Design and deployment of multistable robotic metamaterial

Master's Thesis Defense
May 28th, 2024

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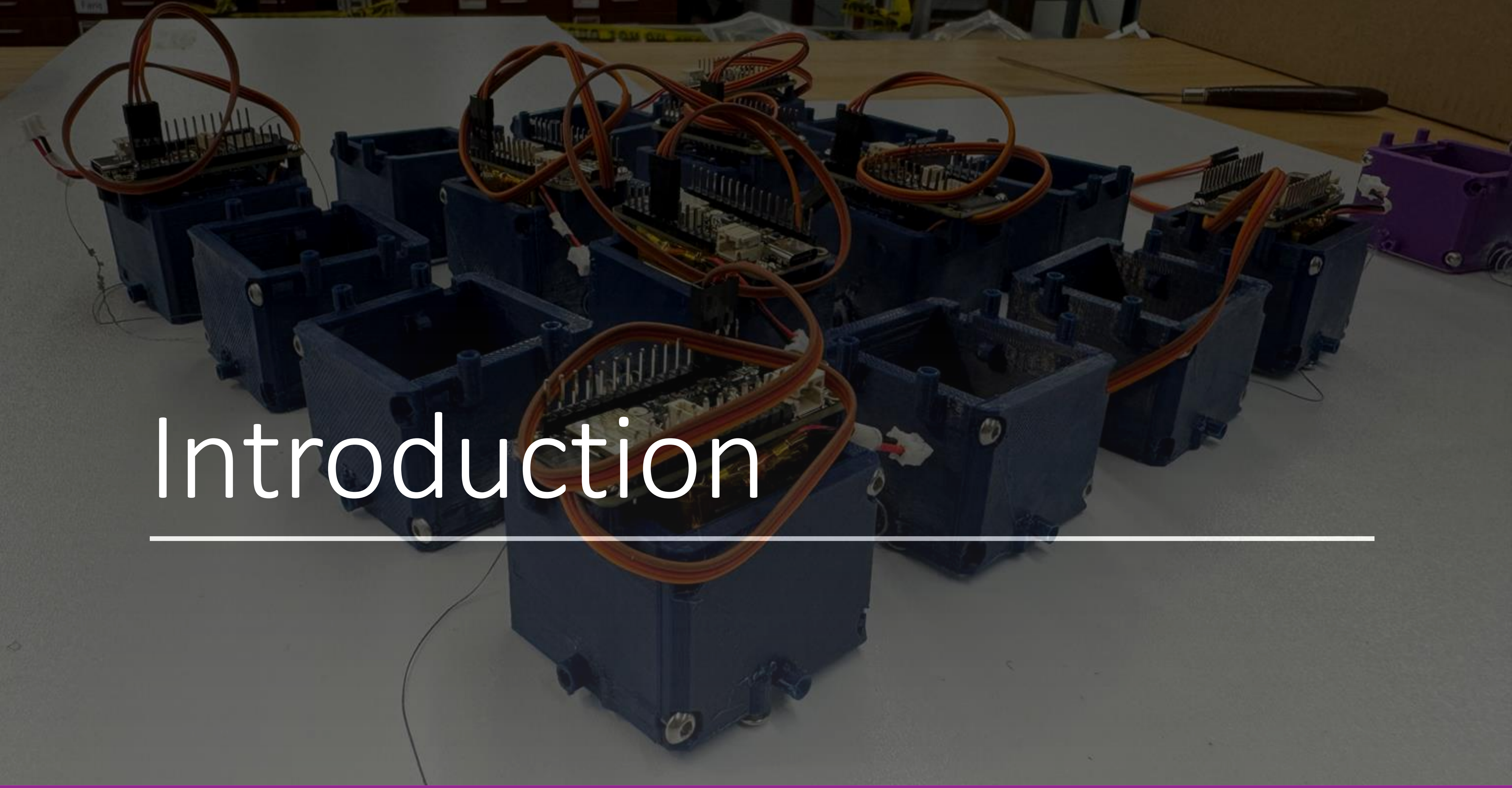
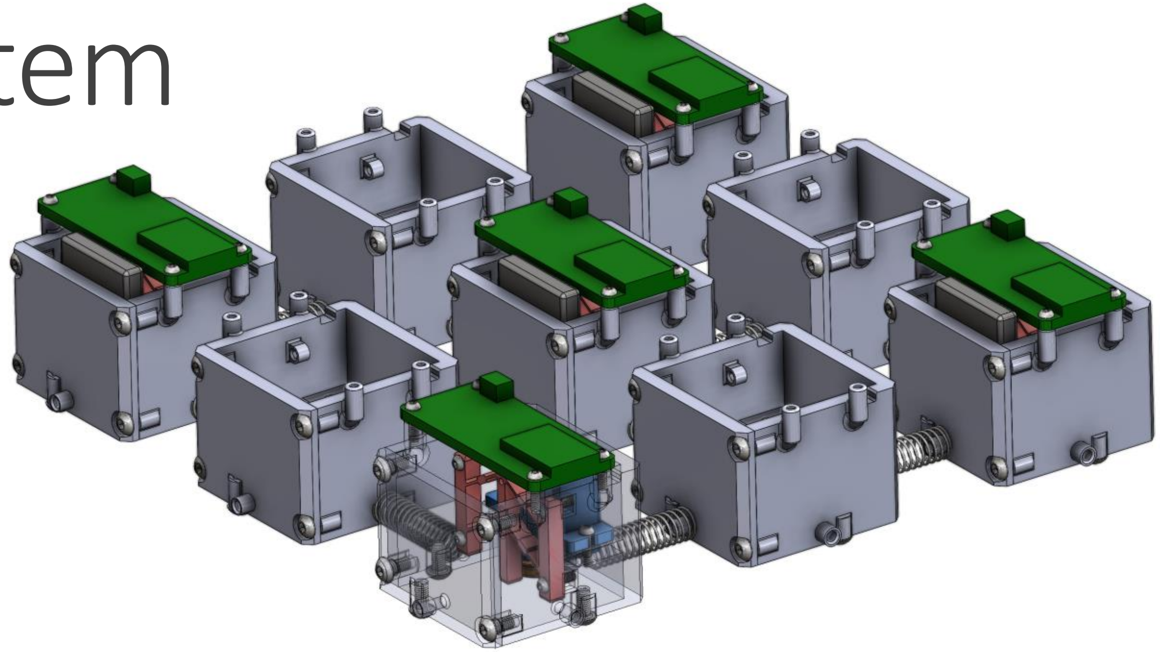
Presentation Outline

1. Project Introduction
2. Prior Research
3. Robotic Metamaterial Design
4. Manipulation Task Primitive
5. Conclusions and Future Work

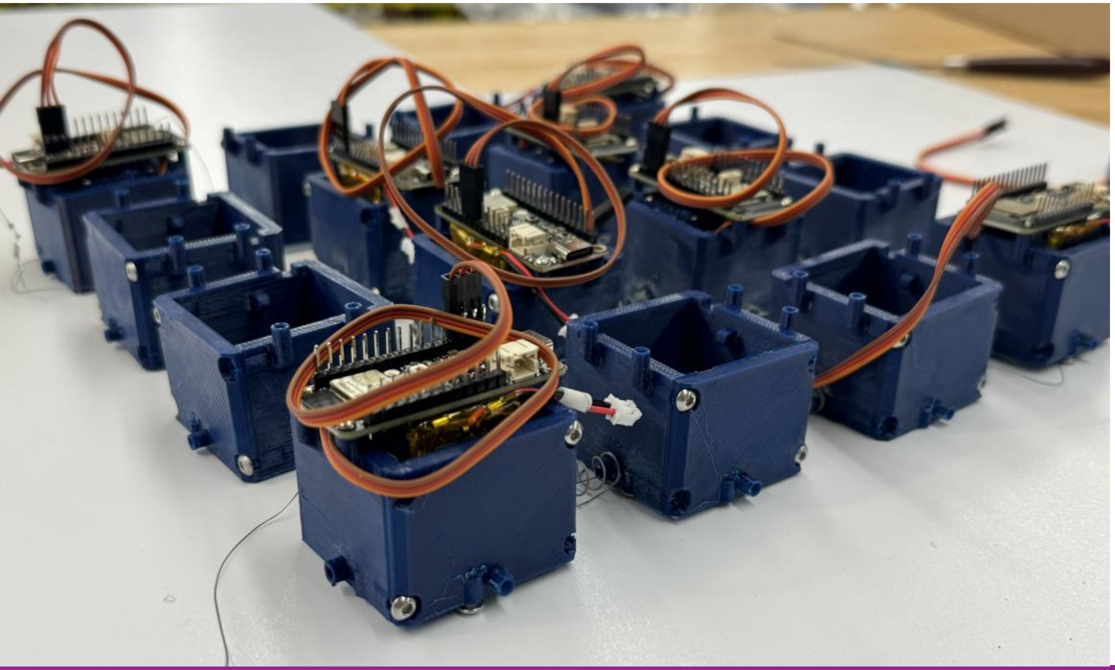
Introduction

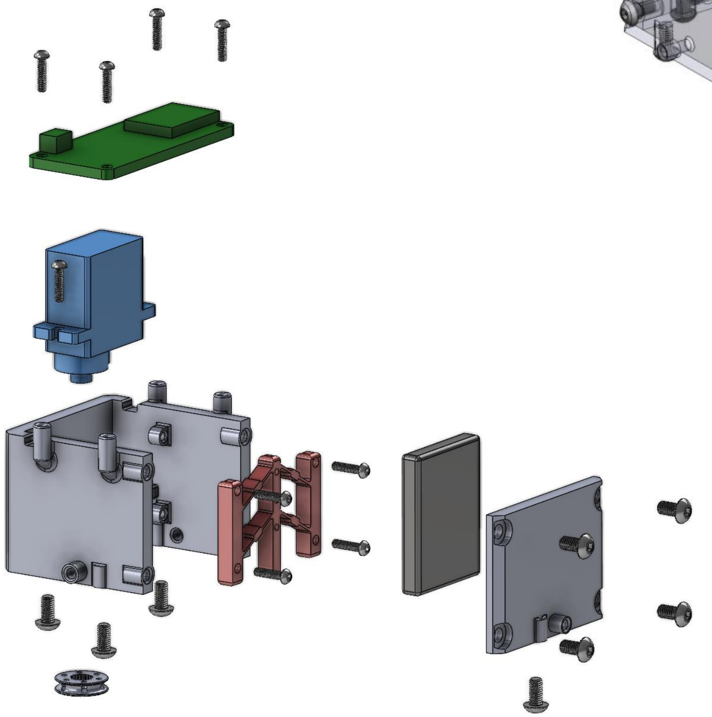


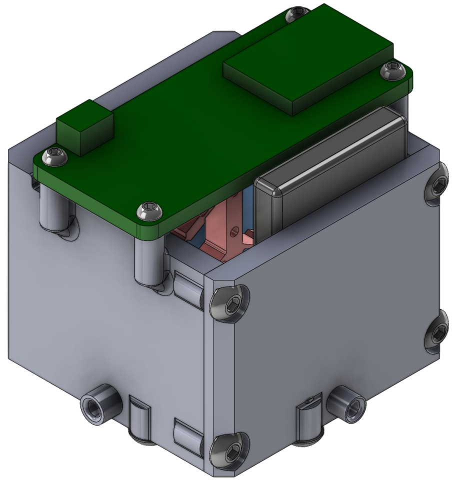
Robotic Metamaterial System



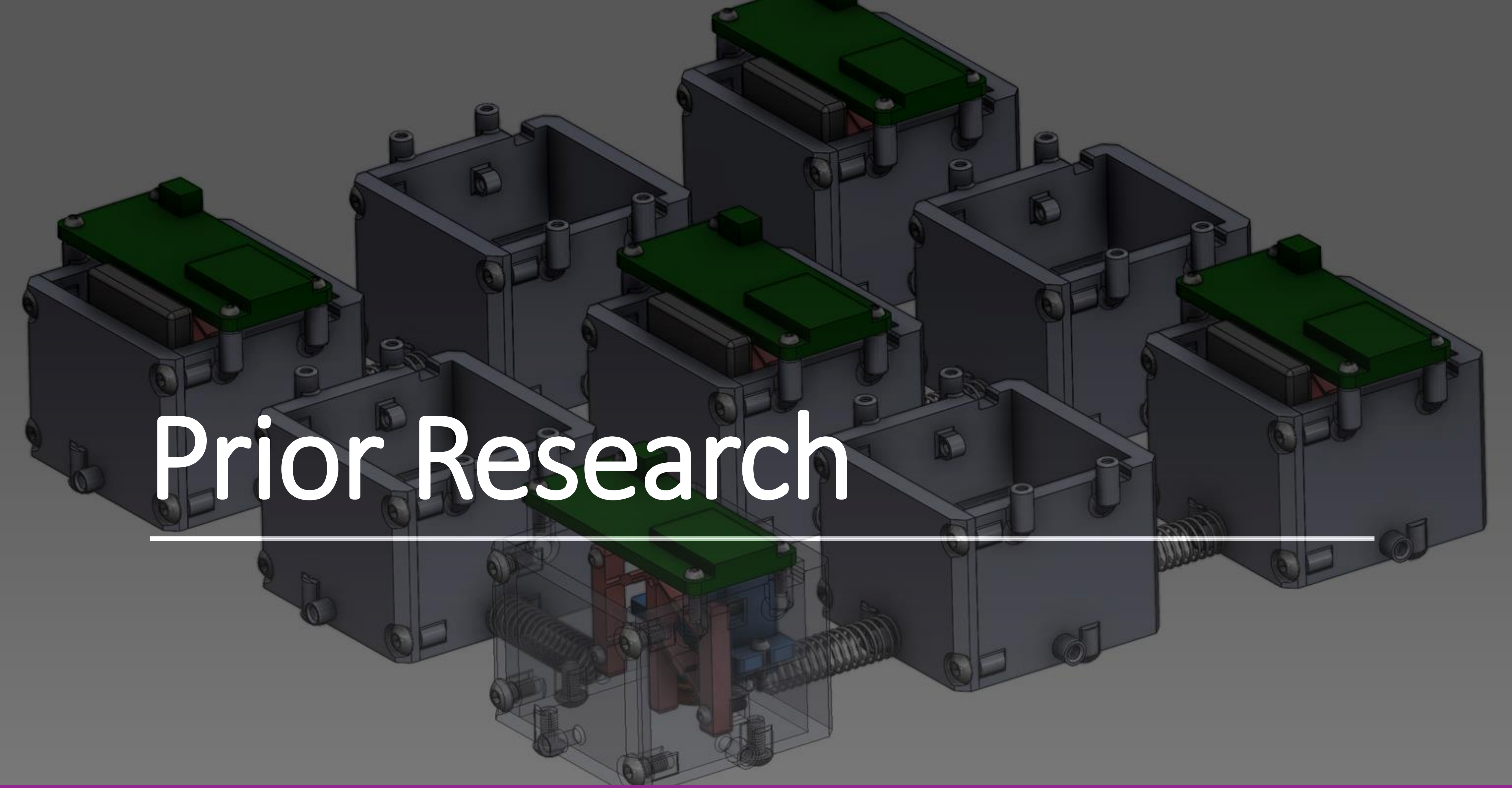
Contributions: The design, manufacturing process, and software interface for a novel robotic metamaterial.







