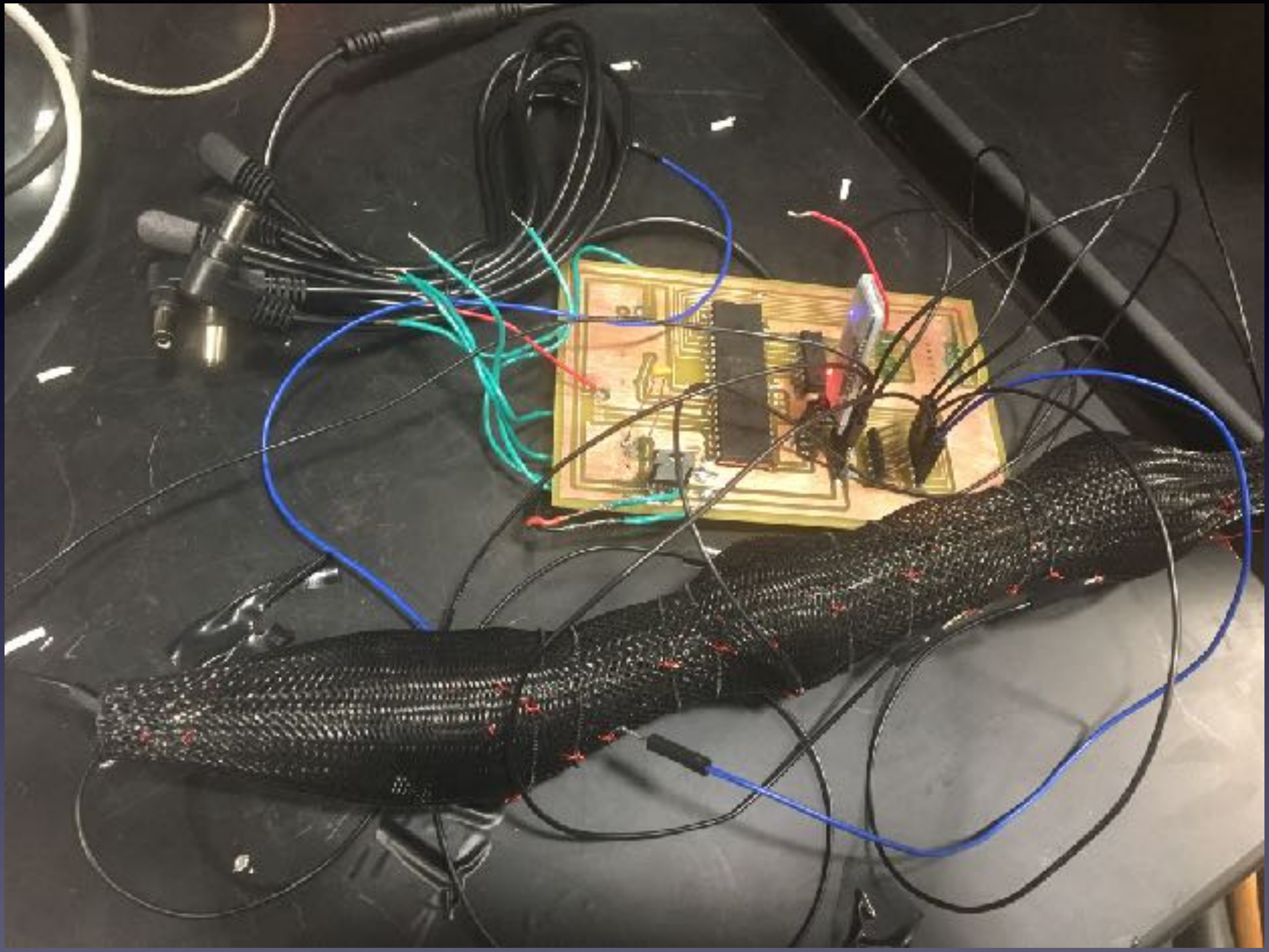
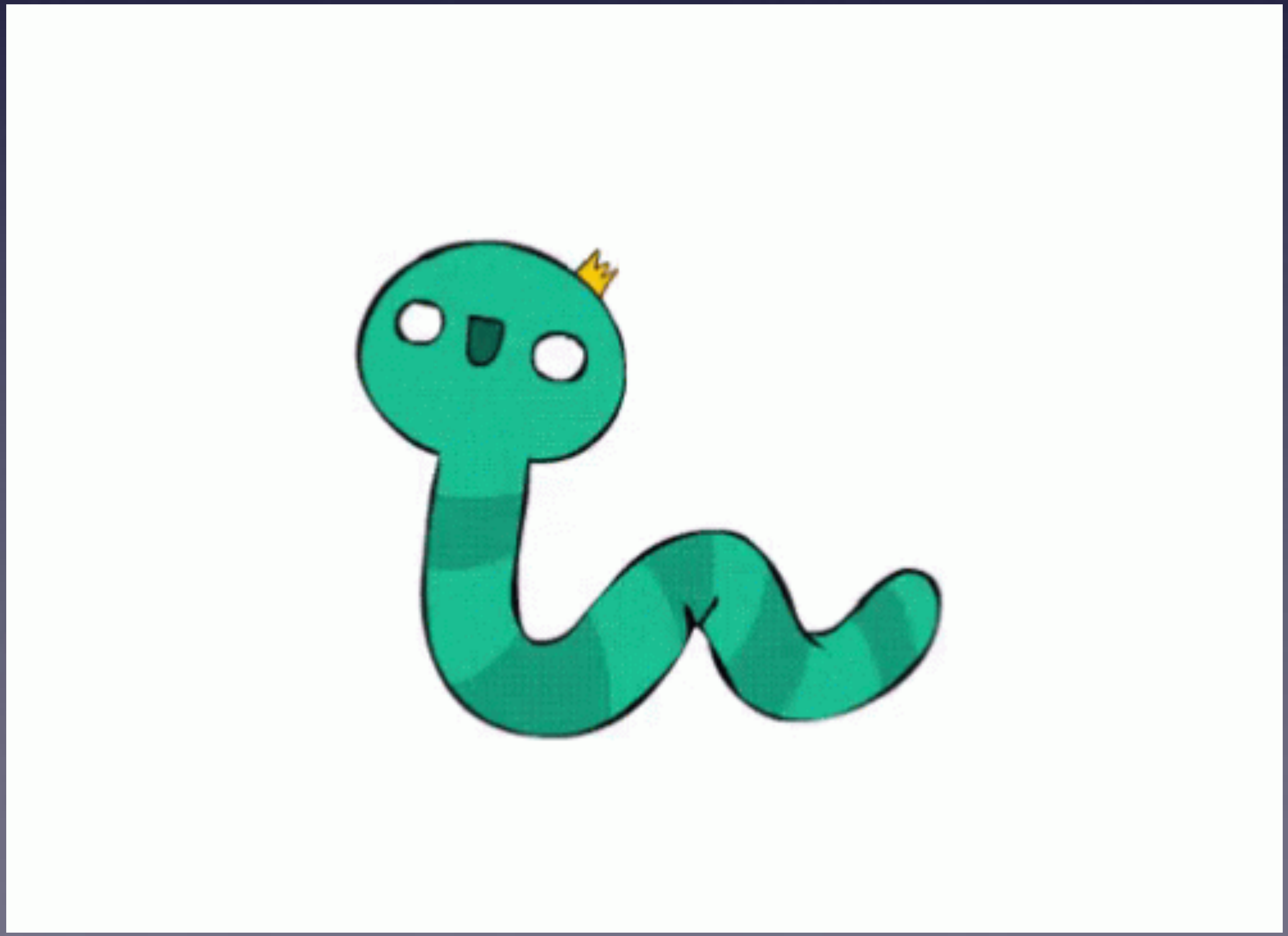
Earth Worm robot

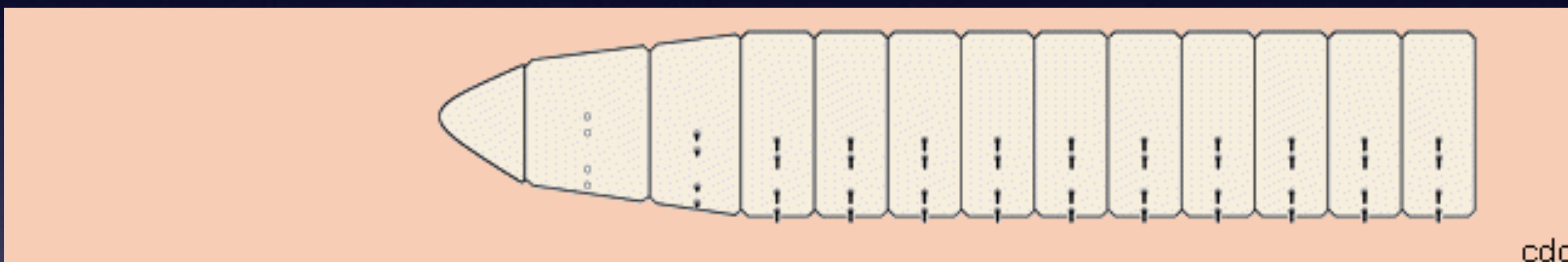


Kunakorn Puntawong
Zehua Li

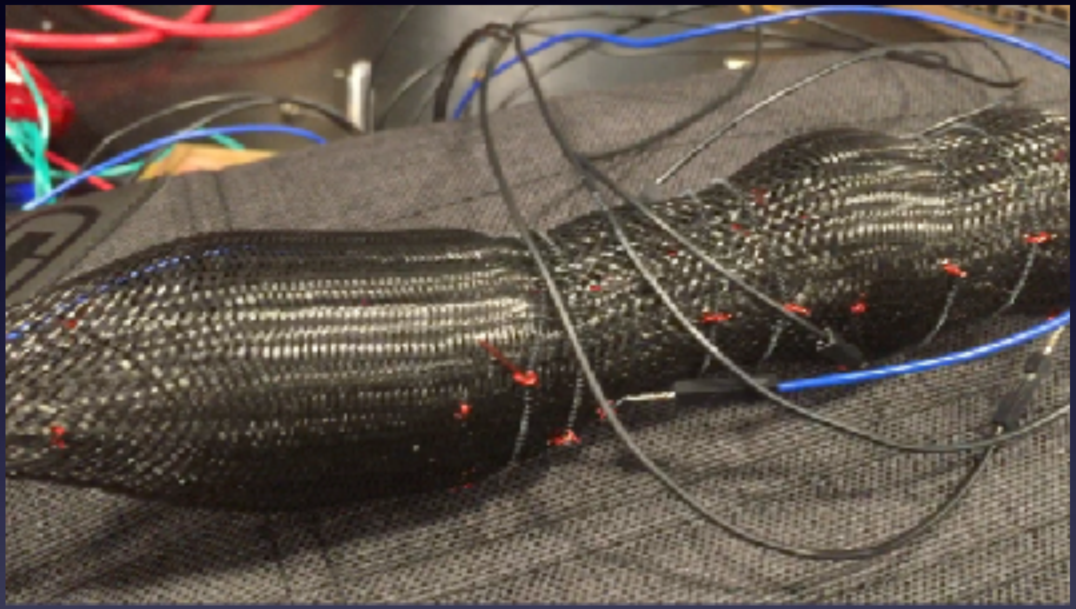
Objective

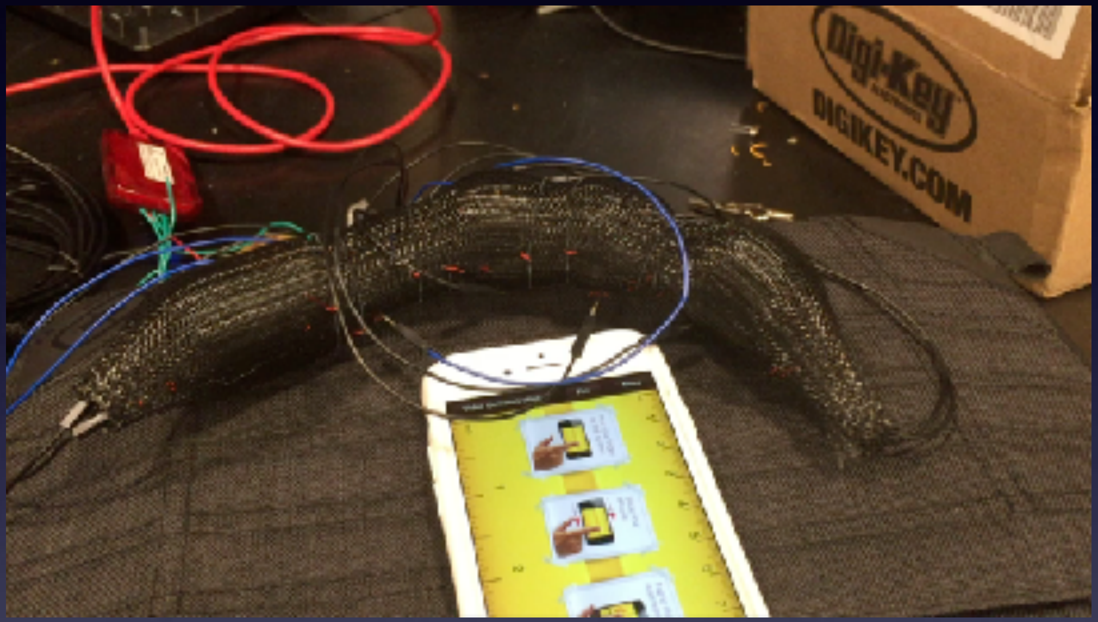
- Small robots for traversing complex terrains with narrow openings
- Emulate Earthworm robot with artificial muscle made from Nitinol wires

