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GEM3
Genes by Environment
Modeling · Mechanisms · Mapping

IDAHO EPSCoR

Developing Wireless Tags using Laser Induced Graphene for Sagebrush VOC Detection

Seed Grant: *Wireless Sensors for Detecting Chemical Phenotypes: Eavesdropping on Sagebrush Mechanisms and the Environment*

Purpose of the Seed Grant

- Volatile organic compounds (VOCs) are emitted by sagebrush in response to abiotic (e.g., drought, temperature) and biotic (e.g., herbivores) stressors.
- We are lacking the ability to measure the concentration of VOCs in real-time over a large geographic area
- This project explores the effectiveness of laser-induced graphene transducers to respond to the VOCs emitted by sagebrush
- This project also seeks to develop wireless sensing tags capable of monitoring VOC emissions in real-time and over a wide geographic area.

Collaborators

NORTHWEST
NAZARENE UNIVERSITY

- Dr. Josh Griffin
- Dr. Ben Pearson

BOISE STATE
UNIVERSITY

- Dr. Jen Forbey
- Dr. David Estrada
- Cadré Francis

Senior Design Team (F21-S22)

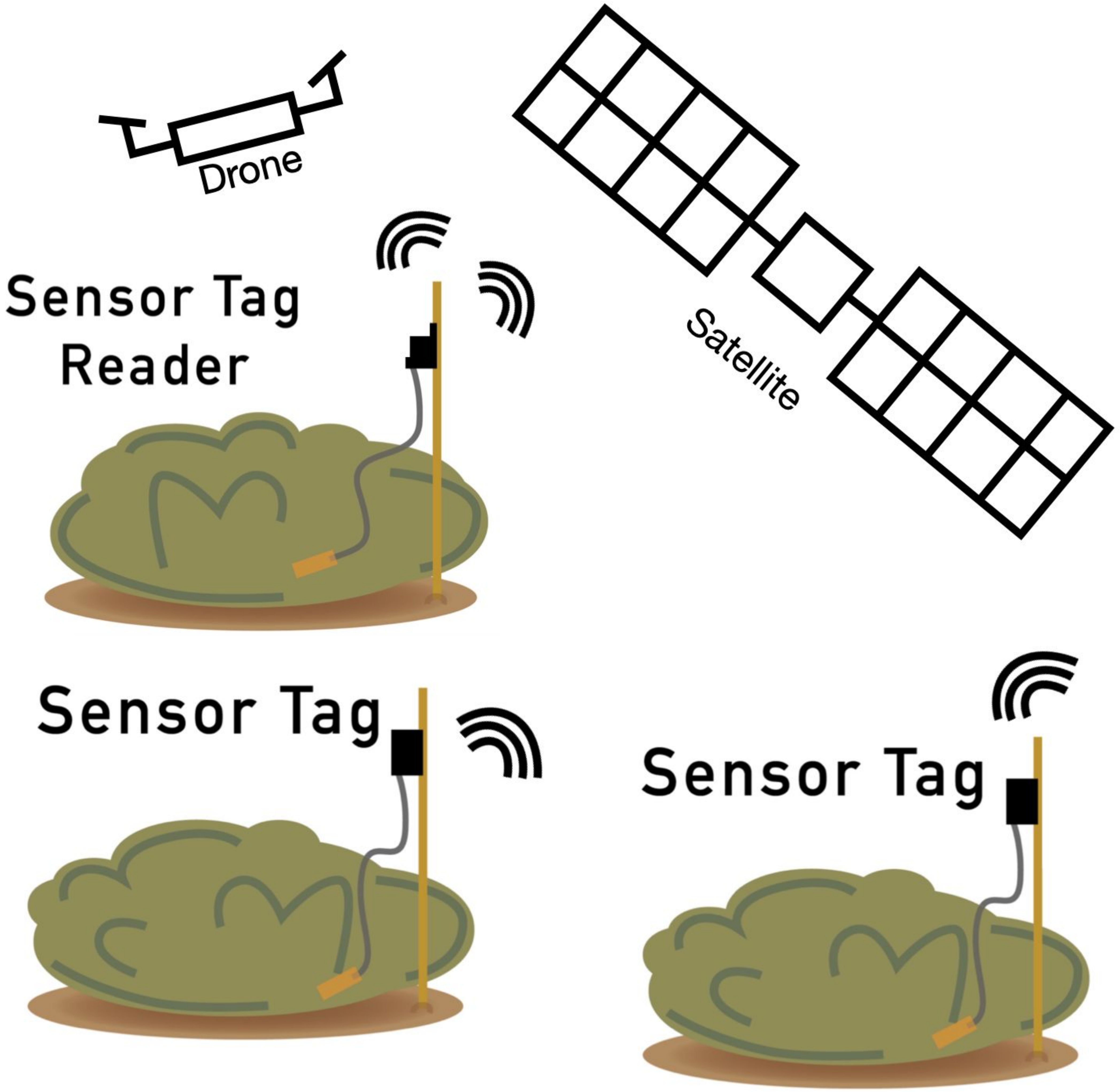
Alex Nadermann

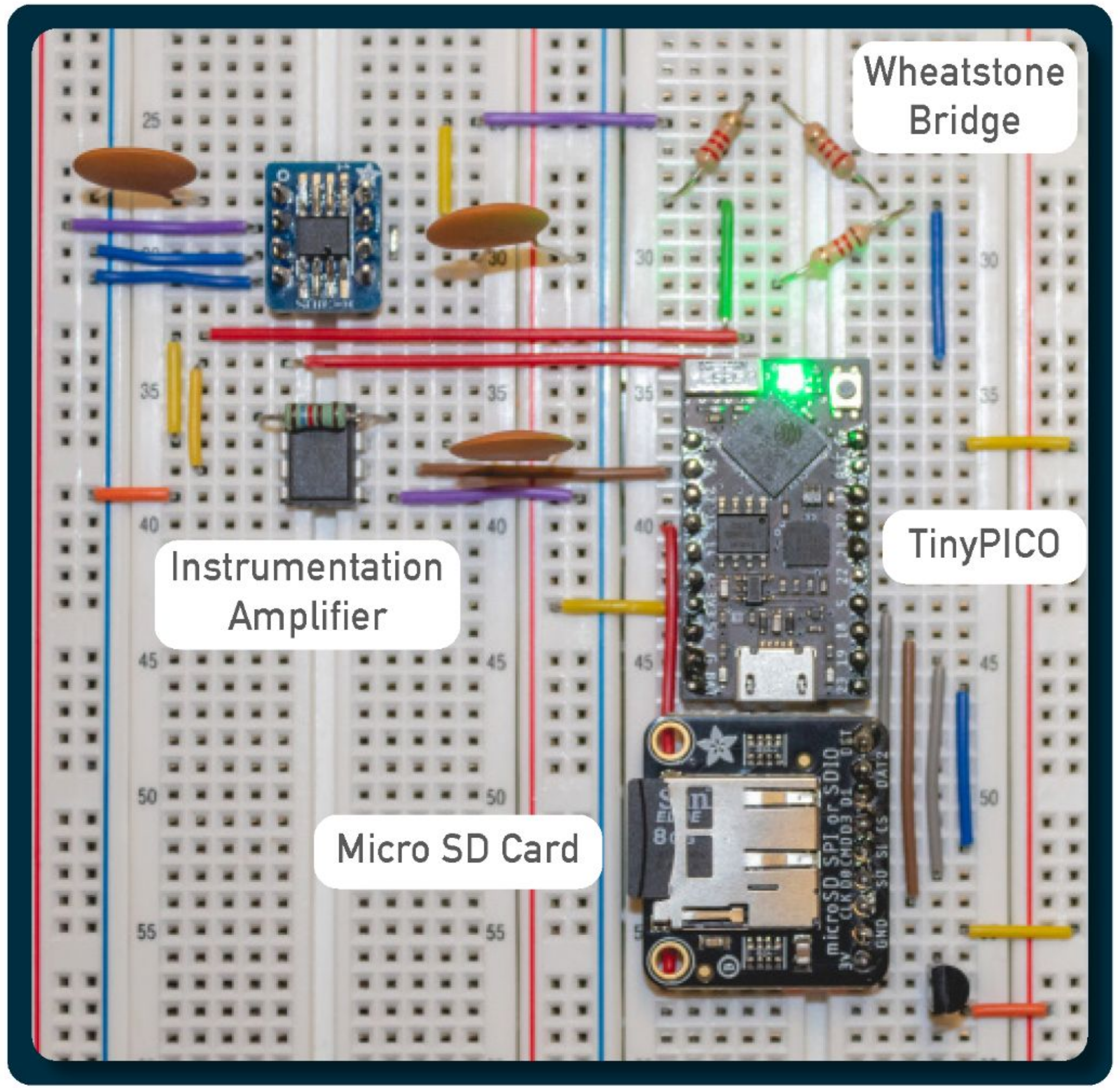
Jonathan Ryan

Nick Irwin

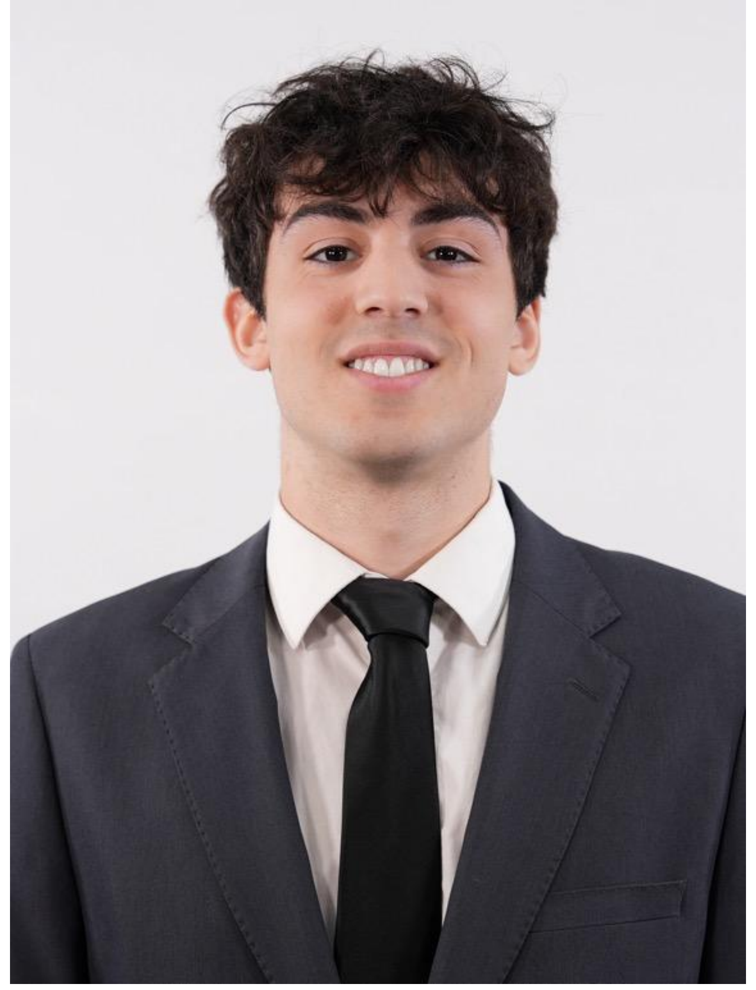
Sensor Tag and Reader Prototype 1.0

- Tags based on Arduino microcontroller
- Capable of reading temperature, humidity, and soil moisture sensors
- Employed generic 2.4 GHz communication between tags and reader (range ~28 ft)
- Demonstrated communication with Iridium satellite
- Battery life relatively short (~28 days for reader and ~24 days for tag)





Undergraduate Research Team (Sum22-S23)

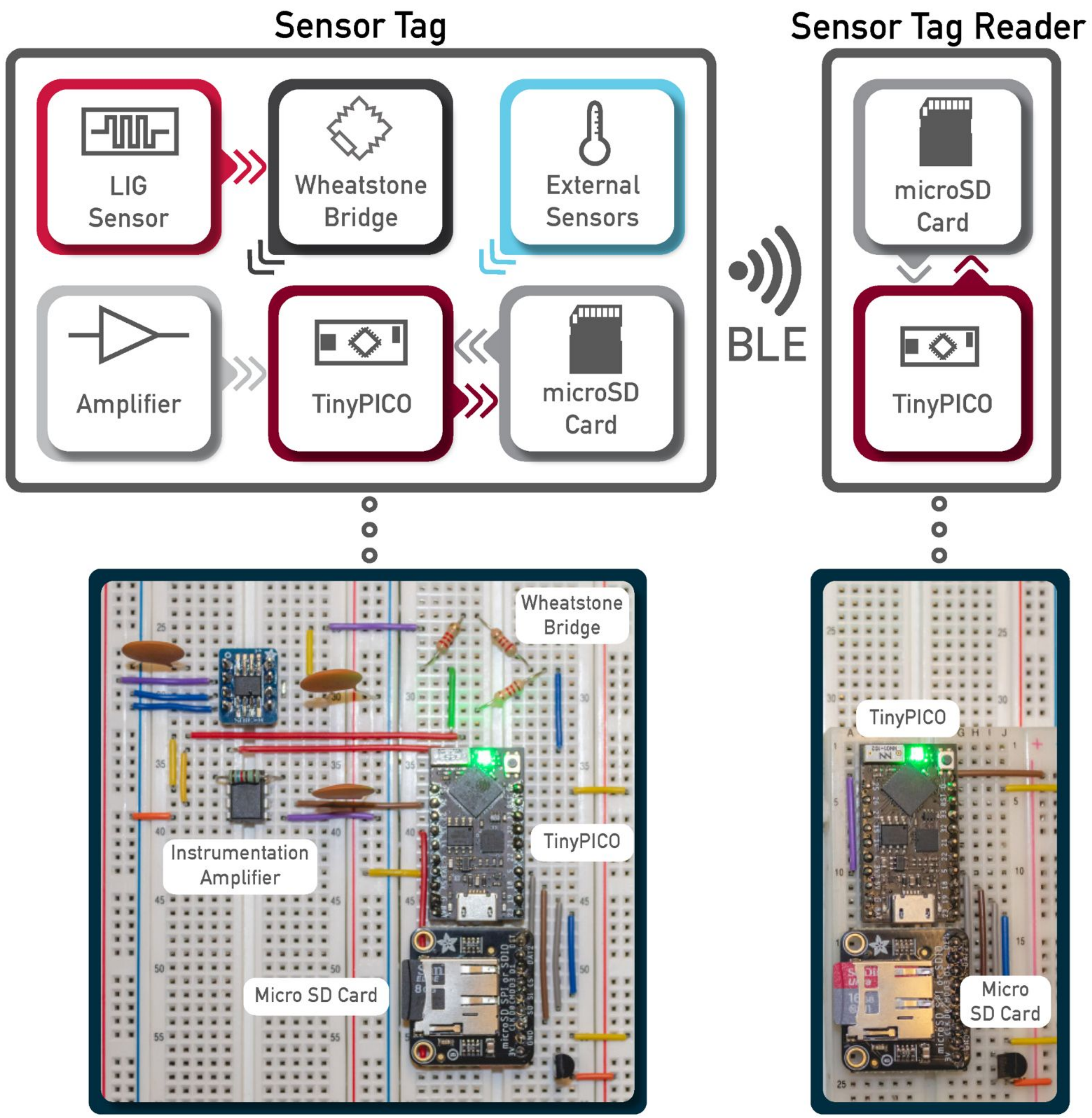


Sam Mark

Riley Mark

Sensor Tag and Reader Prototype 2.0

- Redesigned tag and reader using a TinyPico board (based on ESP32 microcontroller)
- Communication between tag and reader implemented using BlueTooth Low Energy
- Implemented circuitry (Wheatstone bridge) to read resistance of LIG transducer
- Read range > 100m
- Low power consumption results in expected battery life of approximately 326 days*