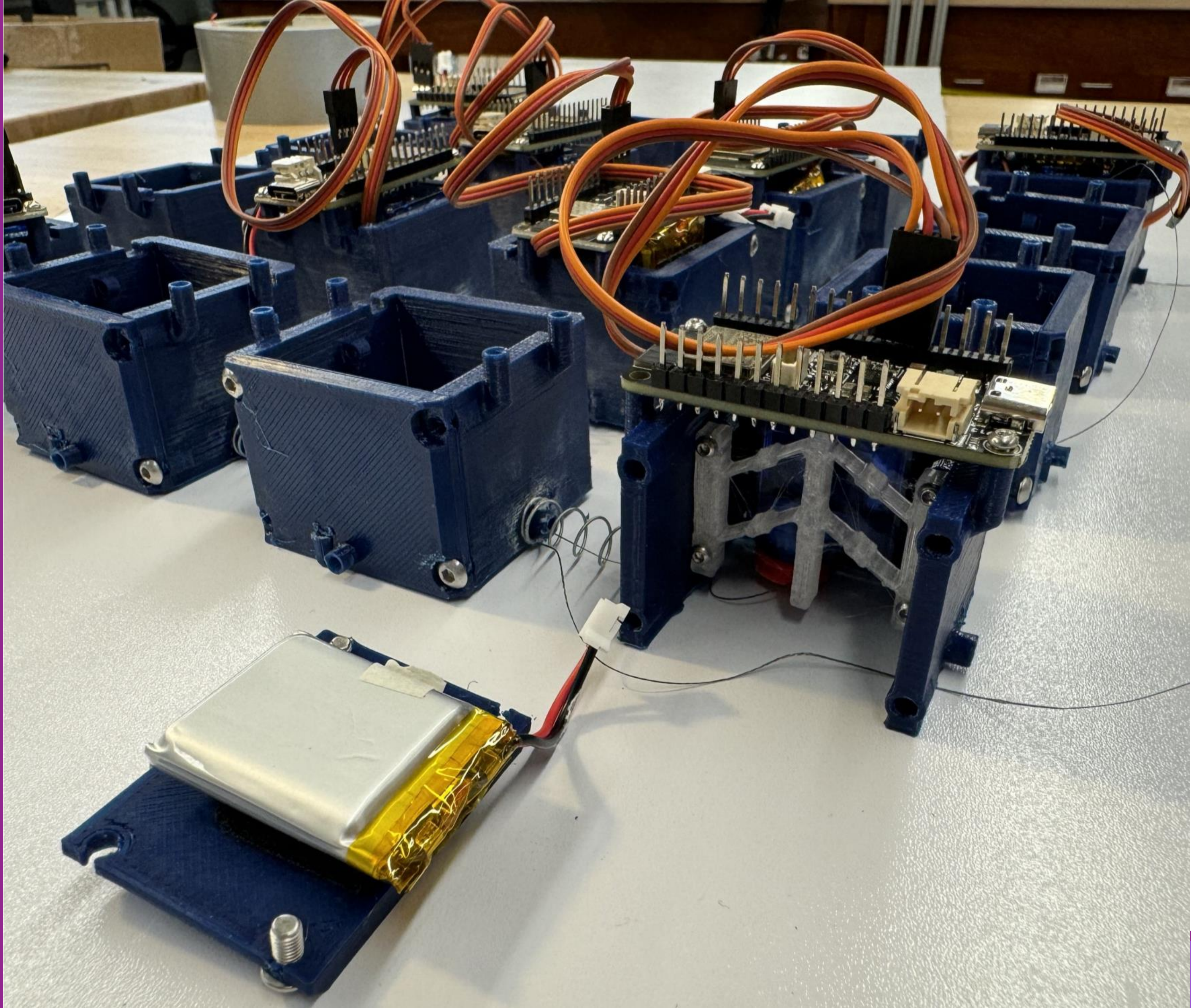
Prior Research



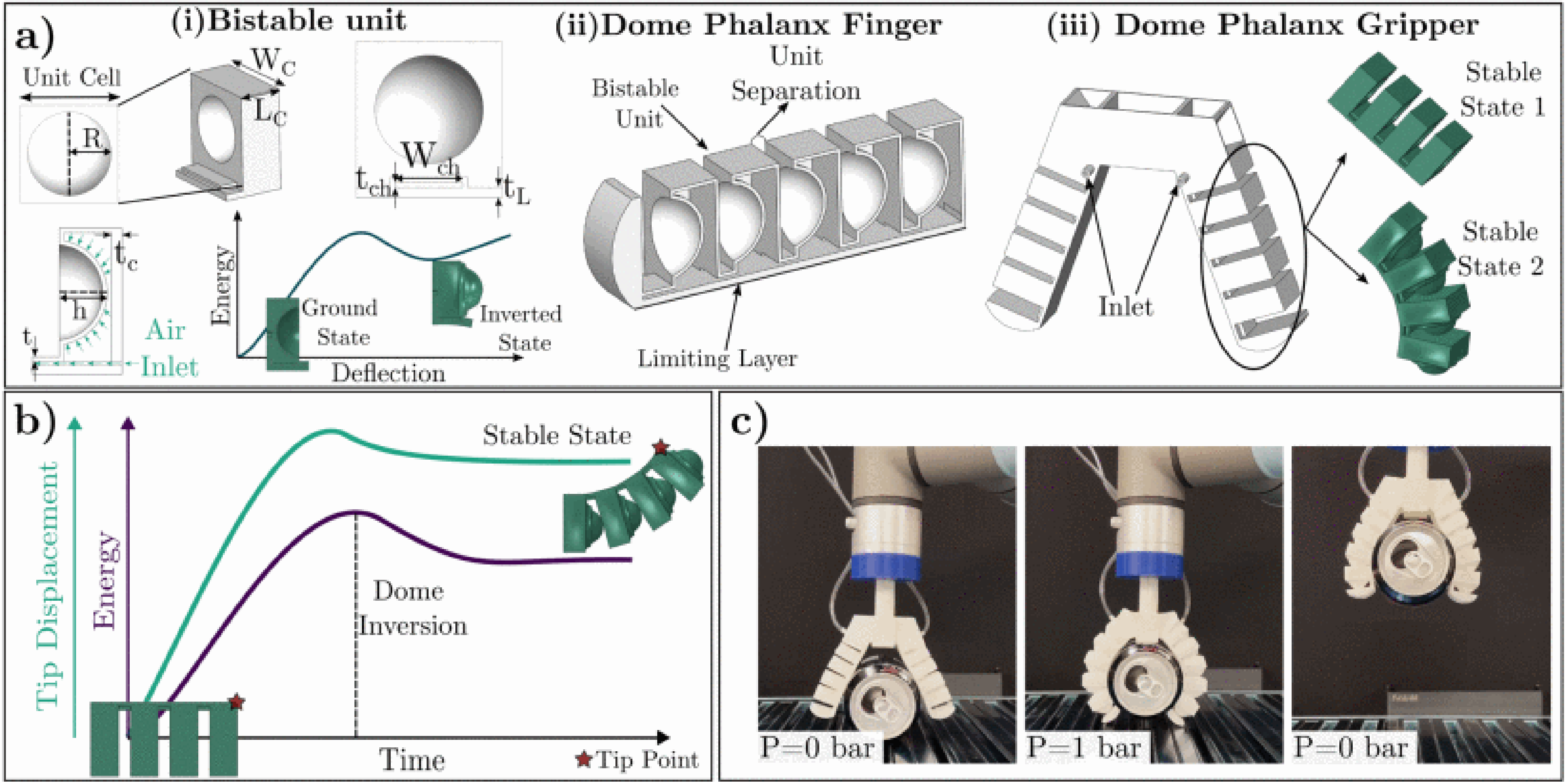
Overview Robotic metamaterials

Metamaterials leverage anisotropic properties in a material to exhibit unique, and useful behavior

- Enable robots to perform tasks traditional rigid robots struggle with
- Capable of multiple task primitives
- Robots which can adapt to highly dynamic environments
- Relatively low cost, low energy, and safe

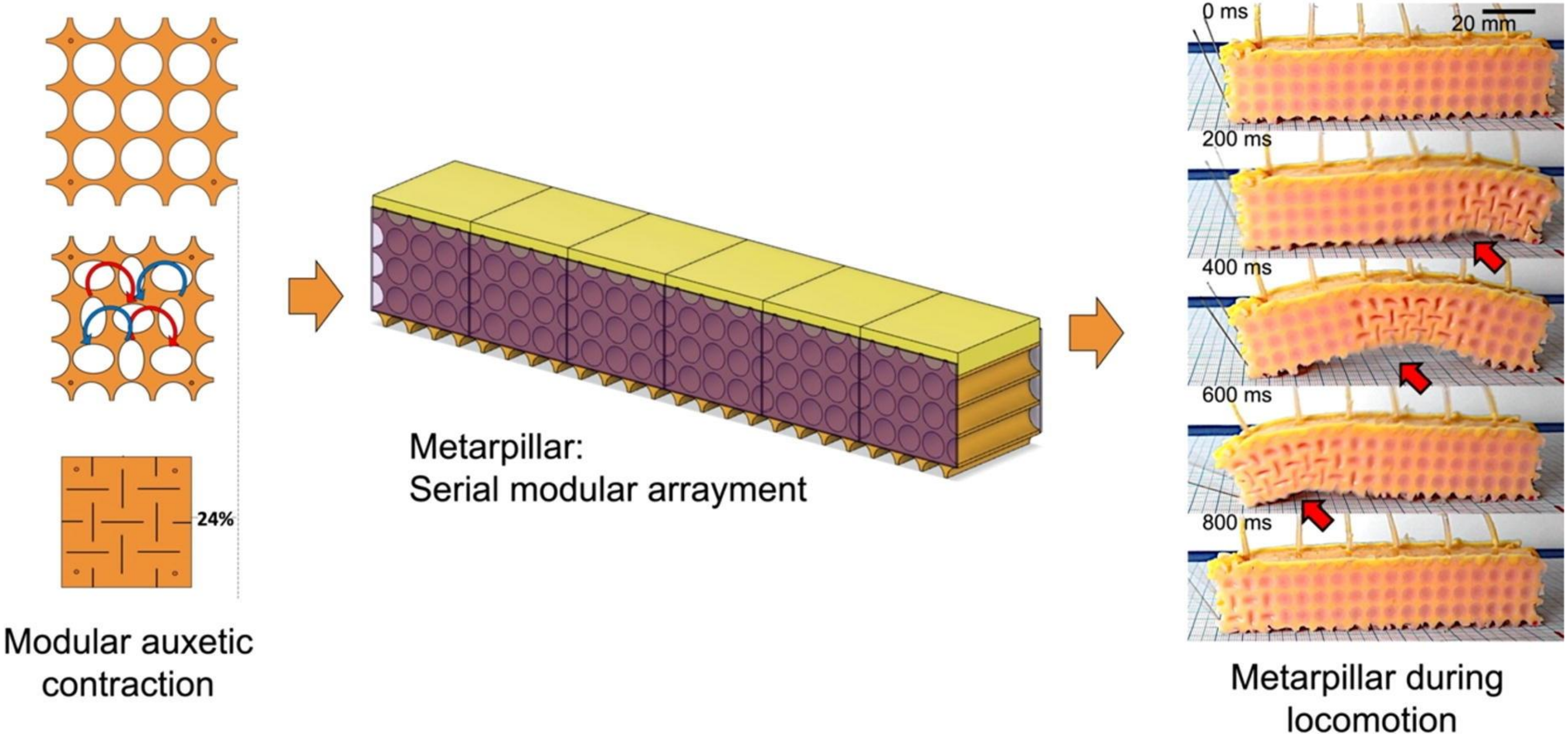


Multistable Soft Grippers, H. Morgan et al.



