MAE 162E

F.R.E.D.

Folding Robotic Exploration Device

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F.R.E.D. Project Goal Recap

- Features
  - Inspired by origami
  - Transformative ability; folds into a cube
  - Locomotive mobility
- Applications
  - Challenges in space optimization
  - Accessibility assistance
  - Environmental monitoring

Design Objectives

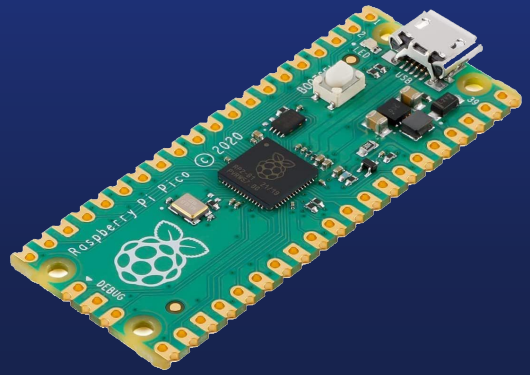
- Fold into multiple configurations
- Easily stored
- Battery-Powered
- Easily reconfigurable
  - Simple base modules (triangles) allow for easy add-ons
  - Can combine into complex geometries
- Internalized electronics
  - Batteries and microcontrollers
  - Wires fed through robot for sleek design

Design Process

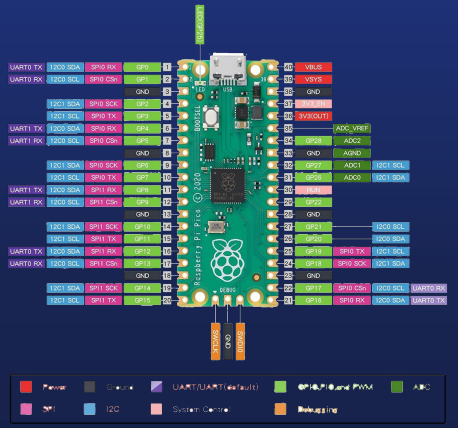
- **Components**
  - Motors
    - Considerations: cost, torque, RPM
  - Controller
    - Moved from Arduino to Pi (more pins)
  - Batteries
    - Produce required power at a low weight

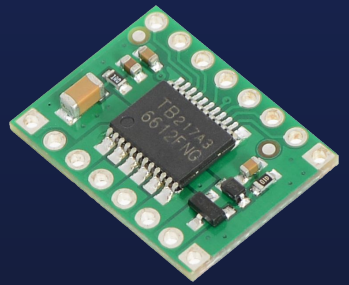
Components

- Controlled with Raspberry pi
- (2) motor drivers
- (4) 986.41:1 motors with encoders, 35 RPM max
- Motors actuate in sequences that produce specific geometries
  - Cube, crab, table, inchworm, waving

