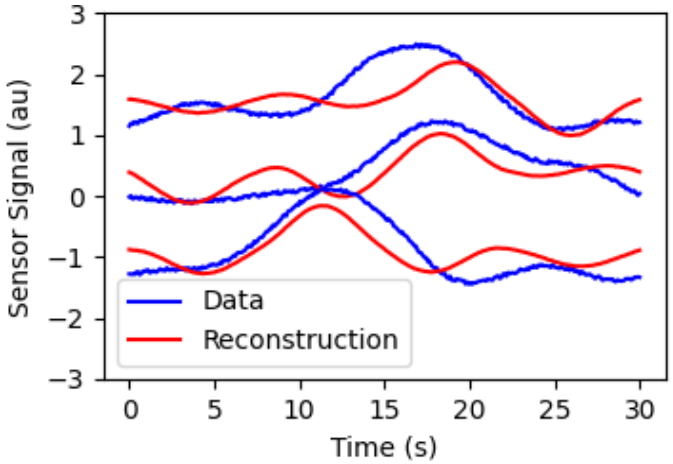
Recognized

Algorithm accurately reconstructs measured chemical signatures



Not Recognized

Algorithm cannot accurately reconstruct unfamiliar chemical signatures



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EMMA Development Progress and Plans

- GEN-1 EMMA Delivered November 2022
  - Expanded sensing capability for GEN-1 versus Phase I prototype
  - GEN-1 includes hardware suitable for running machine learning algorithms for autonomous anomaly detection
- GEN 2 Prototype Development Is Underway
  - Reducing power consumption by adding capability to switch off peripherals and optimizing solid-state sensor packaging
  - Continuing to evaluate additional sensing capability (acid gases, particulate)
  - Developing EMMA Android app to run on Astrobee High Level Processor (HLP)
  - Maturing data storage and processing procedures for machine learning algorithm training
  - SSP 57000 Pressurized Payloads Interface Design Requirements
  - EMI per DSG-RQMT-007

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