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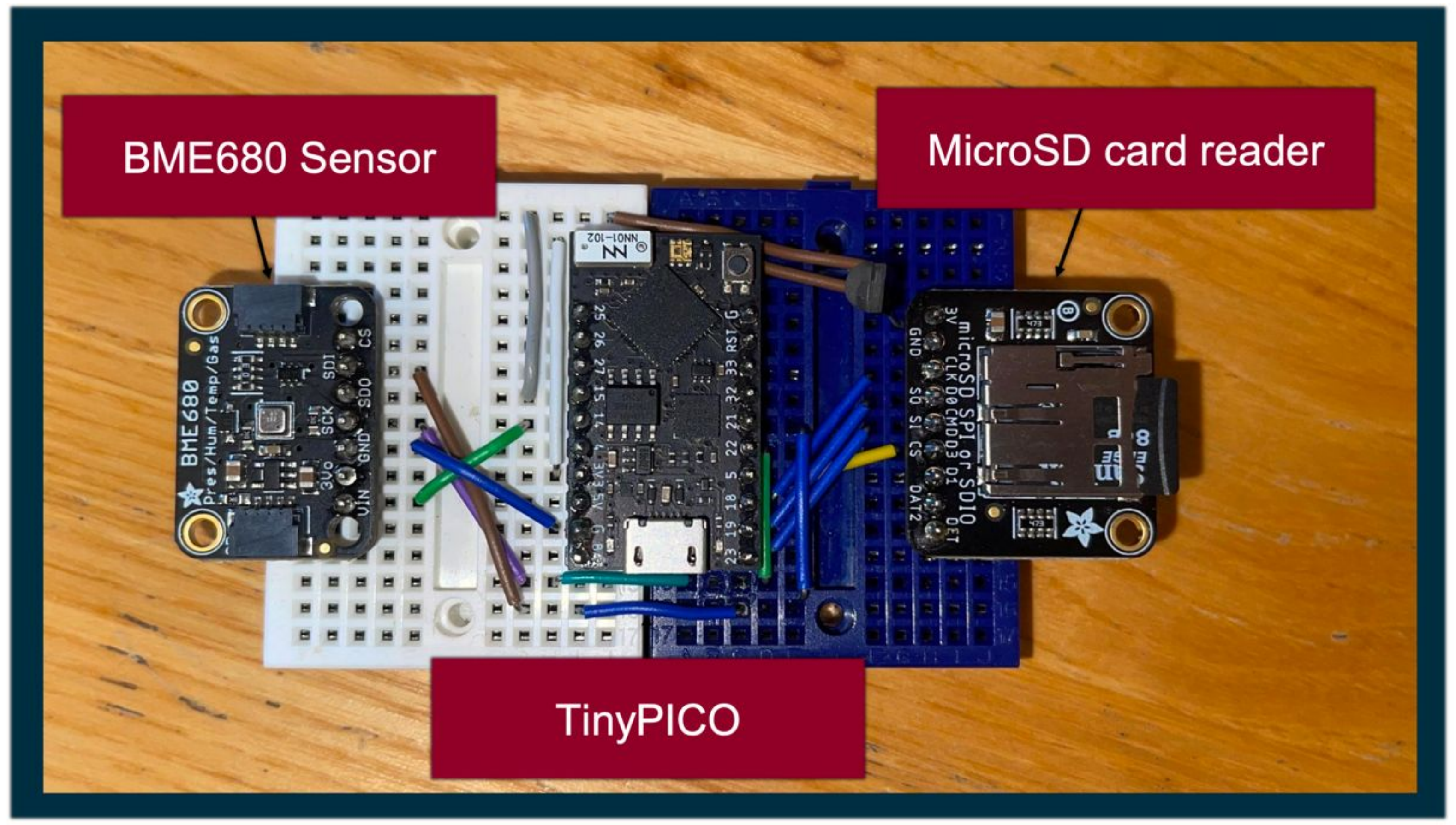
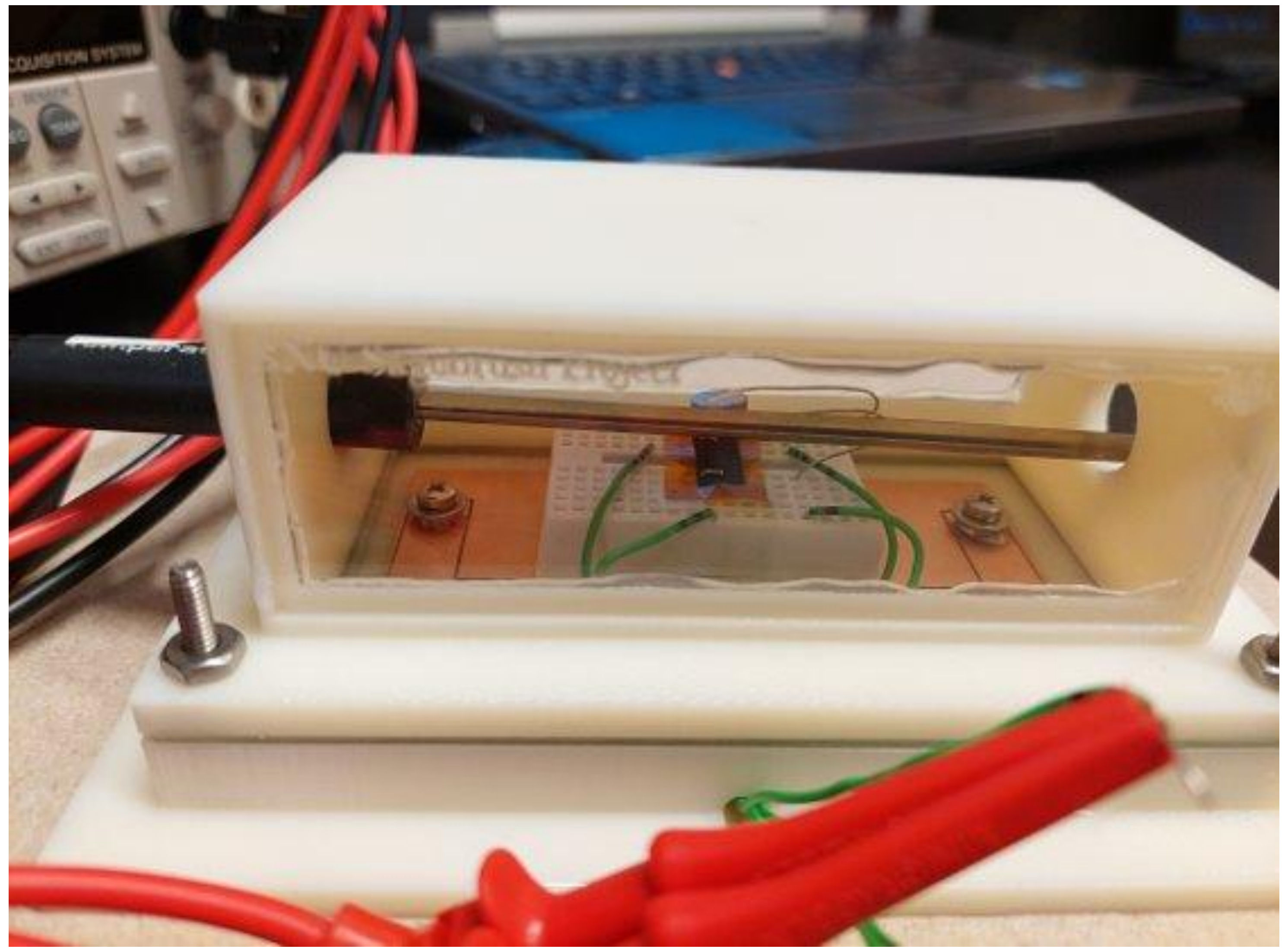
[*] The tag uses a 2200mAh battery and non-linear discharge effects are ignored. The tag samples for 5 seconds every 5 minutes and a transmit data for 5 seconds twice a day

Undergraduate Research Team (Sum23)





Christian Salisbury

Sensor Tag and Reader Prototype 2.1

- Based on sample TinyPico board
- Employed ESP NOW communication protocol
- Demonstrated passing data from one tag to the next
- Similar power consumption as 2.0 prototype

Conclusions

Prototype tag and reader were successfully demonstrated

- Reading LIG transducer
- Communication between reader and tag with acceptable read range
- Battery life of reader and tags satisfactory

Future work

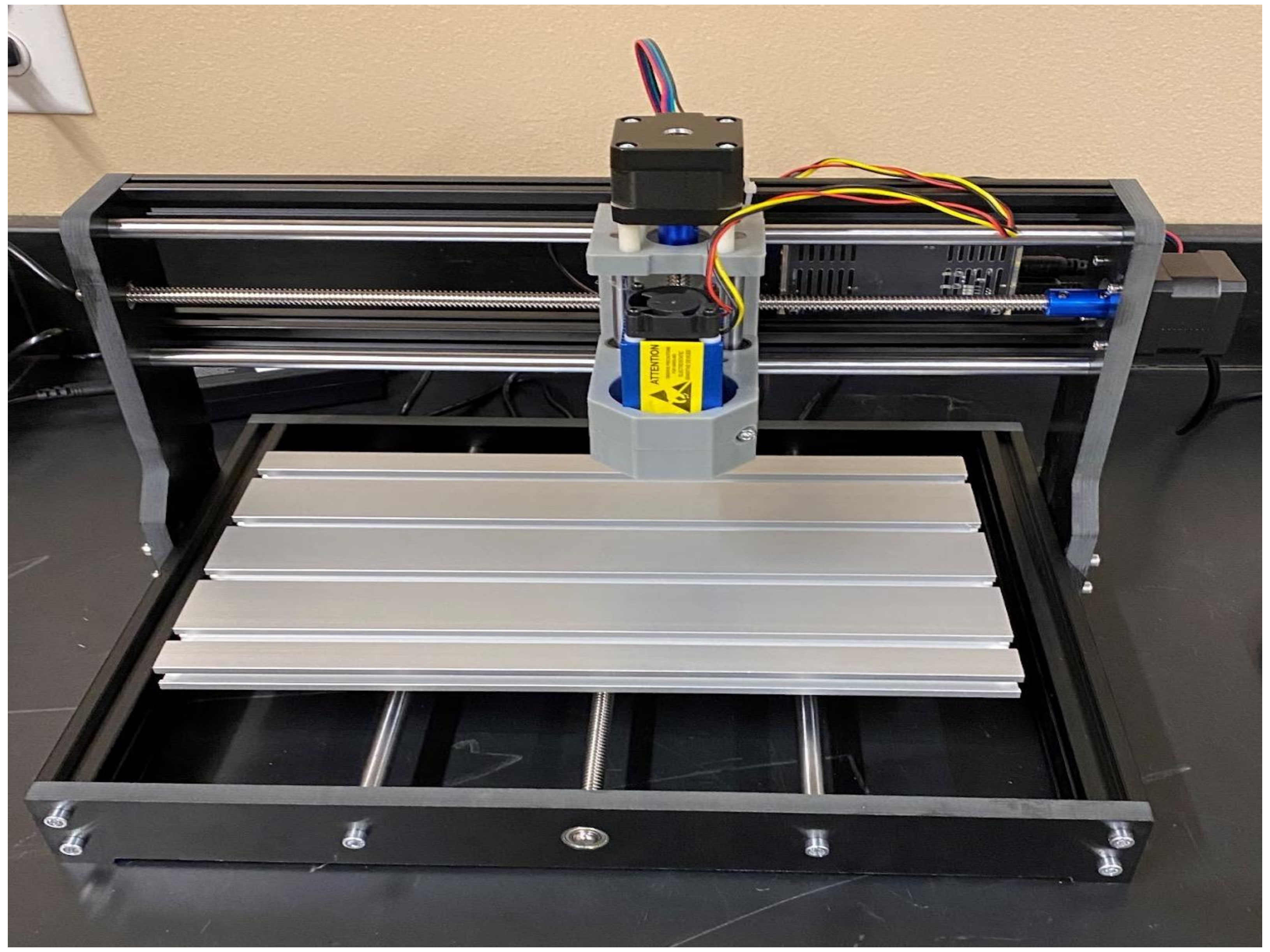
- Explore use of alternative communication protocols (e.g., LoRa)
- Explore inter-operability with existing sensors
- Demonstrate integration with drone

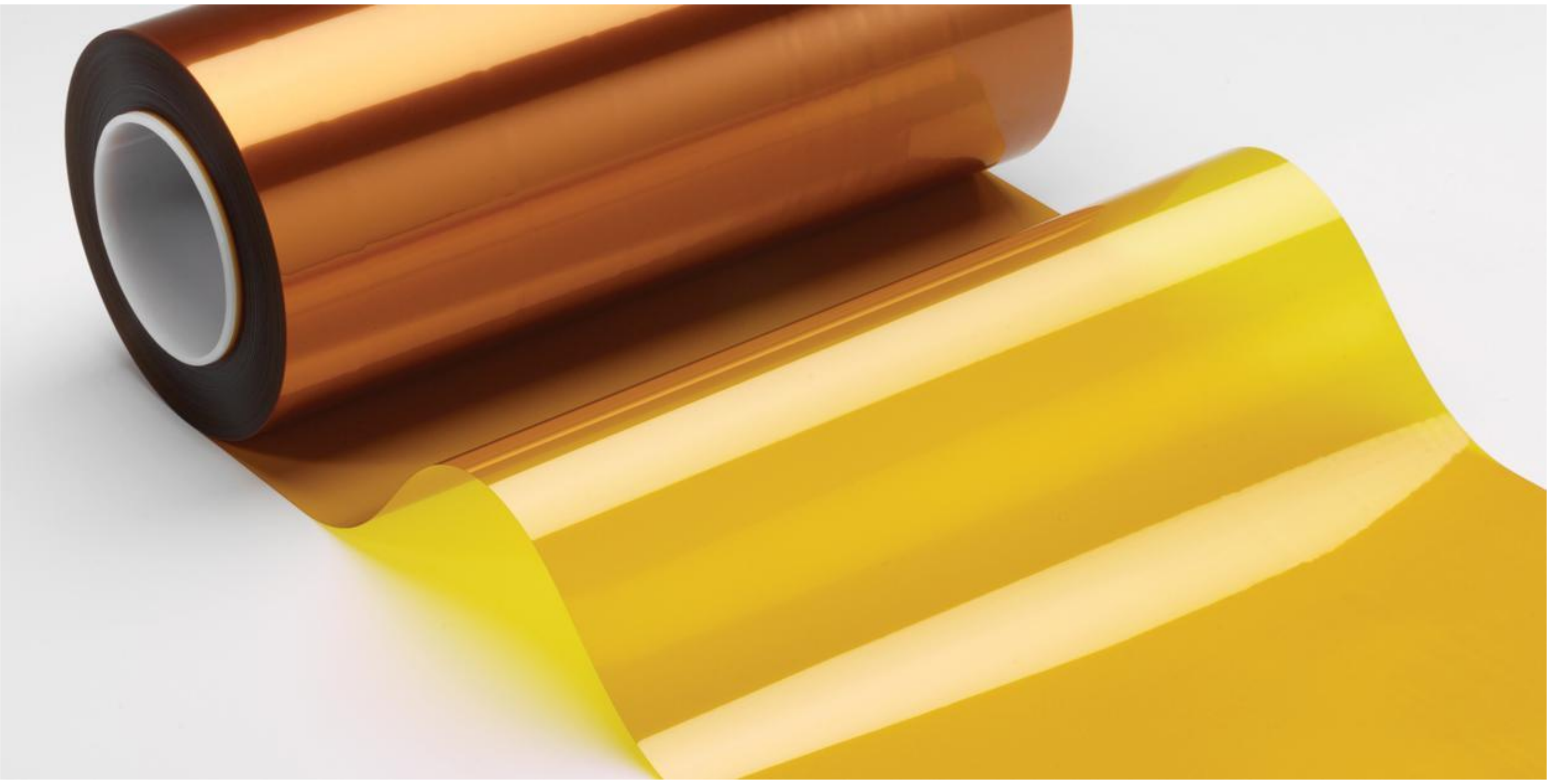
Senior Design Team (F21-S22)

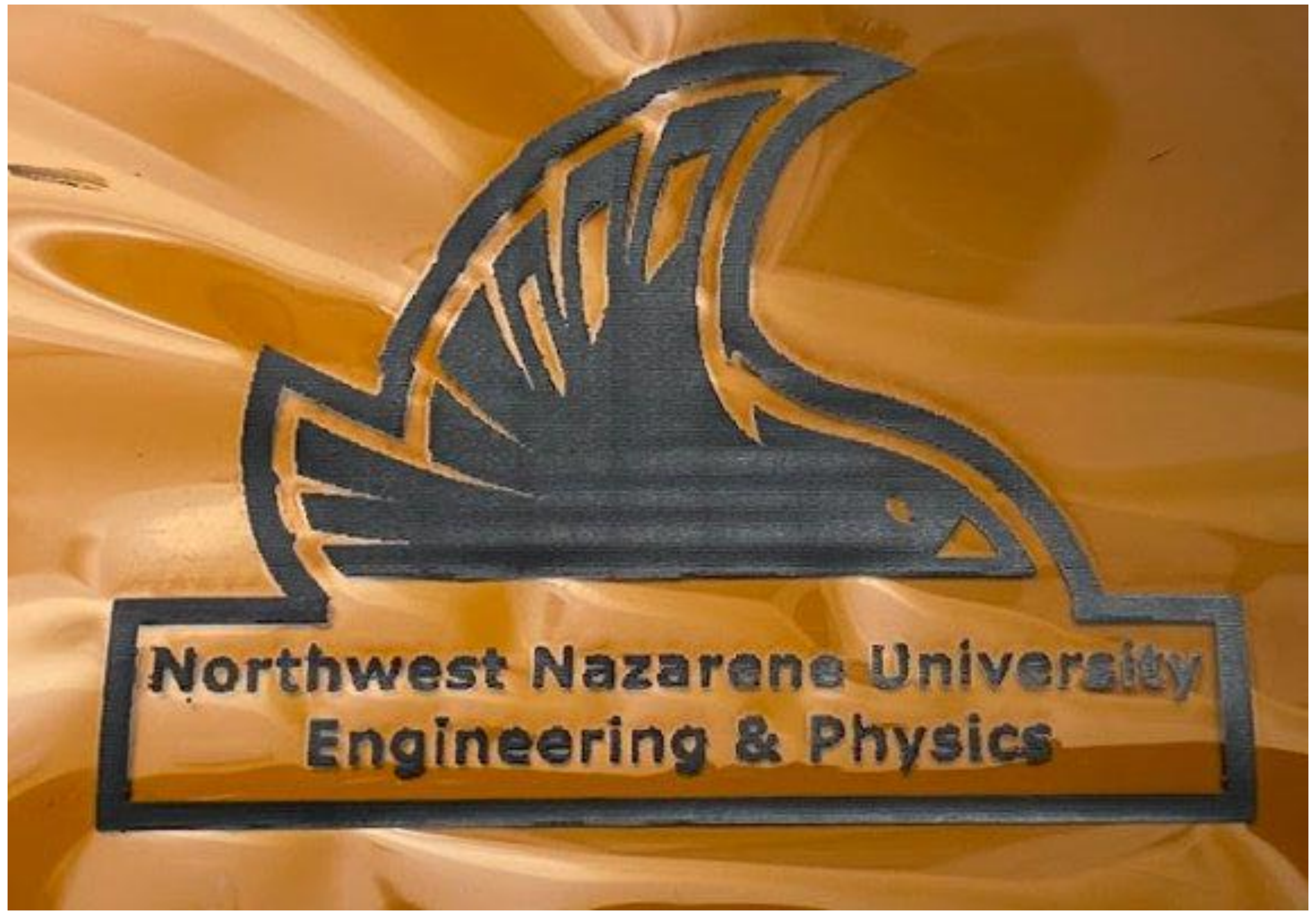
Alex Nadermann

Laser Induced Graphene Process Development

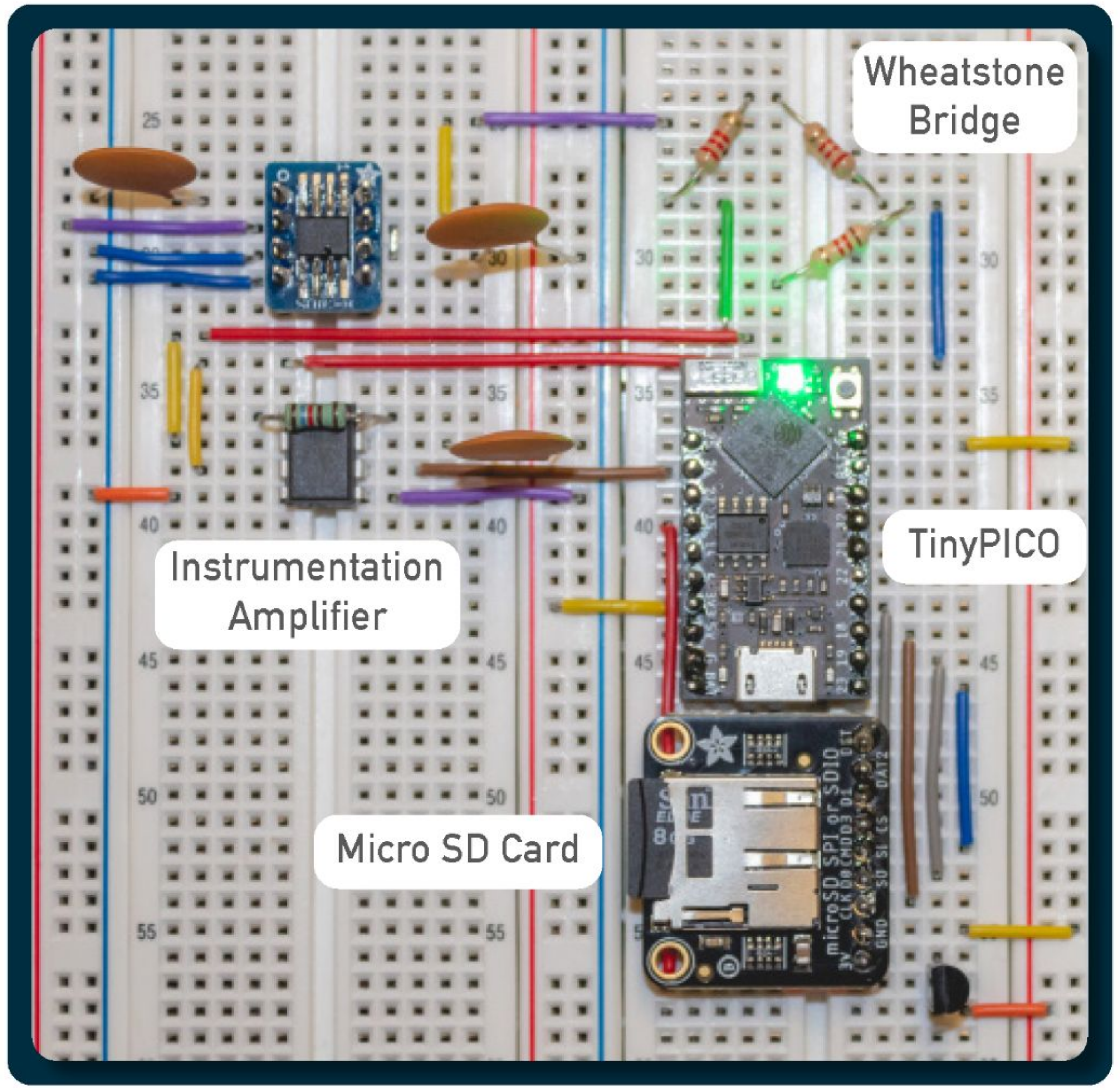
- Apparatus – CNC 3018 Pro Engraver
- Medium – Kapton (polyimide tape)
- Result – Laser Induced Graphene (LIG)
  - 2-D nanomaterial with a porous microstructure
  - Good candidate for chemiresistive sensor