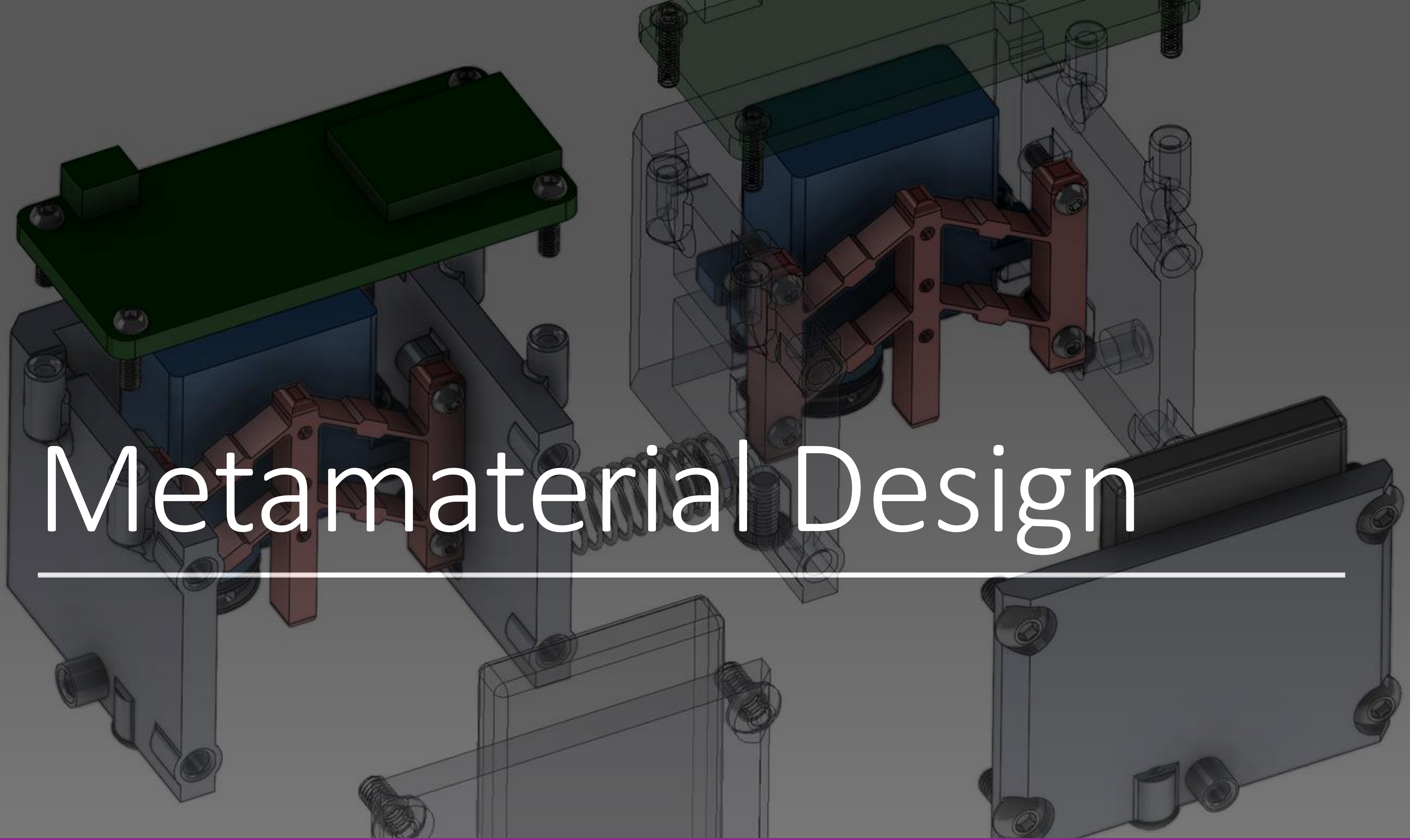
H. Morgan, J. C. Osorio and A. F. Arrieta, "Towards open loop control of soft multistable grippers from energy-based modeling," *2023 IEEE International Conference on Soft Robotics (RoboSoft)*, Singapore, Singapore, 2023, pp. 1-6, doi: 10.1109/RoboSoft55895.2023.10121986.

The Metarpillar, Grossi et al.



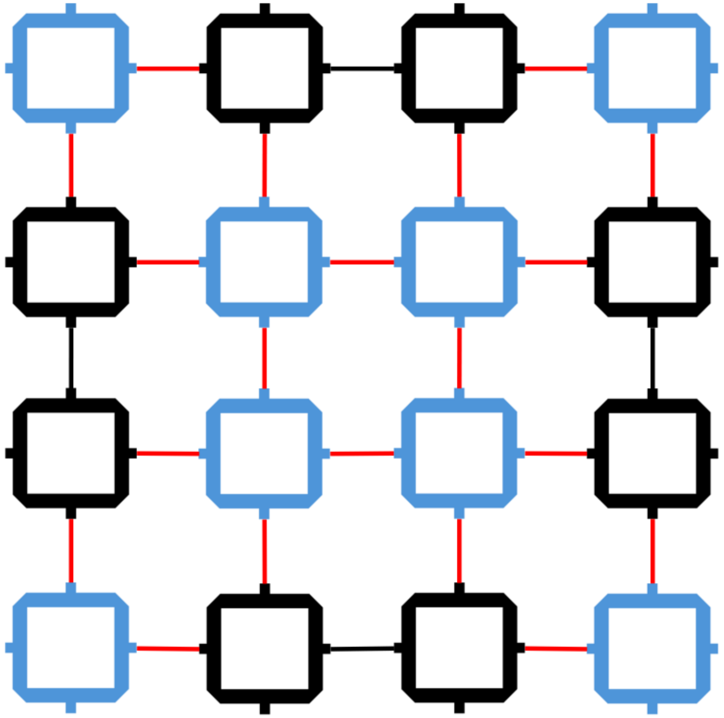
B. Grossi, H. Palza, J.C. Zagal, C. Falcón, G. During, Metarpillar: Soft robotic locomotion based on buckling-driven elastomeric metamaterials, Materials & Design, Volume 212, 2021, 110285, ISSN 0264-1275, https://doi.org/10.1016/j.matdes.2021.110285

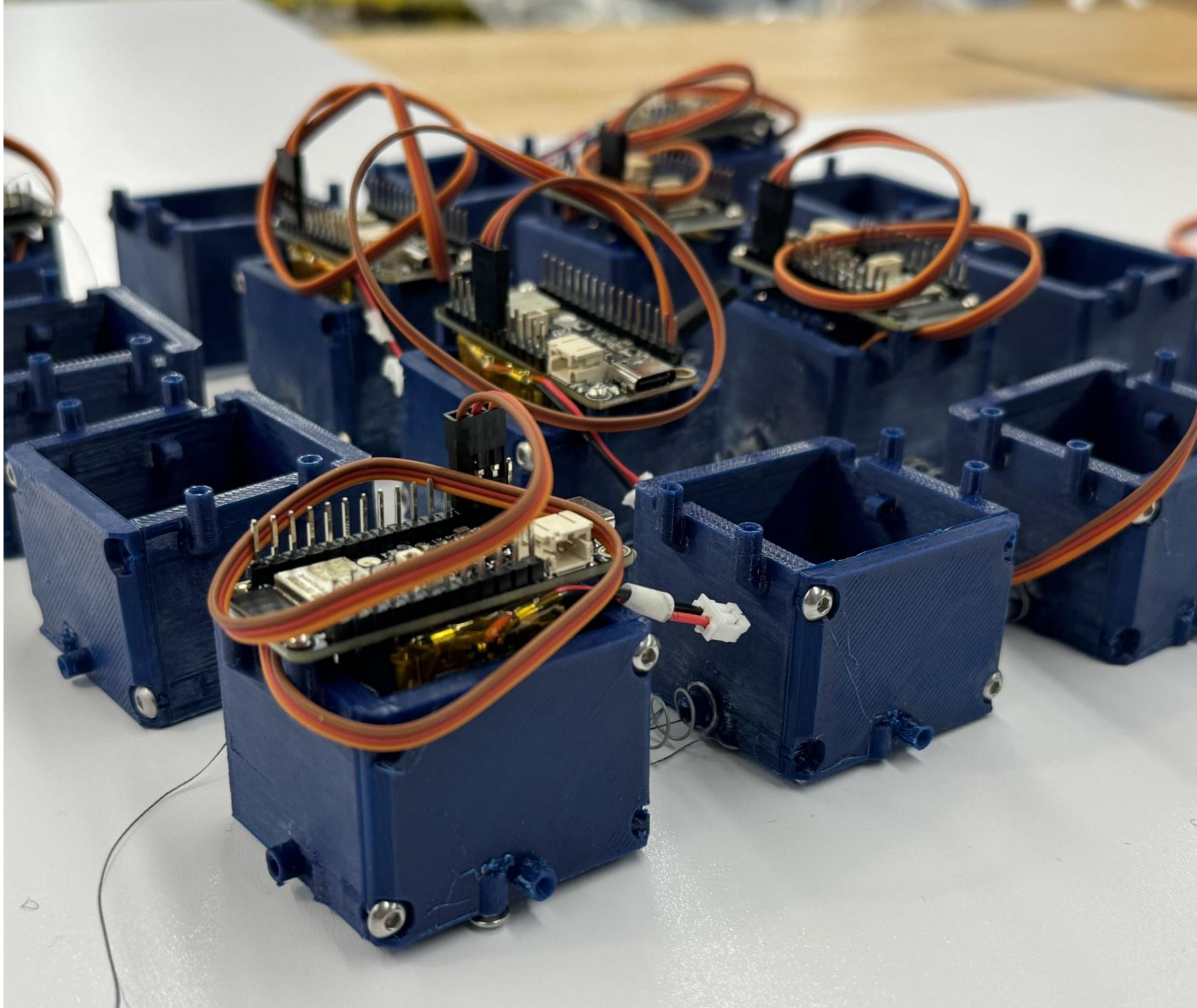
Metamaterial Design



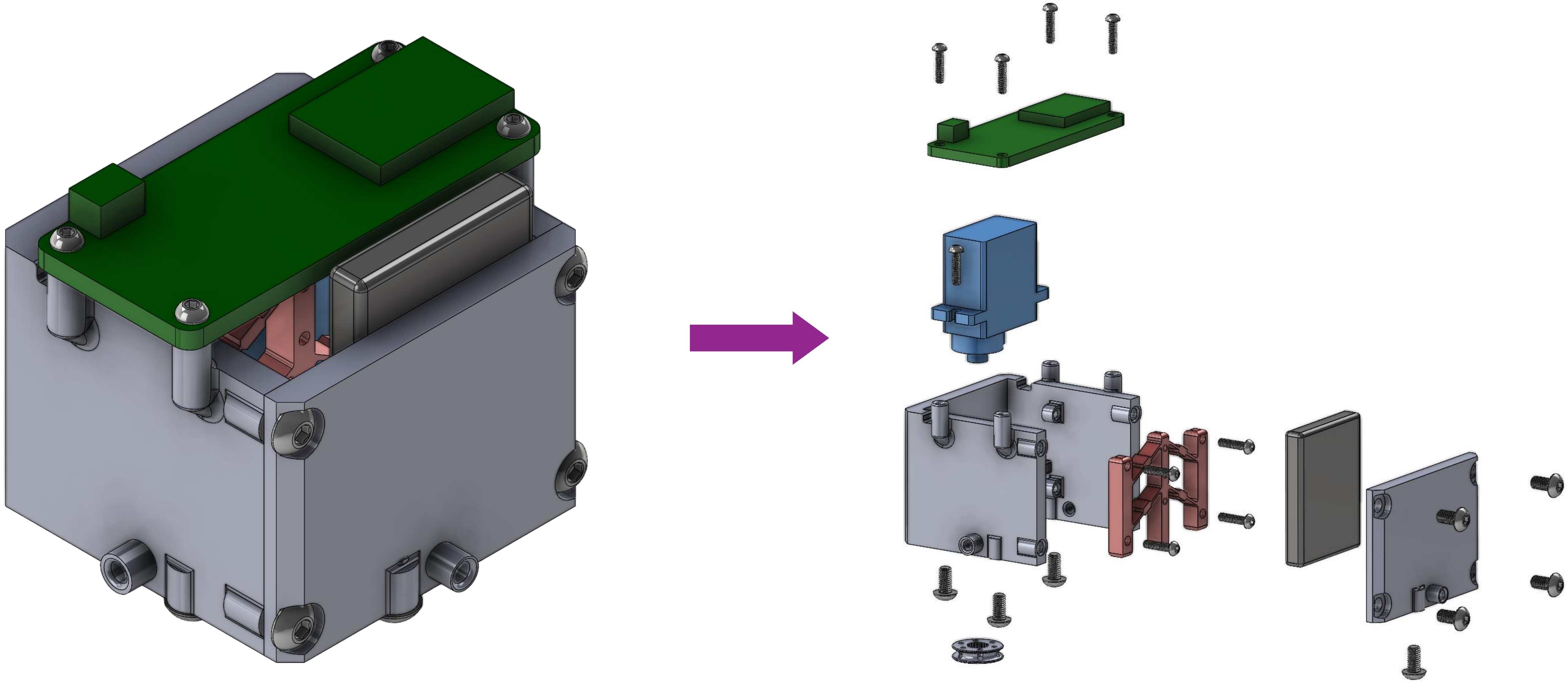
Metamaterial System:

- Lattice structure of modular housings
- Connected via compression springs
- Wireless, individually-controllable nodes
- Nodes tension cables, causing springs to bend