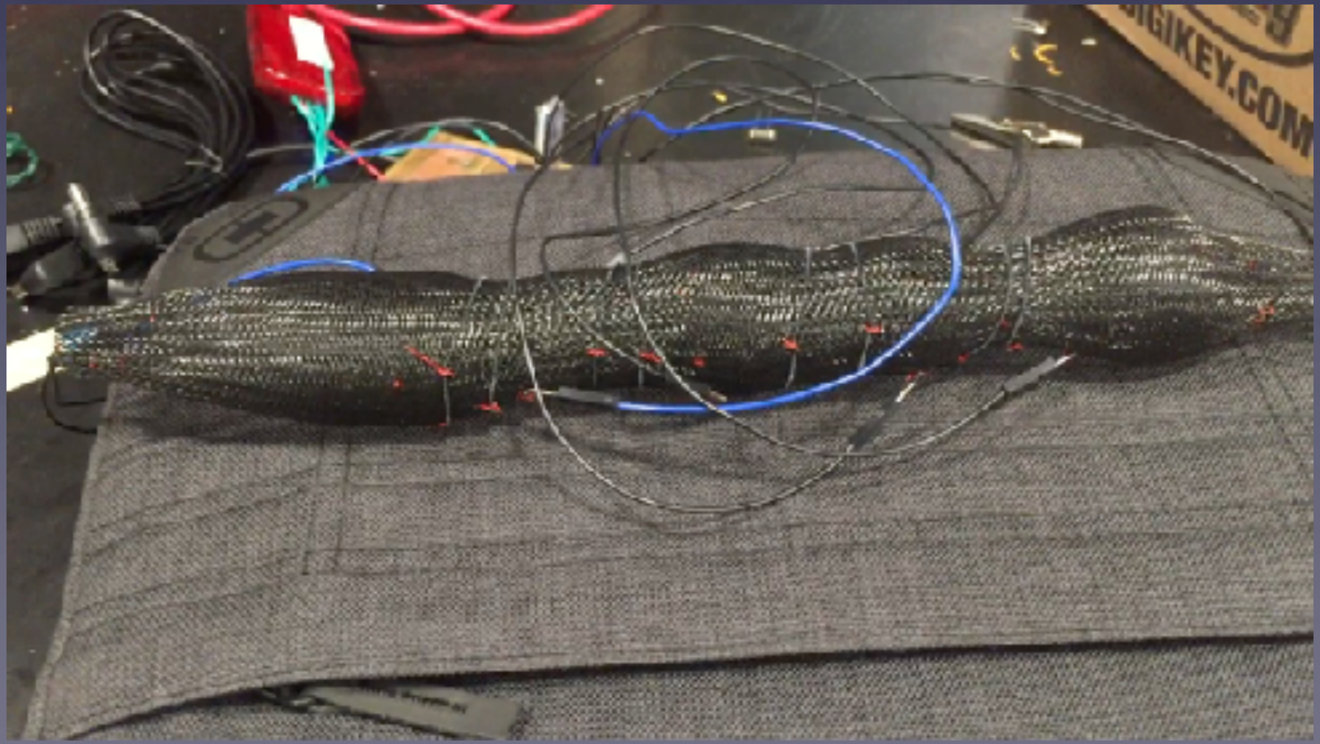



cdd

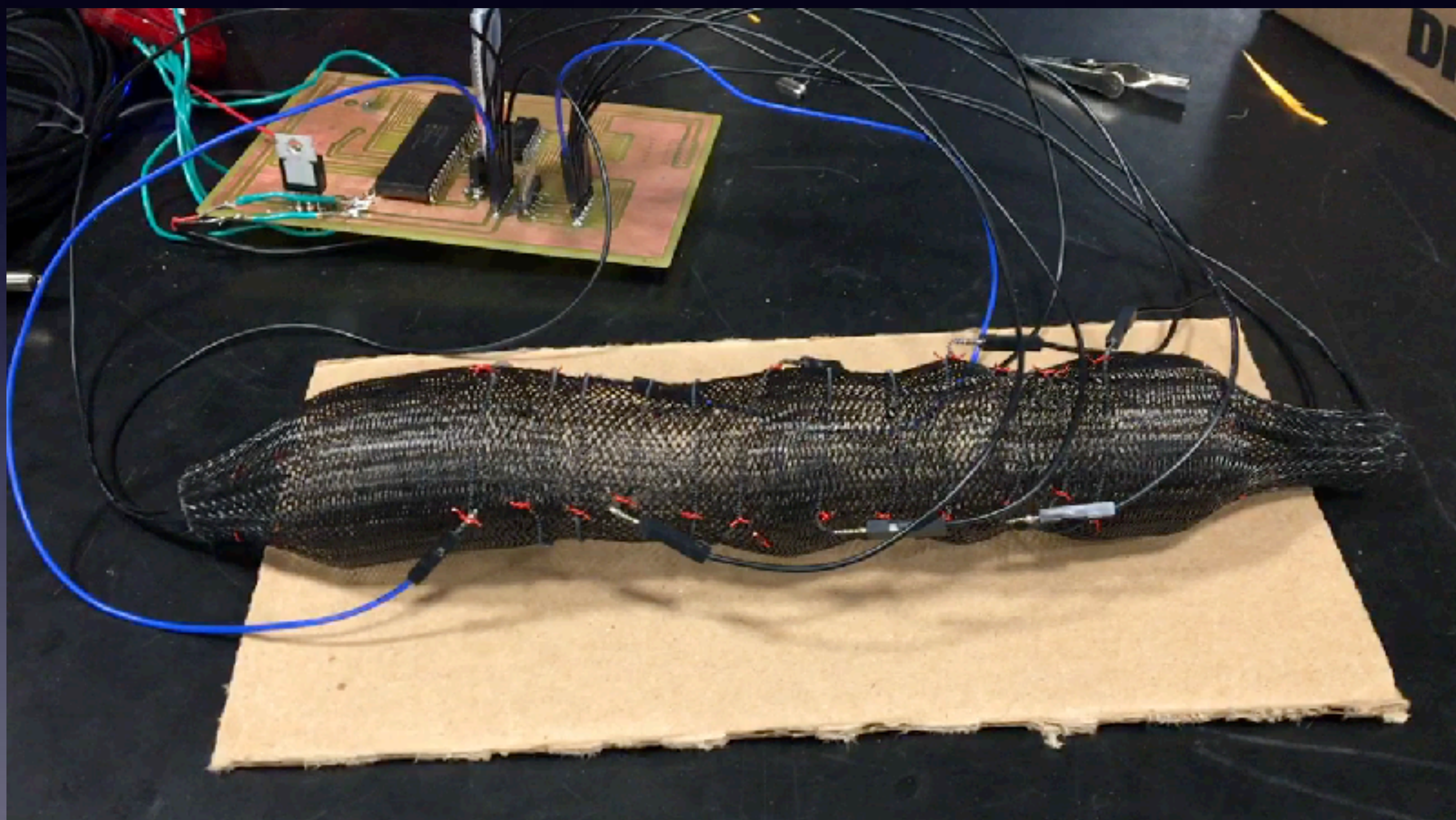
What we accomplished







What we didn't quite accomplish



Designs - Mechanical

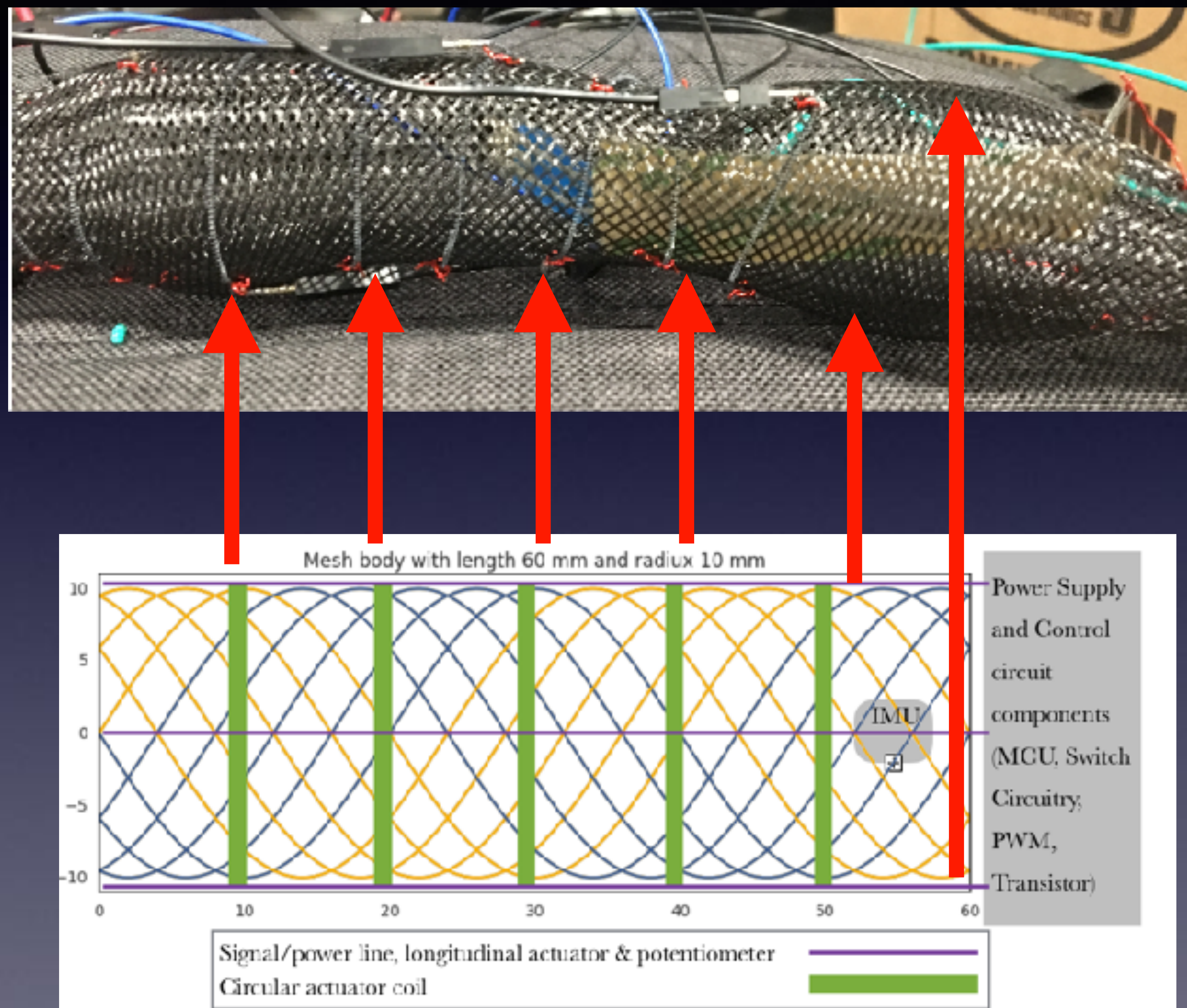
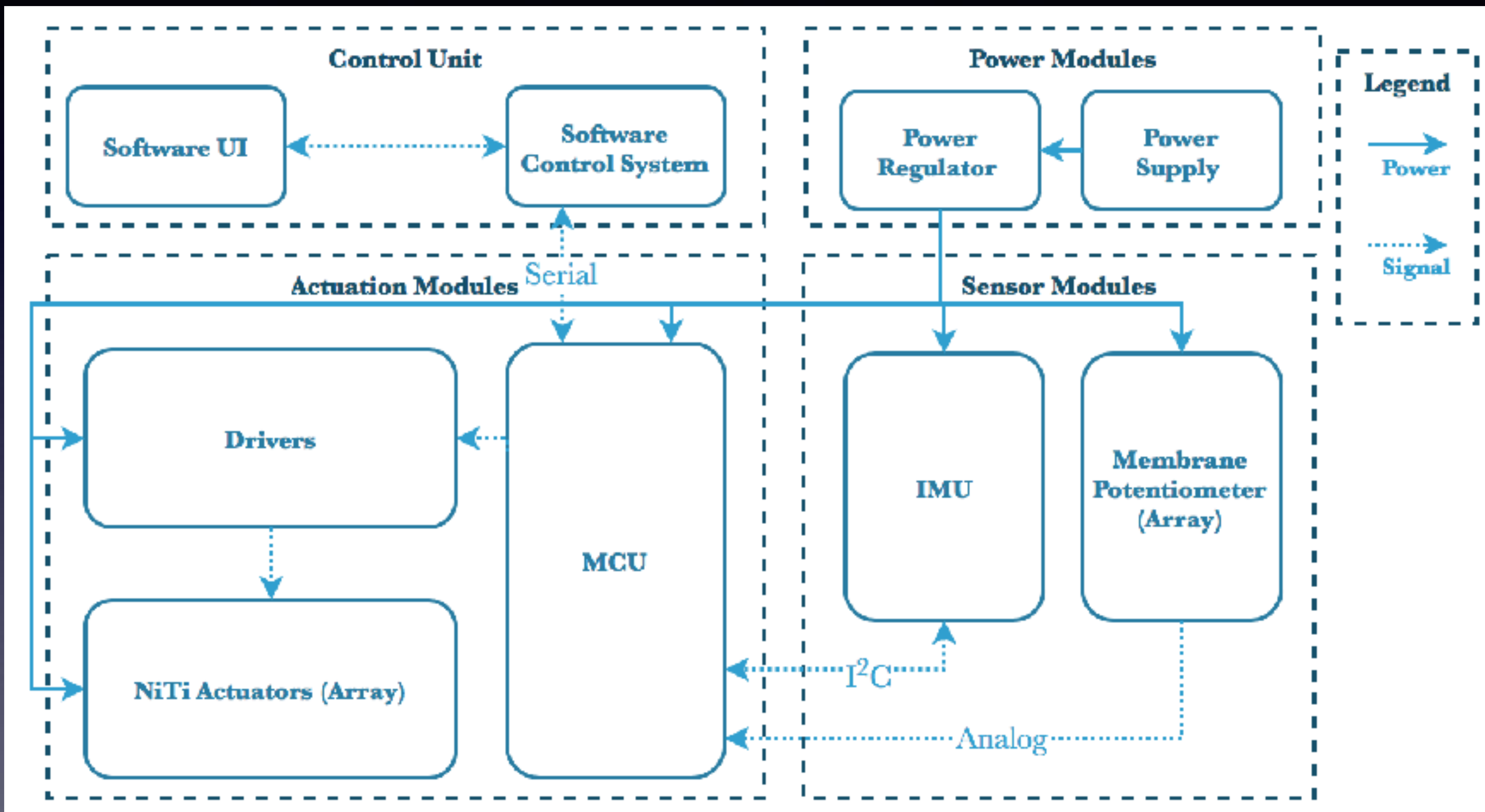