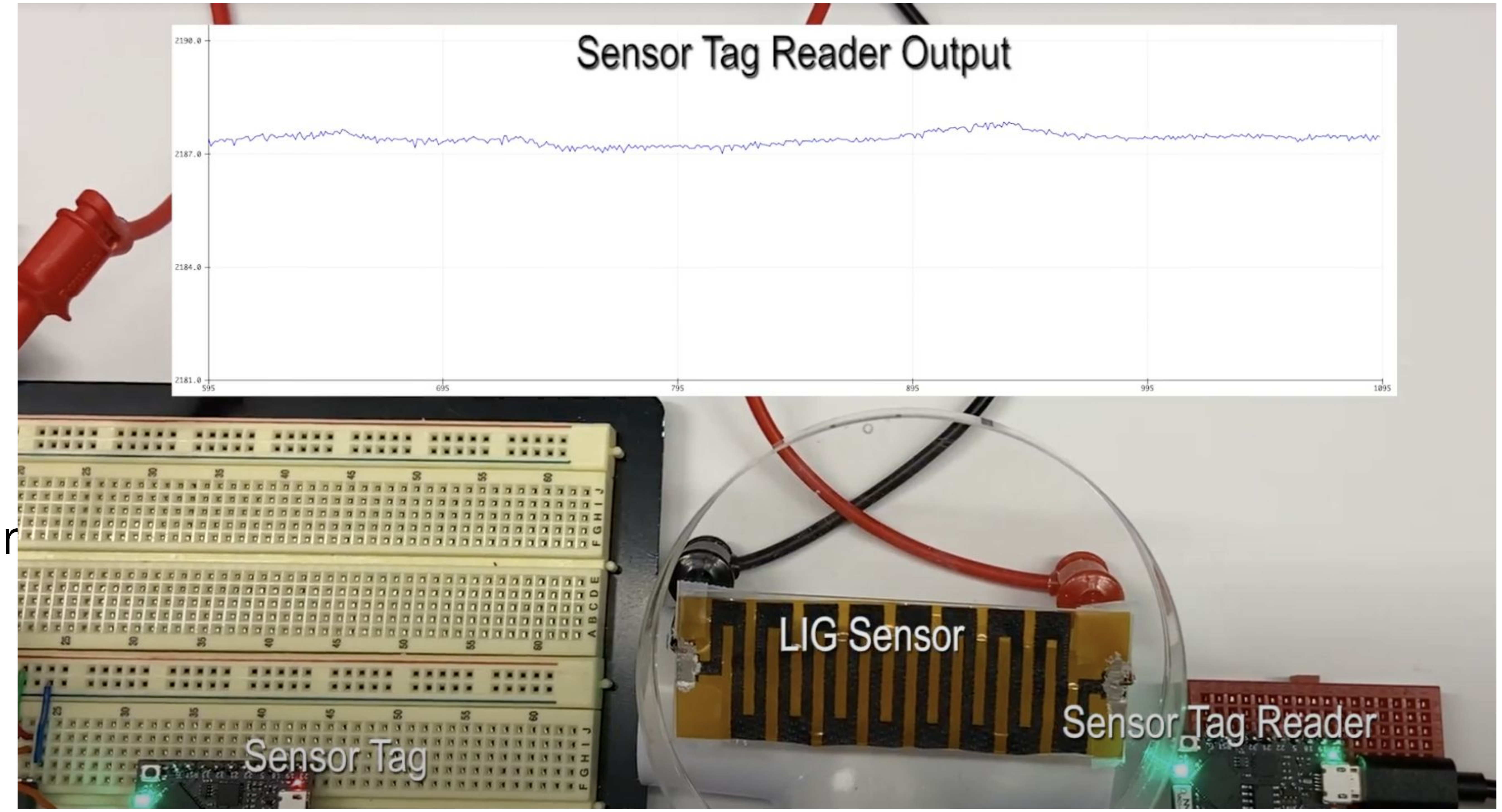
Undergraduate Research Team (Sum22-S23)



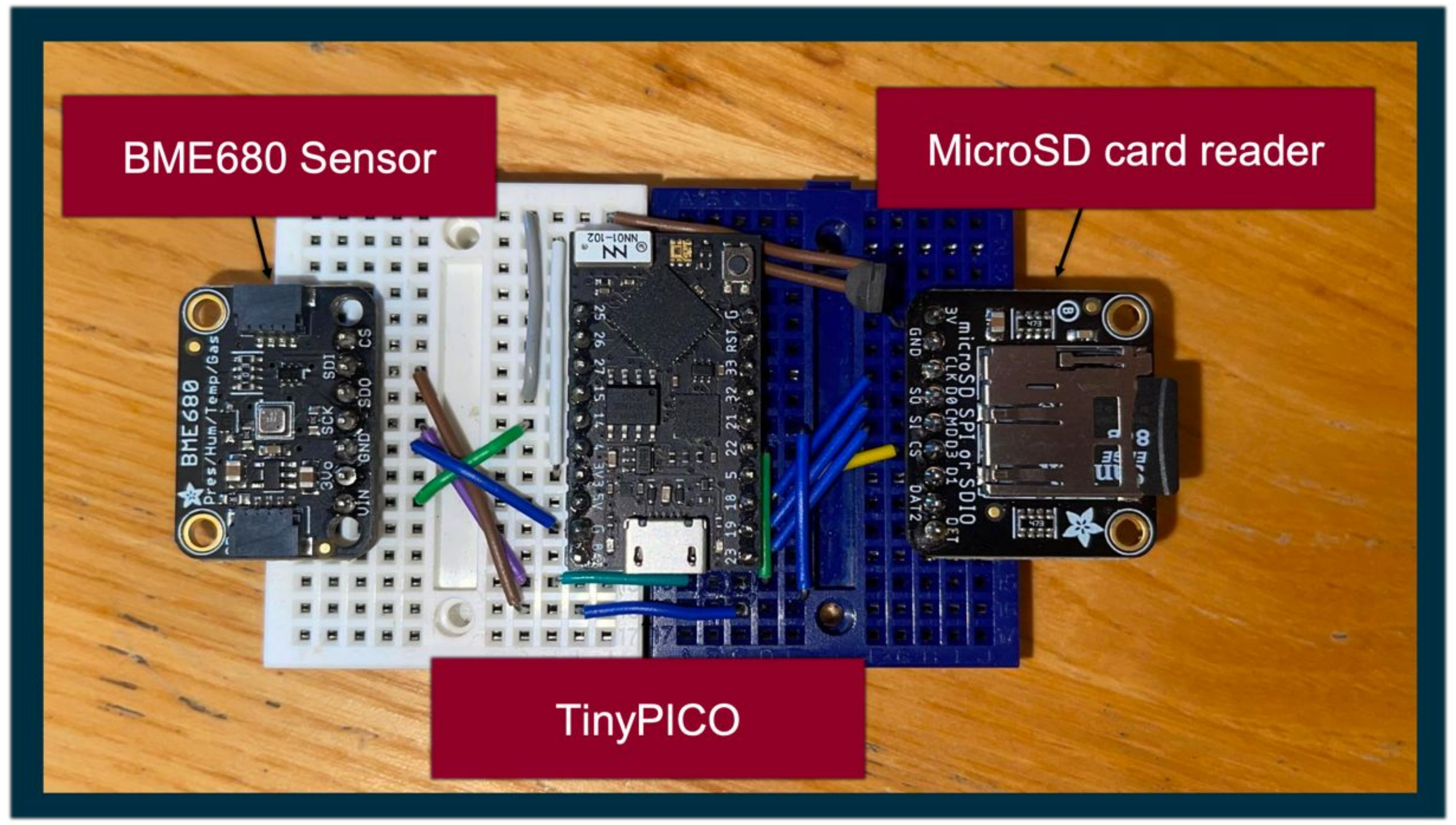
Jaelyn Friberg

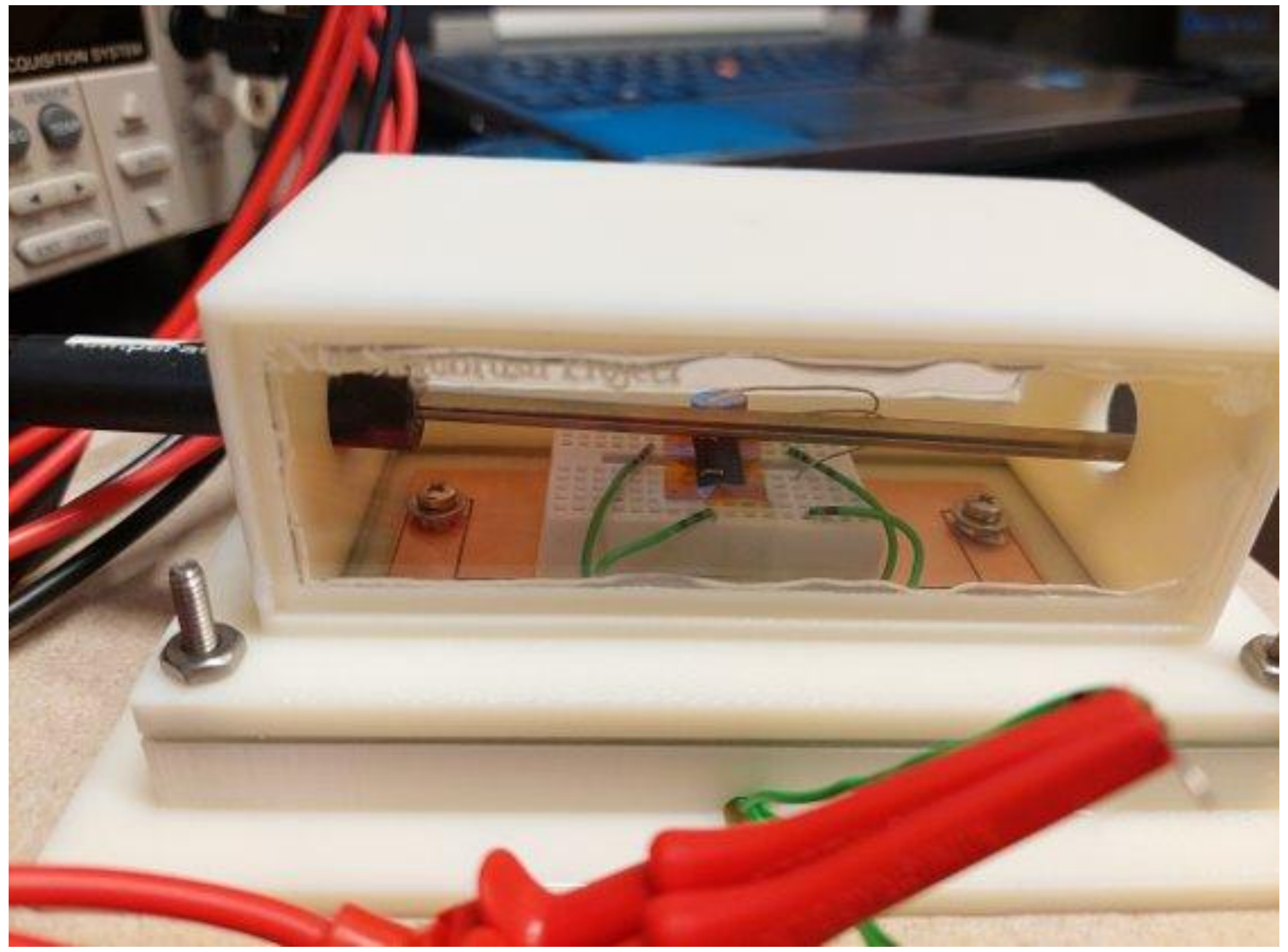
LIG Sensor Development

- Switched to using a Glowforge laser printer
- Experimented with many production variables
    - Pattern shape, laser intensity, laser speed, etc.
- Landed on a serpentine pattern
- Tested full system integration
- Saw slight response to wafting VOC
    - However, showed similar responses to var other stimuli



Undergraduate Research Team (Sum23)