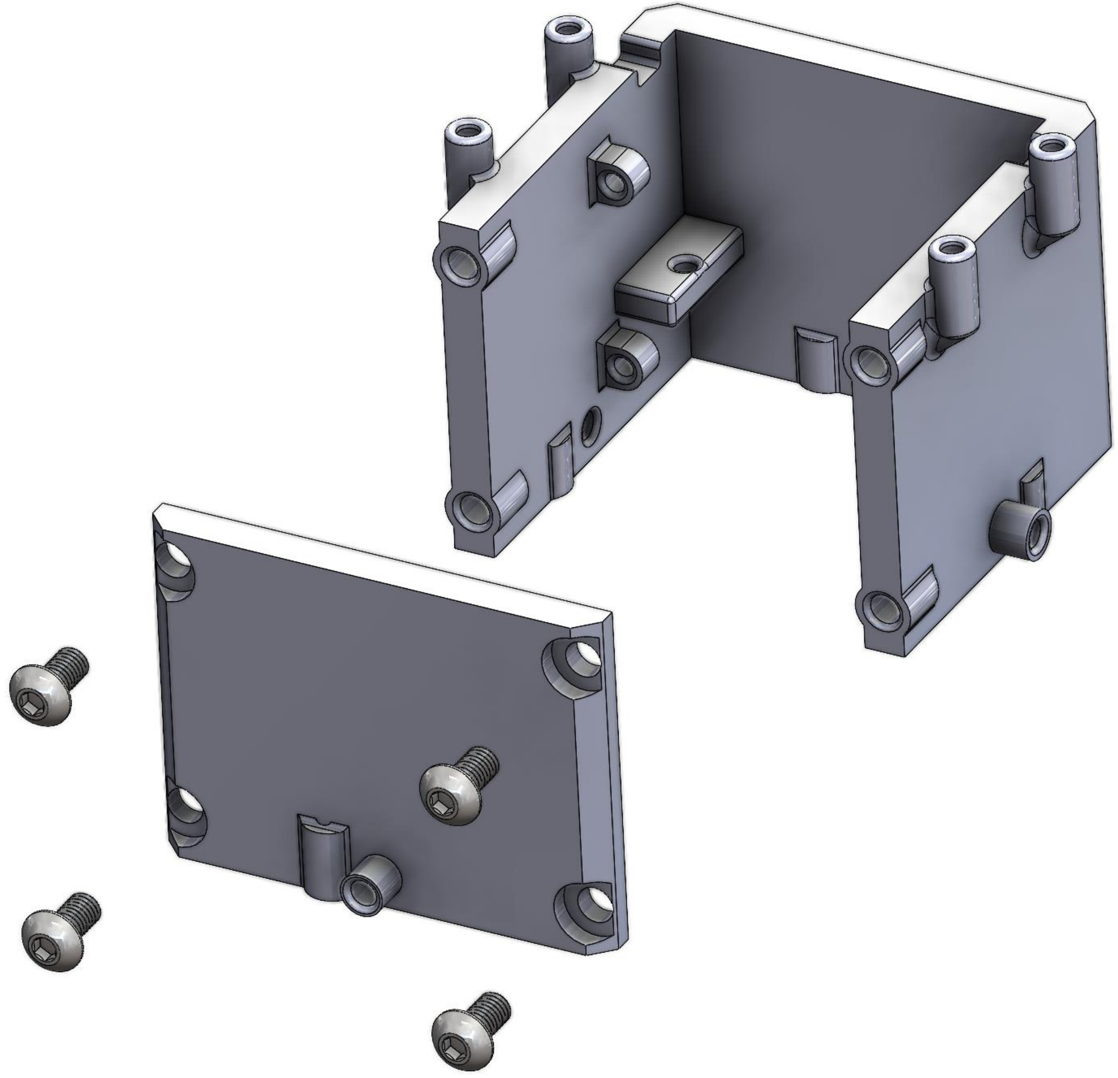


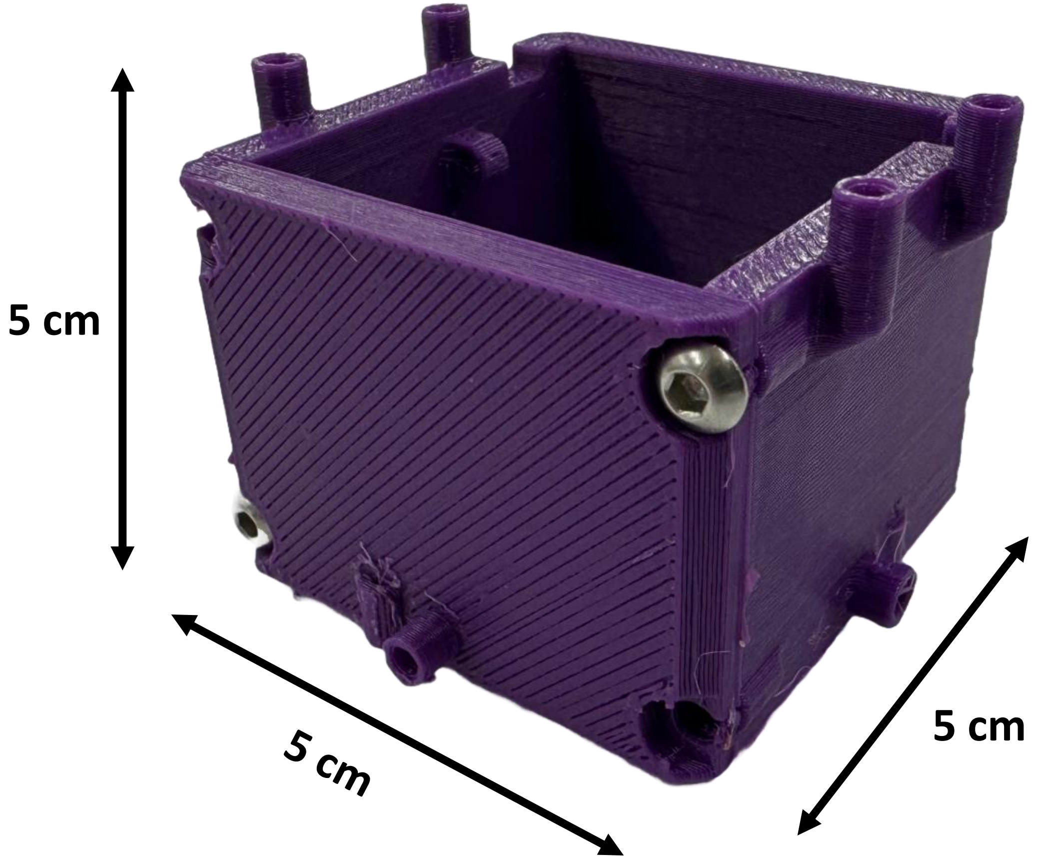


Active Node Assembly

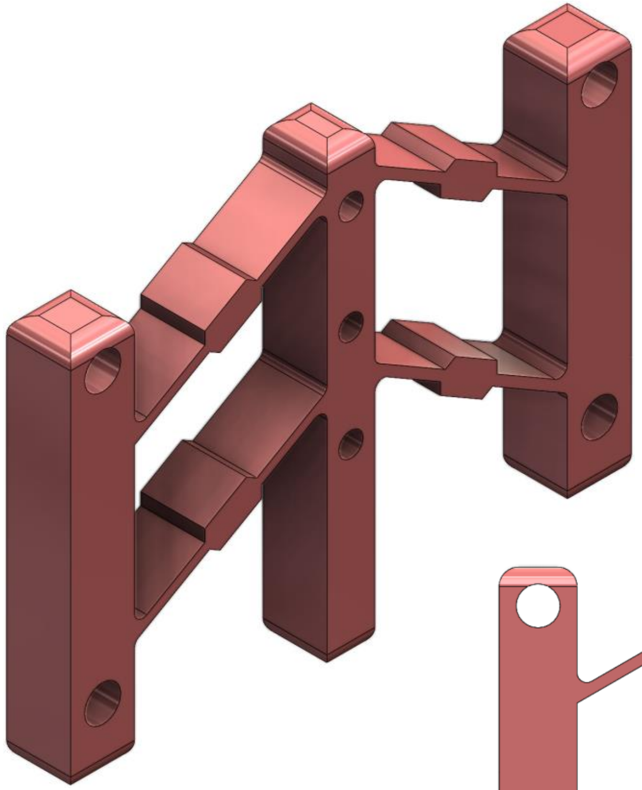


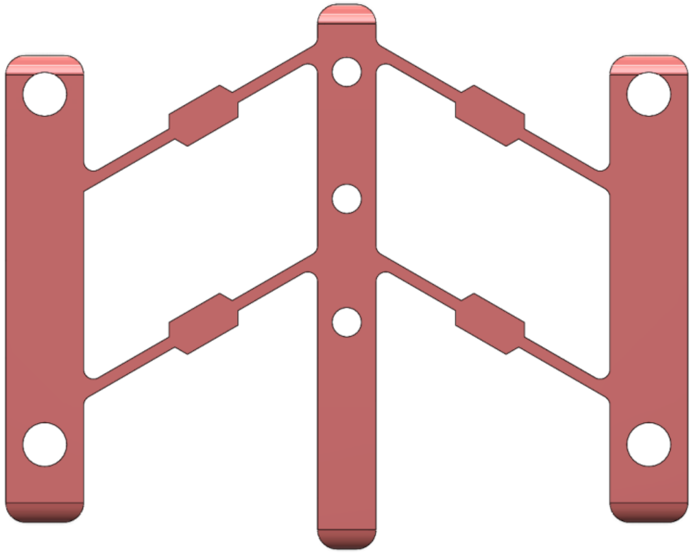
Modular Housing

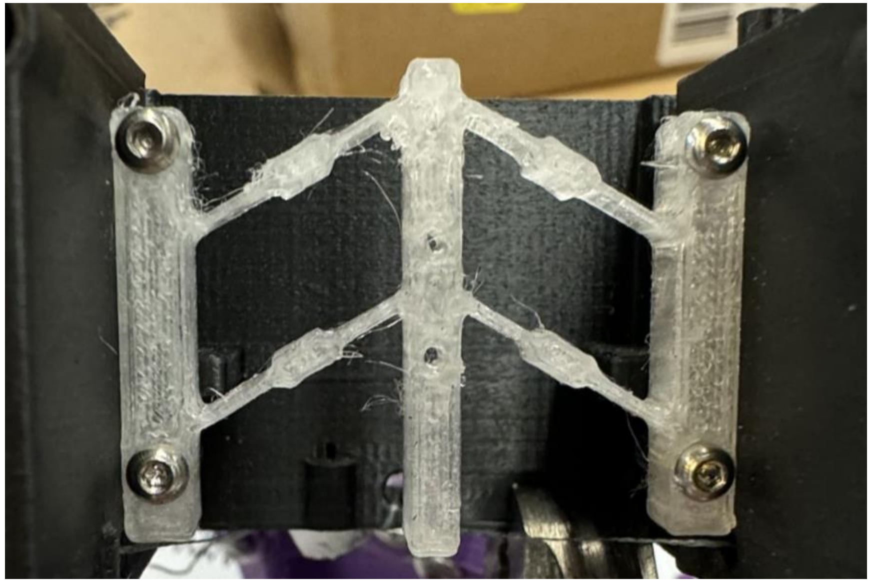


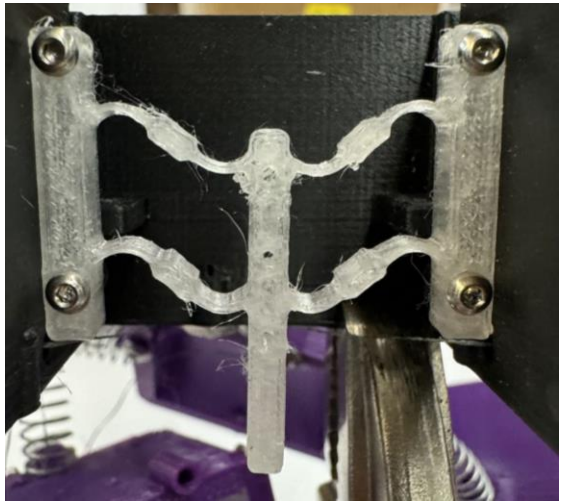


Bistable Compliant Mechanism

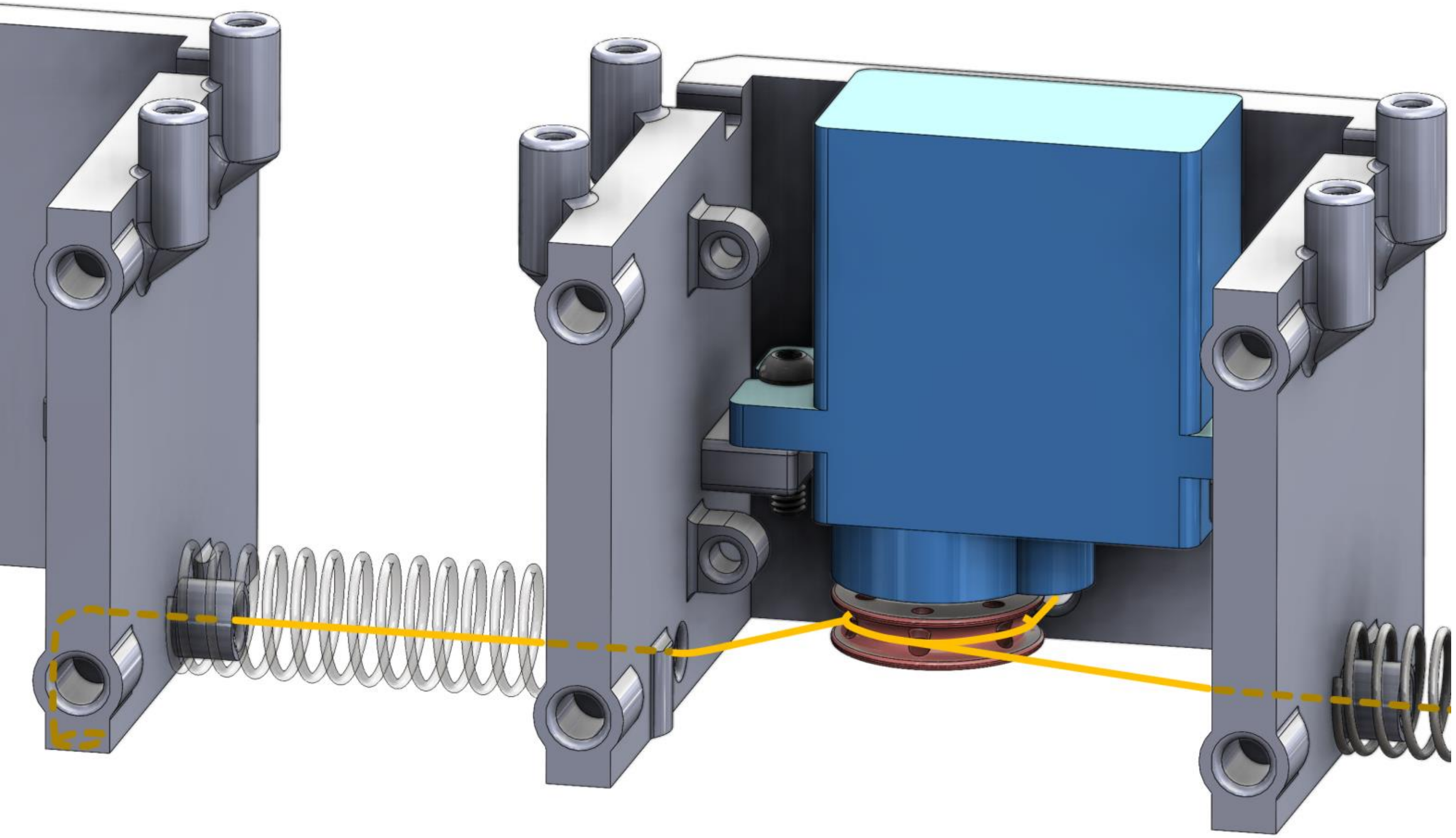


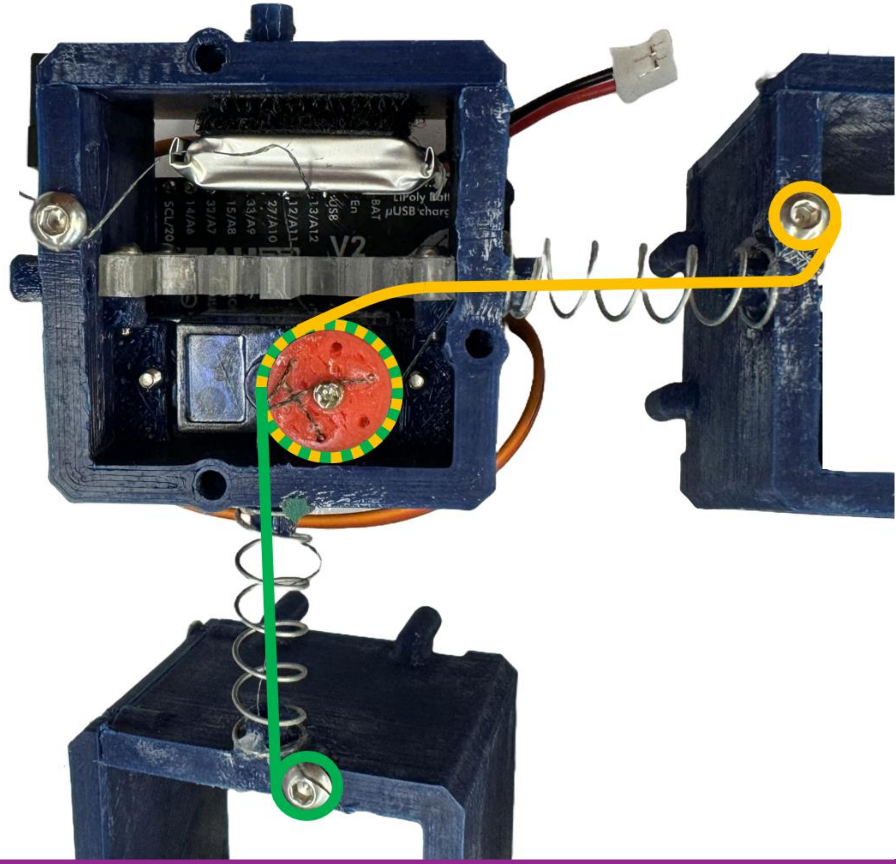




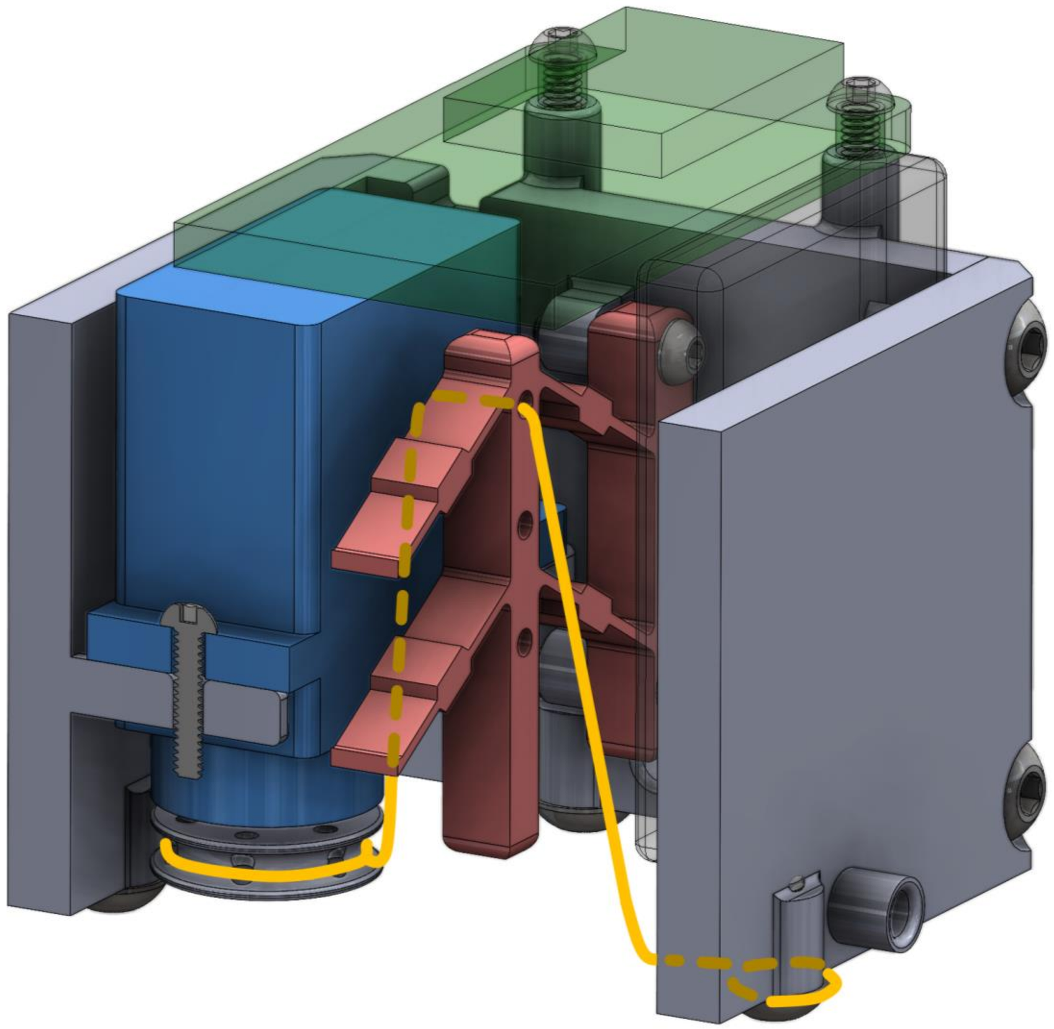


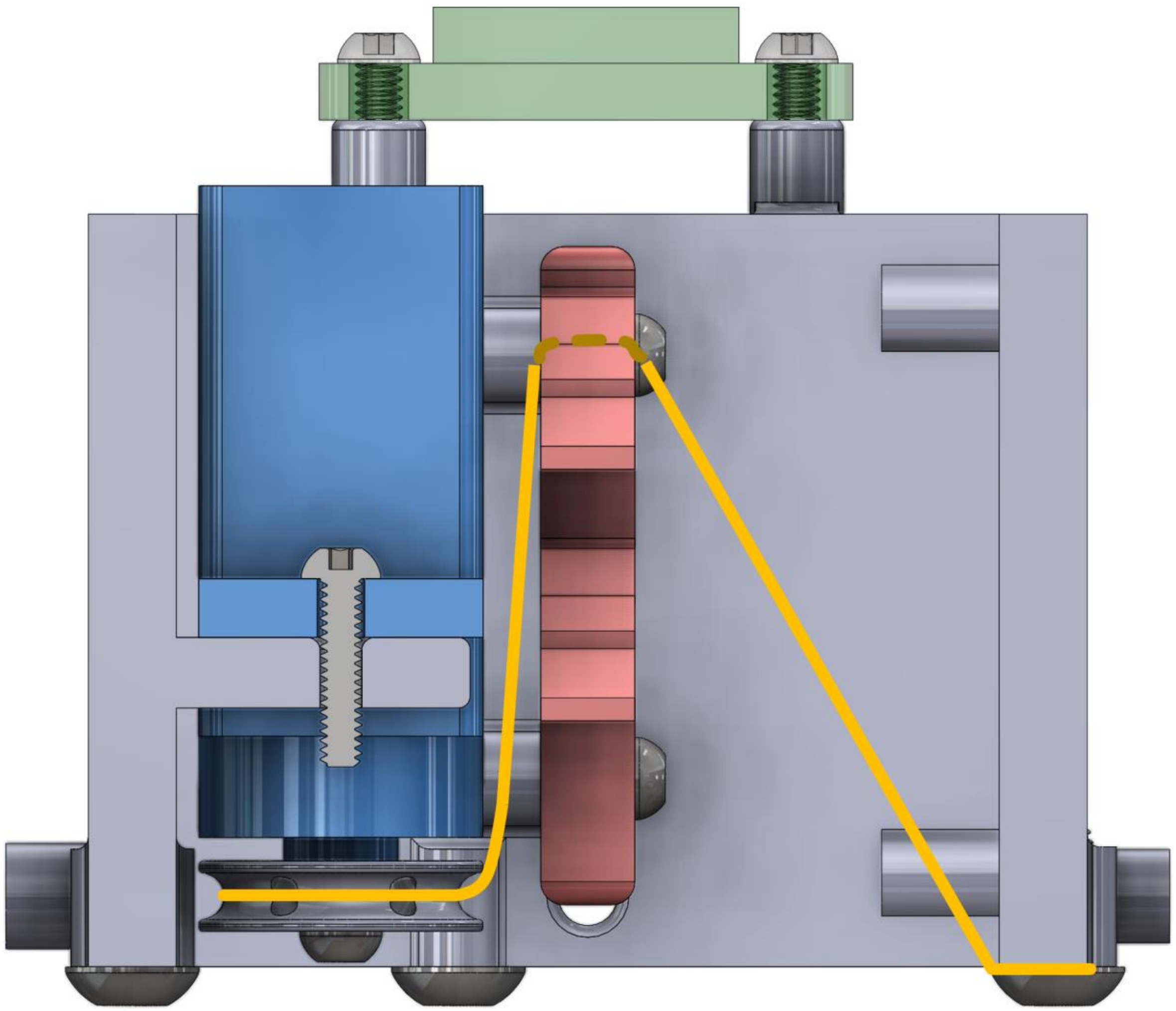
