Hexcavator

Lunar Regolith Excavator Student Competition

Sponsor: Dr. Jonathan E. Clark[1]

April 12, 2012

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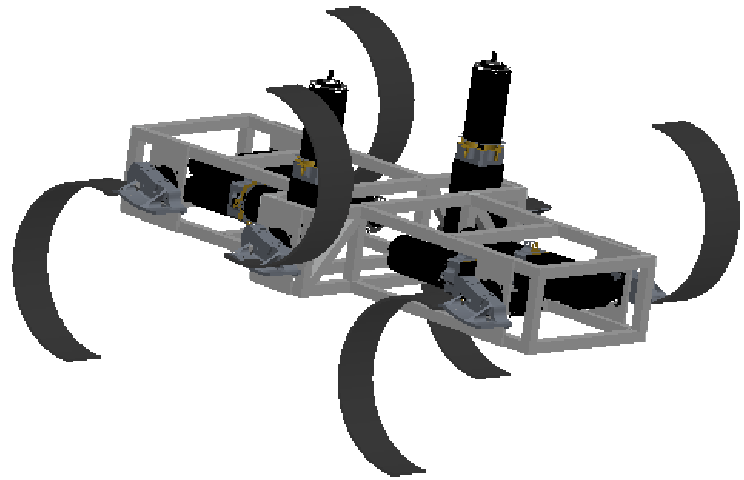
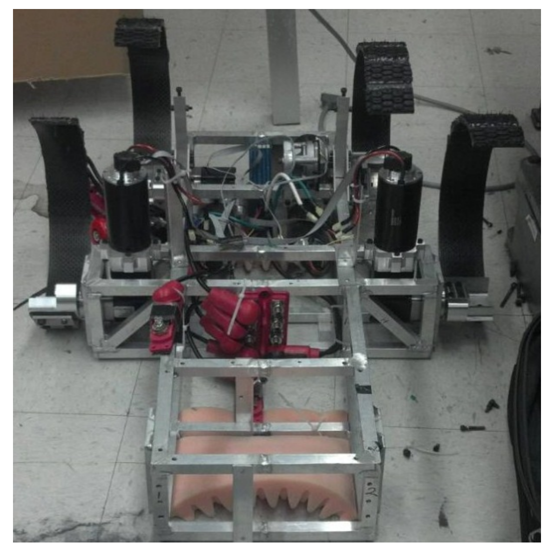
Outline

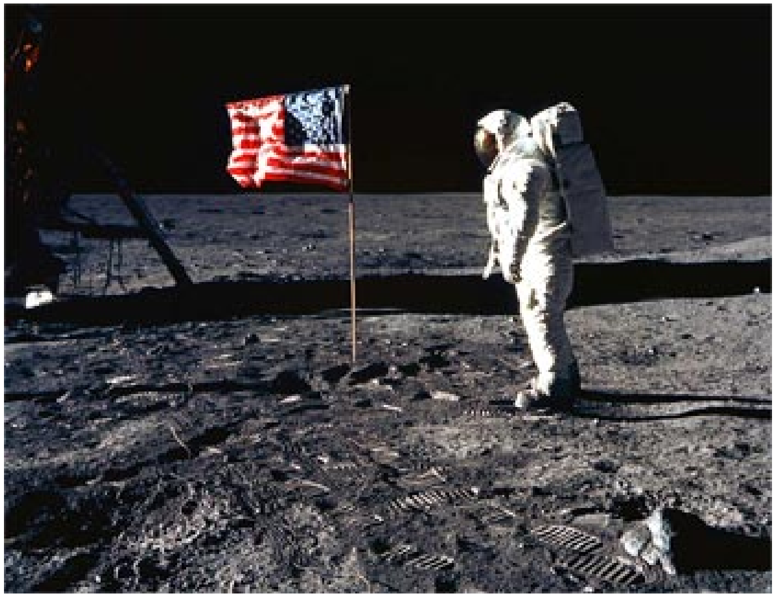
- Project Description
- Locomotion Scheme
- Wireless Communication
- MicroController
- Communication
- Power System
- Excavation Design
- Cost Analysis
- Conclusions





Project Inspiration

- NASA's Third Annual Lunabotics Competition
- Competition Date: May 23, 2012
- Determine feasibility of lunar inhabitance
  - Analyzing lunar soil (regolith)



Customer Requirements

- Initial dimensions: 1.5m x 0.75m x 0.75m
- Maximum weight: 80kg
- WiFi Communication
- Capable of operating in lunar environment
  - Obstacles and craters
- Minimum regolith excavated: 10kg
  - Two, ten minute attempts
- Emergency stop button

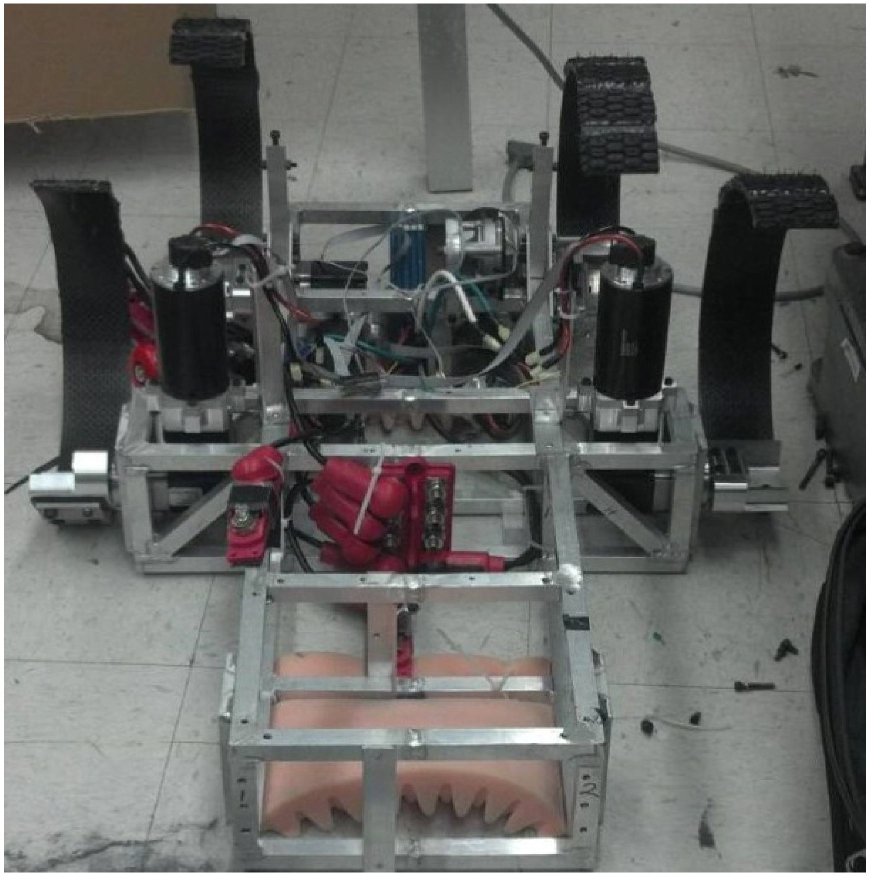
Previous Hexcavator Efforts

Complete:

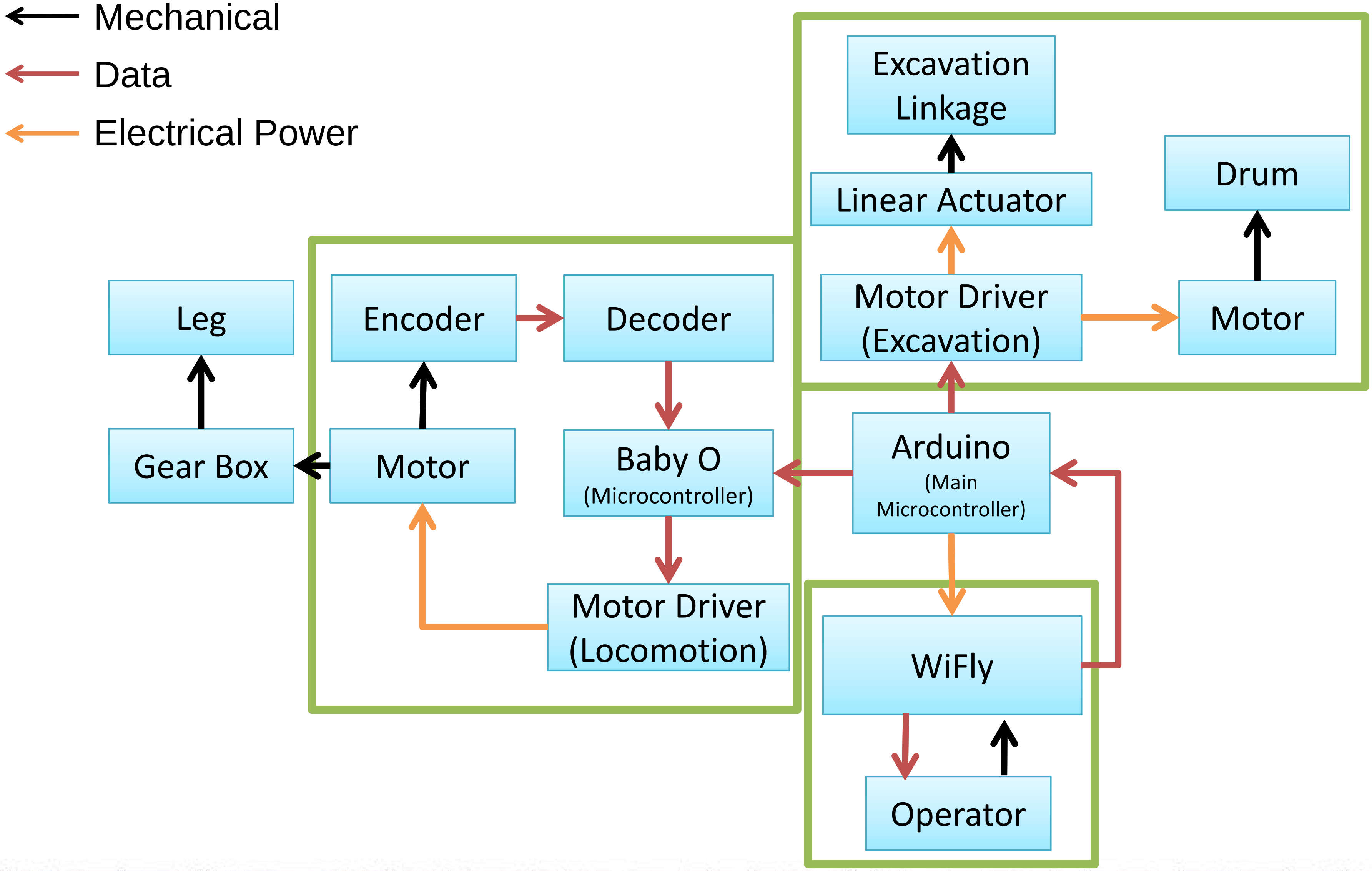
- Frame
- Legs
- Motors
- Batteries
- Stop Button

Needs:

- Excavation
- Controls



Functional Diagram



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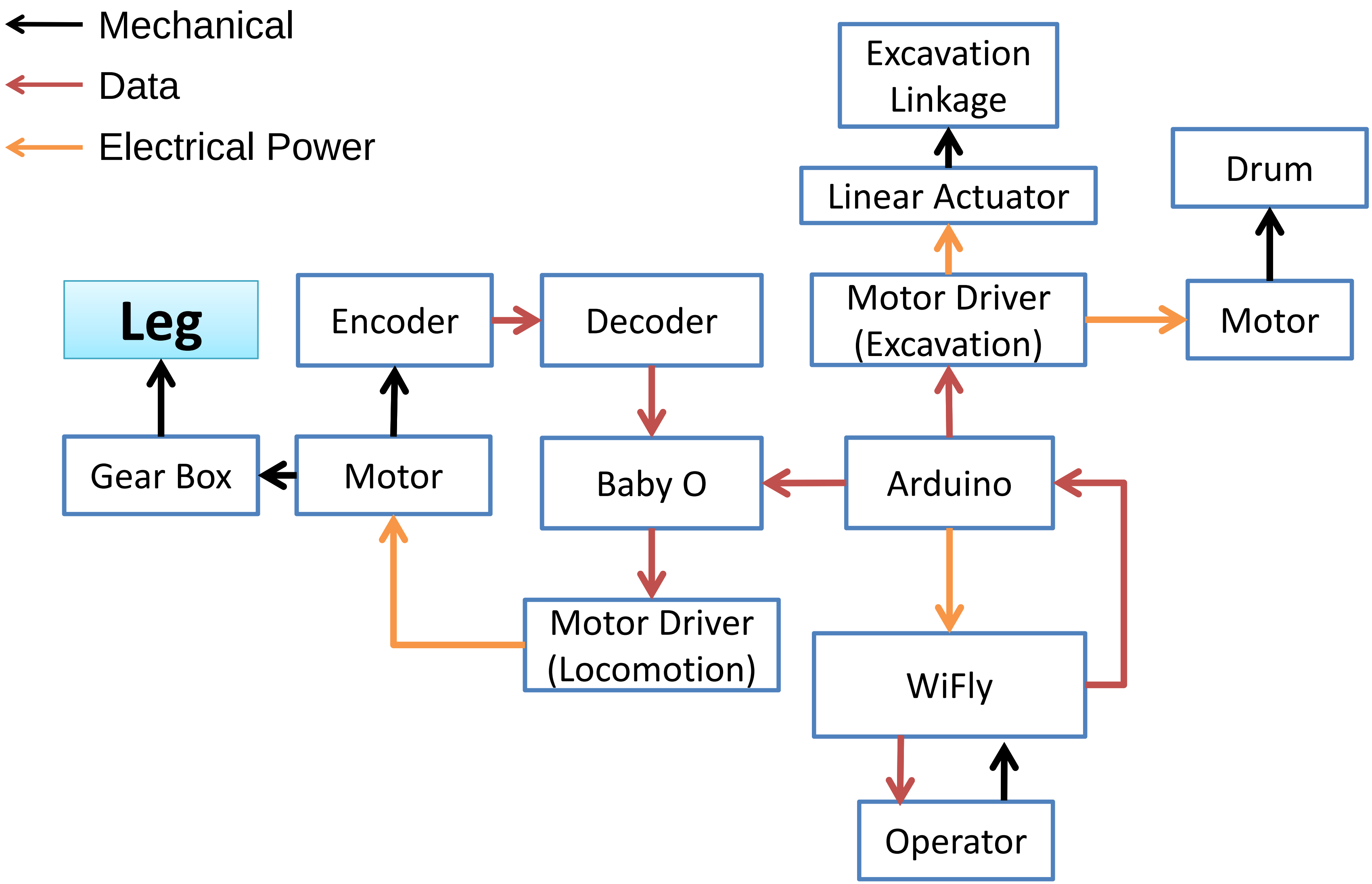
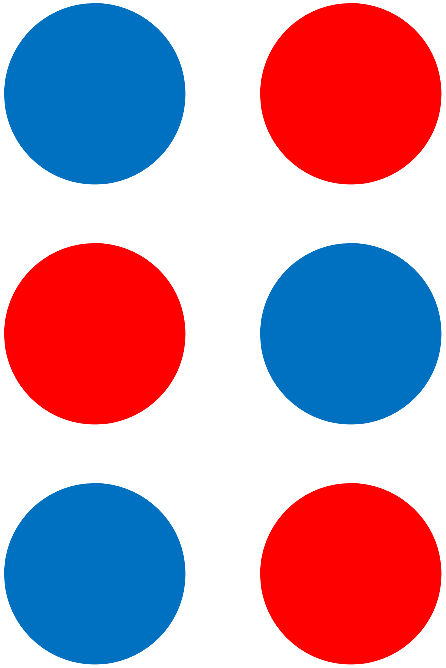


Locomotion

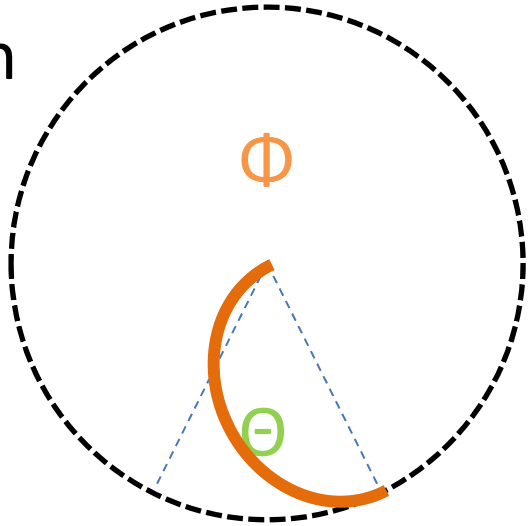
- Hexapedal walker
- Alternating tri-pod gait
- C-Legs
- Uses Bueheler Clock



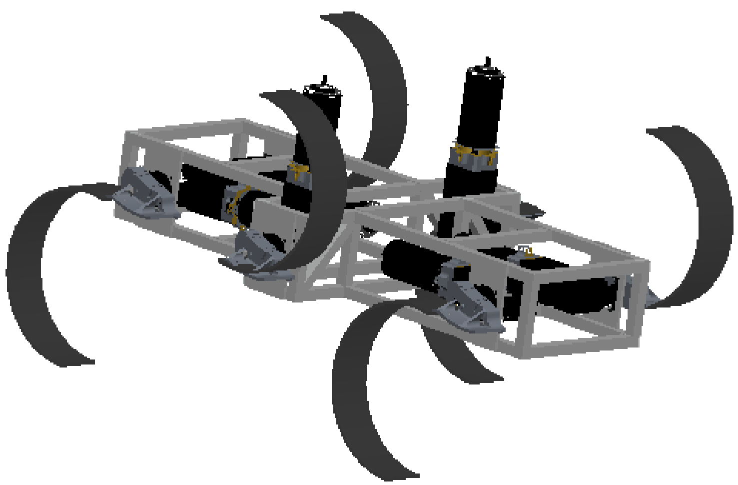
U. Saranli, M. Buehler and D. E. Koditschek, "RHex: A Simple and Highly Mobile Hexapod Robot", International Journal of Robotics Research, vol. 20, no. 7, pp. 616-631, 2001