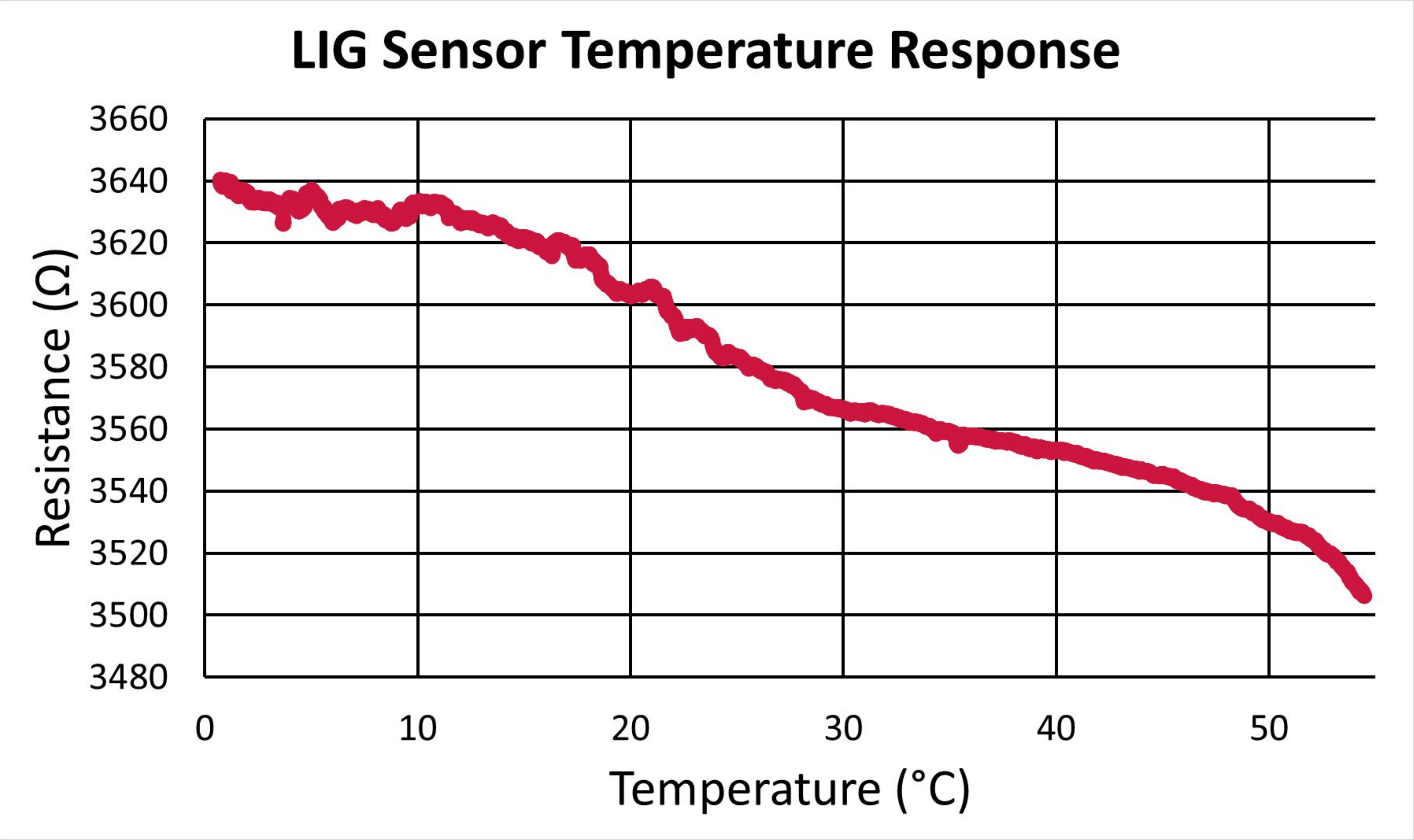


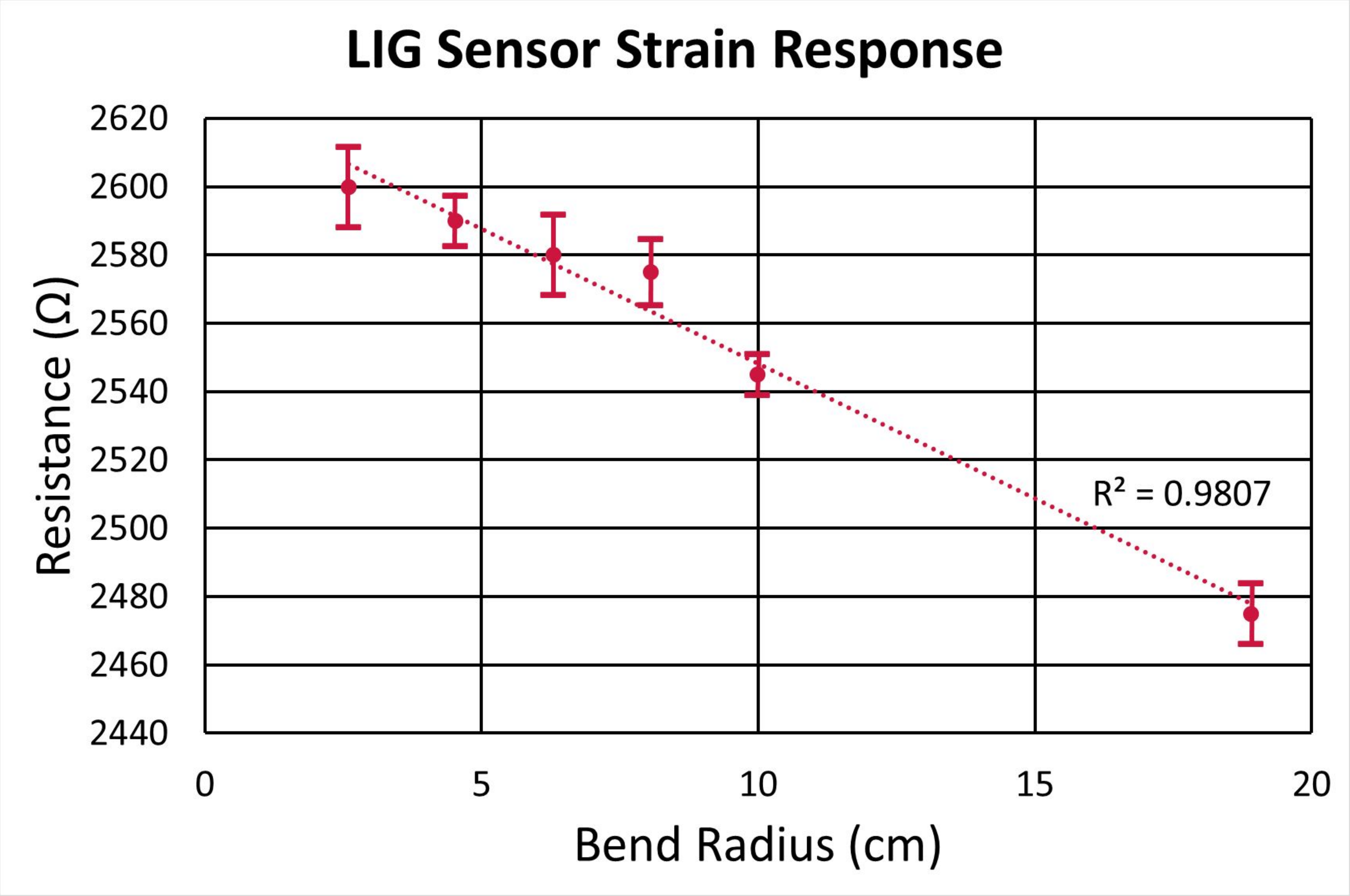


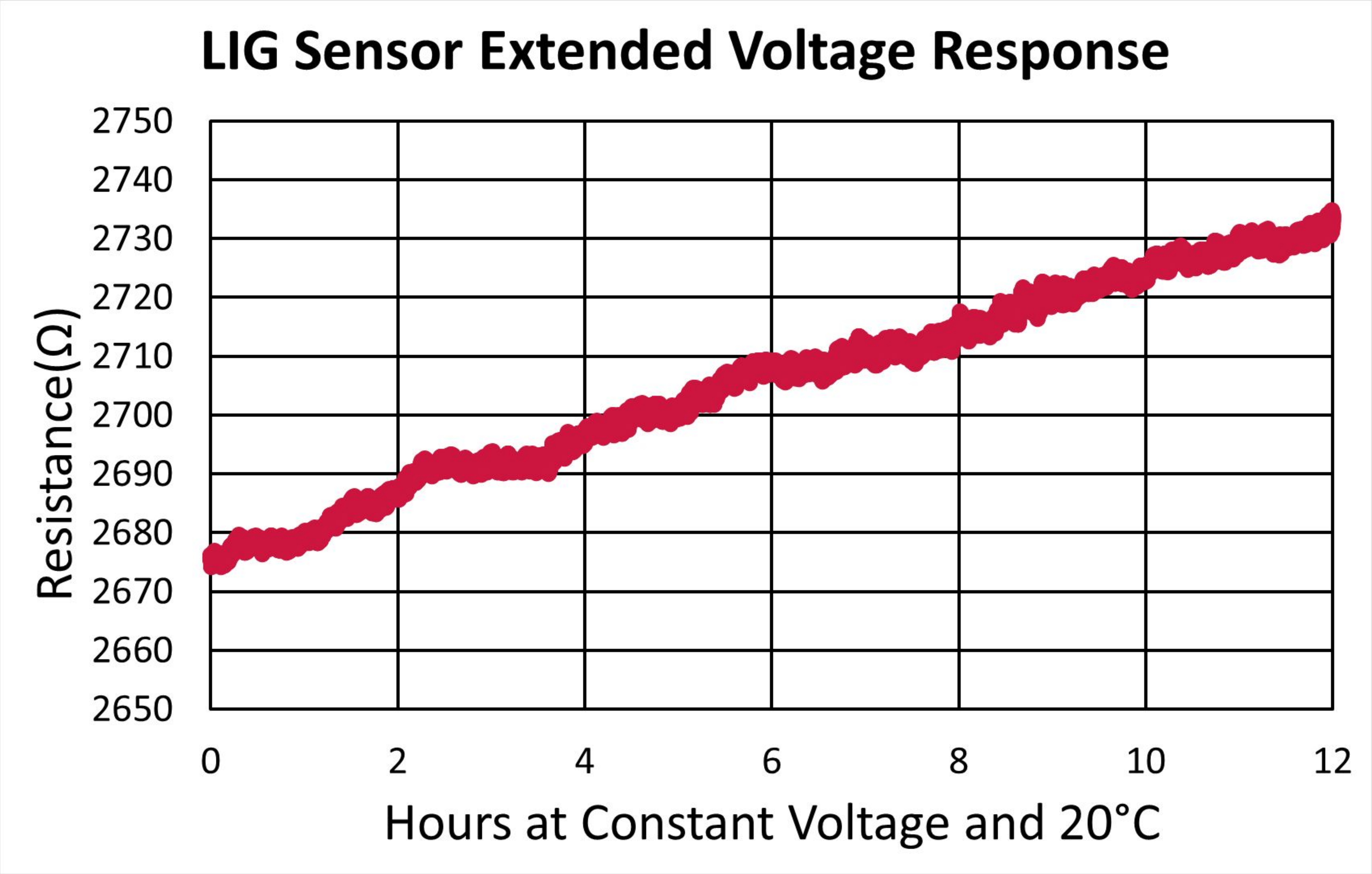
Devin McCall

LIG Sensor Characterization

- Looked into the LIG sensor's
  - Temperature response
  - Degradation at constant voltage and temperature
  - Strain/bending response







Conclusions

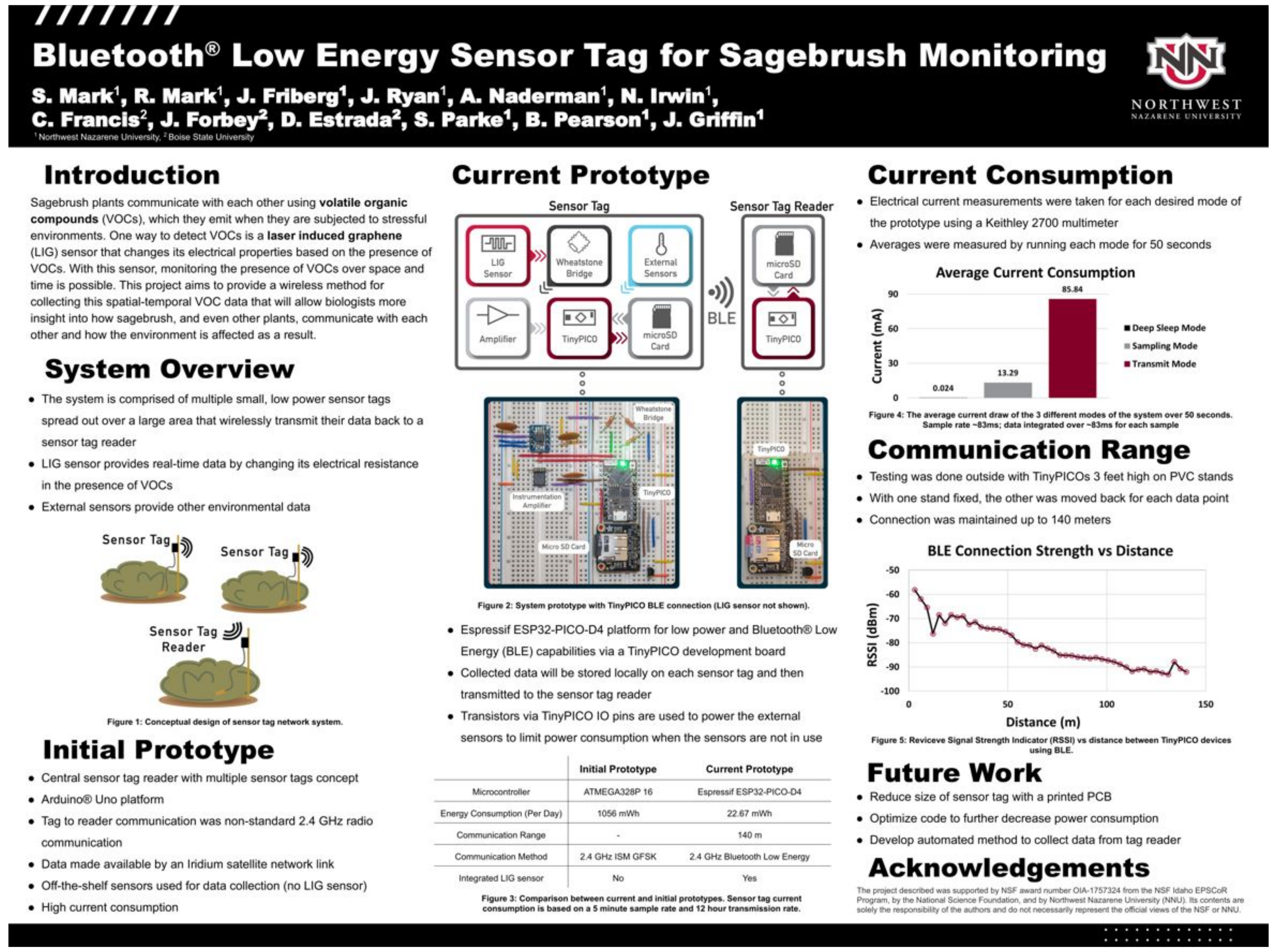
Successfully manufactured and tested LIG sensors

- Explored different manufacturing laser parameters
- Explored temperature response, degradation at constant voltage and temperature, strain/bending response
- Explored LIG sensor response to VOCs

Future work

- Investigate sensitivity and selectivity of the LIG sensor
- Investigate degradation of the LIG sensor

Poster Presentations



Bluetooth® Low Energy Sensor Tag for Sagebrush Monitoring

S. Mark[1], R. Mark[1], J. Friberg[1], J. Ryan[1], A. Naderman[1], N. Irwin[1], C. Francis[2], J. Forbey[2], D. Estrada[2], S. Parke[1], B. Pearson[1], J. Griffin[1]
[1] Northwest Nazarene University, [2] Boise State University

Introduction

Sagebrush plants communicate with each other using **volatile organic compounds** (VOCs), which they emit when they are subjected to stressful environments. One way to detect VOCs is a **laser induced graphene** (LIG) sensor that changes its electrical properties based on the presence of VOCs. With this sensor, monitoring the presence of VOCs over space and time is possible. This project aims to provide a wireless method for collecting this spatial-temporal VOC data that will allow biologists more insight into how sagebrush, and even other plants, communicate with each other and how the environment is affected as a result.

System Overview

- The system is comprised of multiple small, low power sensor tags spread out over a large area that wirelessly transmit their data back to a sensor tag reader
- LIG sensor provides real-time data by changing its electrical resistance in the presence of VOCs
- External sensors provide other environmental data

Figure 1: Conceptual design of sensor tag network system.

Initial Prototype

- Central sensor tag reader with multiple sensor tags concept
- Arduino® Uno platform
- Tag to reader communication was non-standard 2.4 GHz radio communication
- Data made available by an Iridium satellite network link
- Off-the-shelf sensors used for data collection (no LIG sensor)
- High current consumption

Current Prototype

Figure 2: System prototype with TinyPICO BLE connection (LIG sensor not shown).

- Espressif ESP32-PICO-D4 platform for low power and Bluetooth® Low Energy (BLE) capabilities via a TinyPICO development board
- Collected data will be stored locally on each sensor tag and then transmitted to the sensor tag reader
- Transistors via TinyPICO IO pins are used to power the external sensors to limit power consumption when the sensors are not in use

	Initial Prototype	Current Prototype
Microcontroller	ATMEGA328P 16	Espressif ESP32-PICO-D4
Energy Consumption (Per Day)	1056 mWh	22.67 mWh
Communication Range	-	140 m
Communication Method	2.4 GHz ISM GFSK	2.4 GHz Bluetooth Low Energy
Integrated LIG sensor	No	Yes

Figure 3: Comparison between current and initial prototypes. Sensor tag current consumption is based on a 5 minute sample rate and 12 hour transmission rate.

Current Consumption

- Electrical current measurements were taken for each desired mode of the prototype using a Keithley 2700 multimeter
- Averages were measured by running each mode for 50 seconds

Figure 4: The average current draw of the 3 different modes of the system over 50 seconds. Sample rate ~83ms; data integrated over ~83ms for each sample

Communication Range

- Testing was done outside with TinyPICOs 3 feet high on PVC stands
- With one stand fixed, the other was moved back for each data point
- Connection was maintained up to 140 meters

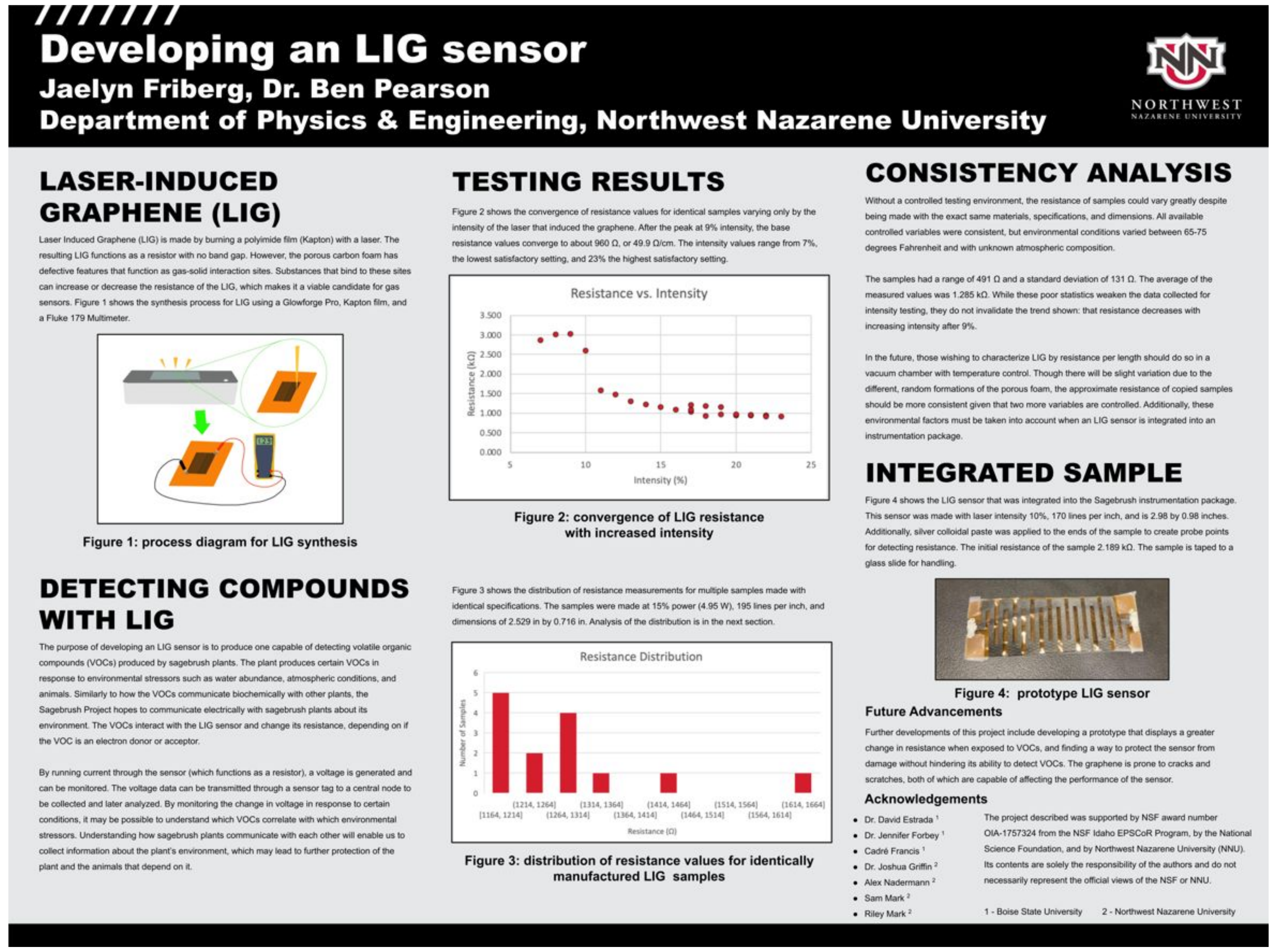
Figure 5: Reviceve Signal Strength Indicator (RSSI) vs distance between TinyPICO devices using BLE.

Future Work

- Reduce size of sensor tag with a printed PCB
- Optimize code to further decrease power consumption
- Develop automated method to collect data from tag reader

Acknowledgements

The project described was supported by NSF award number OIA-1757324 from the NSF Idaho EPSCoR Program, by the National Science Foundation, and by Northwest Nazarene University (NNU). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the NSF or NNU.



Developing an LIG sensor

Jaelyn Friberg, Dr. Ben Pearson
Department of Physics & Engineering, Northwest Nazarene University

LASER-INDUCED GRAPHENE (LIG)

Laser Induced Graphene (LIG) is made by burning a polyimide film (Kapton) with a laser. The resulting LIG functions as a resistor with no band gap. However, the porous carbon foam has defective features that function as gas-solid interaction sites. Substances that bind to these sites can increase or decrease the resistance of the LIG, which makes it a viable candidate for gas sensors. Figure 1 shows the synthesis process for LIG using a Glowforge Pro, Kapton film, and a Fluke 179 Multimeter.

Figure 1: process diagram for LIG synthesis

DETECTING COMPOUNDS WITH LIG

The purpose of developing an LIG sensor is to produce one capable of detecting volatile organic compounds (VOCs) produced by sagebrush plants. The plant produces certain VOCs in response to environmental stressors such as water abundance, atmospheric conditions, and animals. Similarly to how the VOCs communicate biochemically with other plants, the Sagebrush Project hopes to communicate electrically with sagebrush plants about its environment. The VOCs interact with the LIG sensor and change its resistance, depending on if the VOC is an electron donor or acceptor.

By running current through the sensor (which functions as a resistor), a voltage is generated and can be monitored. The voltage data can be transmitted through a sensor tag to a central node to be collected and later analyzed. By monitoring the change in voltage in response to certain conditions, it may be possible to understand which VOCs correlate with which environmental stressors. Understanding how sagebrush plants communicate with each other will enable us to collect information about the plant's environment, which may lead to further protection of the plant and the animals that depend on it.

TESTING RESULTS

Figure 2 shows the convergence of resistance values for identical samples varying only by the intensity of the laser that induced the graphene. After the peak at 9% intensity, the base resistance values converge to about 960 Ω, or 49.9 Ω/cm. The intensity values range from 7%, the lowest satisfactory setting, and 23% the highest satisfactory setting.

Figure 2: convergence of LIG resistance with increased intensity

Figure 3 shows the distribution of resistance measurements for multiple samples made with identical specifications. The samples were made at 15% power (4.95 W), 195 lines per inch, and dimensions of 2.529 in by 0.716 in. Analysis of the distribution is in the next section.

Figure 3: distribution of resistance values for identically manufactured LIG samples

CONSISTENCY ANALYSIS

Without a controlled testing environment, the resistance of samples could vary greatly despite being made with the exact same materials, specifications, and dimensions. All available controlled variables were consistent, but environmental conditions varied between 65-75 degrees Fahrenheit and with unknown atmospheric composition.

The samples had a range of 491 Ω and a standard deviation of 131 Ω. The average of the measured values was 1.285 kΩ. While these poor statistics weaken the data collected for intensity testing, they do not invalidate the trend shown: that resistance decreases with increasing intensity after 9%.

In the future, those wishing to characterize LIG by resistance per length should do so in a vacuum chamber with temperature control. Though there will be slight variation due to the different, random formations of the porous foam, the approximate resistance of copied samples should be more consistent given that two more variables are controlled. Additionally, these environmental factors must be taken into account when an LIG sensor is integrated into an instrumentation package.

INTEGRATED SAMPLE

Figure 4 shows the LIG sensor that was integrated into the Sagebrush instrumentation package. This sensor was made with laser intensity 10%, 170 lines per inch, and is 2.98 by 0.98 inches. Additionally, silver colloidal paste was applied to the ends of the sample to create probe points for detecting resistance. The initial resistance of the sample 2.189 kΩ. The sample is taped to a glass slide for handling.