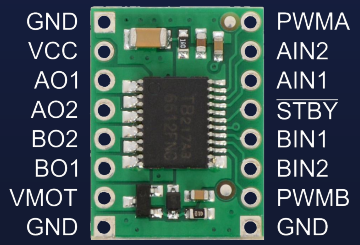


Raspberry Pi Pico





Motor

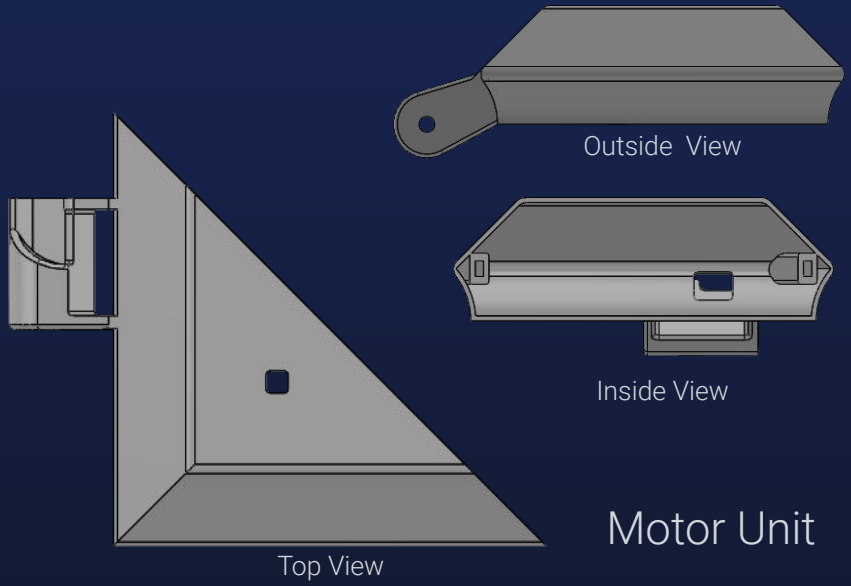


Motor Drivers

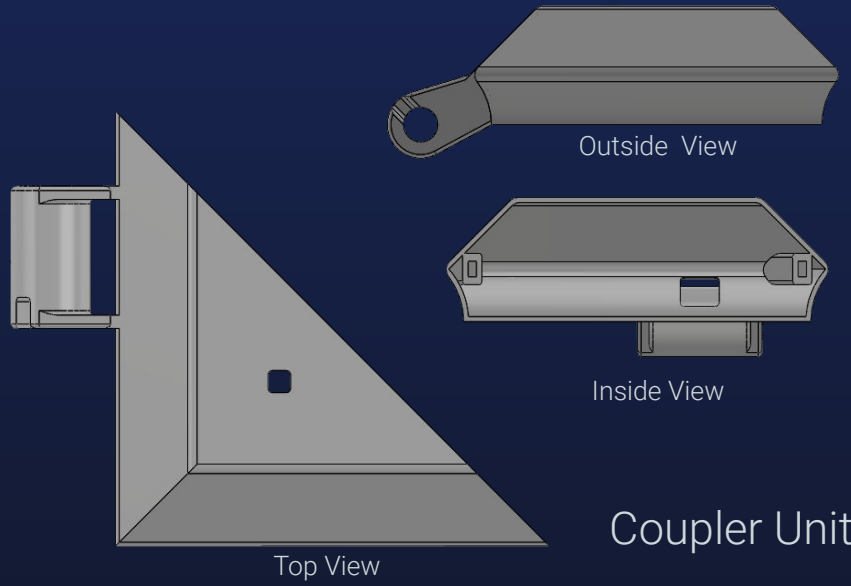
Design Process

- **Geometry**
  - Modelling prototypes
    - Paper
    - 3D printed modules
  - Balancing folding with practicality
  - Joining geometries
  - Altering CAD to fit changing part dimensions