Locomotion Control

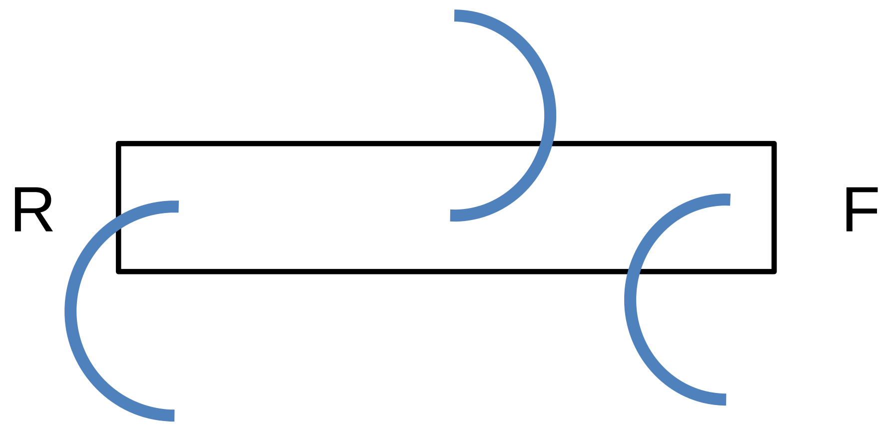
- Solution: Buehler Clock
  - Speed varies depending on position
    - Time of θ = Time of Φ
  - Need to read position of motor
  - While leg is in Φ angle, the angular velocity is 5 times greater than when in θ angle



Locomotion Control



Side View



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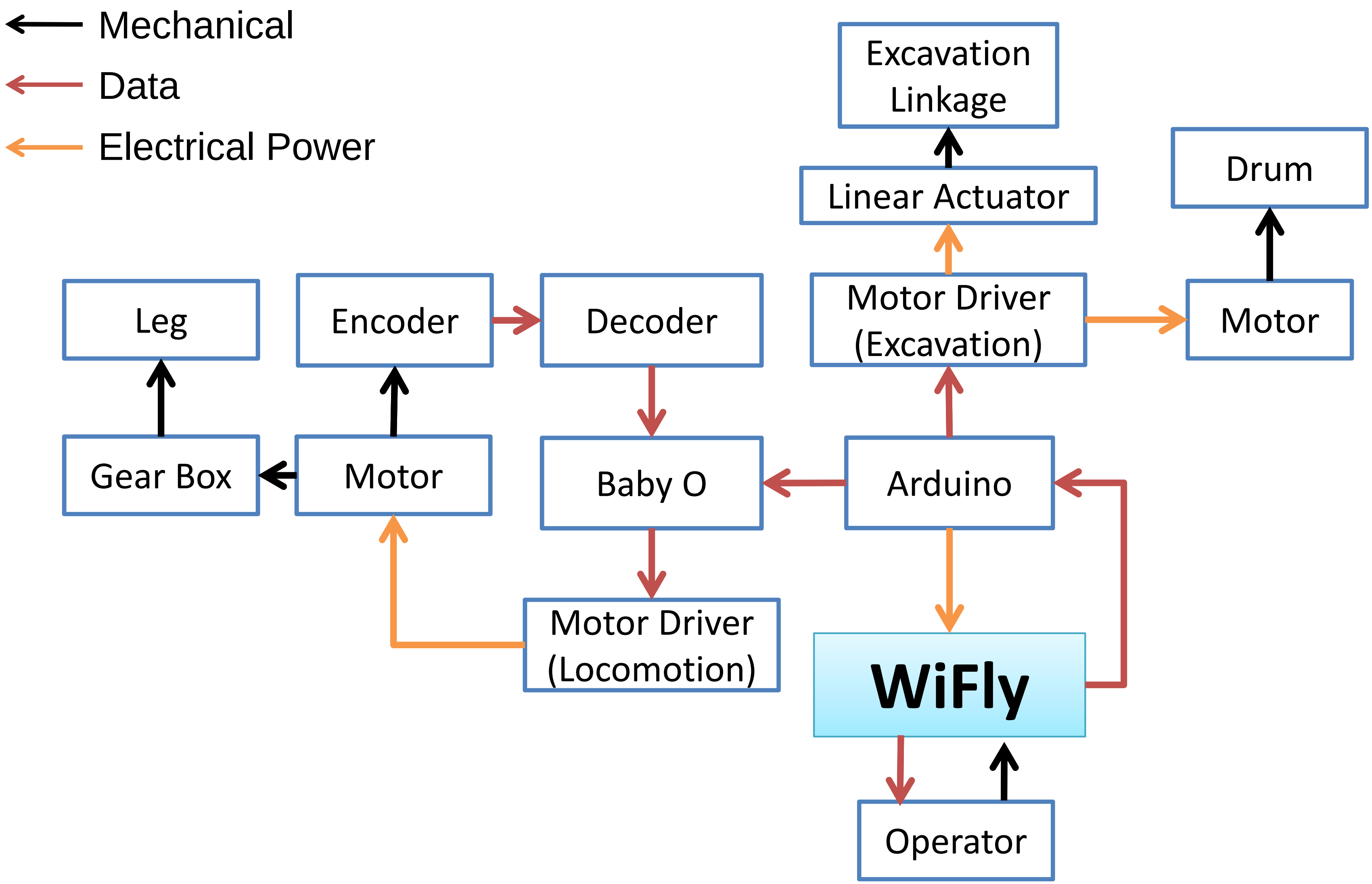
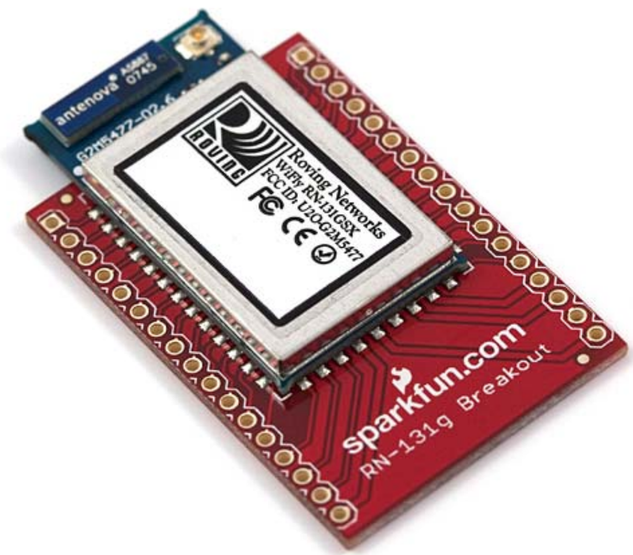