Fig.2 Mesh structure of the robot (length = 60 mm, radius = 20 mm)

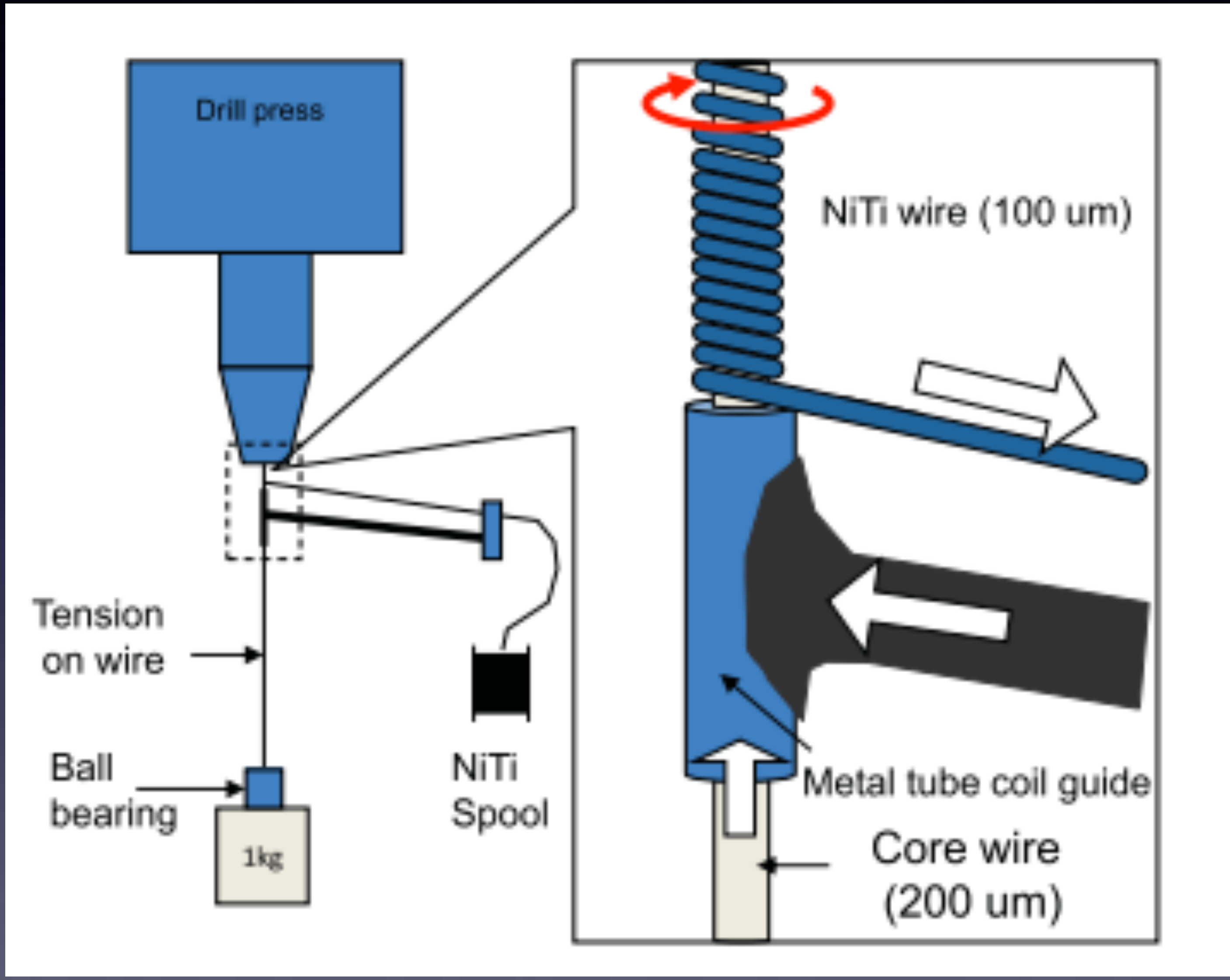
Designs - Block Diagram

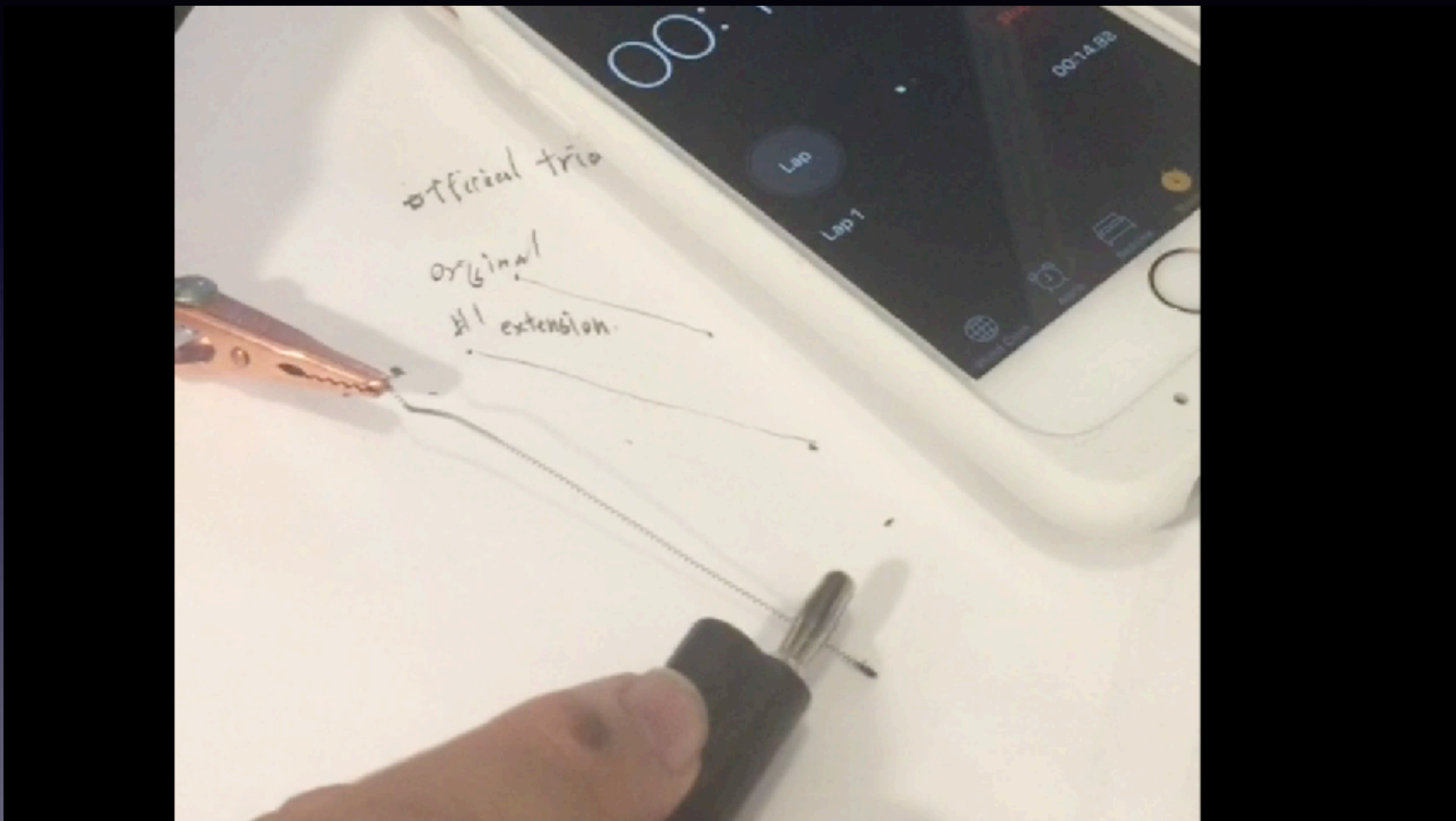


Modules

- Actuation
- Sensor
- Power
- Control

Actuator - Nitinol Manufacturing

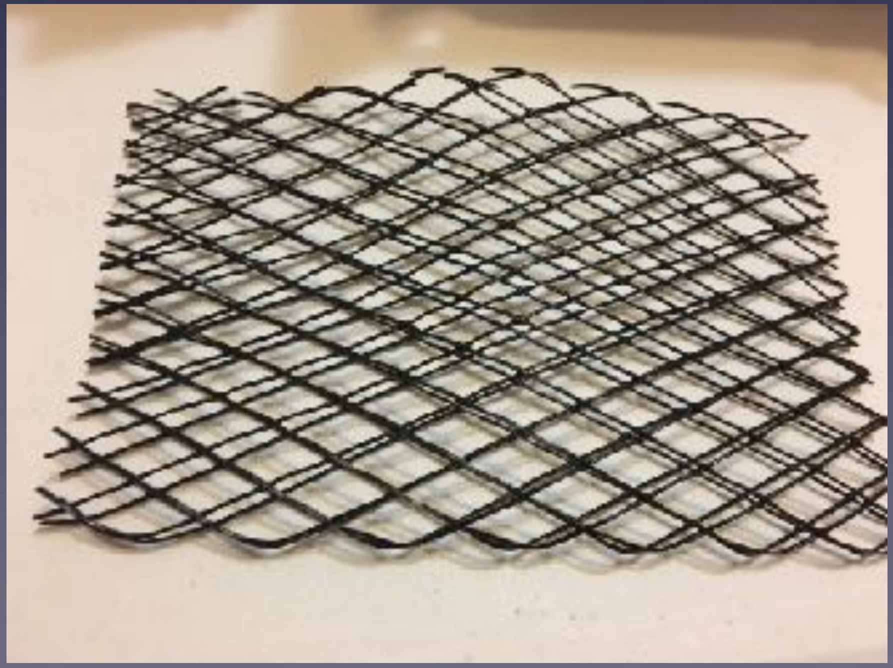


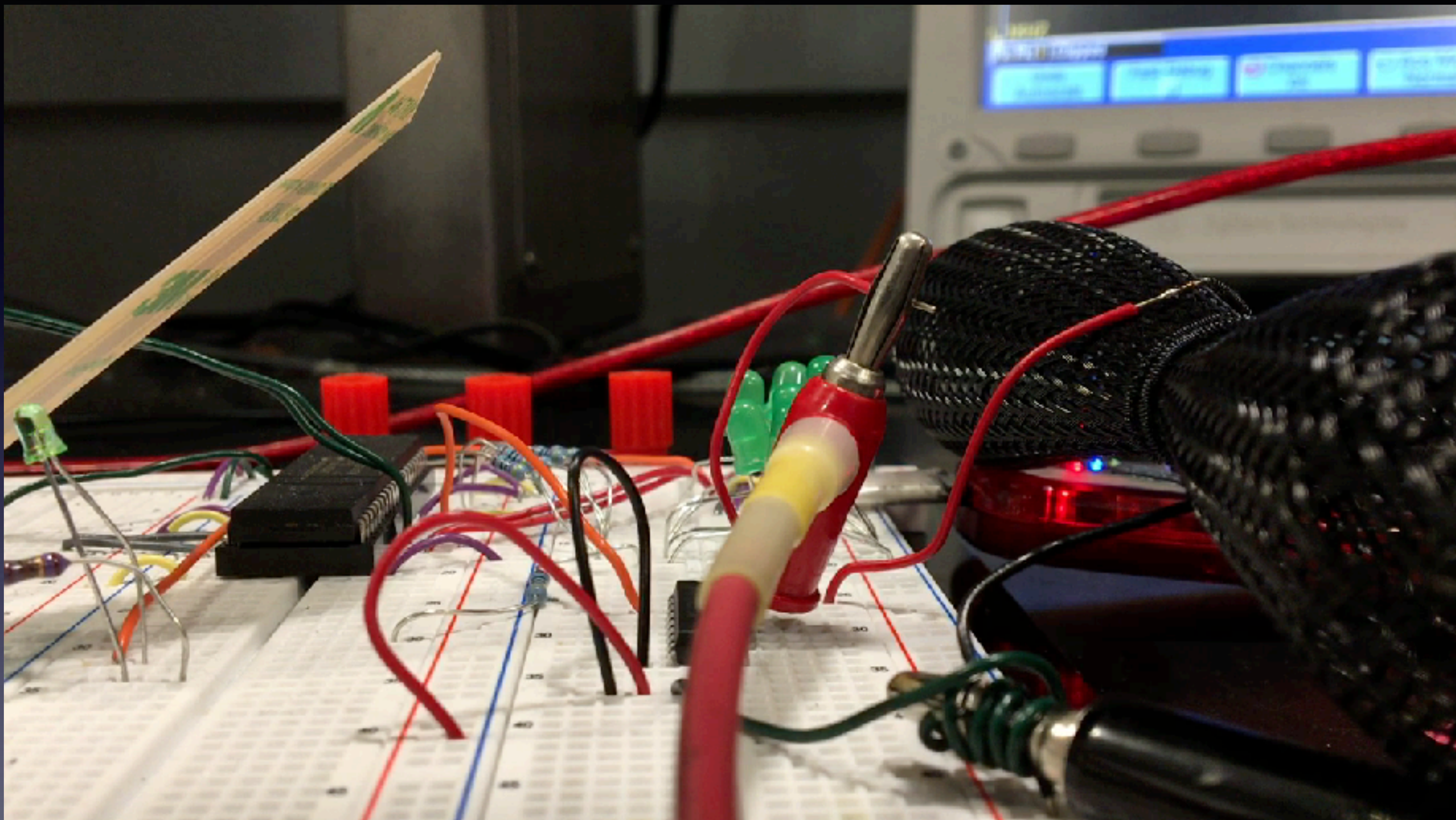

official trio
original
extension
Lap
Lap 1

Body - research and manufacturing



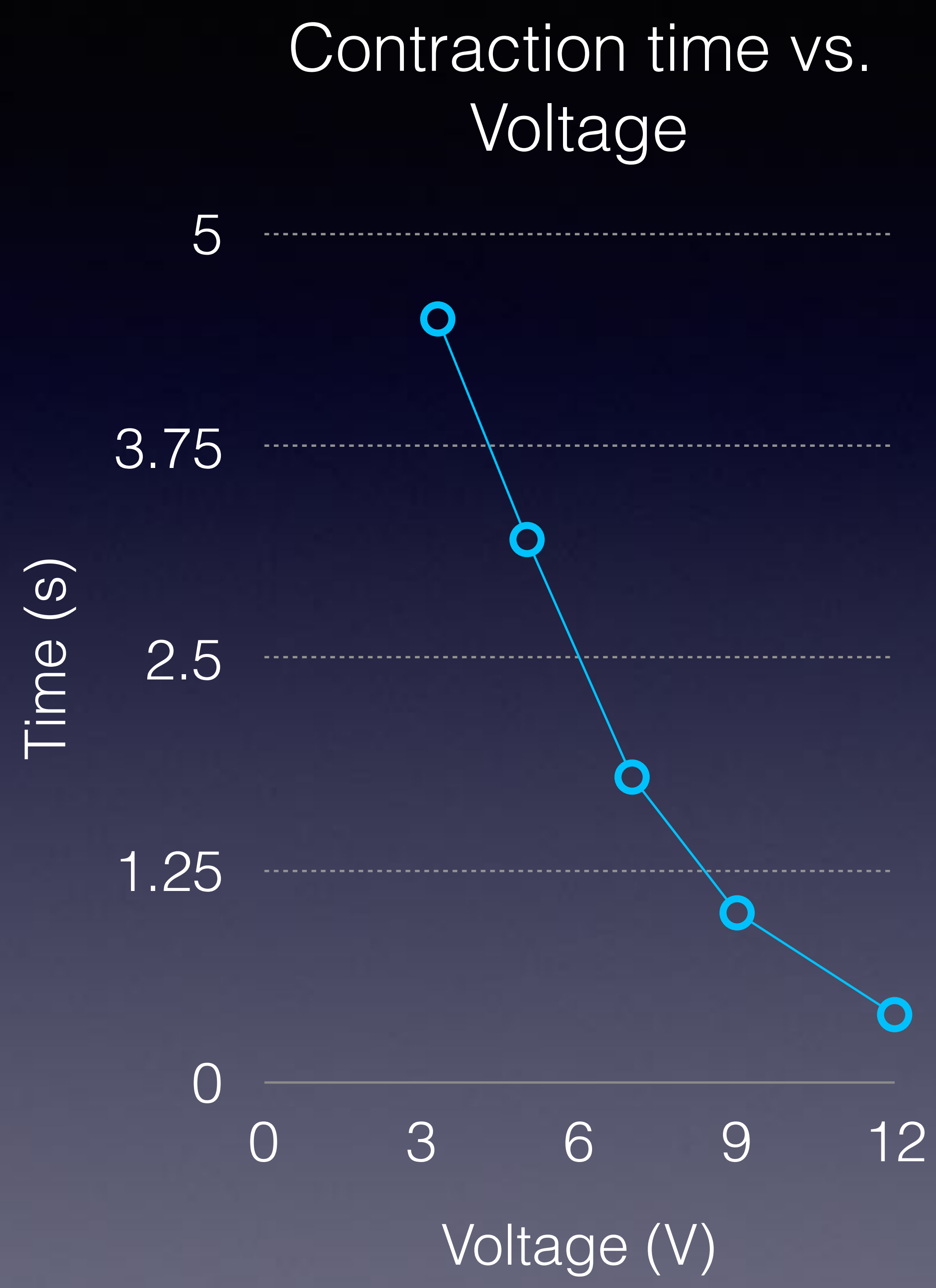


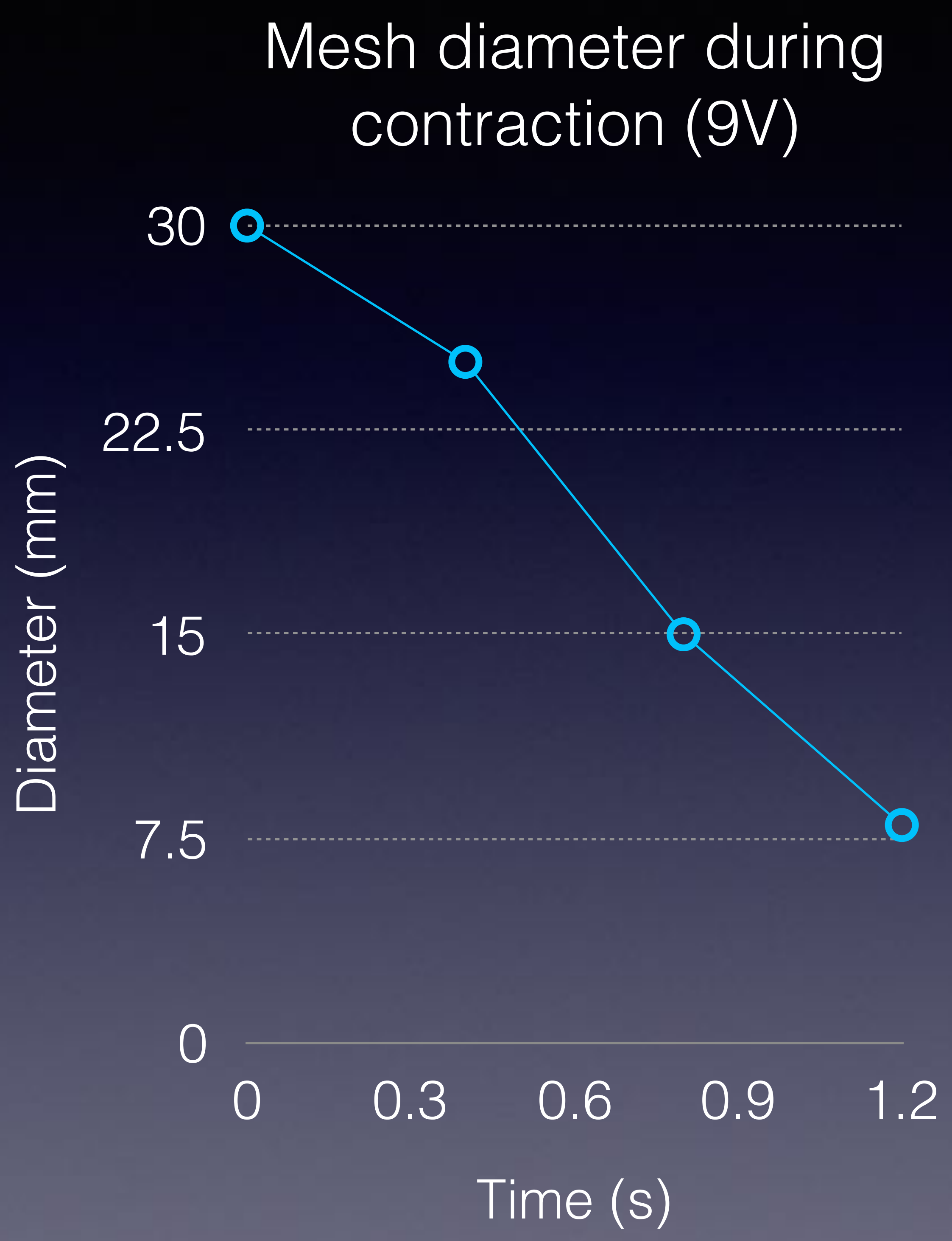




Actuation - problems encountered

- Contraction time too slow
- Wire is too stiff (4x stiffer than original design)