Geometry - Final CAD Model - Units

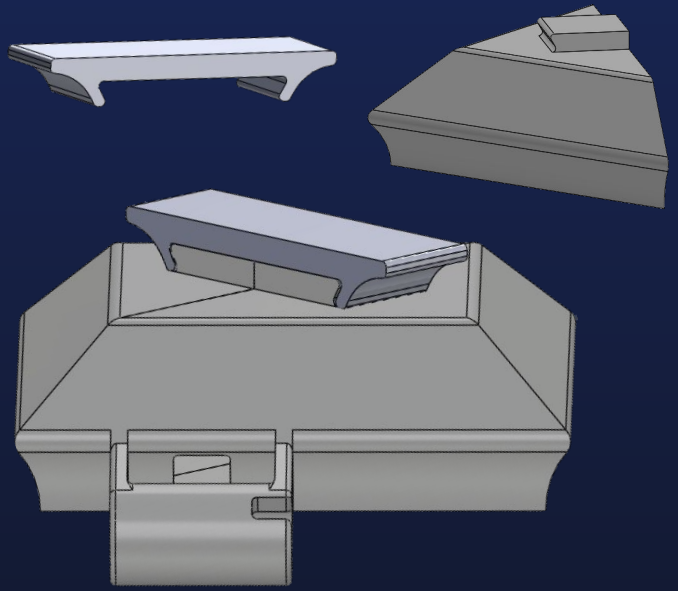


Motor Unit

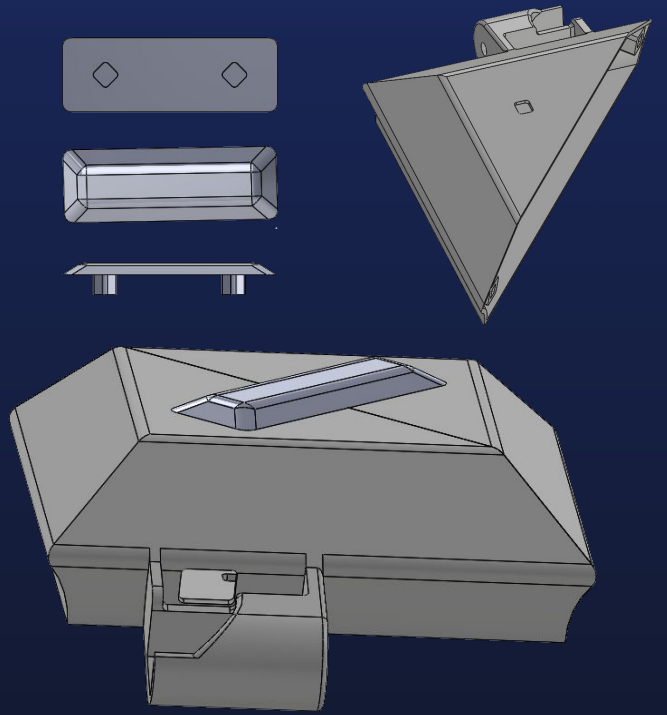


Coupler Unit

Geometry - Joining



Version 1



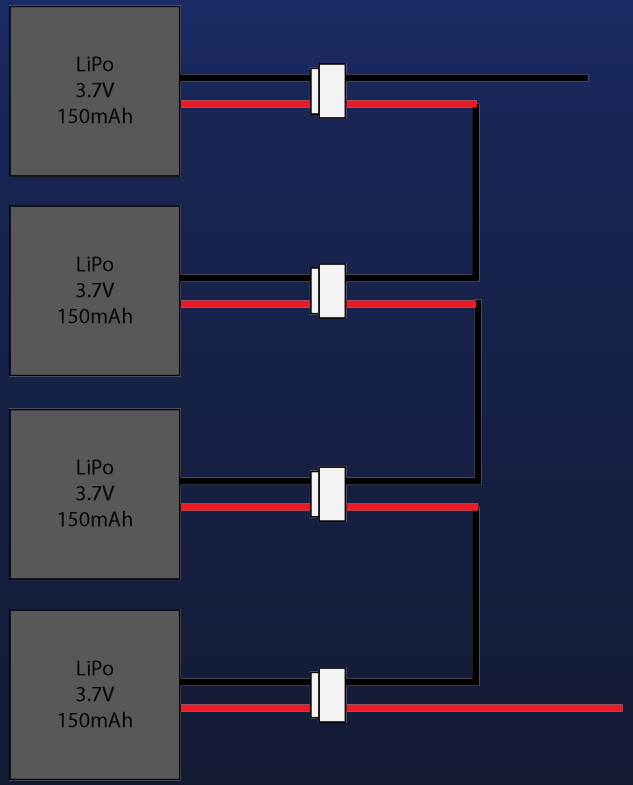
Version 2

Code Overview

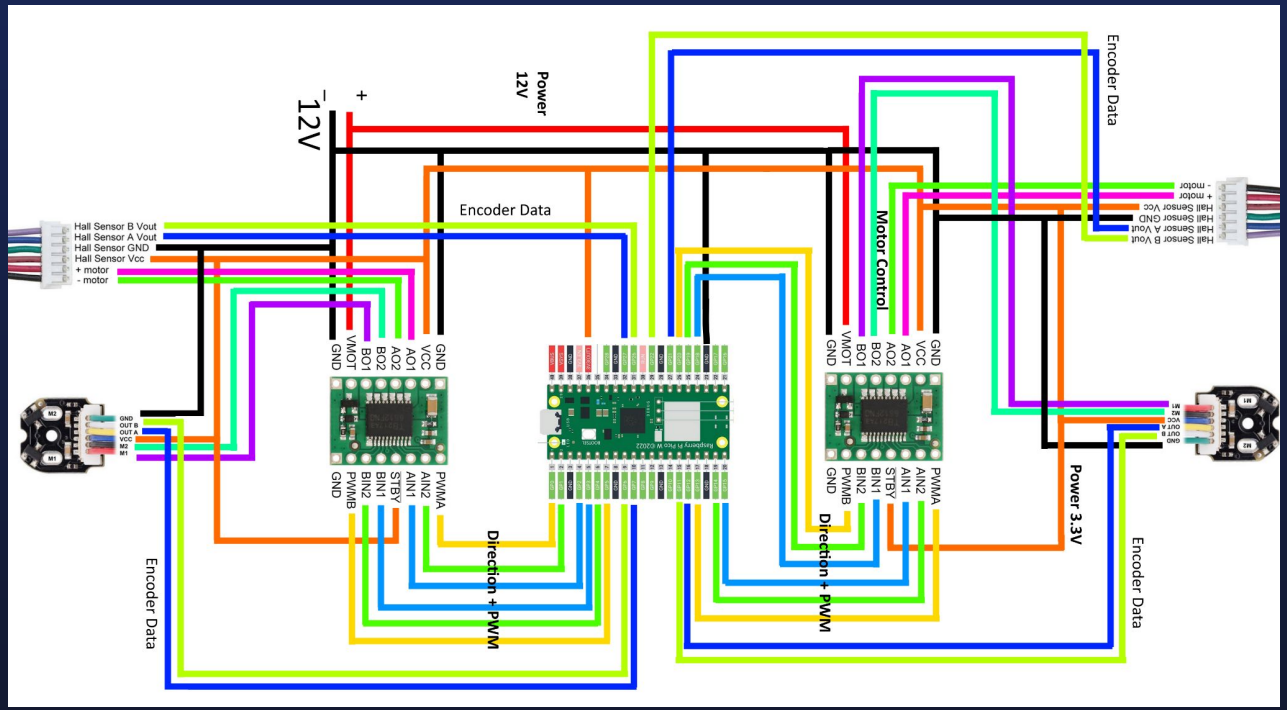
- Created a motor class to instantiate each of the four motors
  - Assigned PWM, IN1, IN2, ENC1, ENC2 pins to each
- Made class-level functions
  - Encoder tick function, update control function, motor driver functions, set target position
- General functions
  - Isolate, adjust_motor
- Configuration functions
  - Cube, crab, table, start_loco, locomotion, wave

Design Process

- **Electronics**
  - Batteries:
    - 2 packs - 4 batteries each
    - 4 Lithium Polymer Batteries in series, 3.7V, 150mAh
  - Power Requirements:
    - Motor: 12V
    - Raspberry Pi: 1.8-5.5V, 80mA
    - Motor Drivers: 2.7V



Wiring Configuration



Design Process

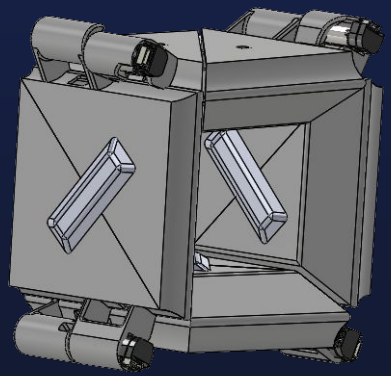
- **Motor Control - Programming**
  - When should each motor turn on? In what order?
  - Troubleshooting motor controls
  - Selecting PWM values
  - Writing pre-set functions for different configurations