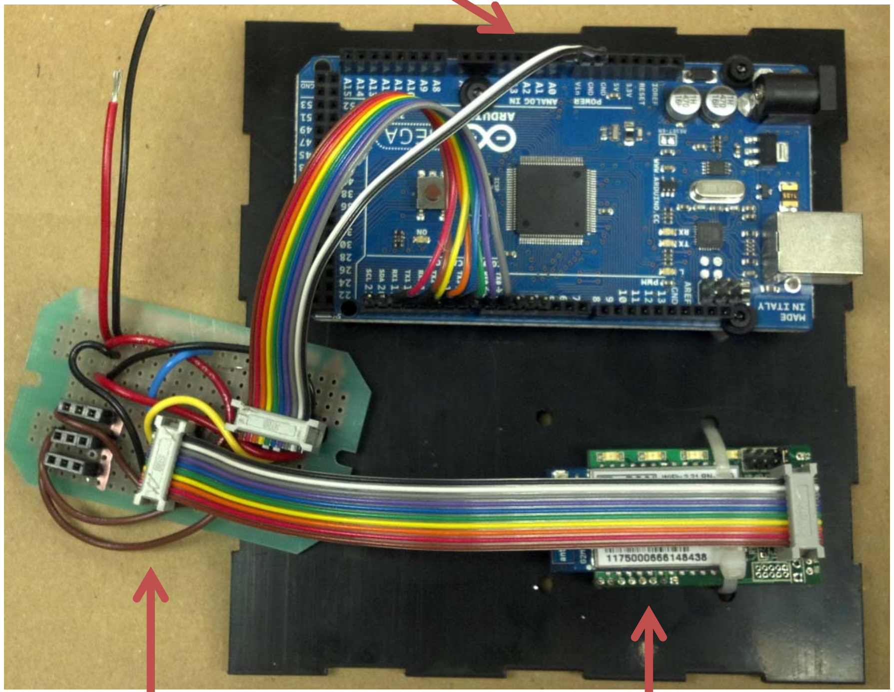
WiFly GSX

- Standalone Wireless LAN
- Wireless UART (Universal asynchronous receiver/transmitter) connection
- Minimize bandwidth usage
- Simulated delay



Interfacing with the WiFly

- Receives commands from user
- Controls both speed and desired position
- Communicates directly with microcontroller



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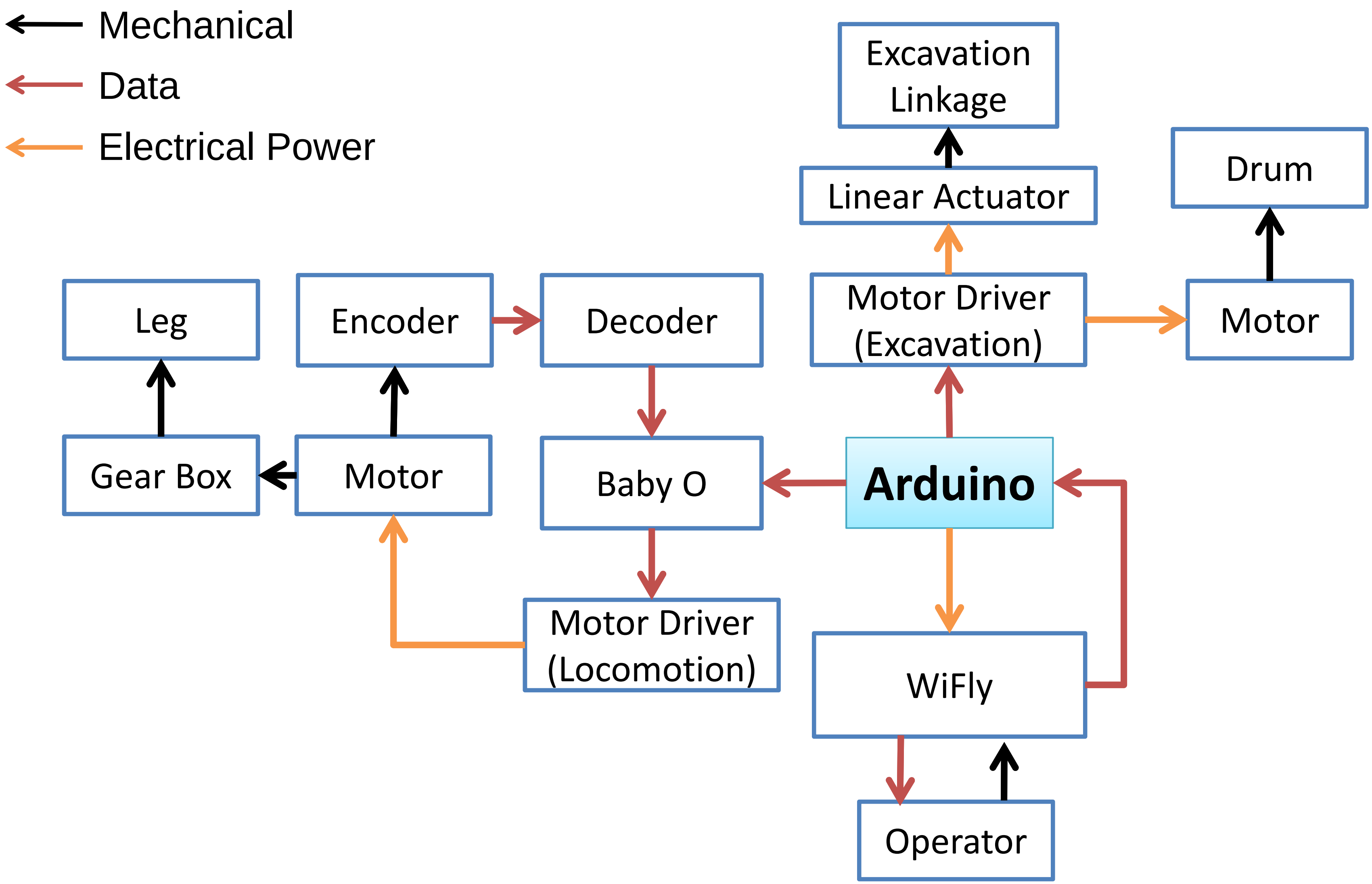
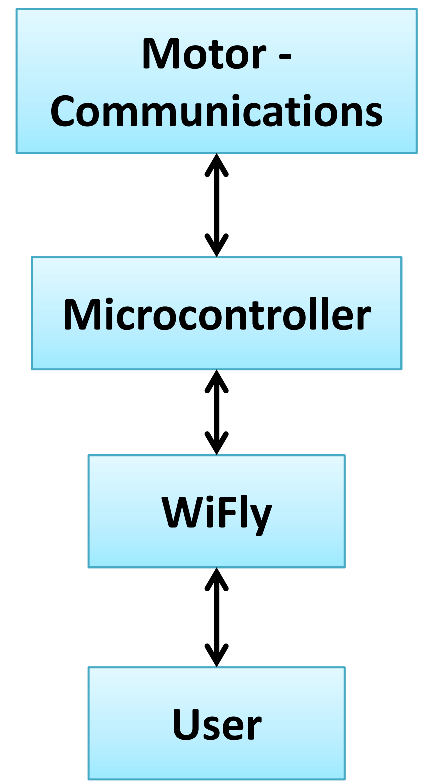