Figure 4: prototype LIG sensor

Future Advancements

Further developments of this project include developing a prototype that displays a greater change in resistance when exposed to VOCs, and finding a way to protect the sensor from damage without hindering its ability to detect VOCs. The graphene is prone to cracks and scratches, both of which are capable of affecting the performance of the sensor.

Acknowledgements

- Dr. David Estrada [1]
- Dr. Jennifer Forbey [1]
- Cadré Francis [1]
- Dr. Joshua Griffin [2]
- Alex Nadermann [2]
- Sam Mark [2]
- Riley Mark [2]

The project described was supported by NSF award number OIA-1757324 from the NSF Idaho EPSCoR Program, by the National Science Foundation, and by Northwest Nazarene University (NNU). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the NSF or NNU.

1 - Boise State University 2 - Northwest Nazarene University

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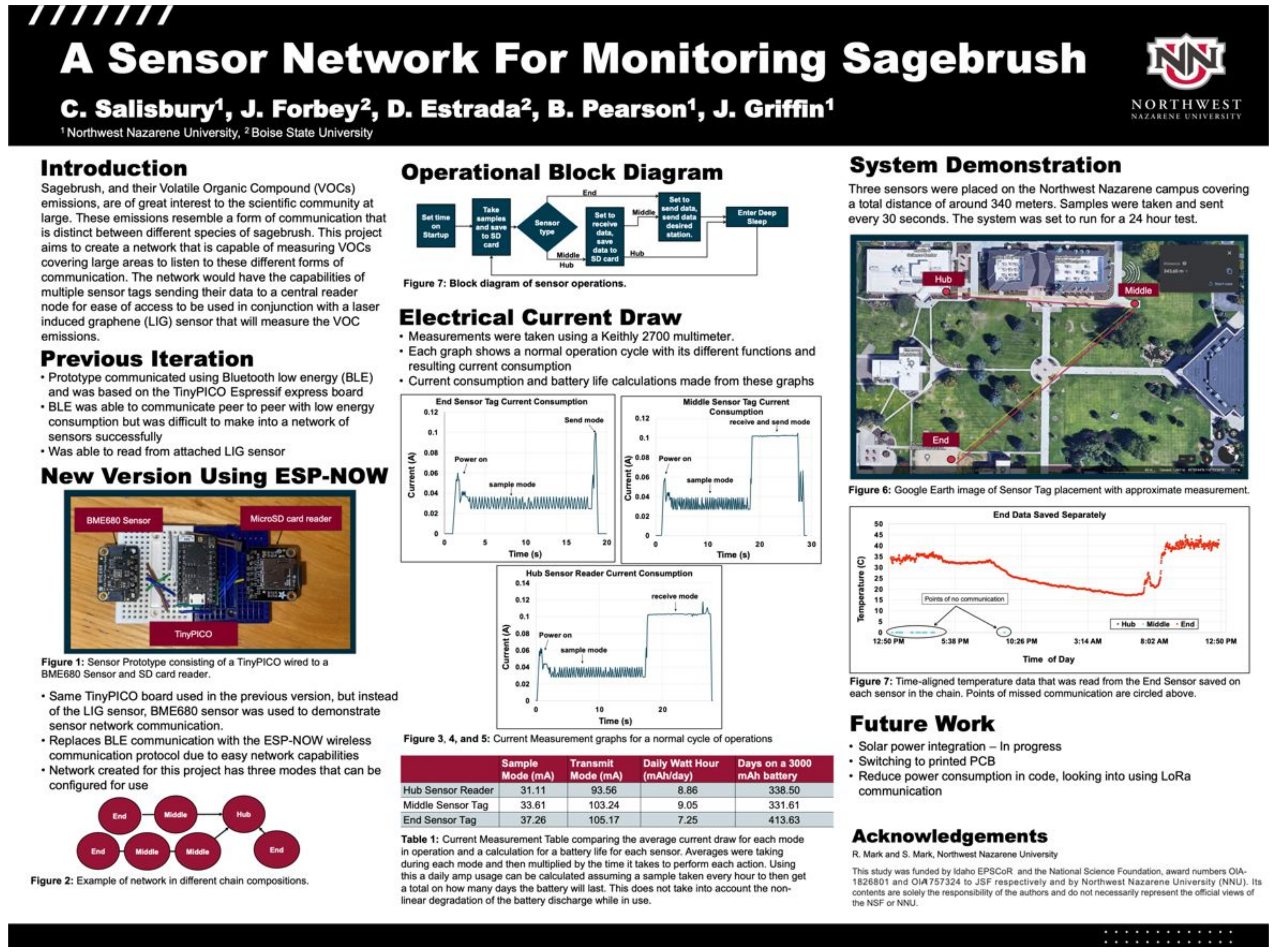

A Sensor Network For Monitoring Sagebrush

C. Salisbury[1], J. Forbey[2], D. Estrada[2], B. Pearson[1], J. Griffin[1]
[1] Northwest Nazarene University, [2] Boise State University

Introduction

Sagebrush, and their Volatile Organic Compound (VOCs) emissions, are of great interest to the scientific community at large. These emissions resemble a form of communication that is distinct between different species of sagebrush. This project aims to create a network that is capable of measuring VOCs covering large areas to listen to these different forms of communication. The network would have the capabilities of multiple sensor tags sending their data to a central reader node for ease of access to be used in conjunction with a laser induced graphene (LIG) sensor that will measure the VOC emissions.

Previous Iteration

- Prototype communicated using Bluetooth low energy (BLE) and was based on the TinyPICO Espressif express board
- BLE was able to communicate peer to peer with low energy consumption but was difficult to make into a network of sensors successfully
- Was able to read from attached LIG sensor

New Version Using ESP-NOW

Figure 1: Sensor Prototype consisting of a TinyPICO wired to a BME680 Sensor and SD card reader.

- Same TinyPICO board used in the previous version, but instead of the LIG sensor, BME680 sensor was used to demonstrate sensor network communication.
- Replaces BLE communication with the ESP-NOW wireless communication protocol due to easy network capabilities
- Network created for this project has three modes that can be configured for use

Figure 2: Example of network in different chain compositions.

Operational Block Diagram

Figure 7: Block diagram of sensor operations.

Electrical Current Draw

- Measurements were taken using a Keithly 2700 multimeter.
- Each graph shows a normal operation cycle with its different functions and resulting current consumption
- Current consumption and battery life calculations made from these graphs

Figure 3, 4, and 5: Current Measurement graphs for a normal cycle of operations

	Sample Mode (mA)	Transmit Mode (mA)	Daily Watt Hour (mAh/day)	Days on a 3000 mAh battery
Hub Sensor Reader	31.11	93.56	8.86	338.50
Middle Sensor Tag	33.61	103.24	9.05	331.61
End Sensor Tag	37.26	105.17	7.25	413.63

Table 1: Current Measurement Table comparing the average current draw for each mode in operation and a calculation for a battery life for each sensor. Averages were taking during each mode and then multiplied by the time it takes to perform each action. Using this a daily amp usage can be calculated assuming a sample taken every hour to then get a total on how many days the battery will last. This does not take into account the non-linear degradation of the battery discharge while in use.

System Demonstration

Three sensors were placed on the Northwest Nazarene campus covering a total distance of around 340 meters. Samples were taken and sent every 30 seconds. The system was set to run for a 24 hour test.

Figure 6: Google Earth image of Sensor Tag placement with approximate measurement.

Figure 7: Time-aligned temperature data that was read from the End Sensor saved on each sensor in the chain. Points of missed communication are circled above.

Future Work

- Solar power integration – In progress
- Switching to printed PCB
- Reduce power consumption in code, looking into using LoRa communication

Acknowledgements

R. Mark and S. Mark, Northwest Nazarene University

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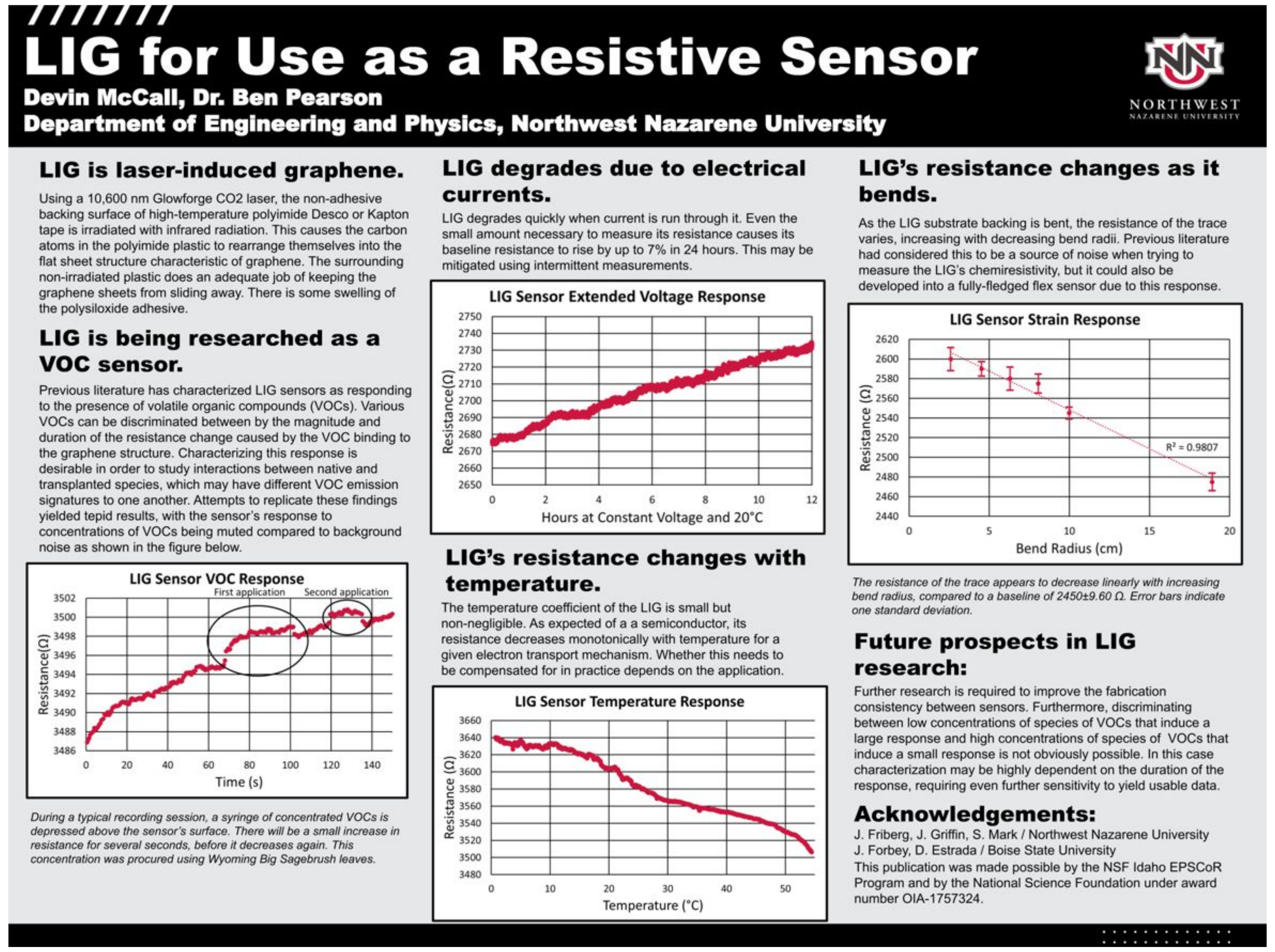

LIG for Use as a Resistive Sensor

Devin McCall, Dr. Ben Pearson
Department of Engineering and Physics, Northwest Nazarene University

LIG is laser-induced graphene.

Using a 10,600 nm Glowforge CO2 laser, the non-adhesive backing surface of high-temperature polyimide Desco or Kapton tape is irradiated with infrared radiation. This causes the carbon atoms in the polyimide plastic to rearrange themselves into the flat sheet structure characteristic of graphene. The surrounding non-irradiated plastic does an adequate job of keeping the graphene sheets from sliding away. There is some swelling of the polysiloxide adhesive.

LIG is being researched as a VOC sensor.

Previous literature has characterized LIG sensors as responding to the presence of volatile organic compounds (VOCs). Various VOCs can be discriminated between by the magnitude and duration of the resistance change caused by the VOC binding to the graphene structure. Characterizing this response is desirable in order to study interactions between native and transplanted species, which may have different VOC emission signatures to one another. Attempts to replicate these findings yielded tepid results, with the sensor's response to concentrations of VOCs being muted compared to background noise as shown in the figure below.

During a typical recording session, a syringe of concentrated VOCs is depressed above the sensor's surface. There will be a small increase in resistance for several seconds, before it decreases again. This concentration was procured using Wyoming Big Sagebrush leaves.

LIG degrades due to electrical currents.

LIG degrades quickly when current is run through it. Even the small amount necessary to measure its resistance causes its baseline resistance to rise by up to 7% in 24 hours. This may be mitigated using intermittent measurements.

LIG's resistance changes with temperature.

The temperature coefficient of the LIG is small but non-negligible. As expected of a a semiconductor, its resistance decreases monotonically with temperature for a given electron transport mechanism. Whether this needs to be compensated for in practice depends on the application.

LIG's resistance changes as it bends.

As the LIG substrate backing is bent, the resistance of the trace varies, increasing with decreasing bend radii. Previous literature had considered this to be a source of noise when trying to measure the LIG's chemiresistivity, but it could also be developed into a fully-fledged flex sensor due to this response.

The resistance of the trace appears to decrease linearly with increasing bend radius, compared to a baseline of 2450±9.60 Ω. Error bars indicate one standard deviation.

Future prospects in LIG research:

Further research is required to improve the fabrication consistency between sensors. Furthermore, discriminating between low concentrations of species of VOCs that induce a large response and high concentrations of species of VOCs that induce a small response is not obviously possible. In this case characterization may be highly dependent on the duration of the response, requiring even further sensitivity to yield usable data.

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J. Friberg, J. Griffin, S. Mark / Northwest Nazarene University
J. Forbey, D. Estrada / Boise State University
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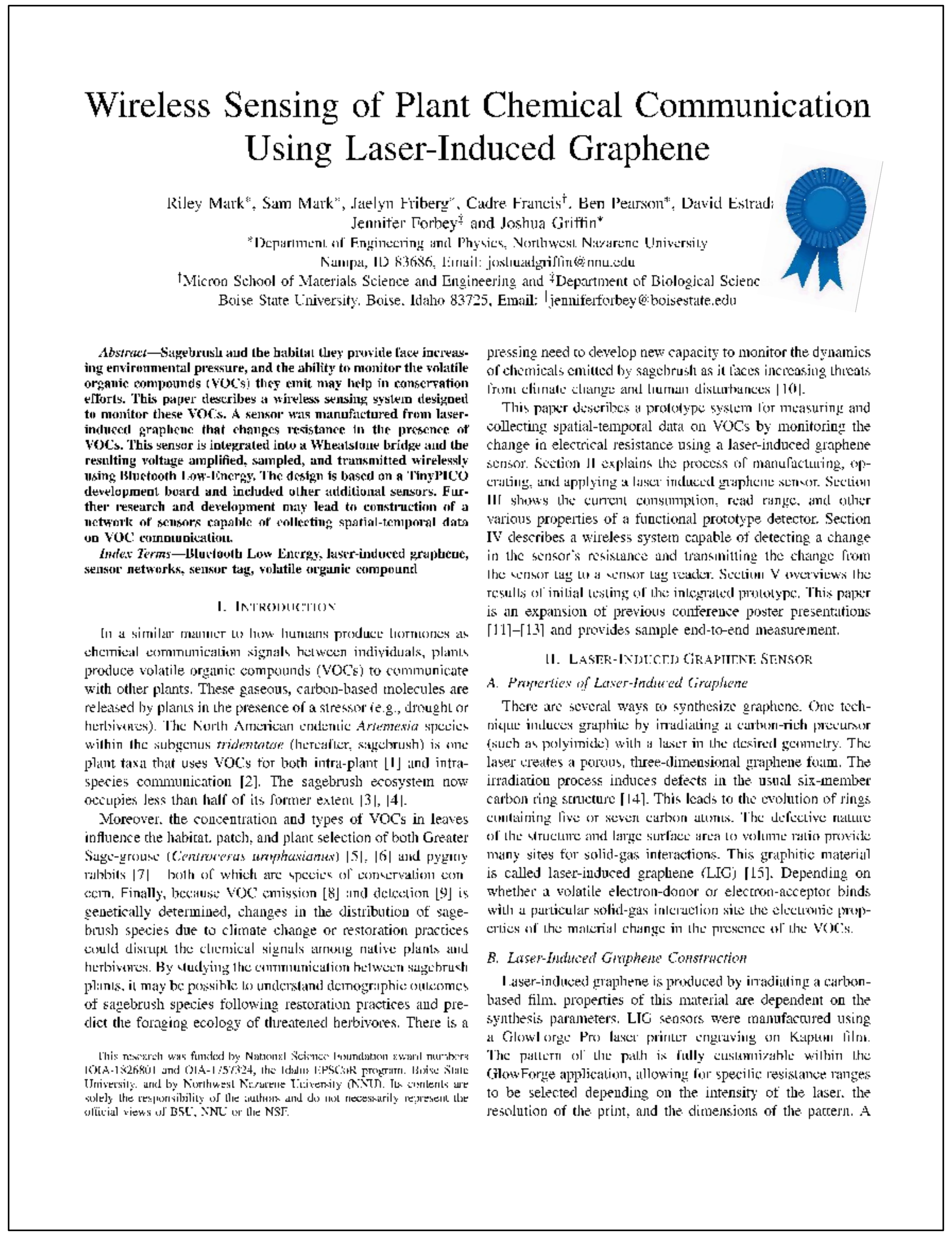

Wireless Sensing of Plant Chemical Communication Using Laser-Induced Graphene

Riley Mark*, Sam Mark*, Jaelyn Friberg*, Cadre Francis†, Ben Pearson*, David Estrad
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***Abstract*—Sagebrush and the habitat they provide face increasing environmental pressure, and the ability to monitor the volatile organic compounds (VOCs) they emit may help in conservation efforts. This paper describes a wireless sensing system designed to monitor these VOCs. A sensor was manufactured from laser-induced graphene that changes resistance in the presence of VOCs. This sensor is integrated into a Wheatstone bridge and the resulting voltage amplified, sampled, and transmitted wirelessly using Bluetooth Low-Energy. The design is based on a TinyPICO development board and included other additional sensors. Further research and development may lead to construction of a network of sensors capable of collecting spatial-temporal data on VOC communication.**

***Index Terms*—Bluetooth Low Energy, laser-induced graphene, sensor networks, sensor tag, volatile organic compound**

I. INTRODUCTION

In a similar manner to how humans produce hormones as chemical communication signals between individuals, plants produce volatile organic compounds (VOCs) to communicate with other plants. These gaseous, carbon-based molecules are released by plants in the presence of a stressor (e.g., drought or herbivores). The North American endemic *Artemesia* species within the subgenus *tridentatae* (hereafter, sagebrush) is one plant taxa that uses VOCs for both intra-plant [1] and intra-species communication [2]. The sagebrush ecosystem now occupies less than half of its former extent [3], [4].

Moreover, the concentration and types of VOCs in leaves influence the habitat, patch, and plant selection of both Greater Sage-grouse (*Centrocerus urophasianus*) [5], [6] and pygmy rabbits [7] both of which are species of conservation concern. Finally, because VOC emission [8] and detection [9] is genetically determined, changes in the distribution of sagebrush species due to climate change or restoration practices could disrupt the chemical signals among native plants and herbivores. By studying the communication between sagebrush plants, it may be possible to understand demographic outcomes of sagebrush species following restoration practices and predict the foraging ecology of threatened herbivores. There is a pressing need to develop new capacity to monitor the dynamics of chemicals emitted by sagebrush as it faces increasing threats from climate change and human disturbances [10].