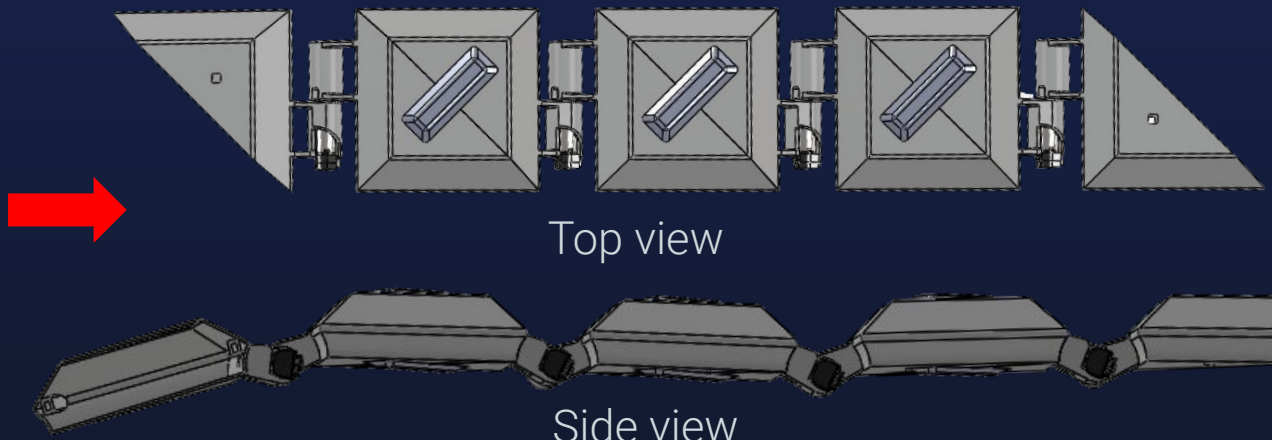
How it works

- Precise position control achieved with encoders
- Motor driver signals motor to brake when desired number of encoder ticks is reached
- PID controller implemented to correct overshoot
  - Braking capabilities of motor driver were also efficient