Microcontroller Selection

Requirements

- Multiple serial connections
- Low power



Design Concepts:

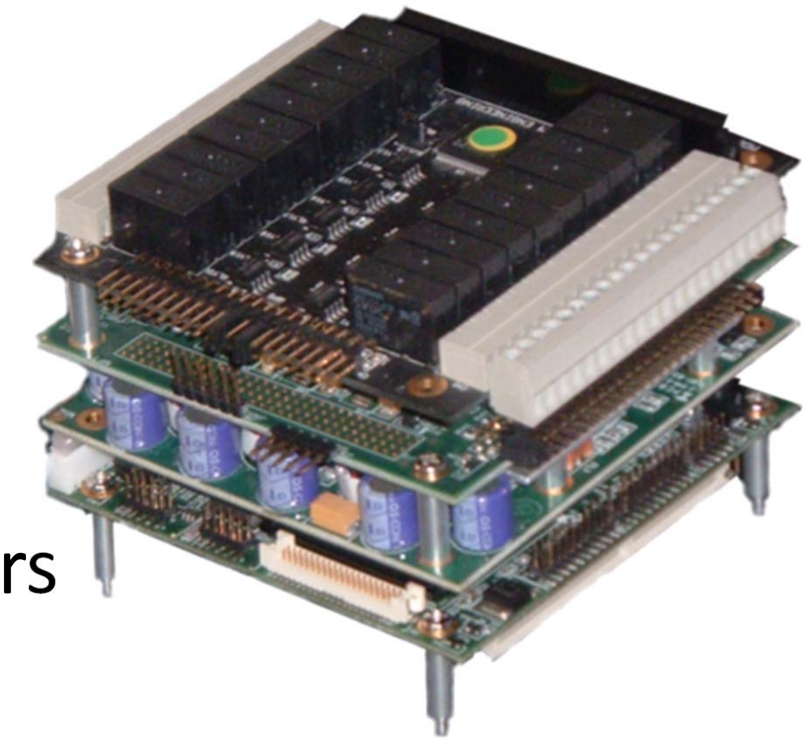
- Netbook
- PC/104
- Arduino Mega 2650

Netbook

- Pros:
  - Components included
  - Physically small
- Cons
  - High bandwidth usage
  - Superfluous ports
  - Limited low level customization

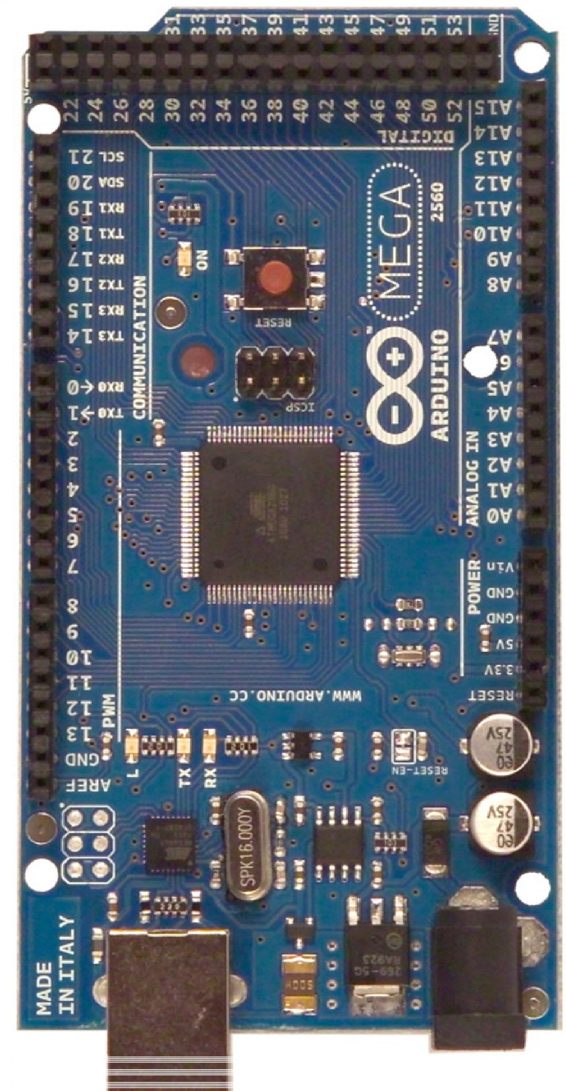
Microcontroller (PC/104)

- Pros
  - Very customizable
- Cons
  - Dimensions
  - In-house developed drivers
  - Expensive



Arduino MEGA 2650

- Pros
  - Inexpensive
  - Easy to use
  - Four serial connections
  - Low bandwidth usage
- Cons
  - Limited lower level control
  - Slow processor