This paper describes a prototype system for measuring and collecting spatial-temporal data on VOCs by monitoring the change in electrical resistance using a laser-induced graphene sensor. Section II explains the process of manufacturing, operating, and applying a laser induced graphene sensor. Section III shows the current consumption, read range, and other various properties of a functional prototype detector. Section IV describes a wireless system capable of detecting a change in the sensor's resistance and transmitting the change from the sensor tag to a sensor tag reader. Section V overviews the results of initial testing of the integrated prototype. This paper is an expansion of previous conference poster presentations [11]–[13] and provides sample end-to-end measurement.

II. LASER-INDUCED GRAPHENE SENSOR

A. Properties of Laser-Induced Graphene

There are several ways to synthesize graphene. One technique induces graphite by irradiating a carbon-rich precursor (such as polyimide) with a laser in the desired geometry. The laser creates a porous, three-dimensional graphene foam. The irradiation process induces defects in the usual six-member carbon ring structure [14]. This leads to the evolution of rings containing five or seven carbon atoms. The defective nature of the structure and large surface area to volume ratio provide many sites for solid-gas interactions. This graphitic material is called laser-induced graphene (LIG) [15]. Depending on whether a volatile electron-donor or electron-acceptor binds with a particular solid-gas interaction site the electronic properties of the material change in the presence of the VOCs.

B. Laser-Induced Graphene Construction

Laser-induced graphene is produced by irradiating a carbon-based film. properties of this material are dependent on the synthesis parameters. LIG sensors were manufactured using a GlowForge Pro laser printer engraving on Kapton film. The pattern of the path is fully customizable within the GlowForge application, allowing for specific resistance ranges to be selected depending on the intensity of the laser, the resolution of the print, and the dimensions of the pattern. A

This research was funded by National Science Foundation award numbers IOIA-1826801 and OIA-1757324, the Idaho EPSCoR program, Boise State University, and by Northwest Nazarene University (NNU). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of BSU, NNU or the NSF.

Best Paper in Idaho Track!

2023 IEEE International Conference on Digital Twins and Parallel Intelligence
https://2023.ieee-dtpi.org/

IEEE DTPI 2023

Call for Papers

7–9 November 2023 in Orlando, FL

2023.IEEE-DTPI.ORG

3rd Annual IEEE International Conference on Digital Twins and Parallel Intelligence

IEEE DTPI 2023 will present the cutting-edge research and technical progress of the rapidly evolving field of digital twinning. The 2023 Conference will follow a distributed hybrid model with physical meetings and presentations in Orlando and online. The conference aims to brings together scholars and industrial practitioners to share scientific and technological advances as well as to gain a deeper understanding of generating digital twins and deriving parallel intelligence. DTPI's particular topics also include standards, theory, practice, and various vertical applications of DTPI, including smart cities, transportation, energy, robotics, manufacturing, healthcare, spectrum management, etc.

Submissions are invited in the following categories:

FULL TECHNICAL PAPERS (4-6 pages), original contributions addressing relevant DTPI topics of interest listed in this CFP. Review, Tutorial and Vision papers are also welcome. Full technical papers will be submitted to Manuscript Central under the "DTPI 2023" issue. The papers will also receive consideration for direct publication in IEEE Journal on RFID. Authors of accepted papers are expected to present their work at the DTPI Conference in Orlando.

SPECIAL SESSIONS (by invitation), consisting of contributions to fill a two-hour session on DTPI topics of interest. Session proposals must be submitted electronically via e-mail (nedam@gatech.edu). A total of six accepted proposals will be invited to submit special session contributions.

EXTENDED ABSTRACTS (1-2 pages), consisting of a lightly reviewed, 1-2 pages abstracts on DTPI topics of interest to be presented in a poster presentation format at the conference.

INDUSTRIAL FORUM & EXHIBITIONS (IF&E), we additionally accept submissions of proposals for tutorials, demonstrations, posters, workshops and talks targeting cutting-edge, industry-centric topics. Trade space is available for discussions and demonstrations.

*The main technical program will only include papers of the highest standard as selected by the TPC, in accordance with the IEEE guidelines. Final manuscripts should be accompanied by a full registration of at least one author before uploading the camera-ready version. Accepted manuscripts will be presented either in oral or poster format.

Topics of interest include, but not limited to:

Theory of Development for DTPI

Information Infrastructure for DTPI

Data Analytics and Artificial Intelligence R&D for DTPI

DTPI Applications in Vertical Areas:

- Smart Cities
- Smart Infrastructure Systems
- Transportation
- Power & Energy Systems
- Autonomous Vehicles
- Human Systems
- Blockchain and Distributed Systems
- Ecology Digital Twins
- Cyber-Physical Social
- Decision Support Systems
- Healthcare
- Robotics
- Manufacture Systems

Industrial Practices of DTPI

Emerging DT Standards & Practices

Authors of Published Papers receive peer reviews by technology leaders from the multi-disciplinary IEEE DTPI and Council on RFID community and are enrolled in the IEEE DTPI 2023 Best Paper Competition.

Accepted papers will be submitted for inclusion into IEEE Xplore subject to meeting IEEE Xplore's scope and quality requirements.

IEEE DTPI 2023
ORGANIZING COMMITTEE:

Executive Chair:	Grace Bochenek (Univ. of Central FL)
General Chair:	Gisele Bennet (MEPSS)
Vice & Local Arrangement Chair:	Mary Jean Amon (Univ. of Central FL)
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IMPORTANT DATES:

Full Technical Papers: 30 July 2023
Acceptance Notification: 24 Sep 2023
Poster Abstracts: 27 July 2023
Special Session Proposals: 27 July 2023
IF&E Proposals: 16 July 2023
Camera-Ready Uploads: 15 Oct 2023
Physical Conference: 7-9 November 2023

Future Collaboration

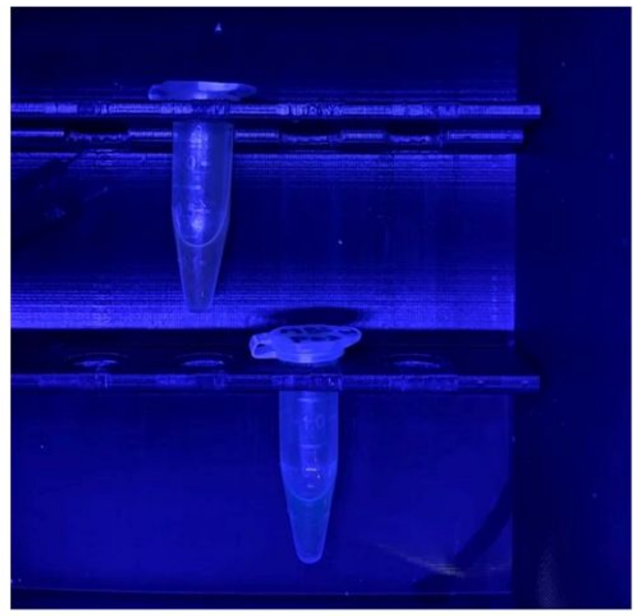
- NNU to serve as an asset-partner with BSU on a recent NSF Research Traineeship (NRT) proposal titled: "NRT-URoL: Transforming Research through Use-Inspired Student Training (TRUST)"

Extra Slides

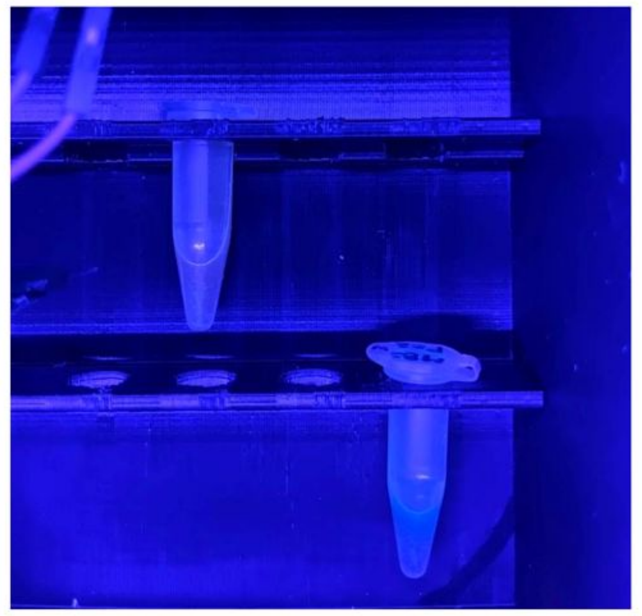
Mobile Darkroom (Sum23)

Allison Verner

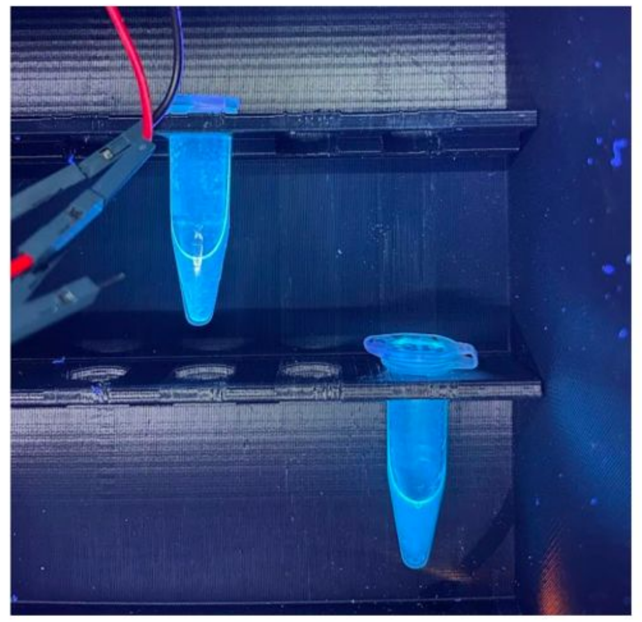
Without an Orange PMMA Filter



410nm
no fluorescence



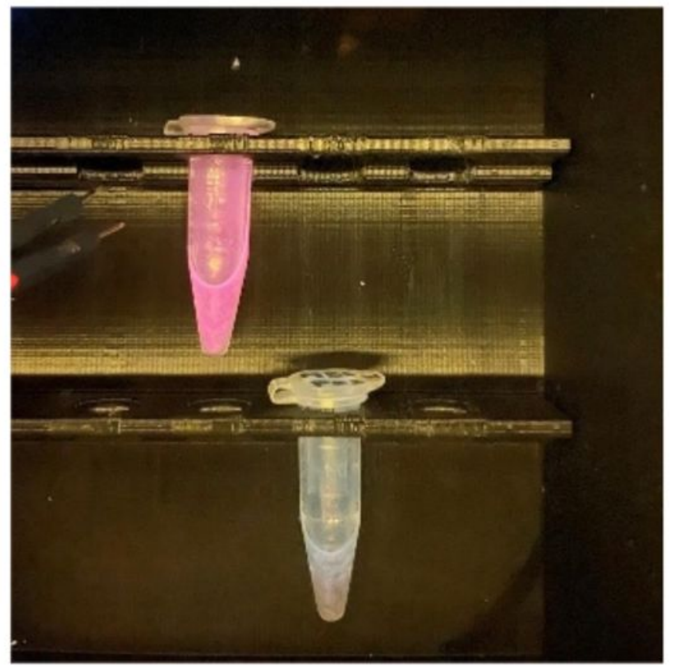
395nm
little fluorescence



365nm
high fluorescence

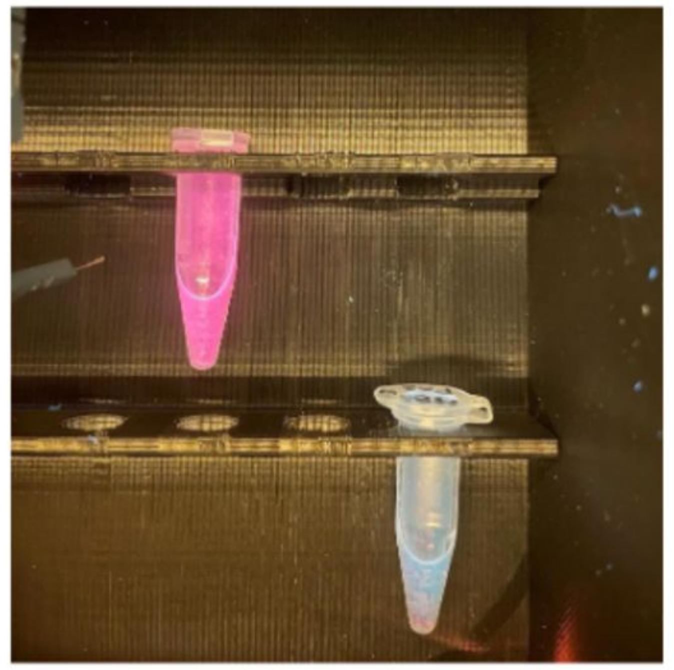
Adding Orange PMMA Filter

In the previous design [1], it was found that by adding an orange filter, the sage brush solution fluoresced differing colors through a phone camera based on species and what the solute was.



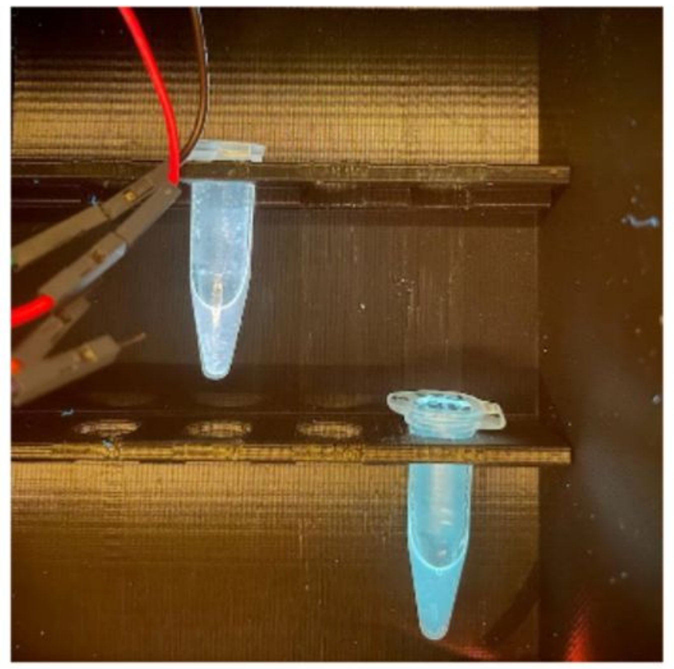
410nm

- Tiny Fluorescence
- Noticeable color change



395nm

- Fluorescence
- Noticeable color change



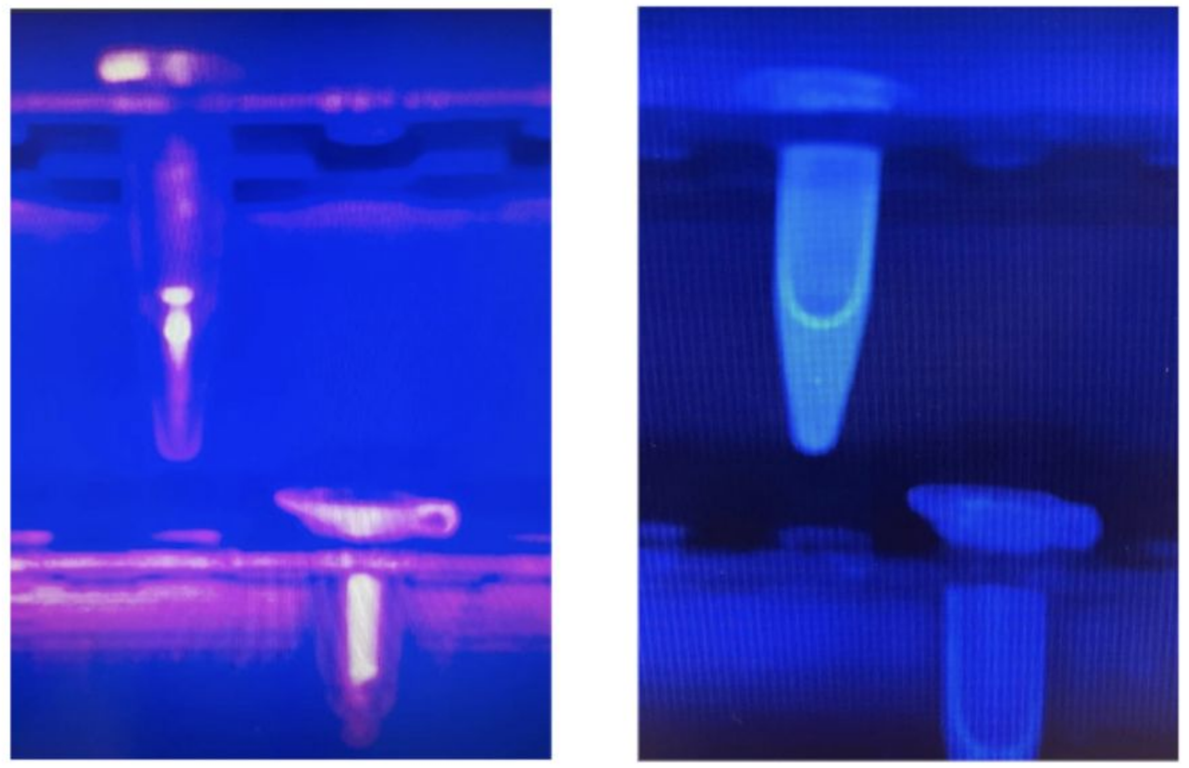
365nm

- Fluorescence
- No noticeable color change

Implementing a Pi Camera

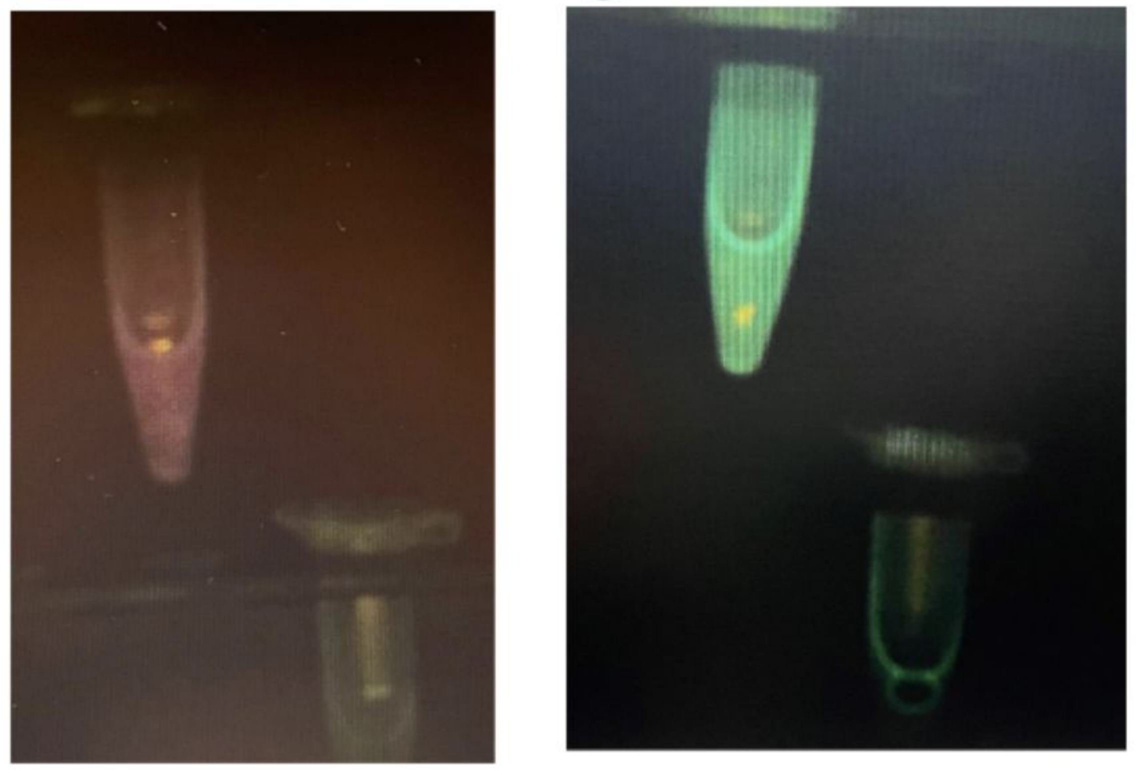
For a more streamlined data collection and further prototyping, a Raspberry Pi camera was implemented.