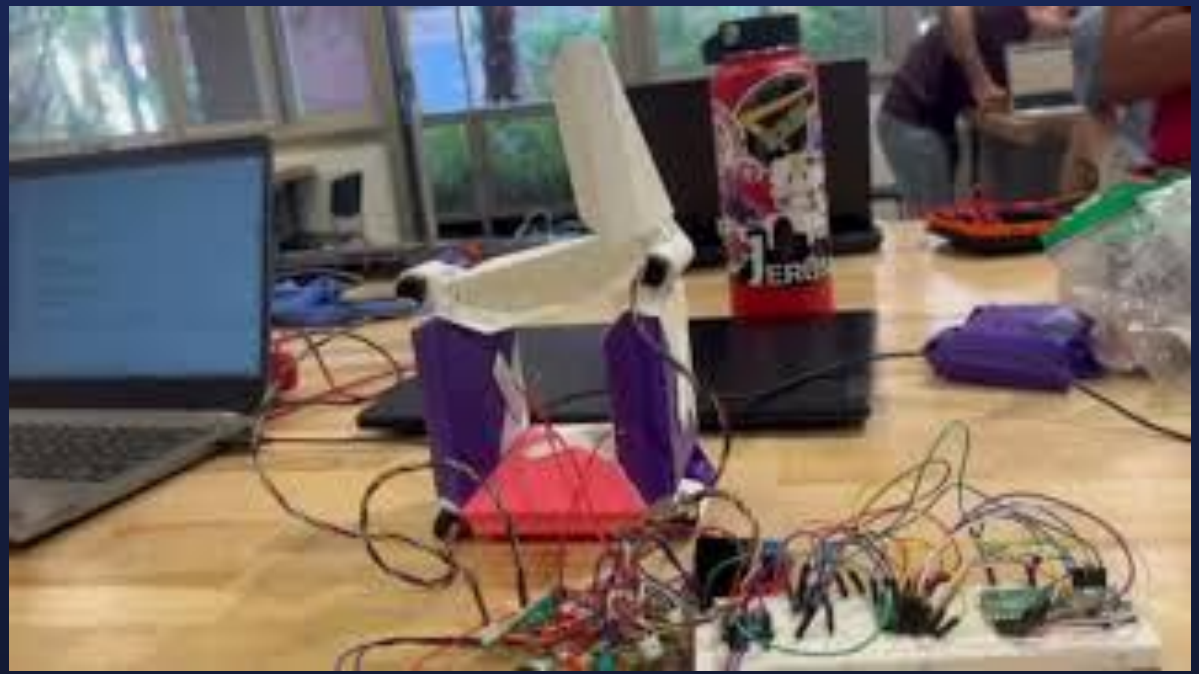
Configurations: Cube and Unfold

- Simplest configuration
- Each motor folds up 90 degrees in order
- Unfold() does the opposite





Configuration: Cube Video



https://youtu.be/Eig6i061Qmo

Configuration: Crab Video

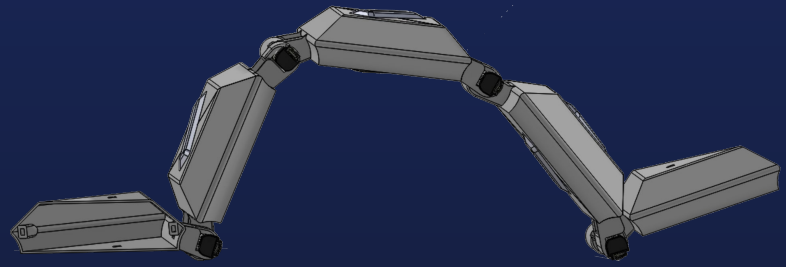
https://youtu.be/X6MKO7SeqyA

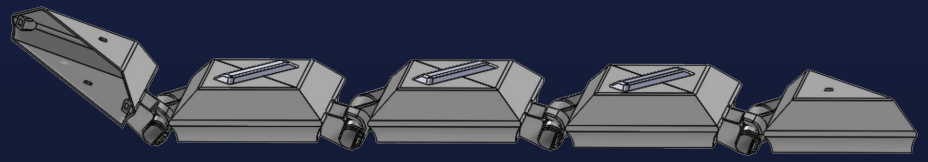
Configuration: Table

https://youtu.be/O6qCLshqof8

Configuration: Inchworm Locomotion

- Motors have to work in conjunction with each other
- Requires more precise angles than cube
- Extensive testing required, simulations complicated
- Explored inchworm-inspired movement





Configuration: Locomotion

https://youtu.be/dt0LUPM4hEQ

Technical Issues

- Fried already-soldered microcontroller
- Broken motor drivers
- Troubleshooting electronics → many potential areas of failure
  - Ex: PWM to wrong pins (despite correct wiring and code)
  - Ex: Faulty connections on motor wires
- Differing PWM values
  - Higher for moving modules up
  - Lower for downwards movement due to gravity
- Finicky tolerance
  - Lots of reprints

Design Objectives Revisited

Achieved:

- Fold into multiple configurations
- Easily stored
- Battery-Powered
- Easily reconfigurable