  - 570grams vs 143 grams
- Worm body (braided sleeving) over heat and burned


Contraction time vs. Voltage
5
3.75
2.5
1.25
0
Time (s)
0
3
6
9
12
Voltage (V)


Mesh diameter during contraction (9V)
30
22.5
15
7.5
0
Diameter (mm)
0
0.3
0.6
0.9
1.2
Time (s)

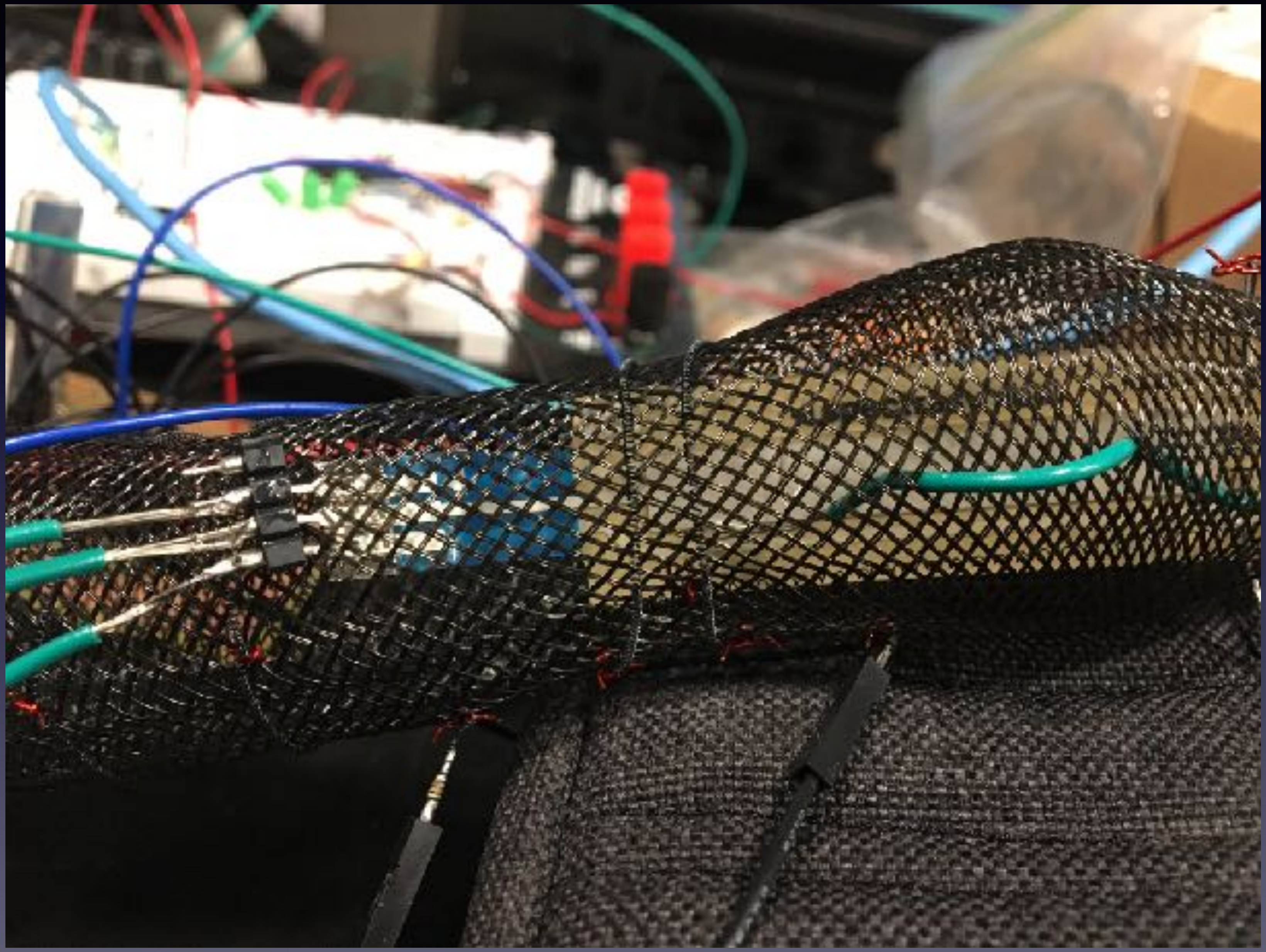
Actuation - problems and resolutions

- ✔ Contraction time - increase power requirement in power modules
- ✗ Stiff wire - need higher precision manufacturing (mechanic injured)
- ✔ Worm body overheating - use a heat resistance braided sleeving (633°F melting point) and sow the actuator