Without Orange Filter



395nm **365nm**

With Orange Filter



395nm **365nm**

Poster Presentations

A Portable Device for Sagebrush Fluorescence

A. Verner[1], J. Forbey[2], B. Pearson[1], J. Griffin[1]
[1]Northwest Nazarene University, [2]Boise State University

Introduction

The chemical composition of sagebrush and other medicinal plants can be roughly determined by viewing the fluorescence of their leaves when placed in solution and illuminated by ultraviolet (UV) light. This project seeks to develop a mobile dark room to quickly identify leaves with interesting chemical composition in the field so that they can be taken to the lab for further analysis. There have been multiple other devices created for field plant identification and diagnosis, but these devices either do not show the specific qualities of the plant that researchers are looking for or they are expensive. This portable darkroom builds on previous work [1] to solve these two issues.

Design Goals

Maintain previous design features by Andrea Meyer [1]
- Portability
- Ability to induce strong fluoresce
- Ability to collect data quickly and reliably
- Cost effectiveness

Improve upon previous design [1]
- Ability to block ambient light
- Holding samples securely
- Durability

Prototyping

First Printed Prototype **Second Printed Prototype**

Pros
- Held eight samples in PCR tubes
- Portable
- Samples viewed from the side

Cons
- Bulky
- Samples were not easily in view

A Smaller Prototype

The previous prototypes were able to hold eight samples, but they tend to be a bit larger, so a smaller box that holds three samples was created for a lighter more portable option.

Final Printed Prototype

- Keeps light out
- Multiple samples are in view
- Holds eight samples in PCR tubes
- Portable and lightweight

Light Tests

UV Spectrums

Spectrum	Wavelength
UV-A	315-400nm
UV-B	280-315nm
UV-C	100-280nm

UV-A was chosen based on prior work [2] because it produces a strong fluorescence and because UV-B and UV-C pose safety hazards to humans.

Lights in Action

Without an Orange PMMA Filter

410nm
no fluorescence

395nm
little fluorescence

365nm
high fluorescence

Adding Orange PMMA Filter

In the previous design [1], it was found that by adding an orange filter, the sage brush solution fluoresced differing colors through a phone camera based on species and what the solute was.

410nm
- Tiny Fluorescence
- Noticeable color change

395nm
- Fluorescence
- Noticeable color change

365nm
- Fluorescence
- No noticeable color change

Implementing a Pi Camera

For a more streamlined data collection and further prototyping, a Raspberry Pi camera was implemented.

Without Orange Filter
395nm 365nm

With Orange Filter
395nm 365nm

Future Work

- Implement a Raspberry Pi Camera with color recognition to eliminate the time to align the phone camera.
- Create a custom UV array that has low current consumption and operates at five volts.

Acknowledgments

A. Meyer, Boise State University, D. Nogales C. Salisbury: Northwest Nazarene University

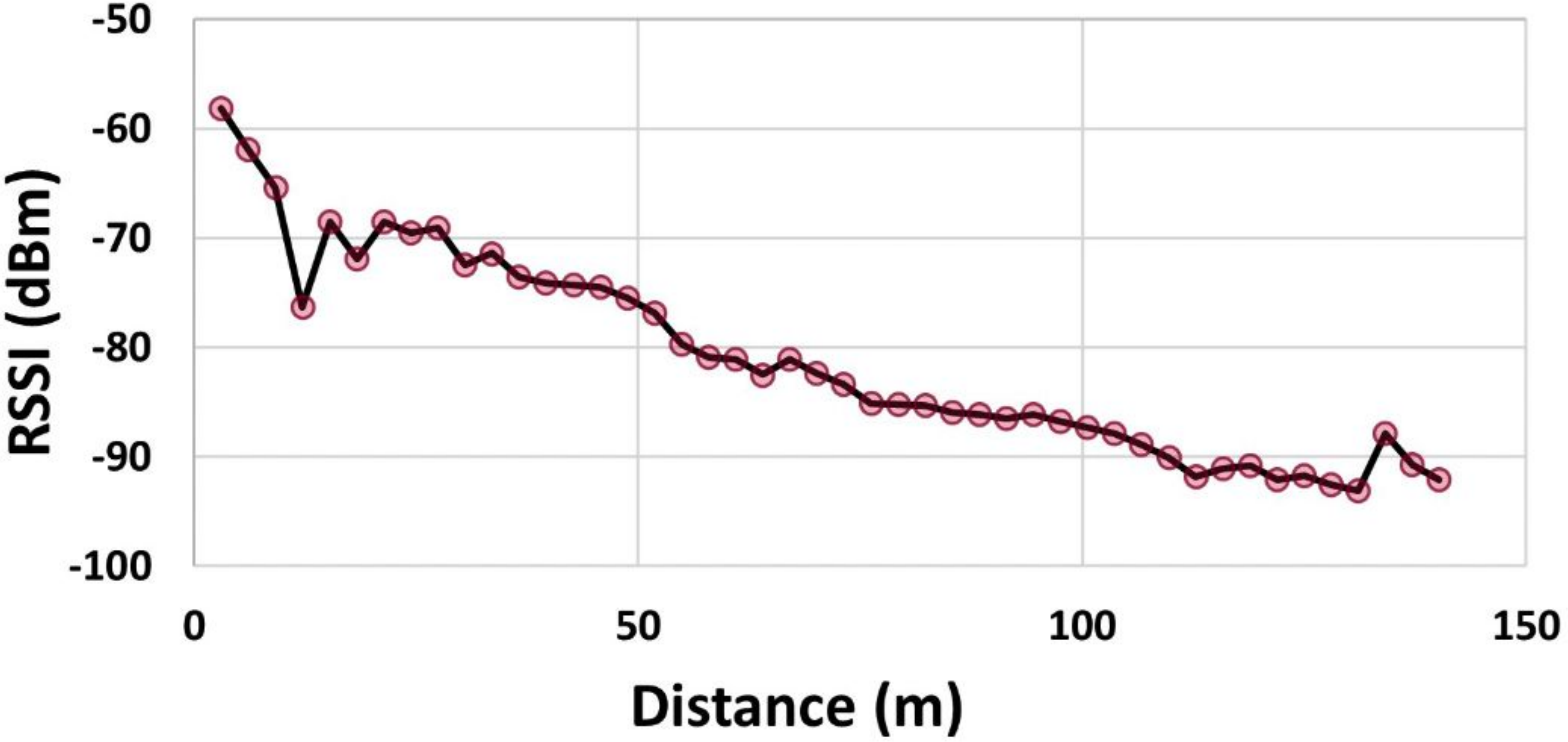
The project described was supported by NSF award number OIA-1757324 from the NSF Idaho EPSCoR Program and by the National Science Foundation.

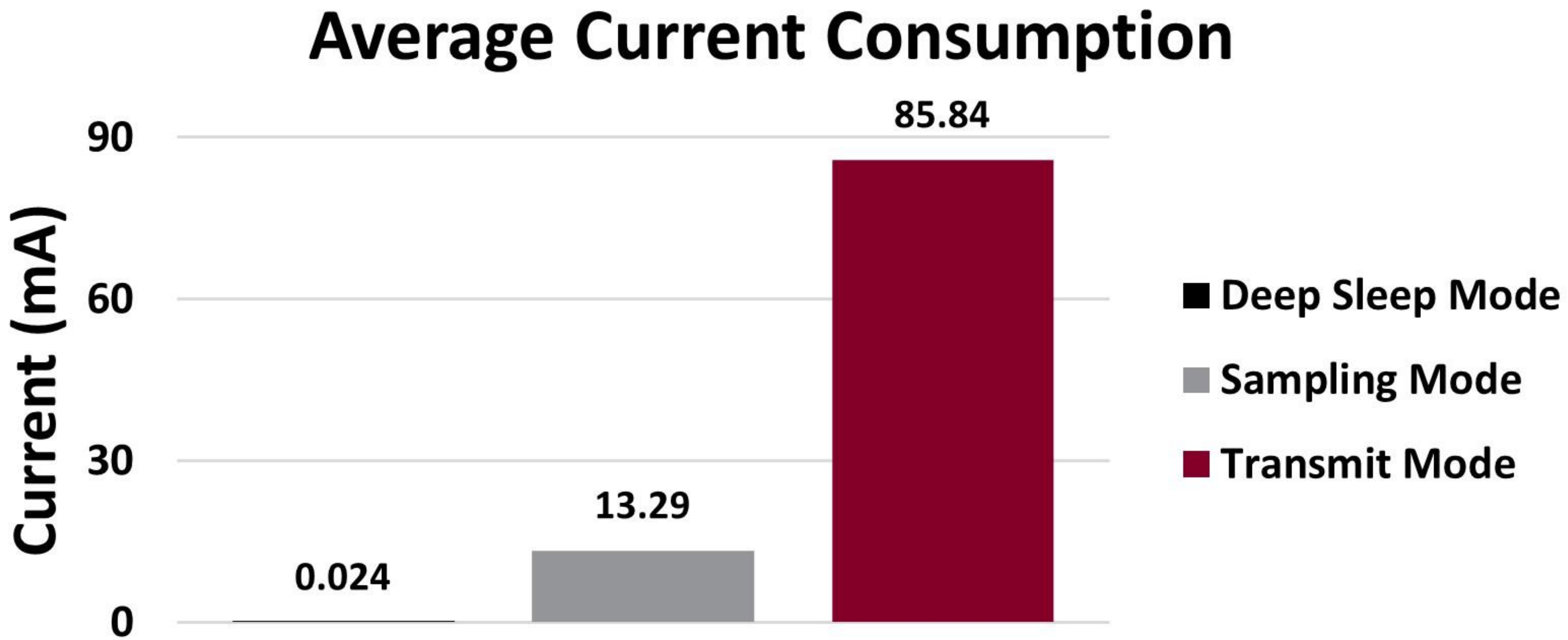
[1] Meyer, Andrea C.; Forbey, Jennifer; Warner, Lisa; Zantman, Aurora; Conner, Debbie; and Meyer, Justan, "Sagebrush UV Fluorescence Viewed and Documented with a Mobile Darkroom" (2022). *2022 Undergraduate Research Showcase*. 105. https://scholarworks.boisestate.edu/under_showcase_2022/105

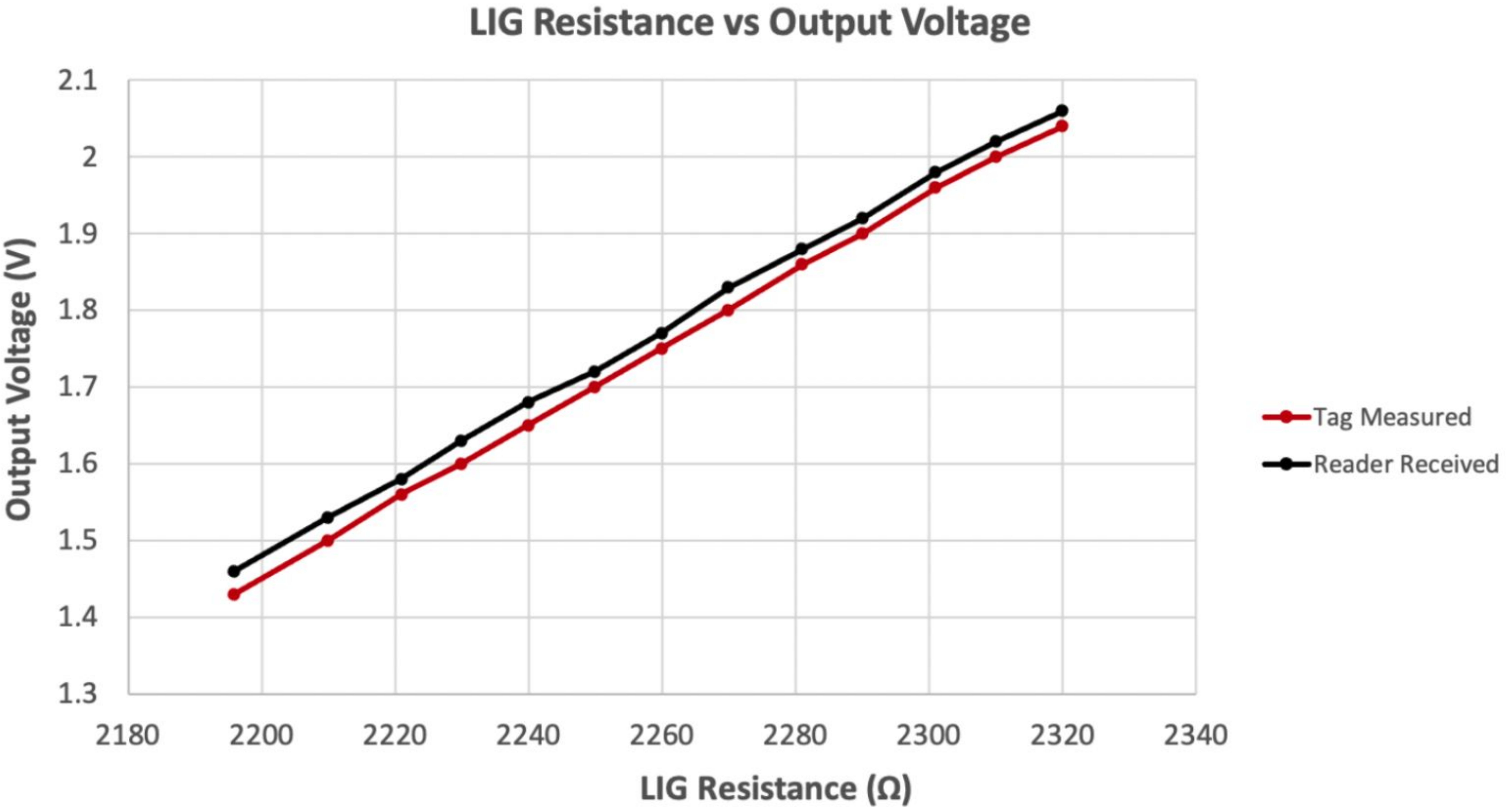
[2] UV Hazards Safety Guideline, UNMC, https://www.unmc.edu/ehs/safety/UVHazardsSafetyGuideline.pdf

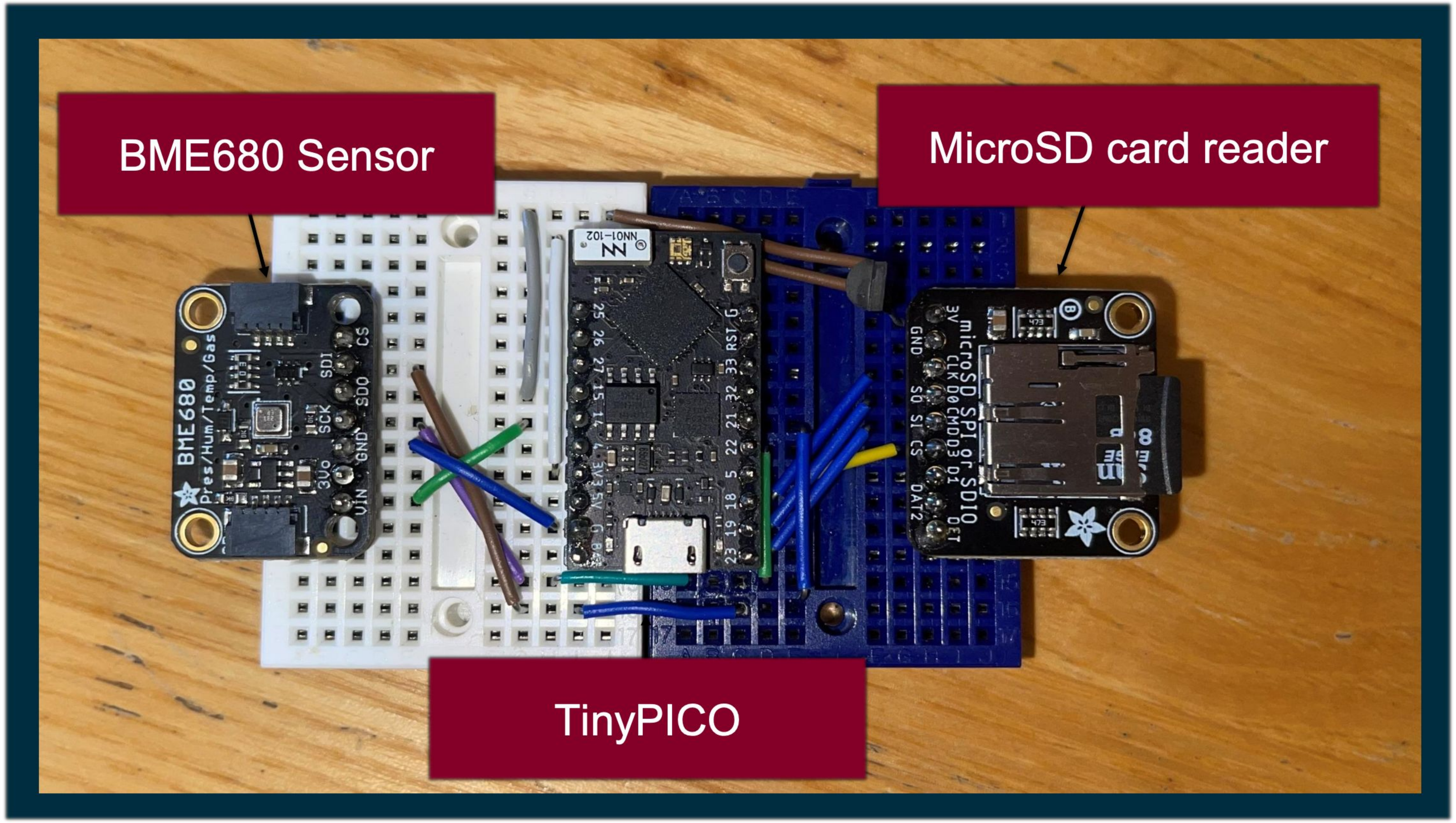
ICUR 2023

BLE Connection Strength vs Distance




Average Current Consumption
Current (mA)
90
60
30
0
0.024
13.29
85.84
■ Deep Sleep Mode
■ Sampling Mode
■ Transmit Mode


LIG Resistance vs Output Voltage
Output Voltage (V)
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
2180
2200
2220
2240
2260
2280
2300
2320
2340
LIG Resistance (Ω)
Tag Measured
Reader Received



BME680 Sensor

MicroSD card reader

TinyPICO

	Sample Mode (mA)	**Transmit Mode (mA)**	**Daily Watt Hour (mAh/day)**	**Days on a 3000 mAh battery**
Hub Sensor Reader	31.11	93.56	8.86	338.50
Middle Sensor Tag	33.61	103.24	9.05	331.61
End Sensor Tag	37.26	105.17	7.25	413.63

Table 1: Current Measurement Table comparing the average current draw for each mode in operation and a calculation for a battery life for each sensor. Averages were taking during each mode and then multiplied by the time it takes to perform each action. Using this a daily amp usage can be calculated assuming a sample taken every hour to then get a total on how many days the battery will last. This does not take into account the non-linear degradation of the battery discharge while in use.