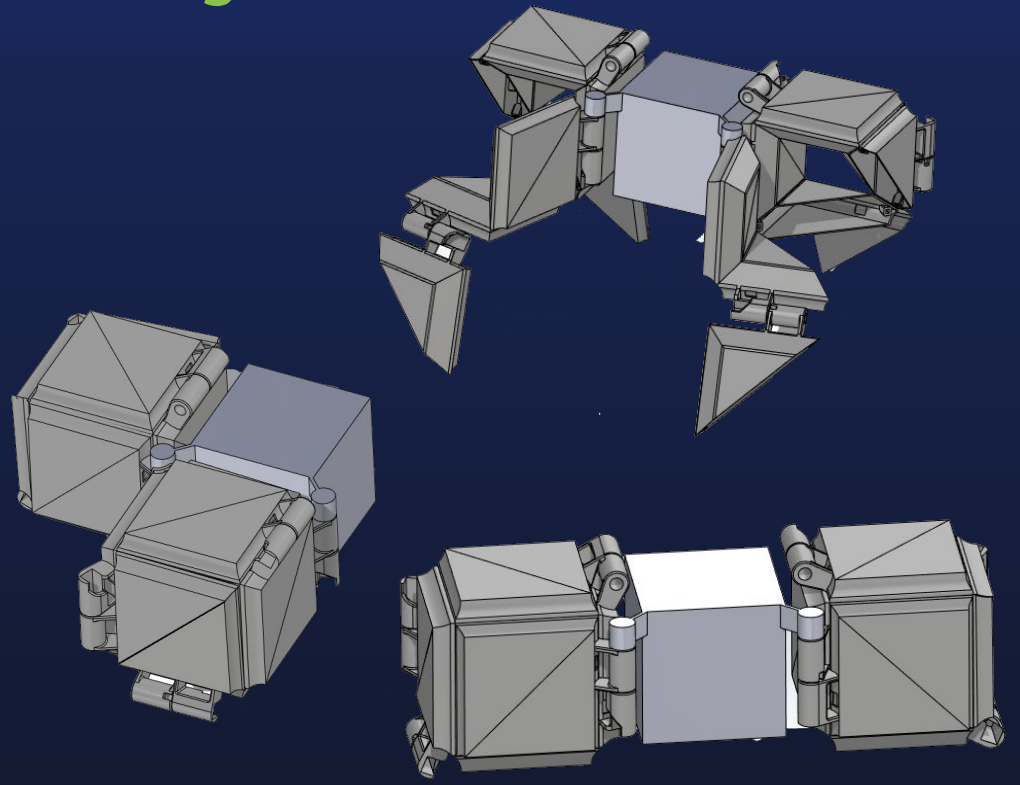
In Progress:

- Internalized electronics
  - Batteries and microcontrollers
  - Wires fed through robot for sleek design

Future Development: Configuration

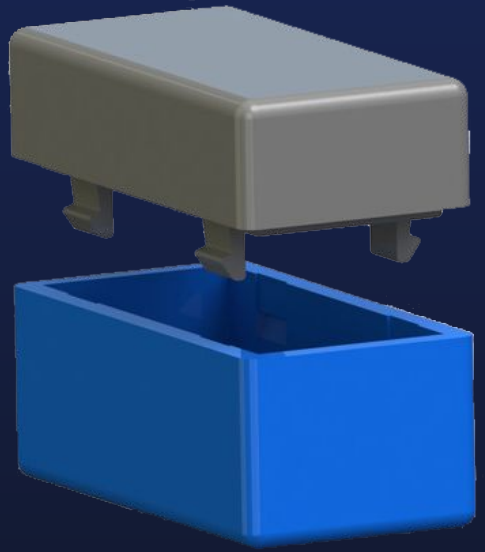
Reach goal for the quarter

- Quad-legged crab configuration
  - Central brain housing in the middle
- Collapses into cubes
  - Can rotate into angled or straight configuration
- Untested - high motor and circuit requirements with limited time



Future Development: Joining

Snap fit design



3-Minute Video

https://youtu.be/K9EnpdS-j-Y

Thank you!