Actuation - requirements and verification

Requirement	Quantification	Verification	Points
Maximum movement speed	≥ 10 m/h	1.Drive the robot with the signal to achieve the highest velocity over a certain distance and measure the elapsed time. 2.use the elapsed time to calculate the speed.	7 ✗
Maximum bending radius	≤ 0.5 meter	1.Command the robot to perform maximum bends. 2. Measure the radius of arc of the bends	4 ✔
Average cross-sectional weight	≤ 0.6 kg/m	Weight the robot and divide by length	4 ✔
Maximum longitudinal extension (from contracted form)	≥ 20%	1. Send the command to the robot to perform maximum extension. 2. Measure the length before and after the extension	6 ✔
Maximum circumferential contraction (from extended from)	≥ 10%	1. Send the command to the robot to perform maximum contraction. 2. Measure the circumference before and after the contraction.	6 ✔

Sensors and feedback control



Sensors and feedback control

- Setup was not responsive
- Current solution - abandoned the use of band potentiometer and use open loop controls
- Potential solution - use other means to measure worm contraction (actuator temperature, resistivity)

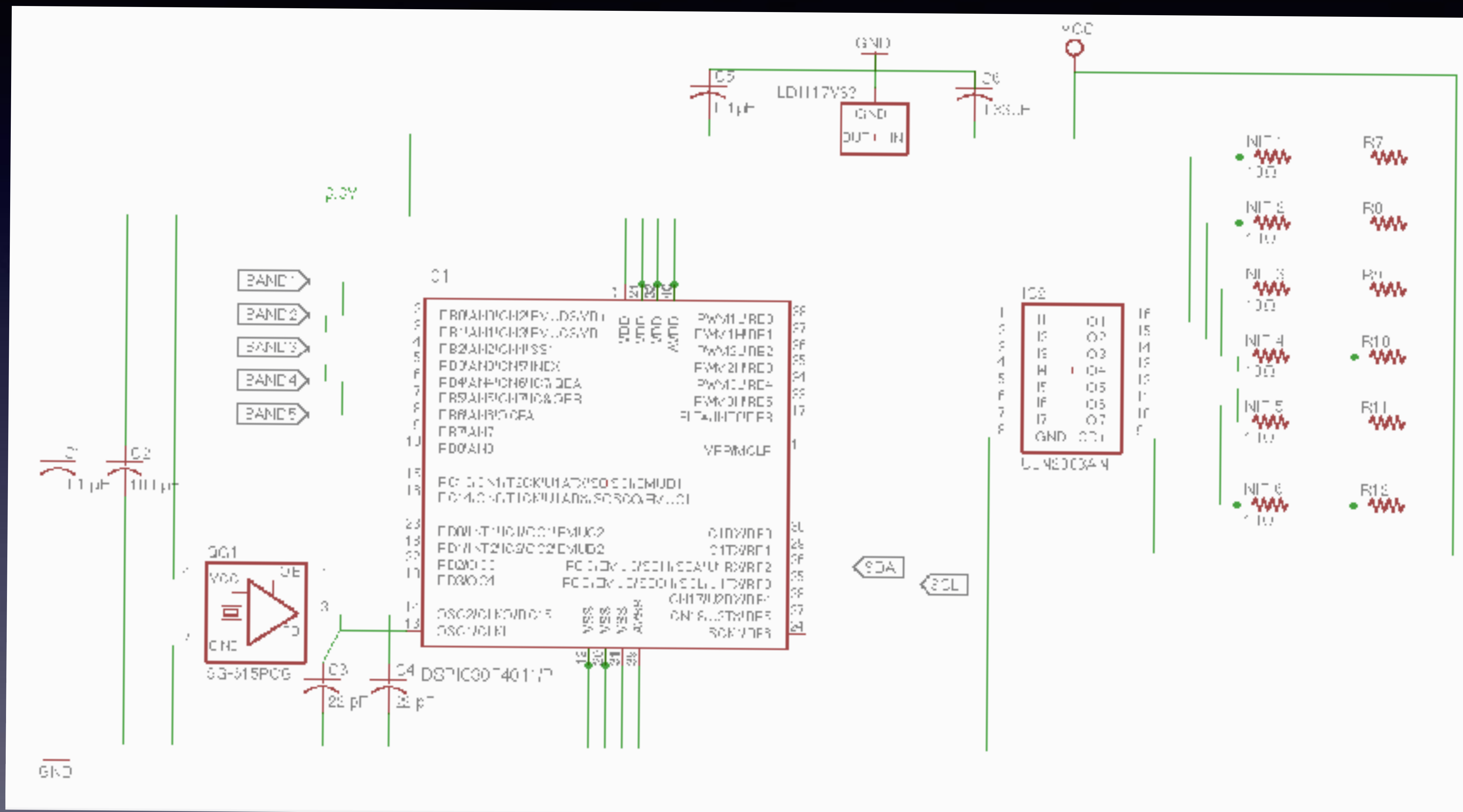
Sensors - requirement and verification

Sensor			
Requirement	**Quantification**	**Verification**	**Points**
Band membrane potentiometer accuracy	±10% horizontal extension measurement	1. Send the command to the robot to perform maximum extension. 2. Measure the length before and after the contraction. 3. Use the band variable resistor to infer the length before and after the contraction. 4. Verify that both inference is within 10% of the actual length.	3 X

Power

- 9V (Darlington transistor and wall adapter)

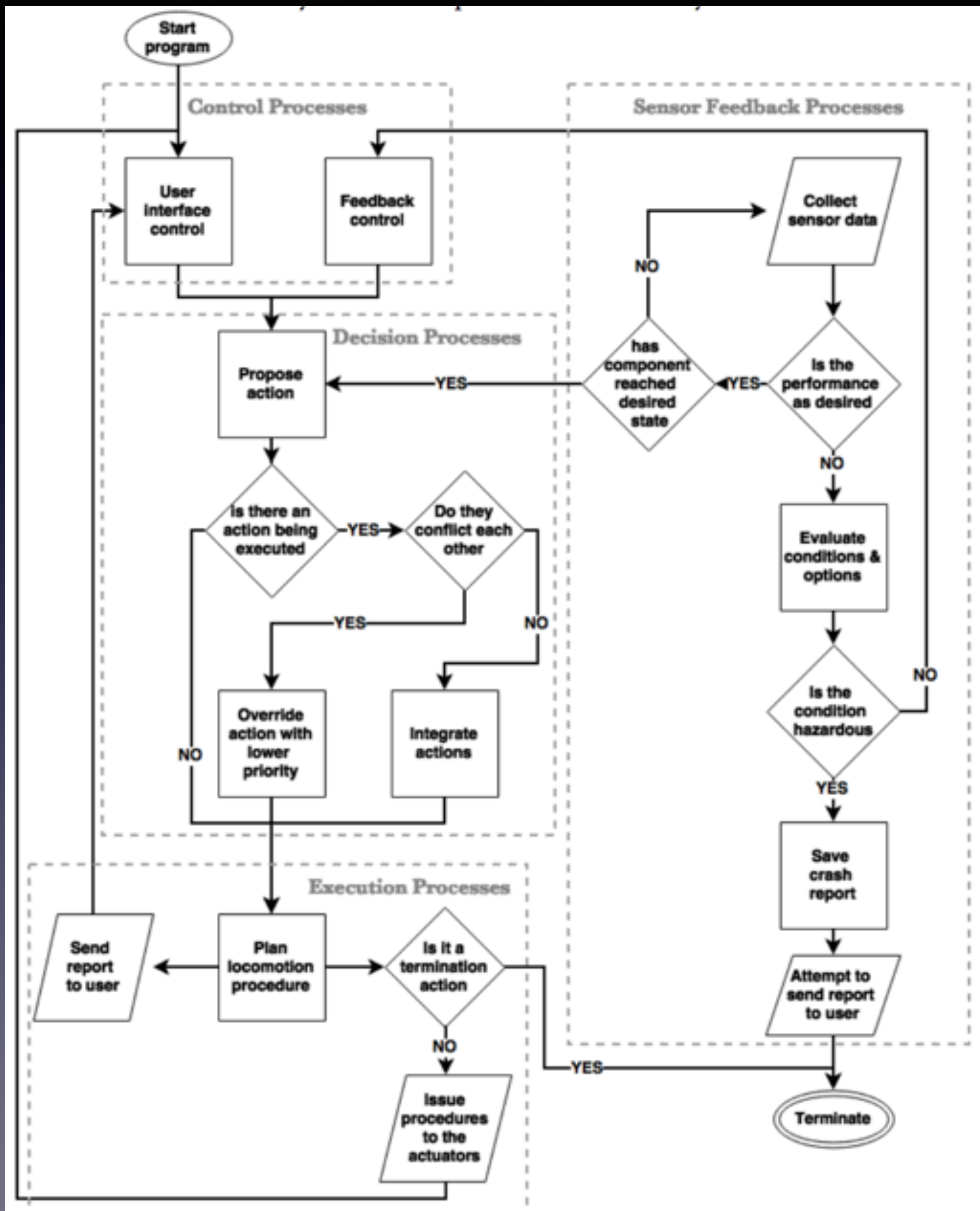
- 5V (Power regular and adapter)


GND
VCC
C5
C6
BAND1
BAND2
BAND4
BAND5
IC2
SDA
SCL
C3
C4
OE
R7
R10
R11
GND

Power - requirements and verification

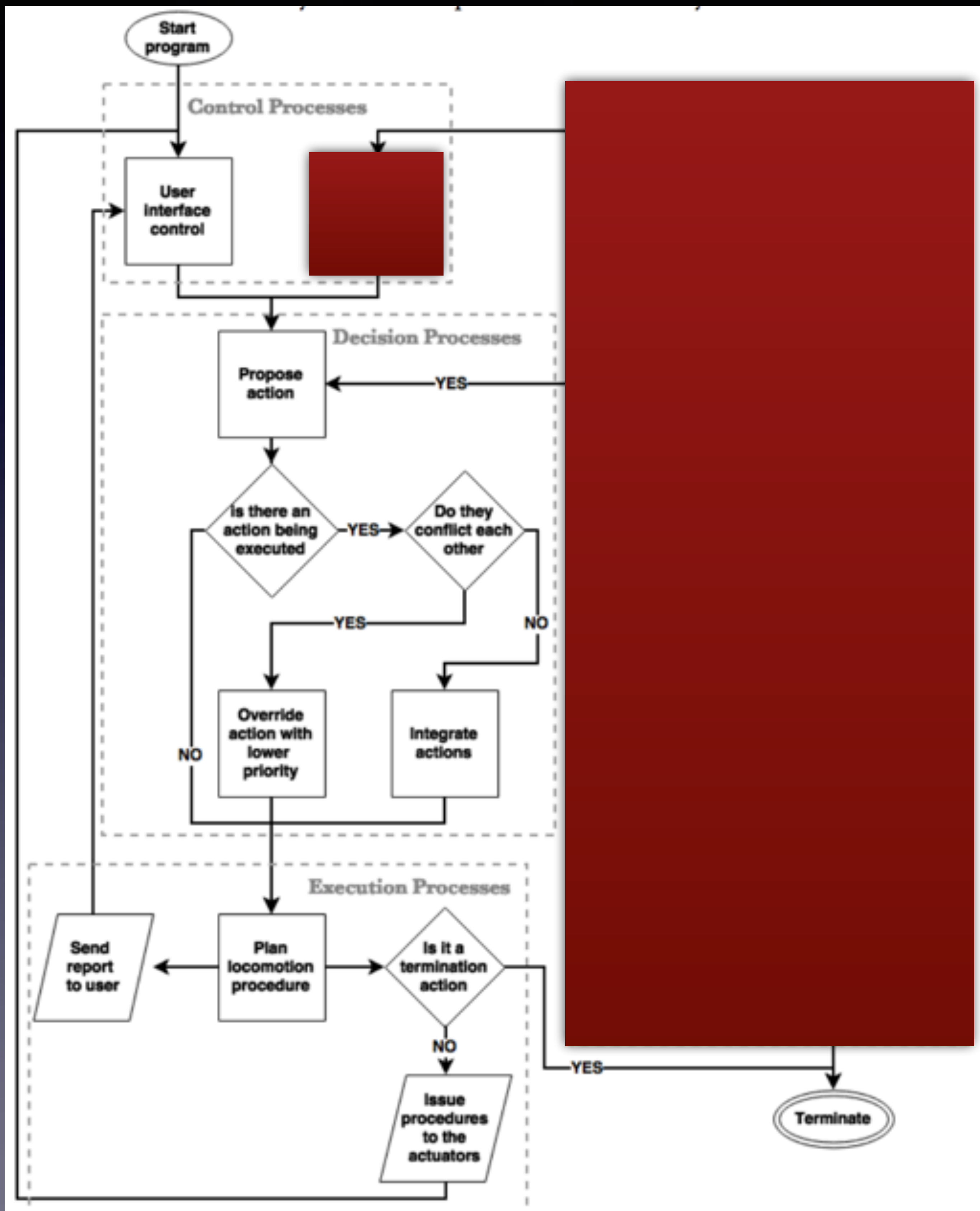
Power			
Requirement	**Quantification**	**Verification**	**Points**
Power regulation	Able to provide 2.7 V to 3.8 V to onboard chips for 30 minutes	1. Drive the circuit with simulated commands for several 30 minutes intervals, and monitor the circuit voltage. 2. Verify the expected voltage is provided.	N/A ✔
Power supply	Able to provide 4 W to the actuators for 30 mins	1. Drive the power supply with adequate load (or the actuators themselves) repeatedly for several 30 minutes intervals, and monitor the circuit. 2. Verify the expected power is provided.	N/A ✔