Tensioning System: Inter-node



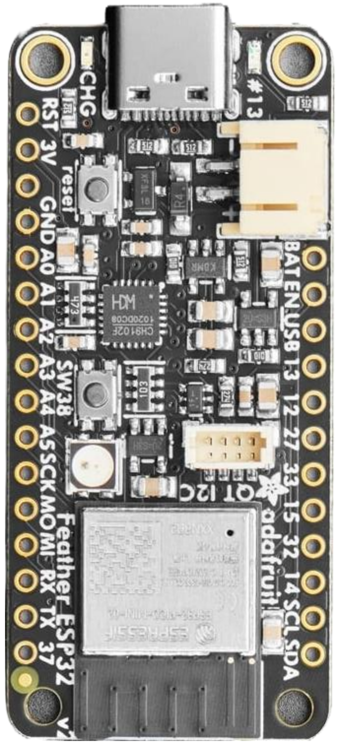


Tensioning System: Bistable Mechanism





Actuator

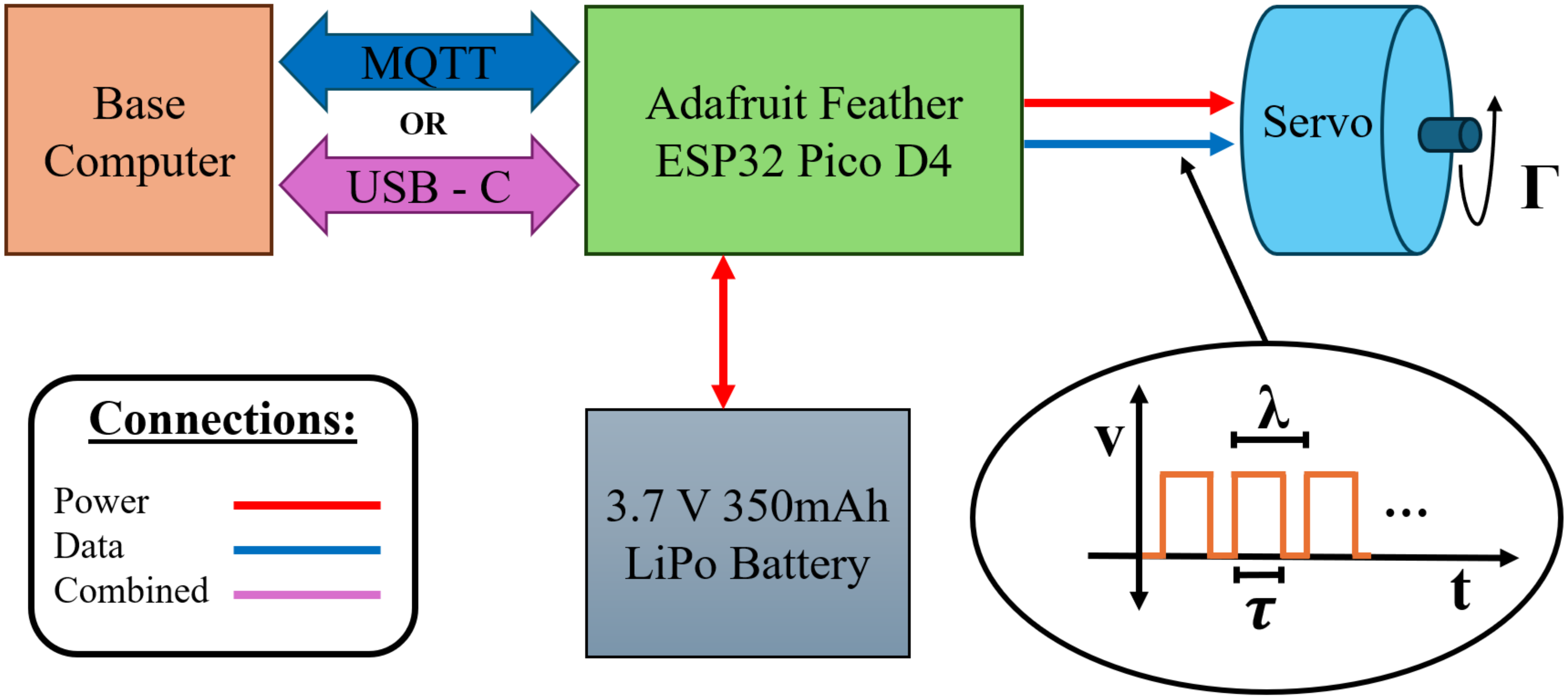


Microcontroller

Power Supply

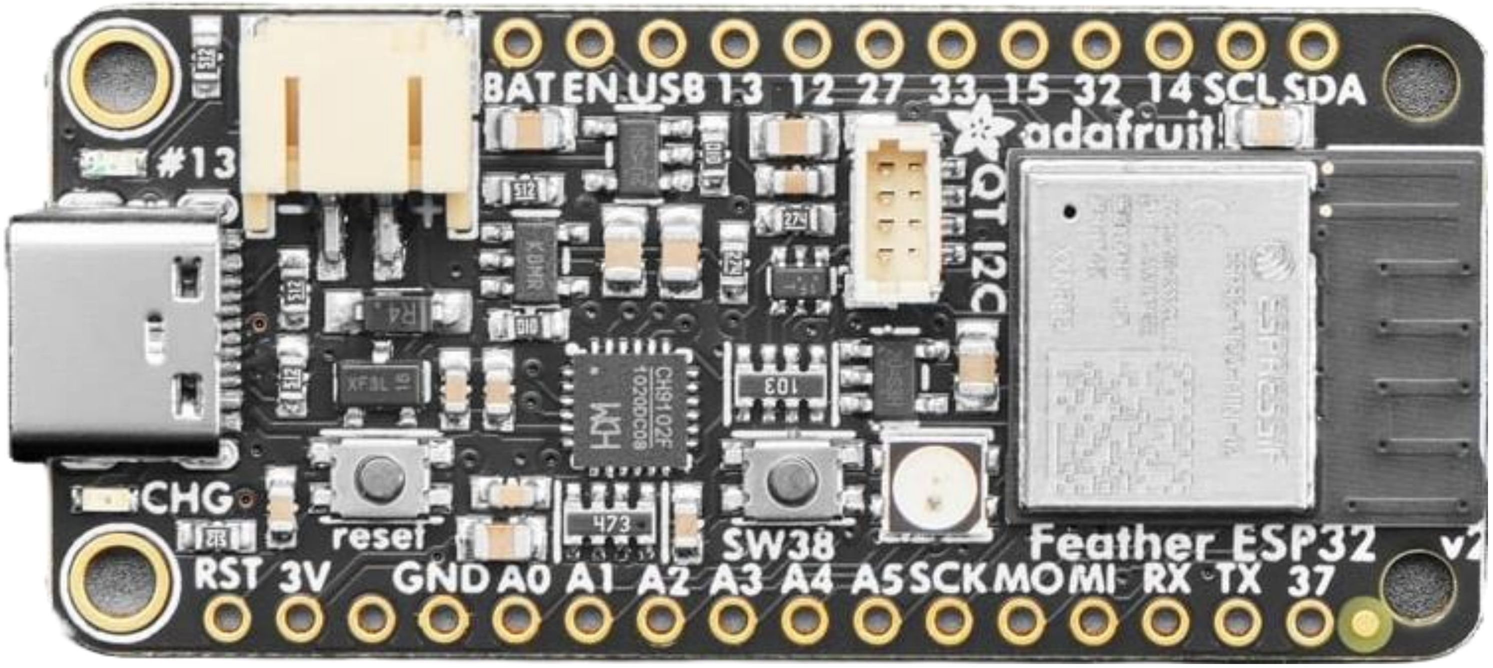
Electrical System Overview

Electrical System Block Diagram



Adafruit Feather ESP32 V2

- Controls the servo actuator
- Communicates with the central controller via MQTT
- Distributes and regulates power to onboard peripheral device
- Displays node state using RGB LED