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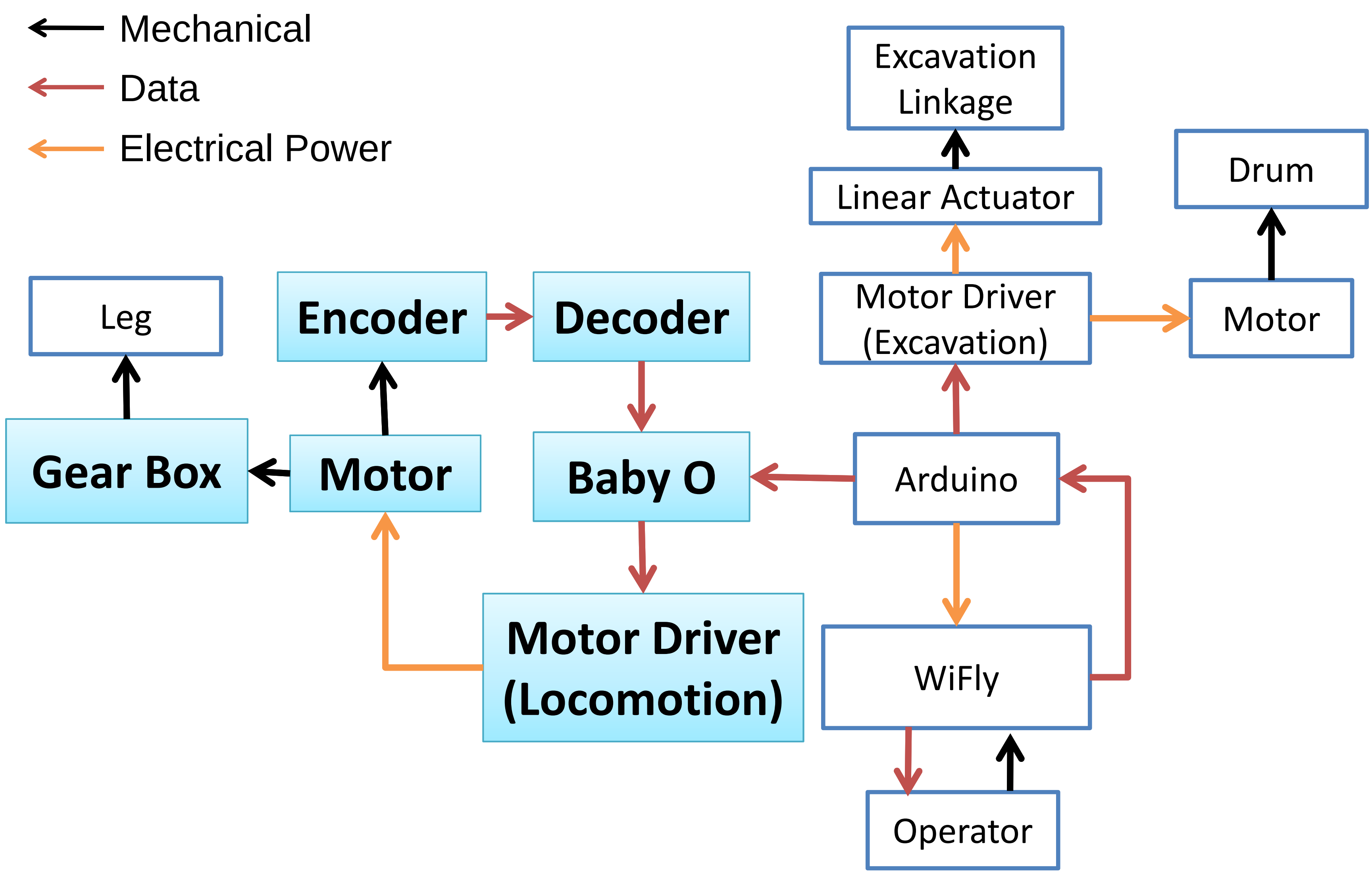
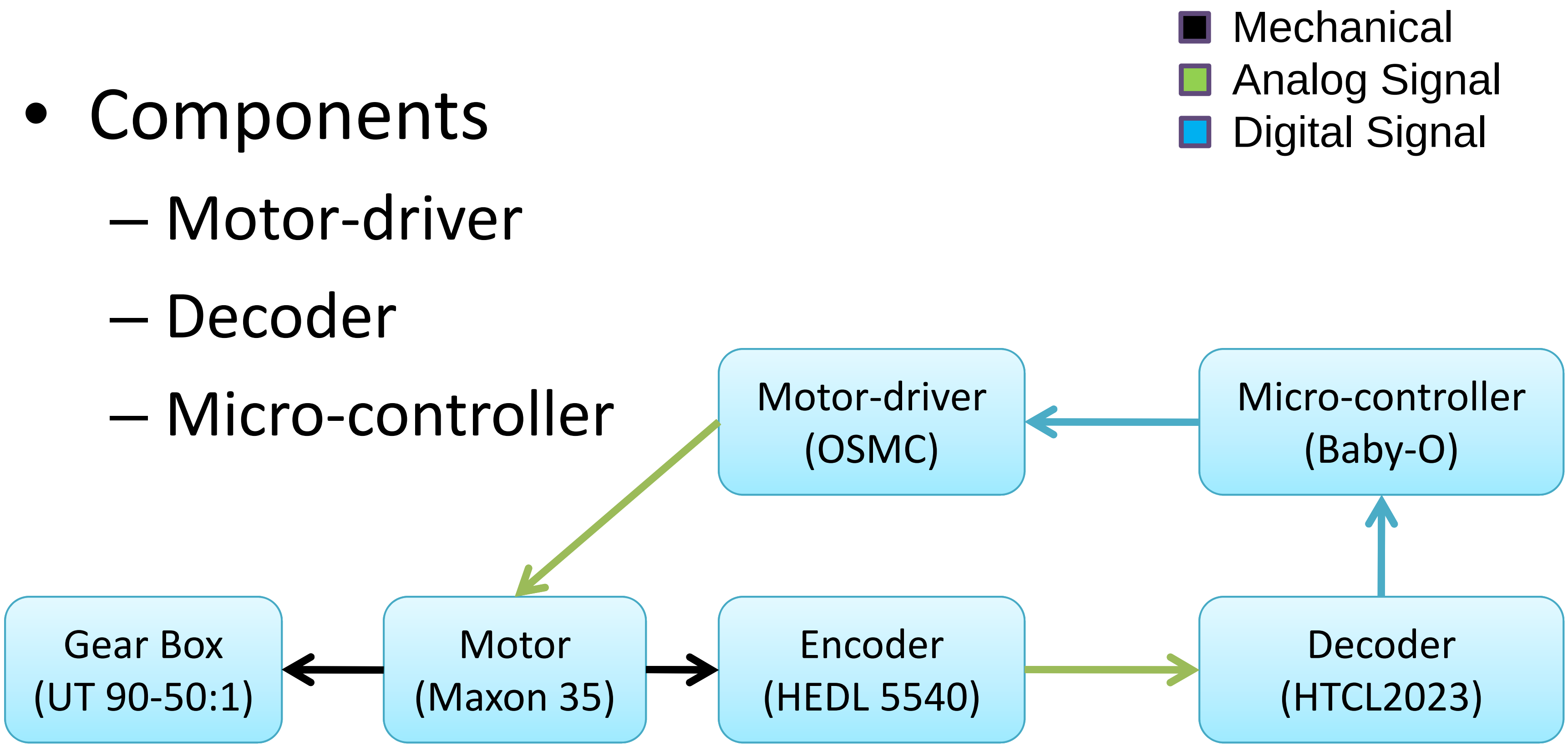