Control



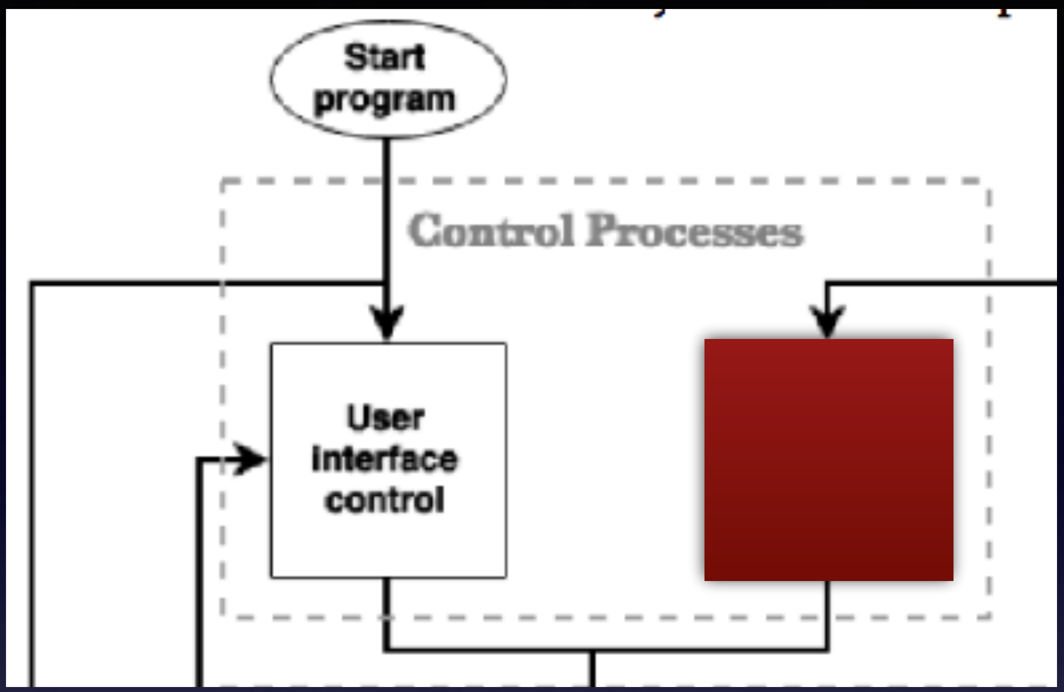
- Command
- Action Decision
- Execution
- Feedback

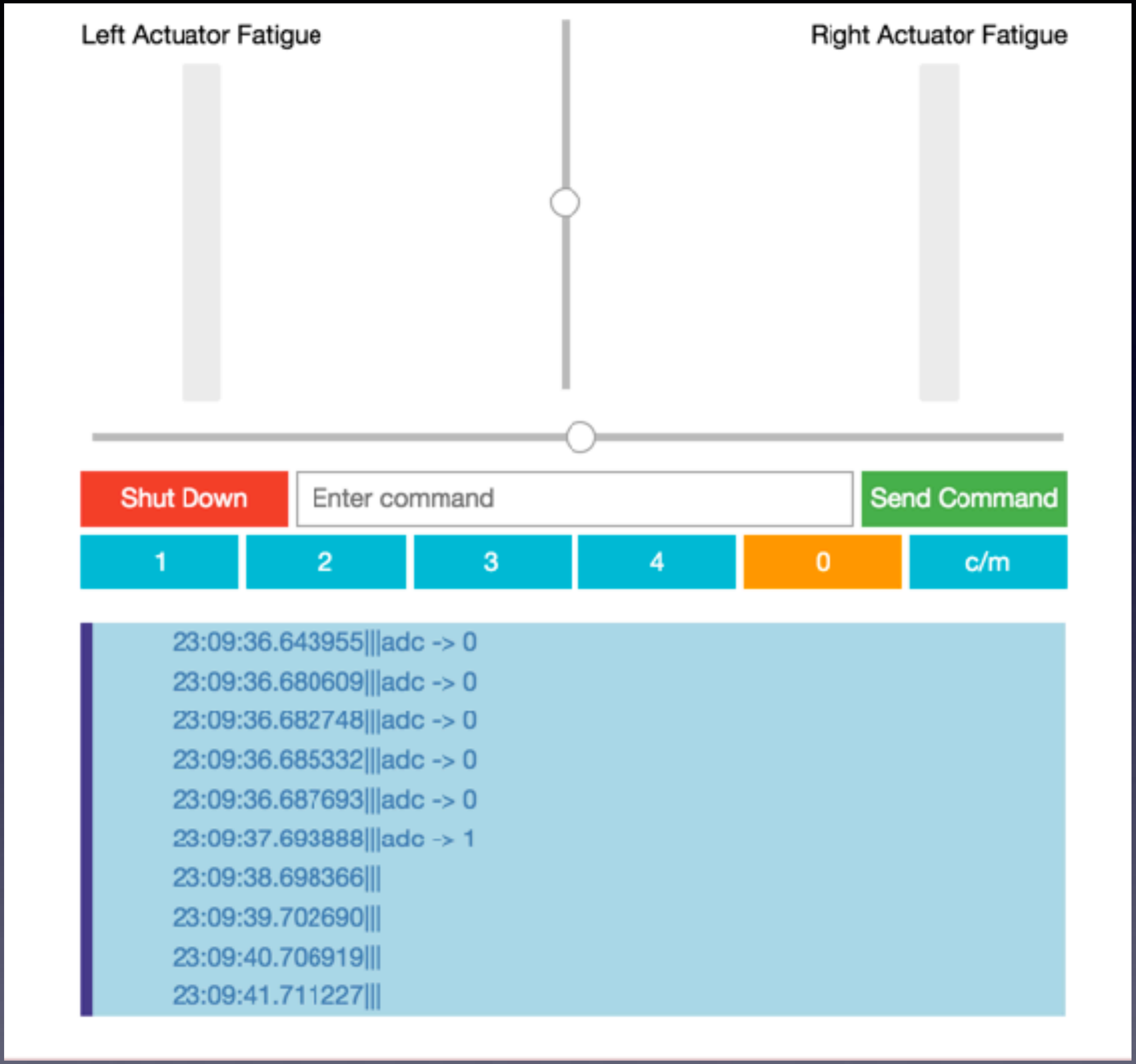
Control



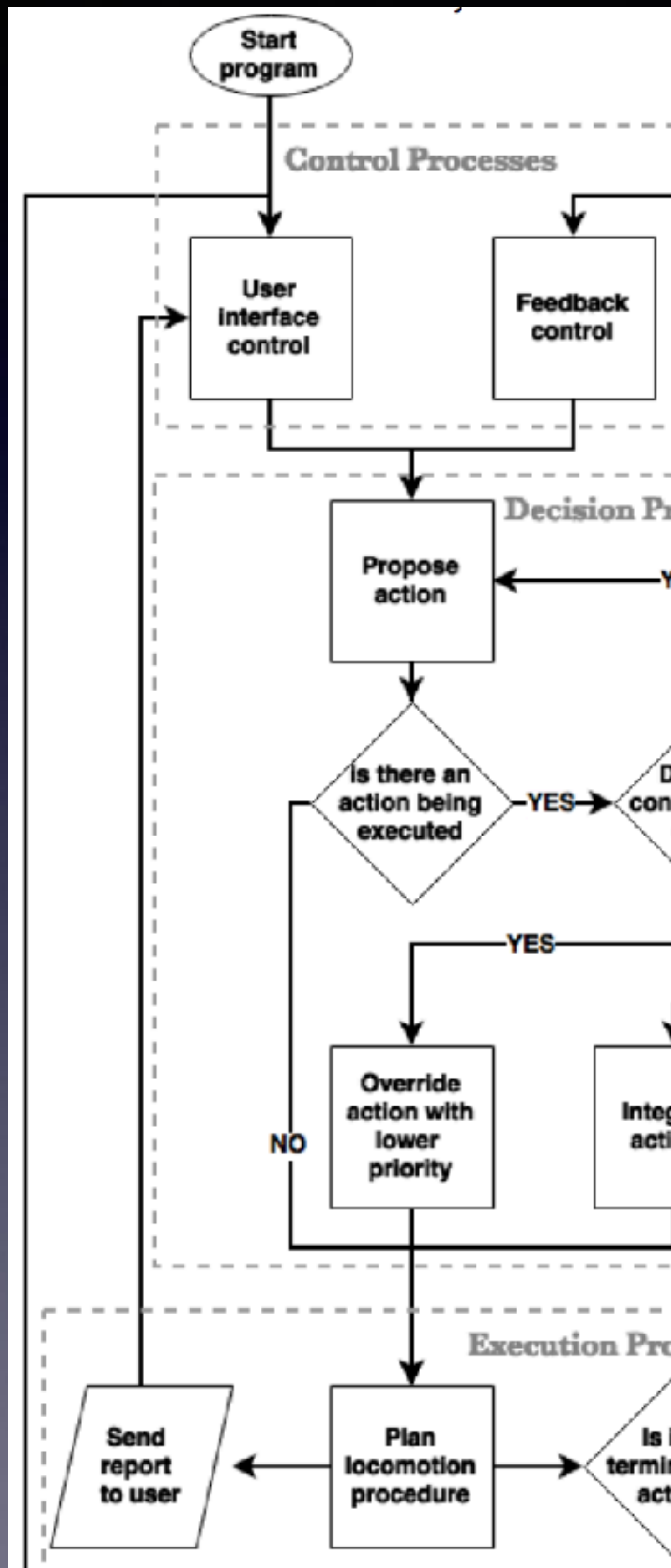
- Command
- Action Decision
- Execution
- ~~Feedback~~