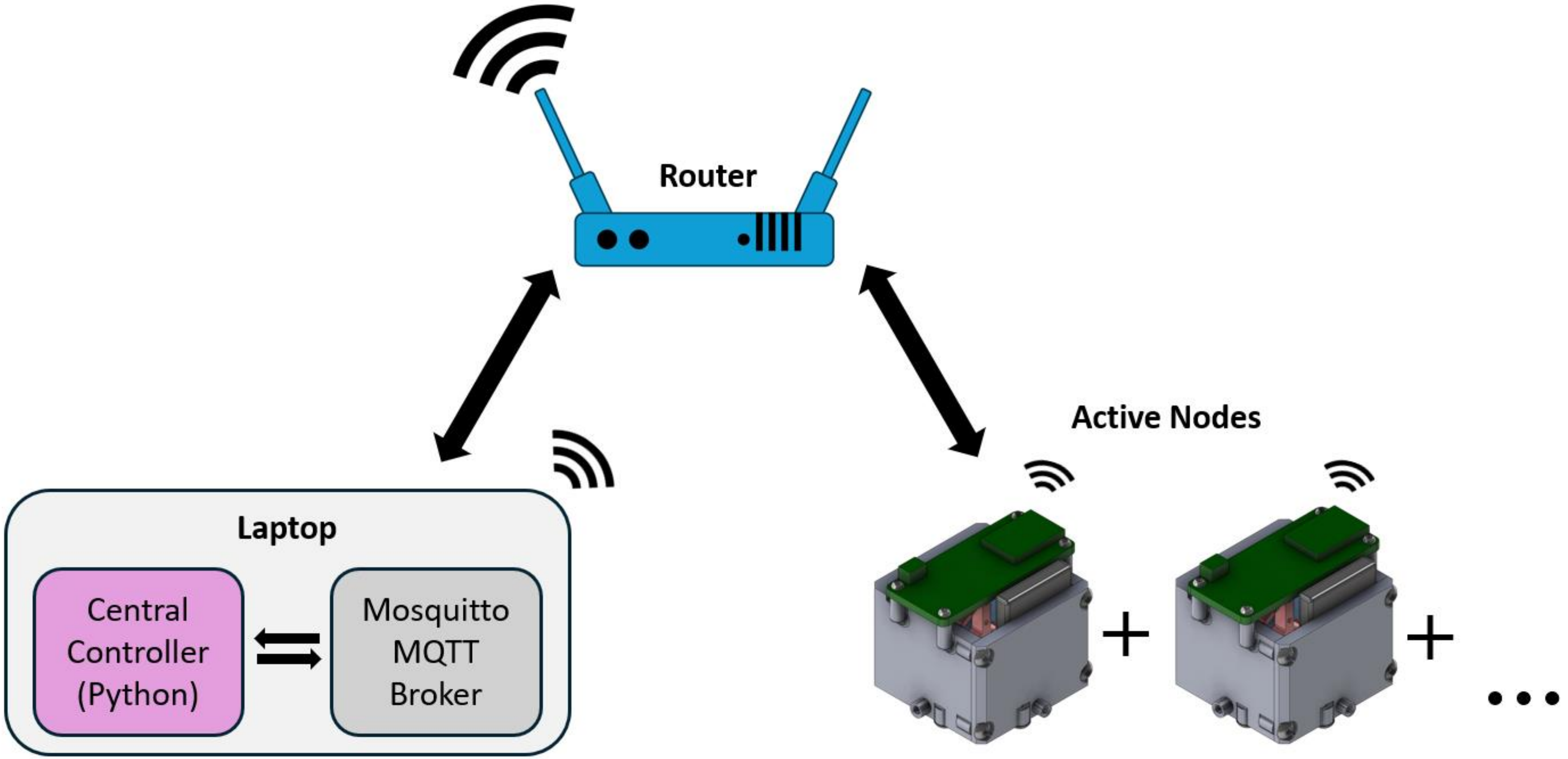


Servo Motor & Power Supply

FeeTech Fs90R Continuous Rotation Servo

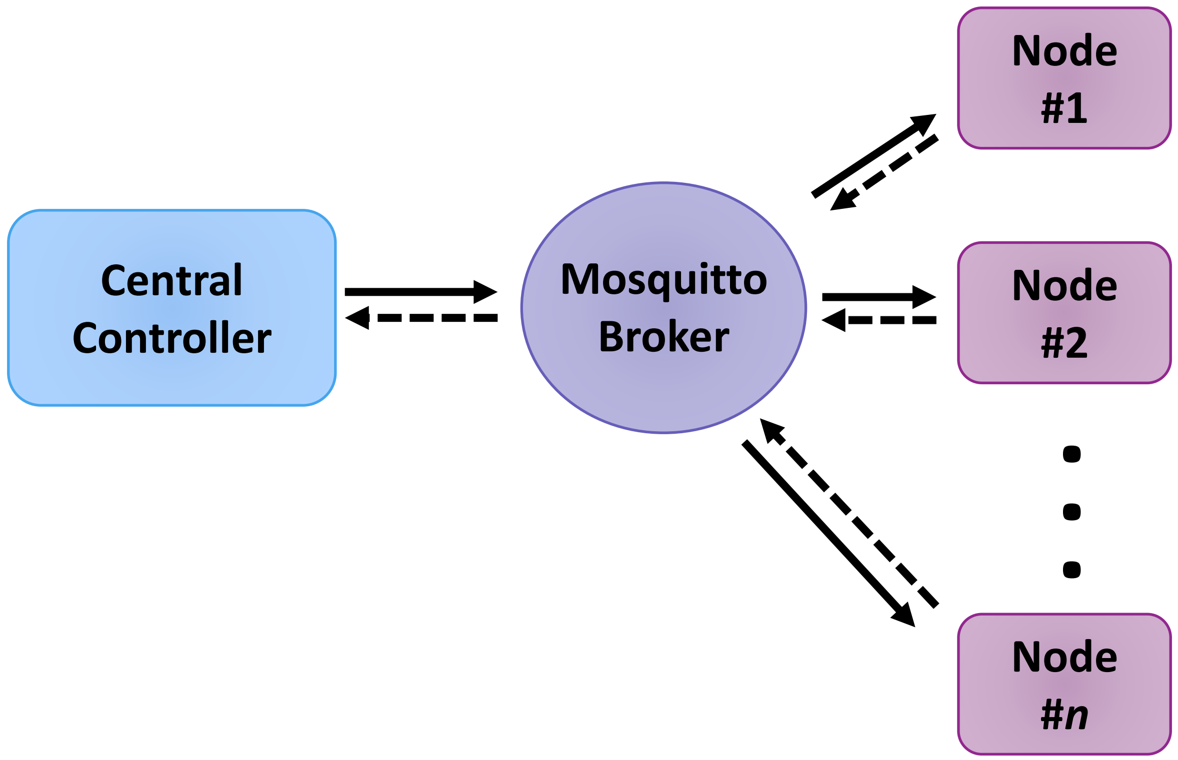
350mAh Lithium Polymer Battery

MQTT Communication Overview



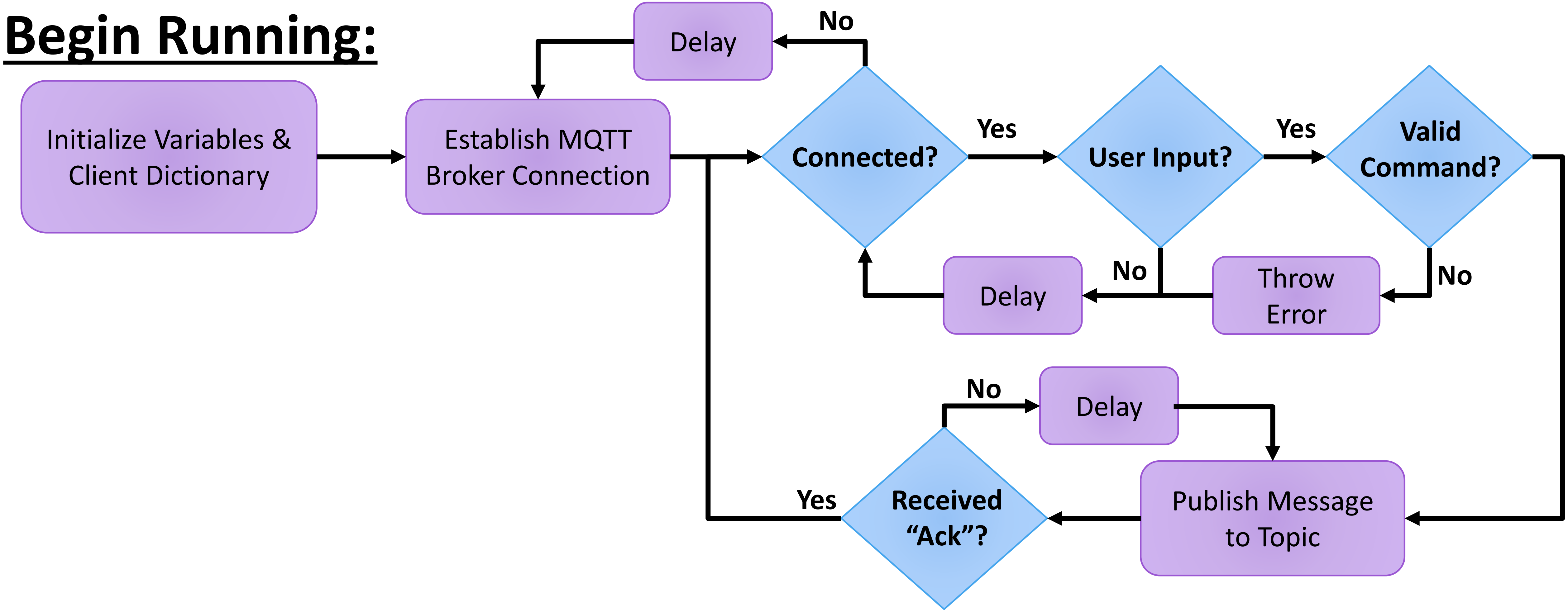
MQTT Structure

- Lightweight publish-subscribe, broker-based network protocol
- Uses Mosquitto broker in local environment to distribute messages
- All clients communicate over Wi-Fi
- Central python controller commands and monitors system
- Highly scalable



