Tech Expo, Spring/Fall 2025 – Team 01

Wearable CO_2 Sensor

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Sponsor

PURDUE UNIVERSITY
Polytechnic Institute

Client

PURDUE UNIVERSITY
Agricultural and Biological Engineering

OVERVIEW

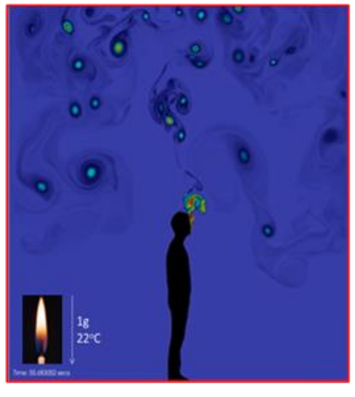
Our capstone project delivers a wearable, head-mounted sensor system that measures CO_2 in real time. In microgravity, exhaled CO_2 pools near the face forming a dangerous "CO_2 bubble", affecting comfort and cognition. Using custom electronics and wireless data transmission, the device provides continuous atmospheric monitoring to improve astronaut safety and support research on air quality in confined or extreme human-operated environments.

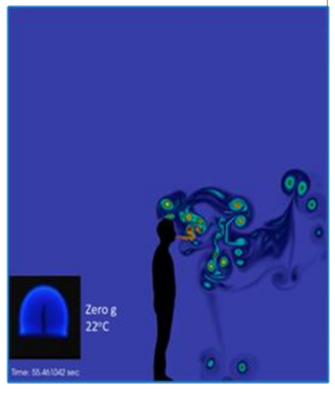
Client Background

Through the Agricultural and Biological Engineering program at Purdue University, Dr. Marshall Porterfield has conducted extensive research on how exhaled CO_2 behaves in microgravity, where disrupted convection leads to dangerous CO_2 accumulation near the breathing zone. As a former NASA Division Director for Space Life and Physical Sciences, he has long investigated human physiological risks in spaceflight environments. Dr. Porterfield previously began developing his own CO_2 sensing system to study this problem, and he brought this project to our team to create a more refined, wearable, real-time gas-monitoring device.

Problem

In microgravity, the lack of buoyant convection prevents normal air circulation, causing exhaled CO_2 to remain concentrated around the nose and mouth instead of dispersing. This trapped "CO_2 bubble" can quickly elevate breathing-zone CO_2 and contribute to headaches, fatigue, and cognitive decline. With ISS levels often reaching 2,000–5,000 ppm, far above Earth's ~420 ppm, the risk of rebreathing becomes significant. **Yet no existing system measures real-time, face-level CO_2 where exposure is most critical.** This challenge also affects submariners, pilots, and others in confined environments, making accurate, high-frequency monitoring essential for health, safety, and mission-critical decision-making.



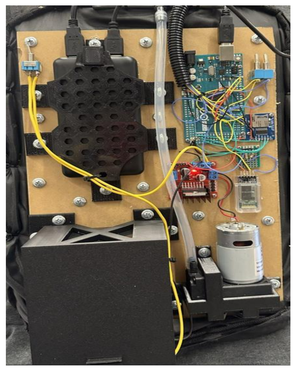


Final Design

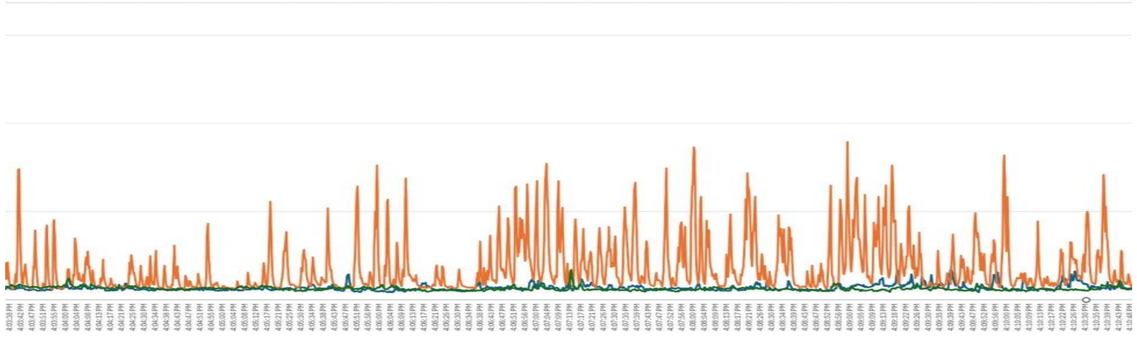
The project utilized an Arduino-based system equipped with three sensors that collected environmental data in parallel. Sensor readings were recorded directly to an onboard SD card, enabling easy transfer to external devices where the data could be automatically formatted in Excel for analysis. A Bluetooth connection allowed a phone to control the system in real time, including starting and stopping measurements, managing the air pump, and storing data. This setup allowed CO_2 measurements to be tracked over time, revealing clear breathing patterns and confirming accurate sensor performance. The entire system was integrated into a backpack-mounted design, powered by two separate batteries—one for the motor and one for the electronic components—ensuring stable operation, portability, and user-controlled functionality for real-world testing.

Critical Components:

- **Microcontroller:** Arduino2560, Power Cable
- **CO_2 Sensors:** 3x SprintIR-6S
- **Air Pump:** Qiangsens Micro Vacuum, LN298N Motor Driver, Airflow Splitter, Silicon Tubing
- **Storage:** Adafruit MicroSD Breakout Board, SD Card
- **Bluetooth:** HM-10 Bluetooth Module, PCB, Resistors
- **Power:** Portable 5V & 12V Batteries
- **Devices:** Android Phone BT, Charging Cable
- **Mounts:** Medical Head Strap, Backpack, 3D Prints, Screws
- **Miscellaneous:** Electrical Wires, Switches, Air Tubing, Zip Ties



Data Collection Results



Meet the Team

Comprised of three hard-working students, our diverse backgrounds came together seamlessly to meet both the client's requirements and the course objectives. Our team includes majors in Electrical, Computer, Energy Engineering Technology.

Client Requirements & Results

	Requirements	Actual
Sensor Accuracy	± 50 PPM	*± 70 PPM*
Sensor Range	0-10,000 PPM	*0-50,000 PPM*
Sensor Sampling Rate	≥1 Hz real-time	*≥ 3 Hz real-time*
Testing Duration	≥ 2 hours	*≥ 2 hours*
Conformability Factor	Lightweight, non-intrusive	*Lightweight, ergonomic, non-intrusive*