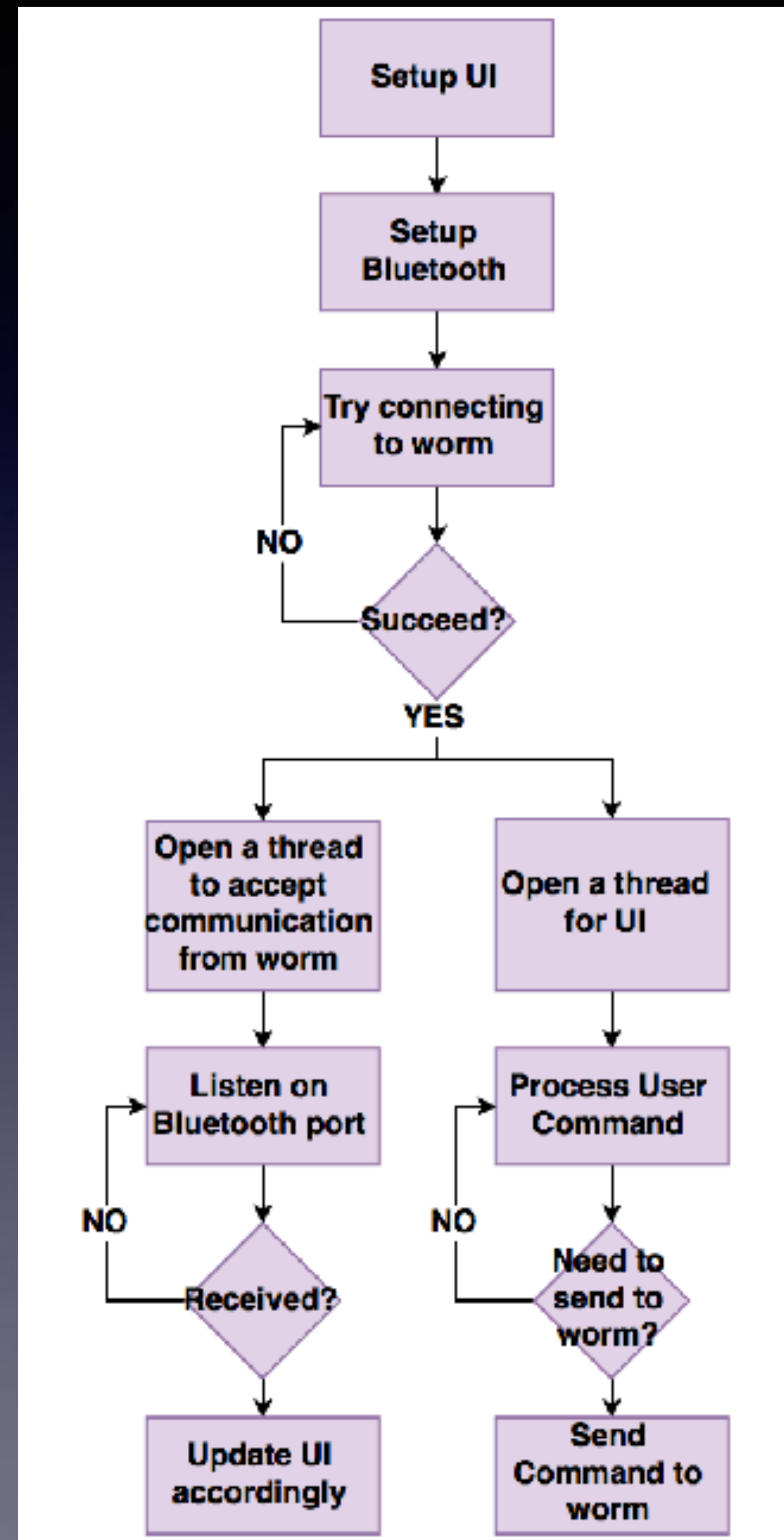
User Interface



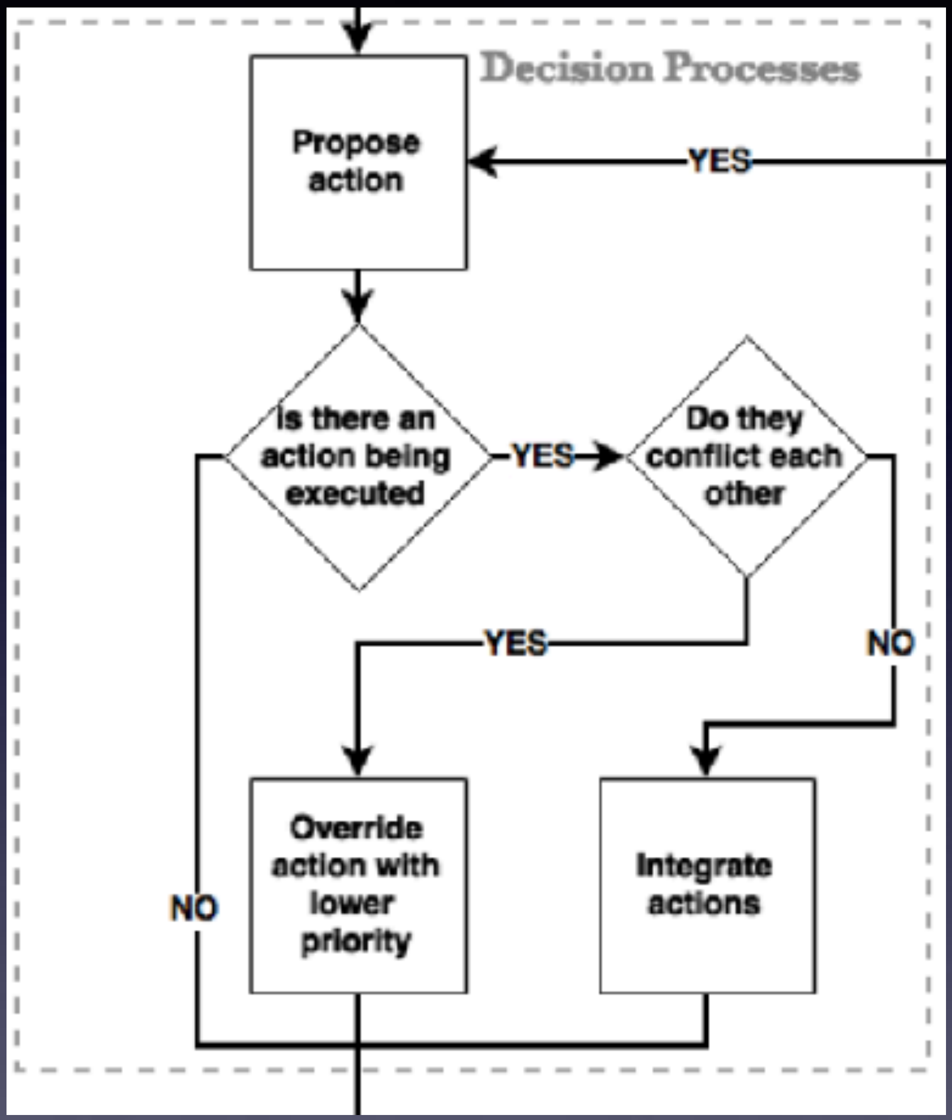


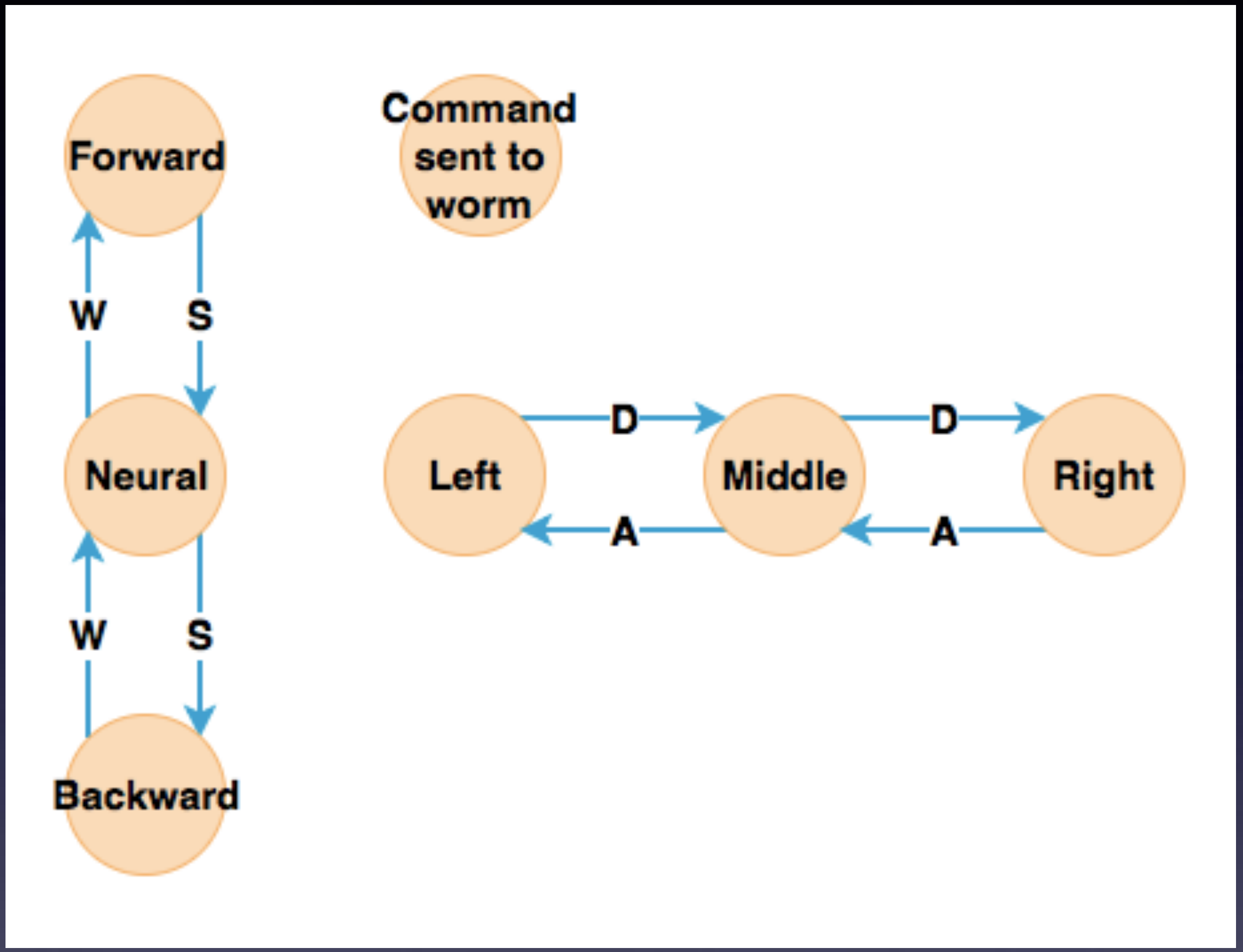
Communications



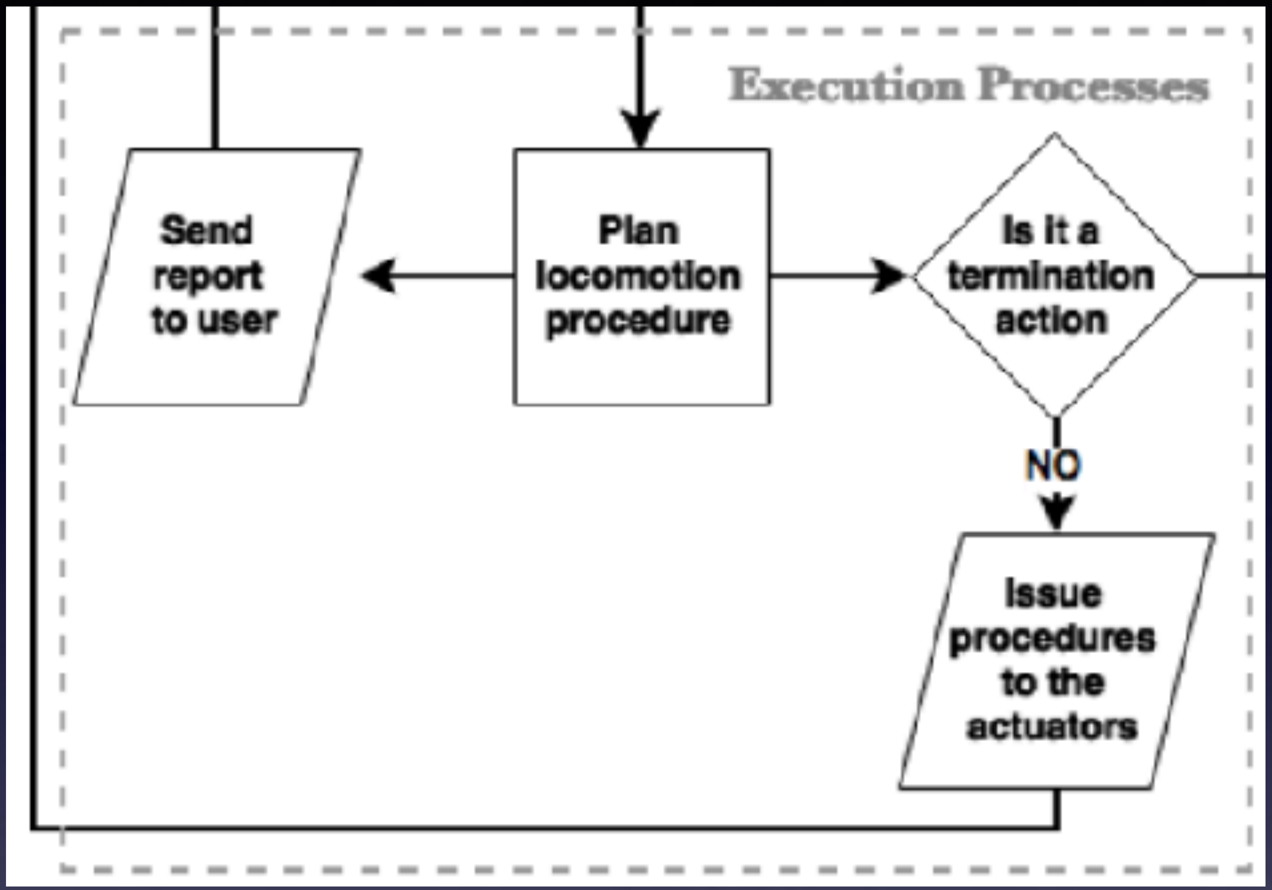


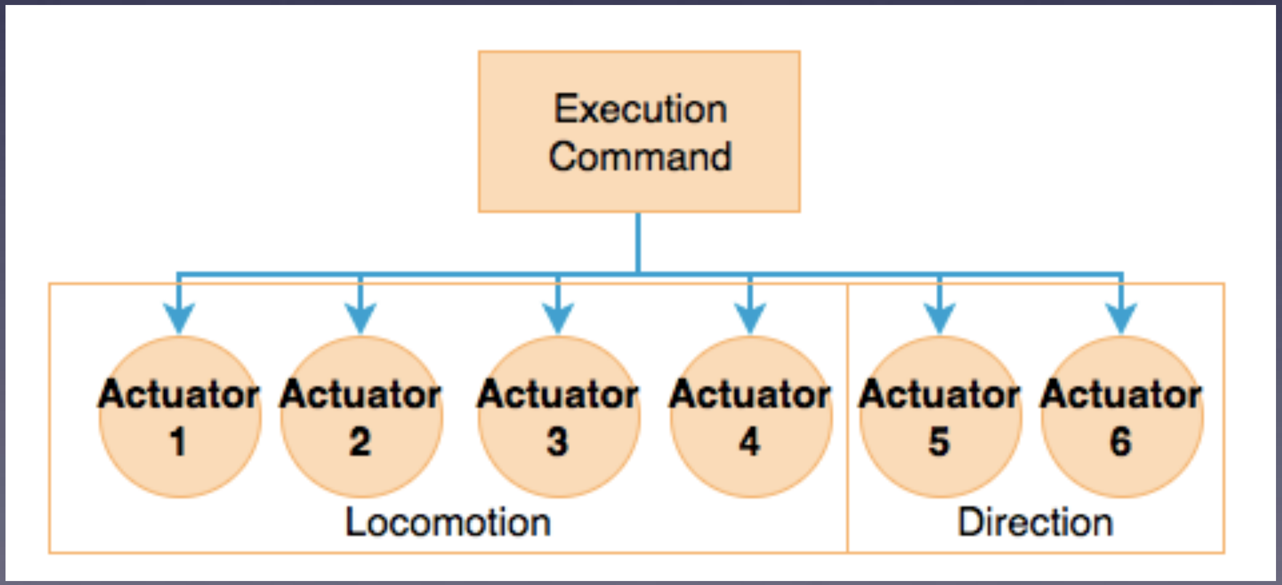
Action Decision

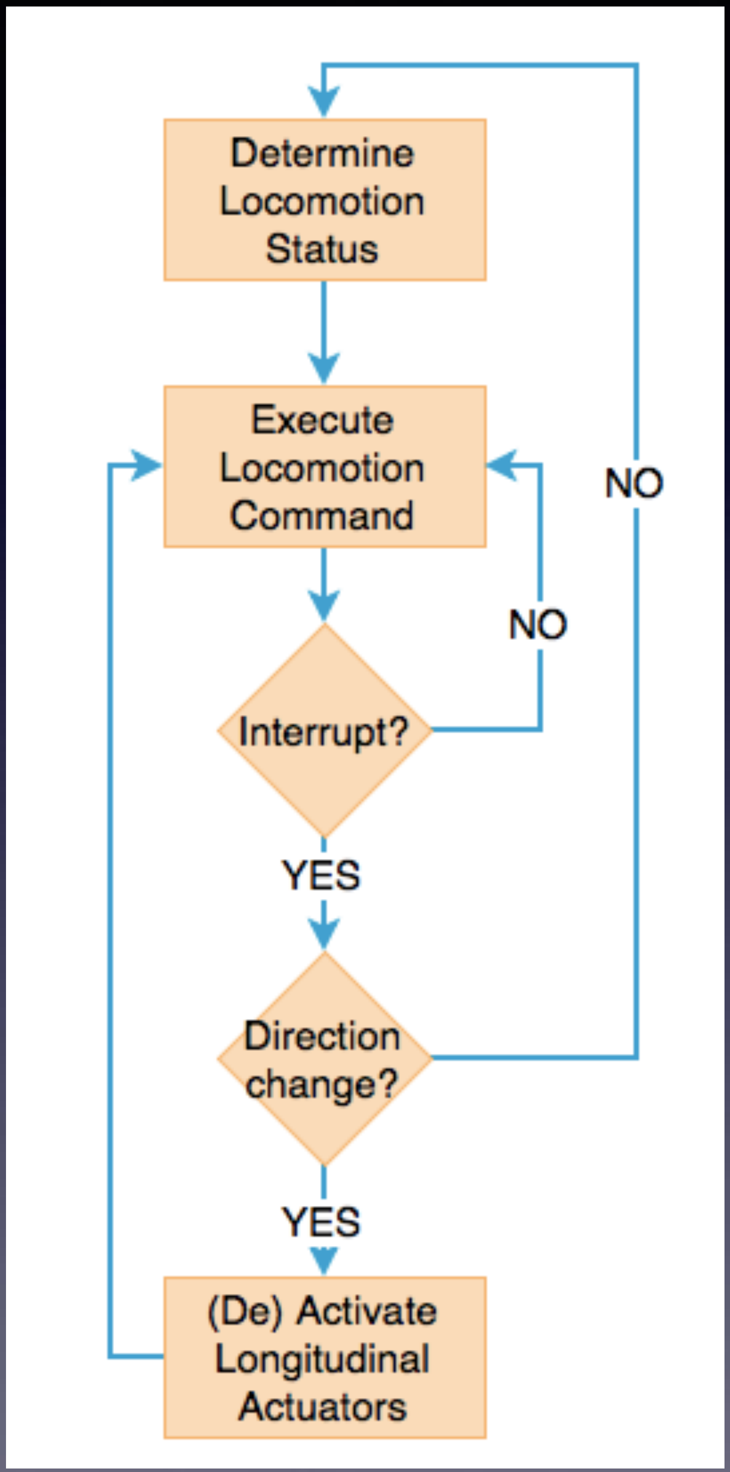




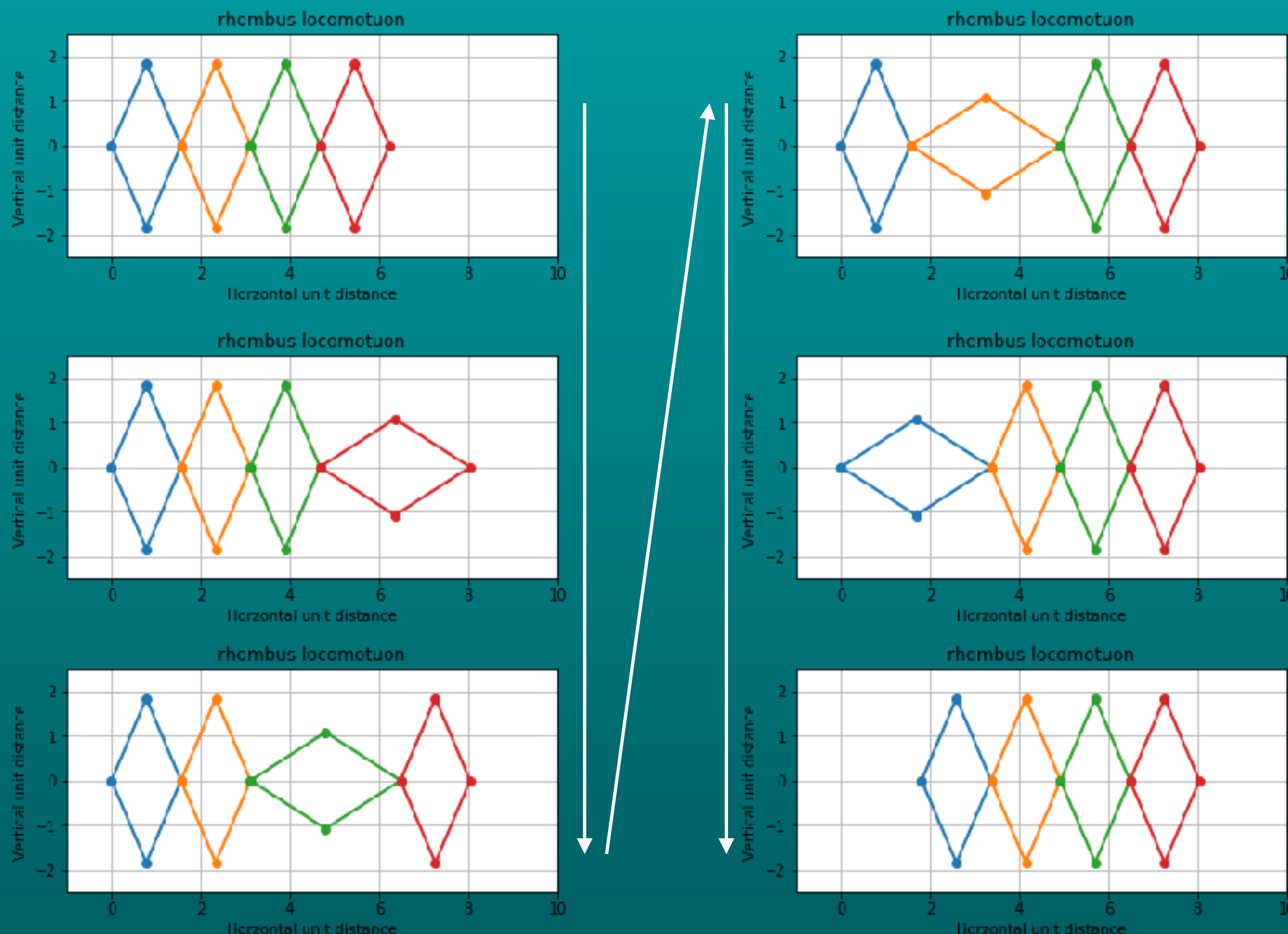
Execution


Execution Processes
Send report to user
Plan locomotion procedure
Is it a termination action
NO
Issue procedures to the actuators

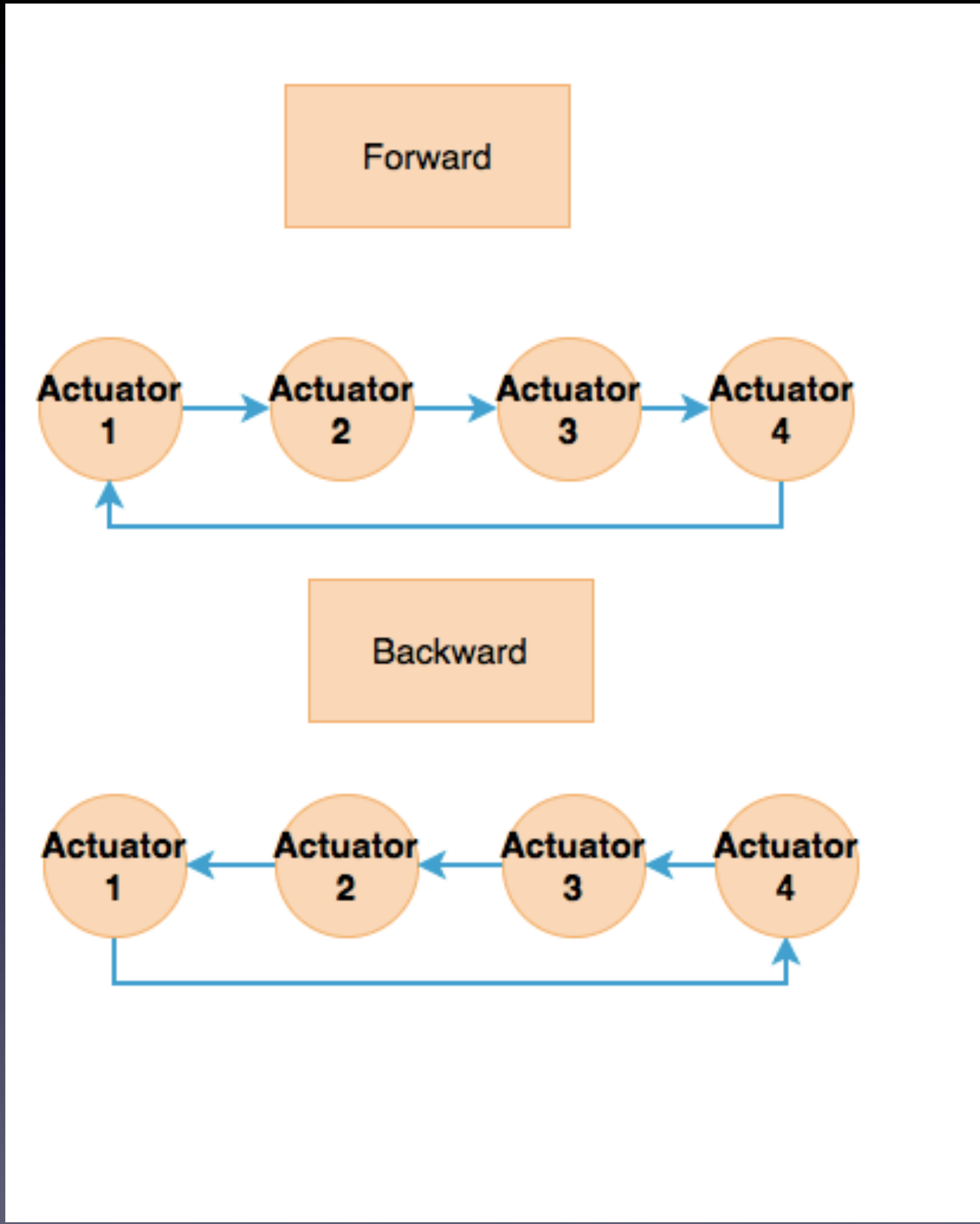

Execution Command
Actuator 1
Actuator 2
Actuator 3
Actuator 4
Actuator 5
Actuator 6
Locomotion
Direction


Determine Locomotion Status
Execute Locomotion Command
NO
NO
Interrupt?
YES
Direction change?
YES
(De) Activate Longitudinal Actuators

Locomotion Planning



Execution



- Duty Cycle
- Actuation time (0.5-2s)

Software - Requirements and Verifications

Control Module			
Requirement	**Quantification**	**Verification**	**Points**
Sensor feedback response time	≤ 150 ms between sensor input and control output	1. Provide artificial input from a waveform generator, process the data with the algorithm, then output the data and measure both input and output with an oscilloscope. (Experiment for 1 minute.) 2. Verify that the average time difference between the two signals is less than 150 ms.	4 ✔
User input response time	≤ 150 ms between user input and control output	1. Attached an led to the output port of the MCU. 2. Press a button on the computer to send a command that will light up the led. 3. Use a slow motion camera to measure the time difference between the moment the key is pressed and the moment the led lights up.	4 ✔

10.3 ms

- 72.3 ms

Further work

- Improve current design
- Soft robotics
- Prosthetic application

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