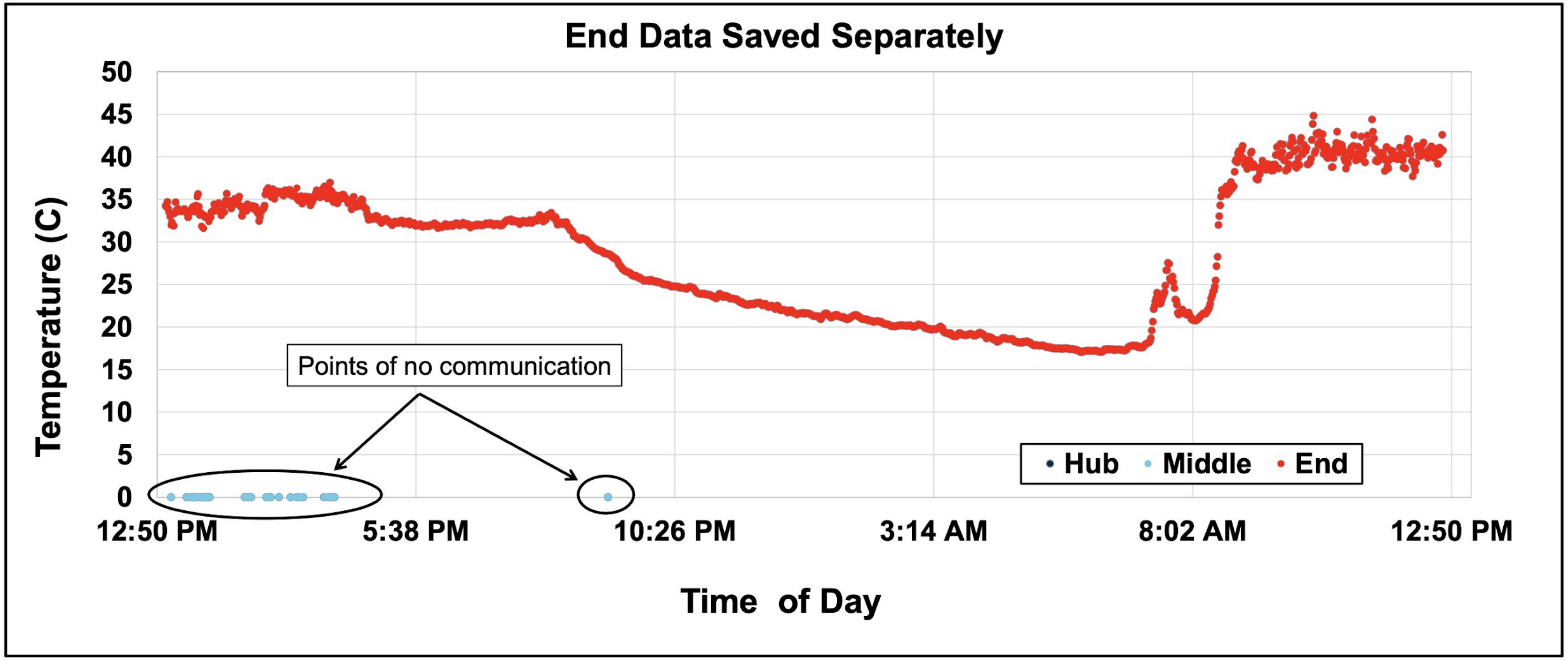
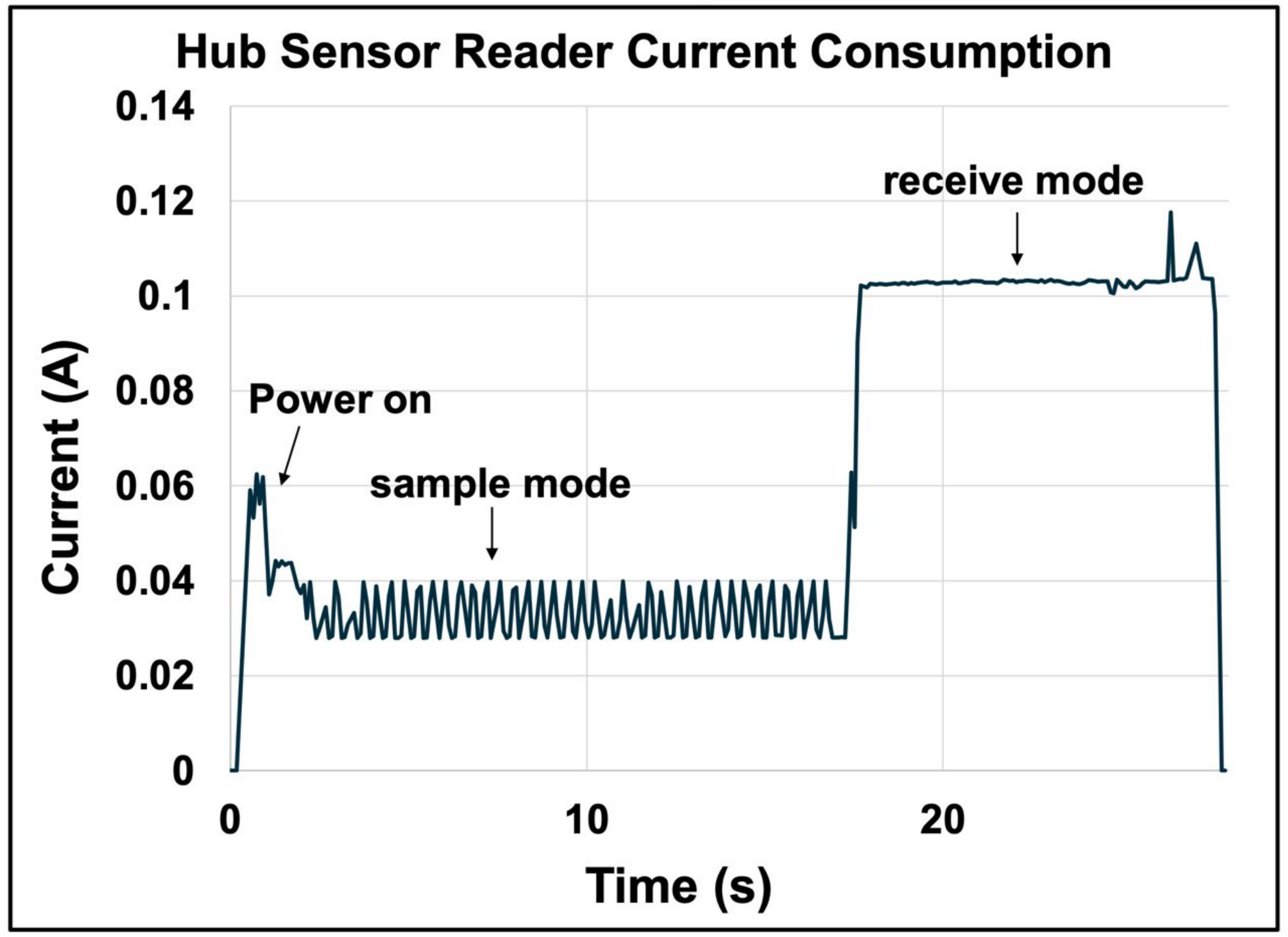
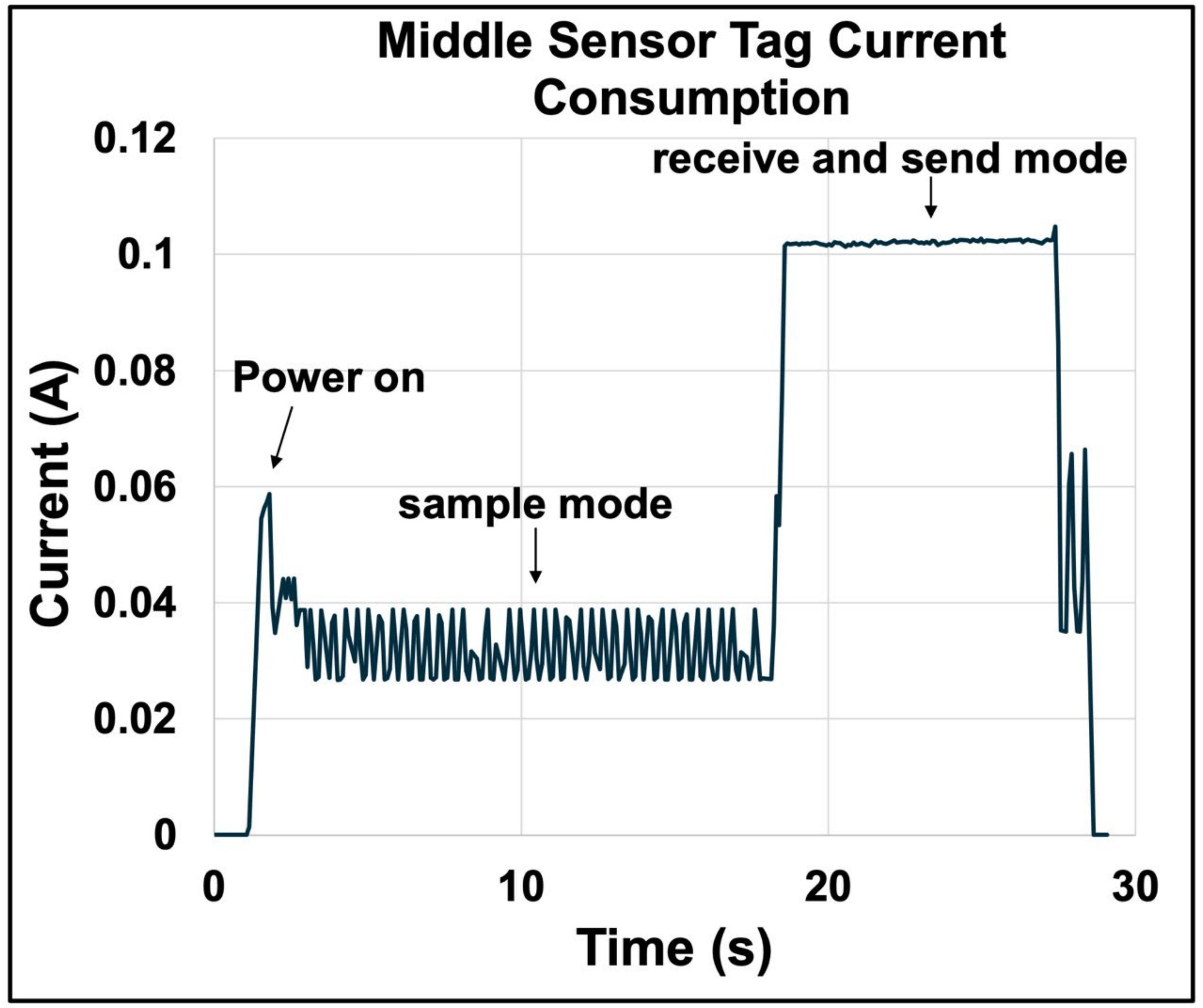
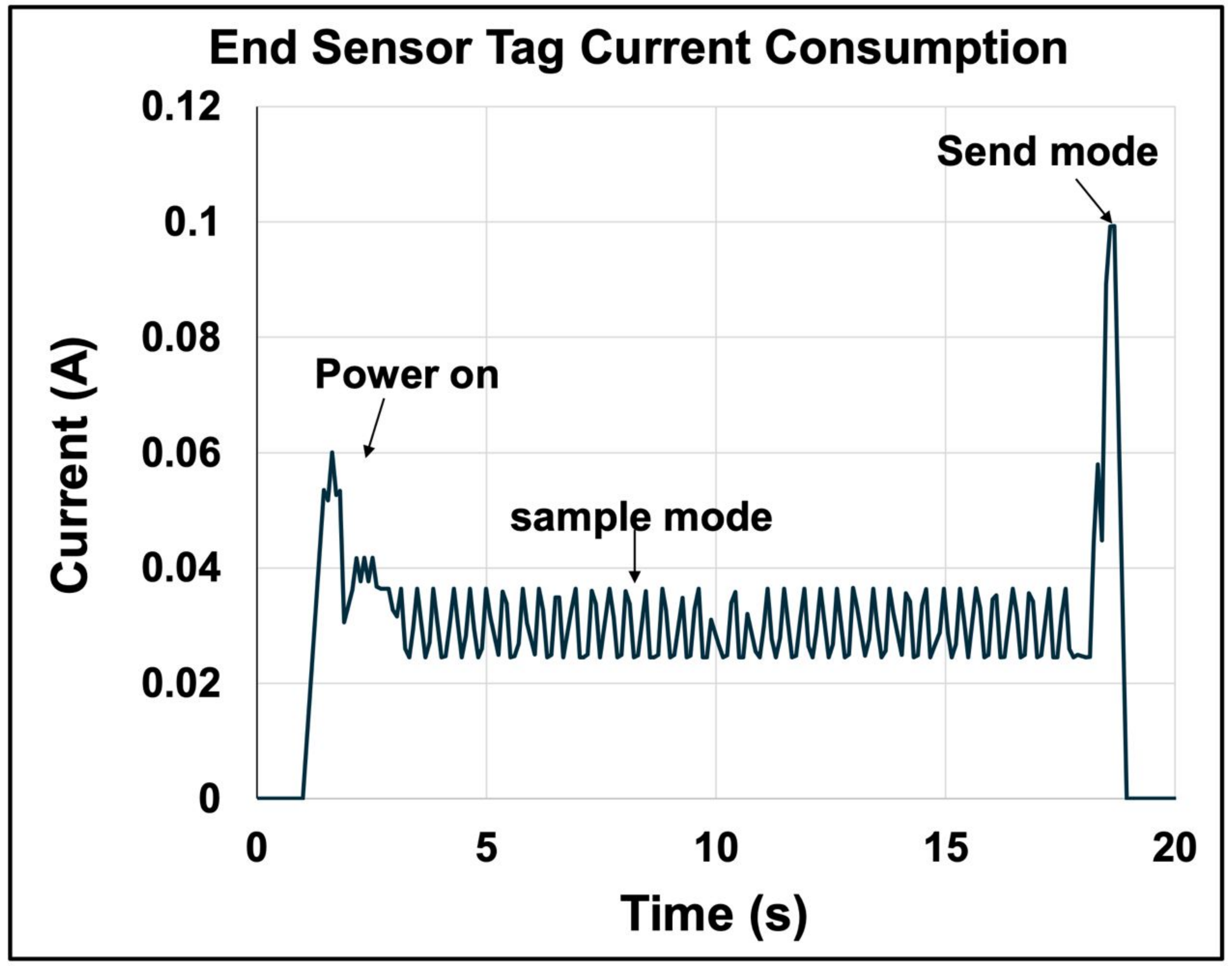
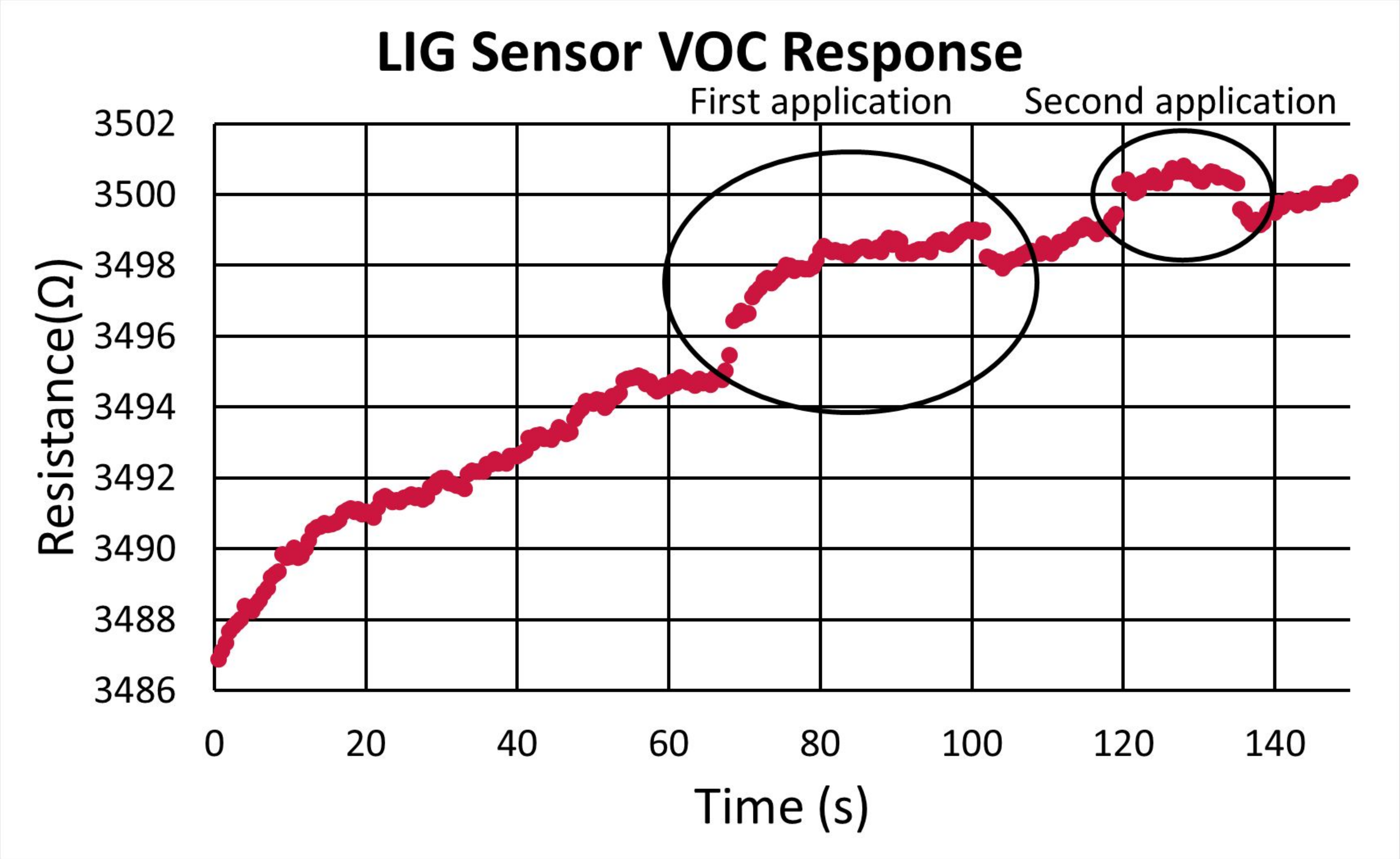


Figure 7: Time-aligned temperature data that was read from the End Sensor saved on each sensor in the chain. Points of missed communication are circled above.


Hub Sensor Reader Current Consumption


Middle Sensor Tag Current Consumption


End Sensor Tag Current Consumption


LIG Sensor VOC Response
First application
Second application
Resistance(Ω)
3502
3500
3498
3496
3494
3492
3490
3488
3486
0
20
40
60
80
100
120
140
Time (s)