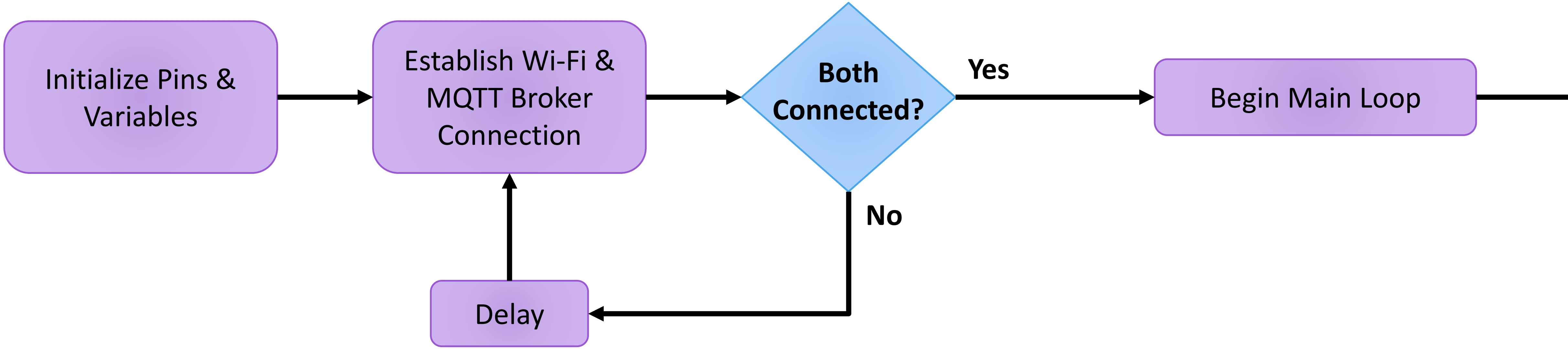
Basic Controller Algorithm: Control Node(s)

Begin Running:

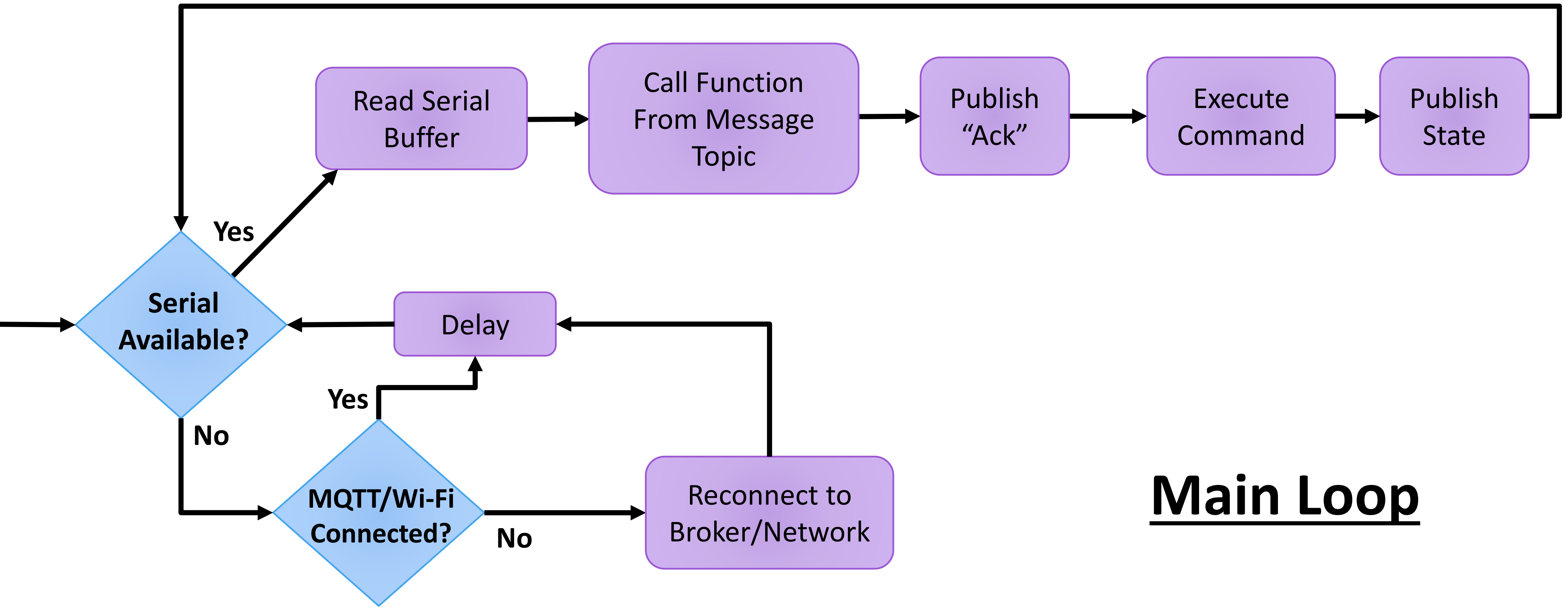


Embedded Software

Begin Running:

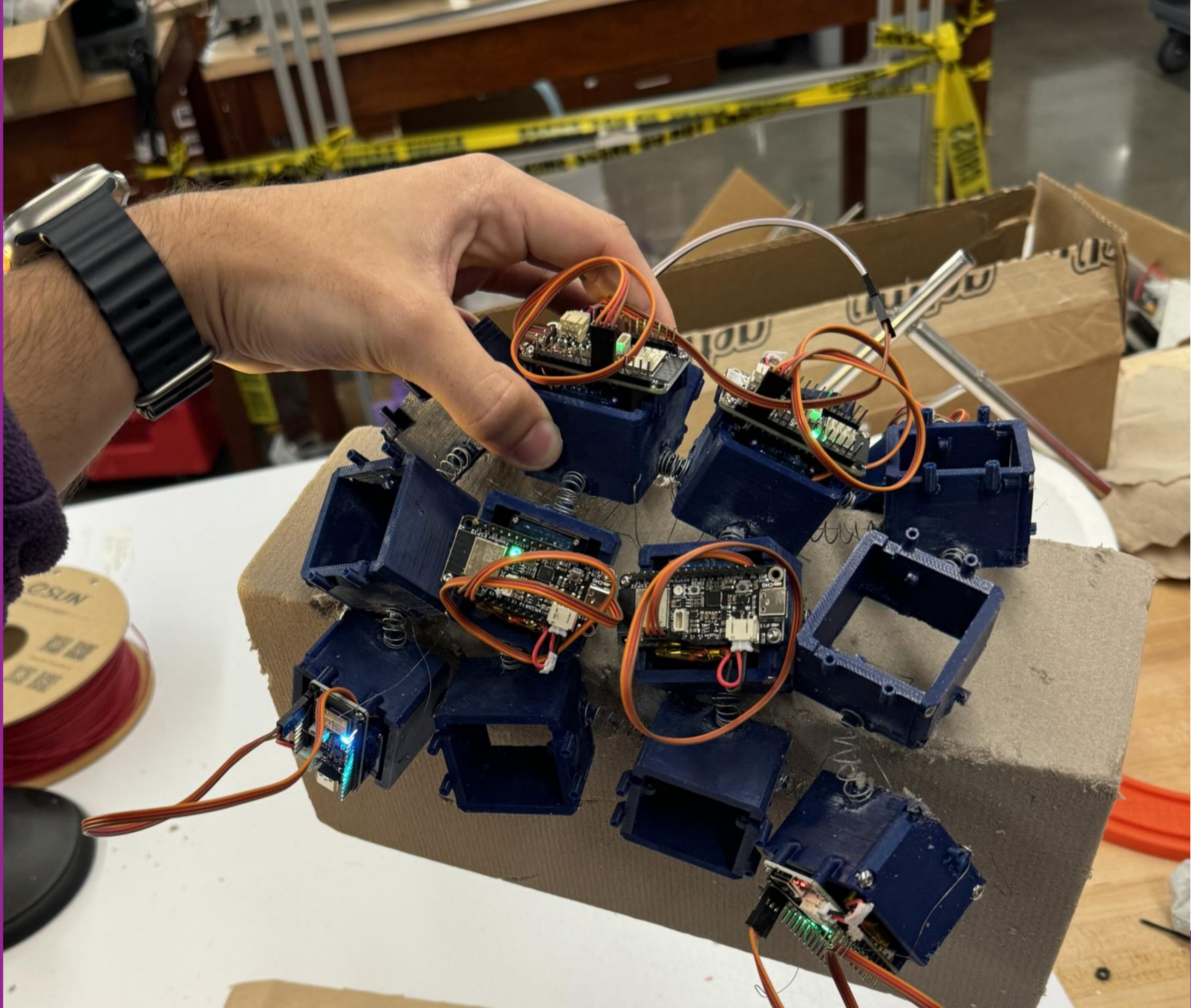


Embedded Software

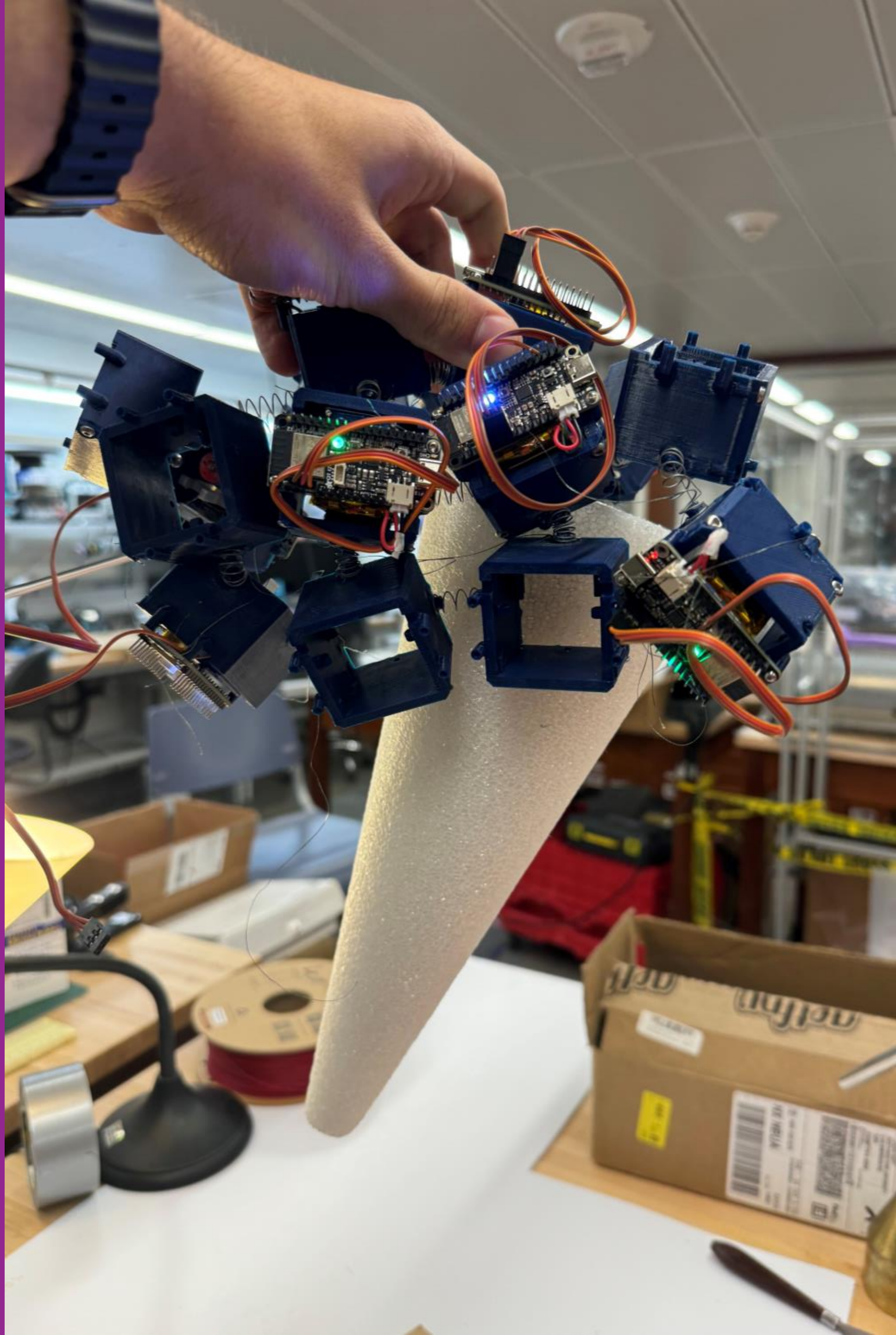


Manipulation Task Primitive

Manipulating a rectangular prism



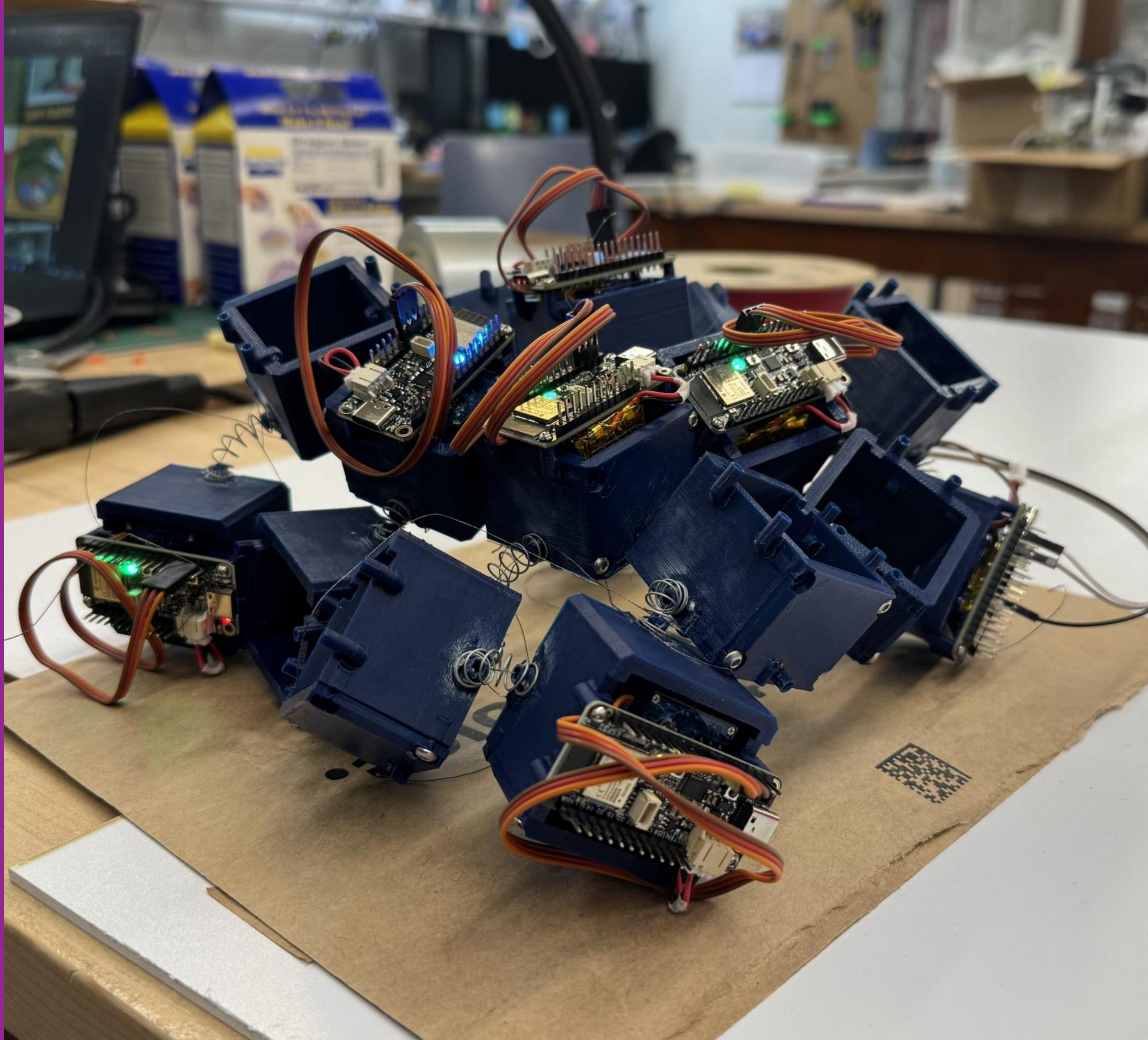
Manipulating a cone:



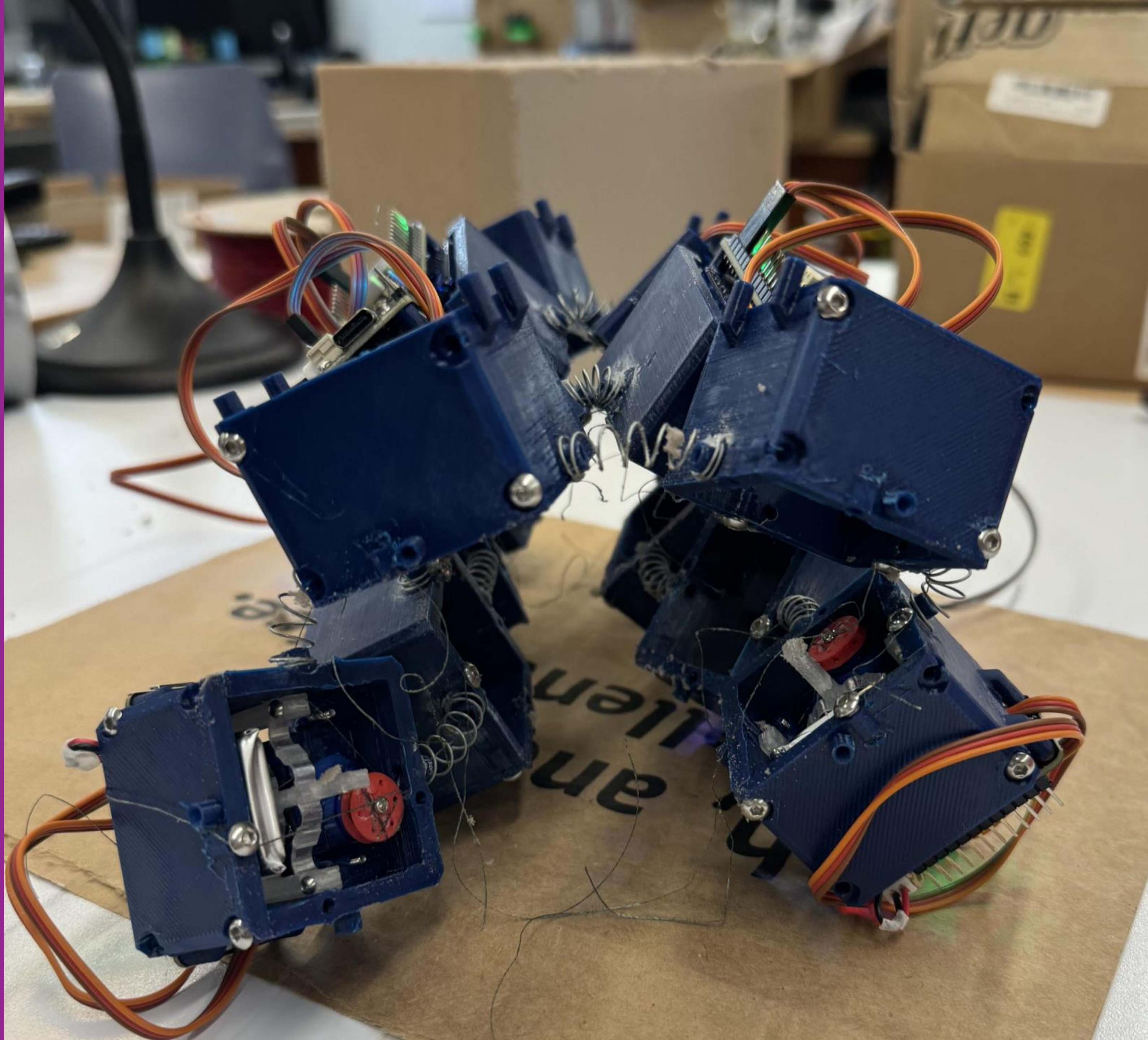
Locomotion Primitive

I am performing experiments in the days leading up to the experiment to see if I can get the platform to locomote. I will display results here.

Hemisphere Stable Structure:



“Folded” Stable Structure:



Conclusions & Future Work

Comparison to other systems

Strengths:

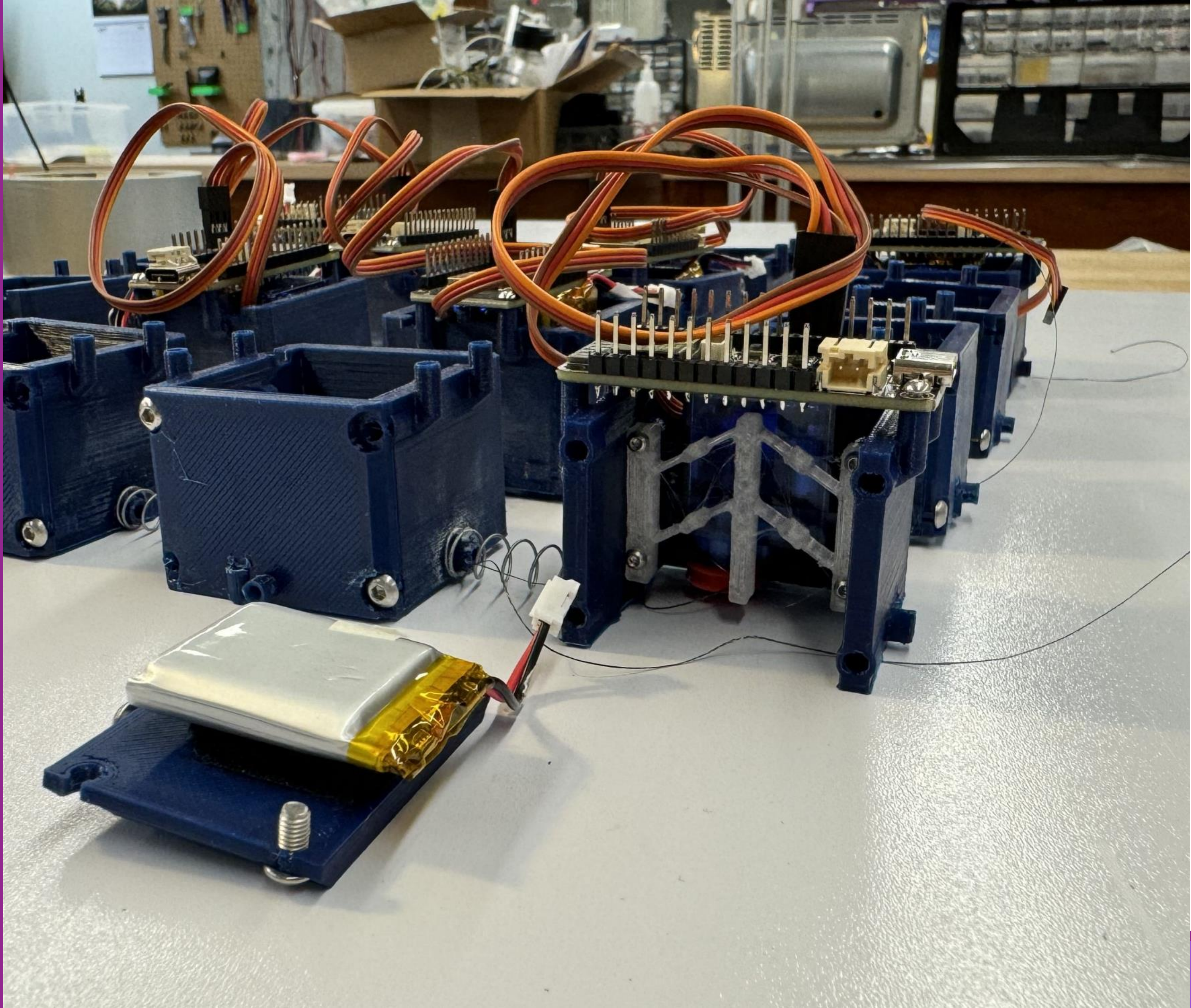
- Modular design
- Easy to assemble system
- Highly scalable
- Easy to reconfigure for biased structure
- Multiple task primitives

Weaknesses:

- Limited Precision
- Non-deterministic behavior
- Struggles with high mass objects

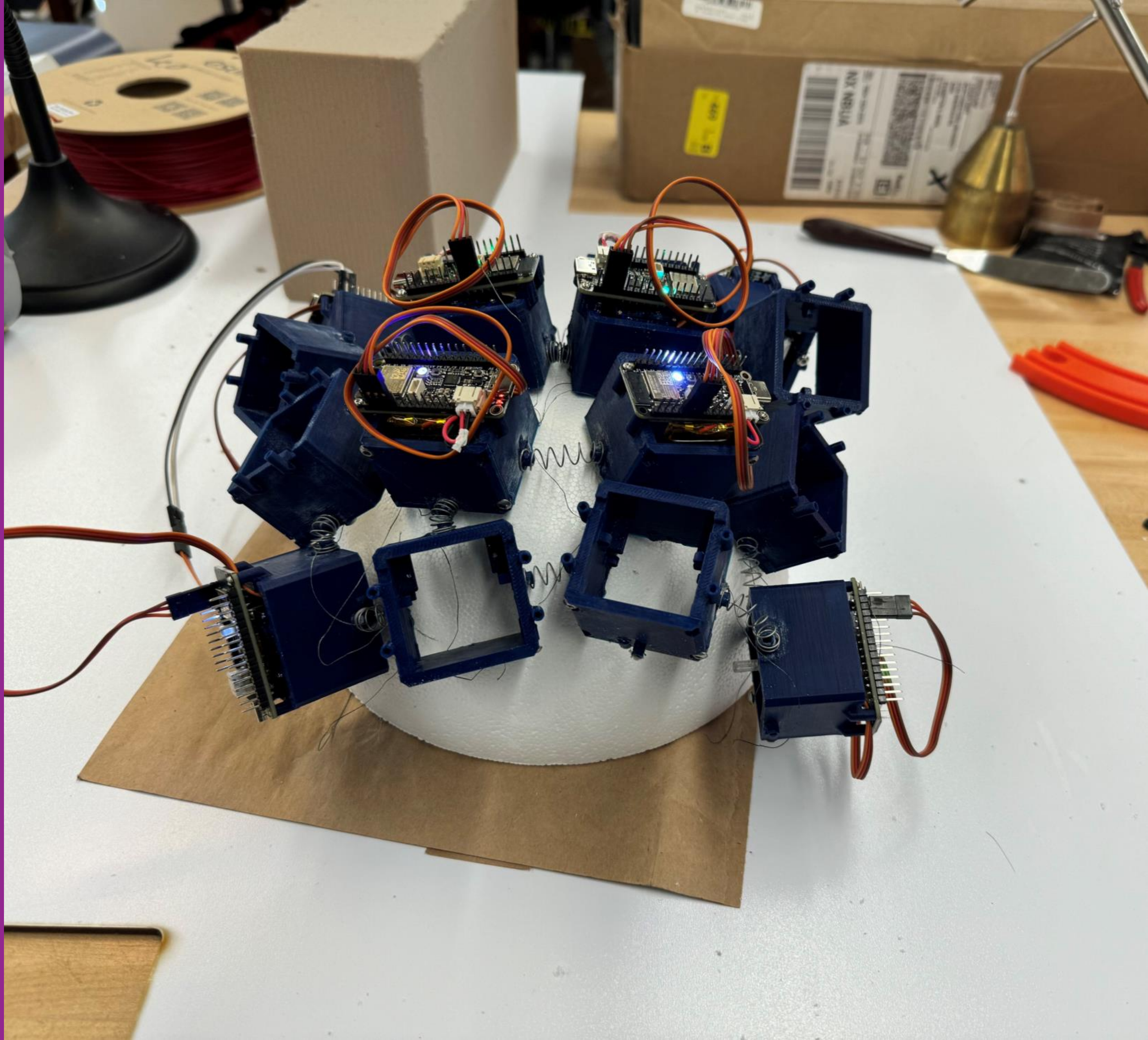
Future Work

- Planar locomotion
- 3D Locomotion
- Mechanical sensing and object recognition



Conclusions:

This system provides evidence to the usefulness of robotic metamaterials by performing manipulation (and locomotion?) tasks with trivial control methods and high adaptability.



Thank you for coming!

QUESTIONS?