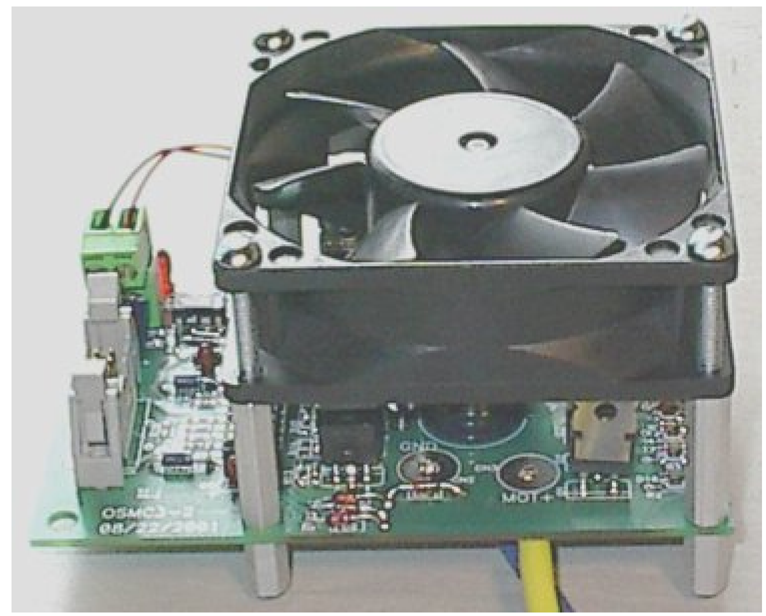
Custom Motor-Controller

- Components
  - Motor-driver
  - Decoder
  - Micro-controller



Motor-Driver

- OSMC Motor-driver
- Intersil HIP4081A
- 160A continuous
- 400A surge
- Voltage control



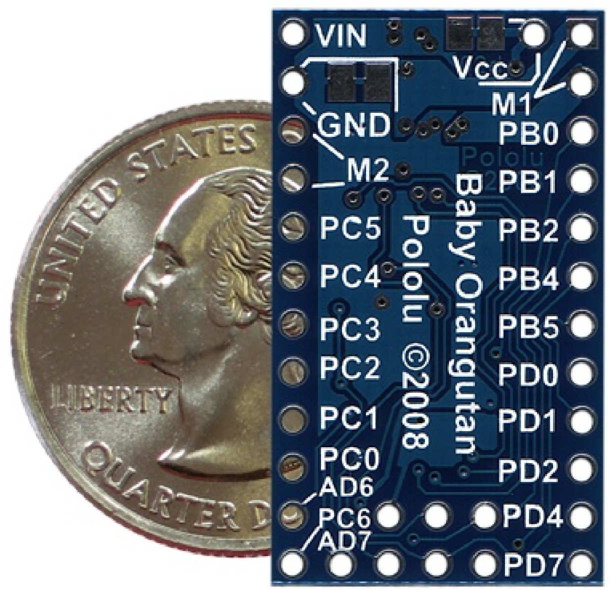
Decoder and Encoder

- HCTL2023-SC
- 32bit
  - Used to track multiple revolutions
- Quadrature

- HEDL 5540-A13
- 500 counts per revolution

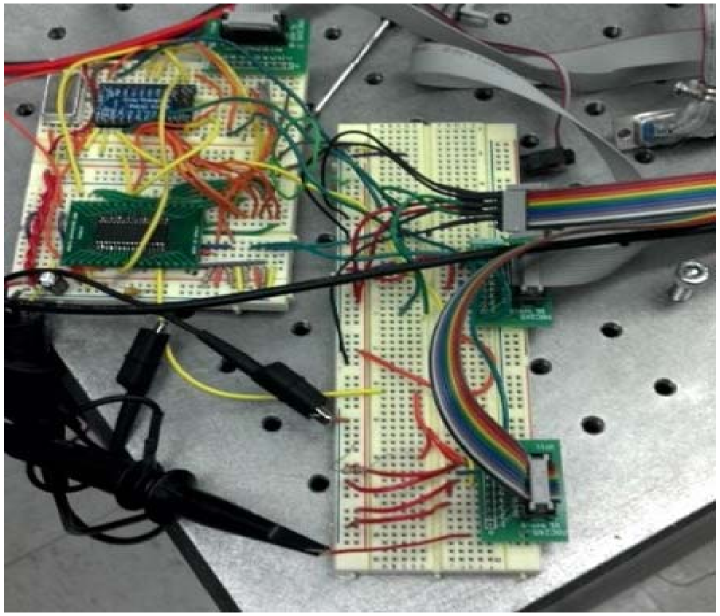
Baby Orangutan

- Atmega 328P
- 20MHz
- 18 I/O lines
- 1.2” x 0.7”
- 1.5g

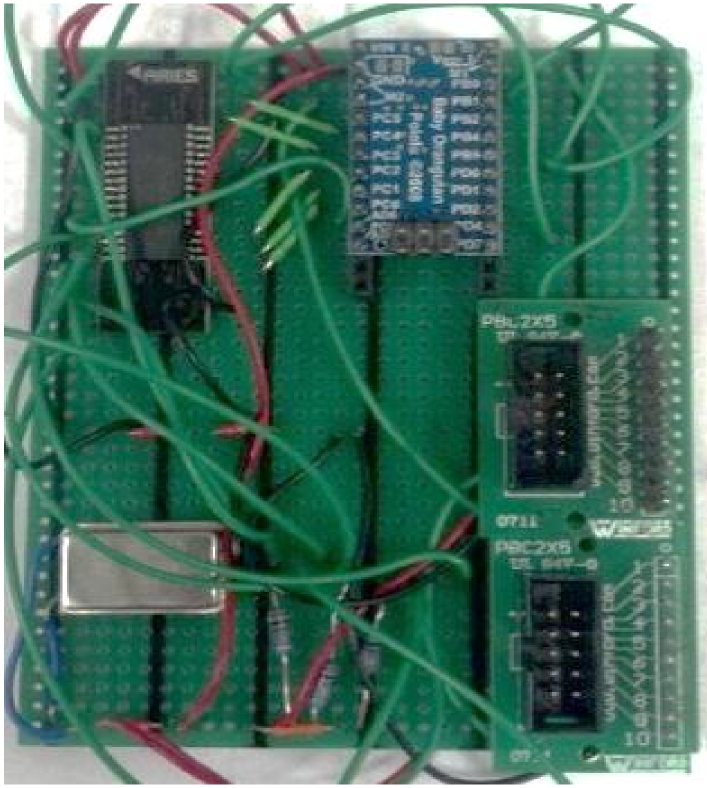


Prototyping of Motor Controller

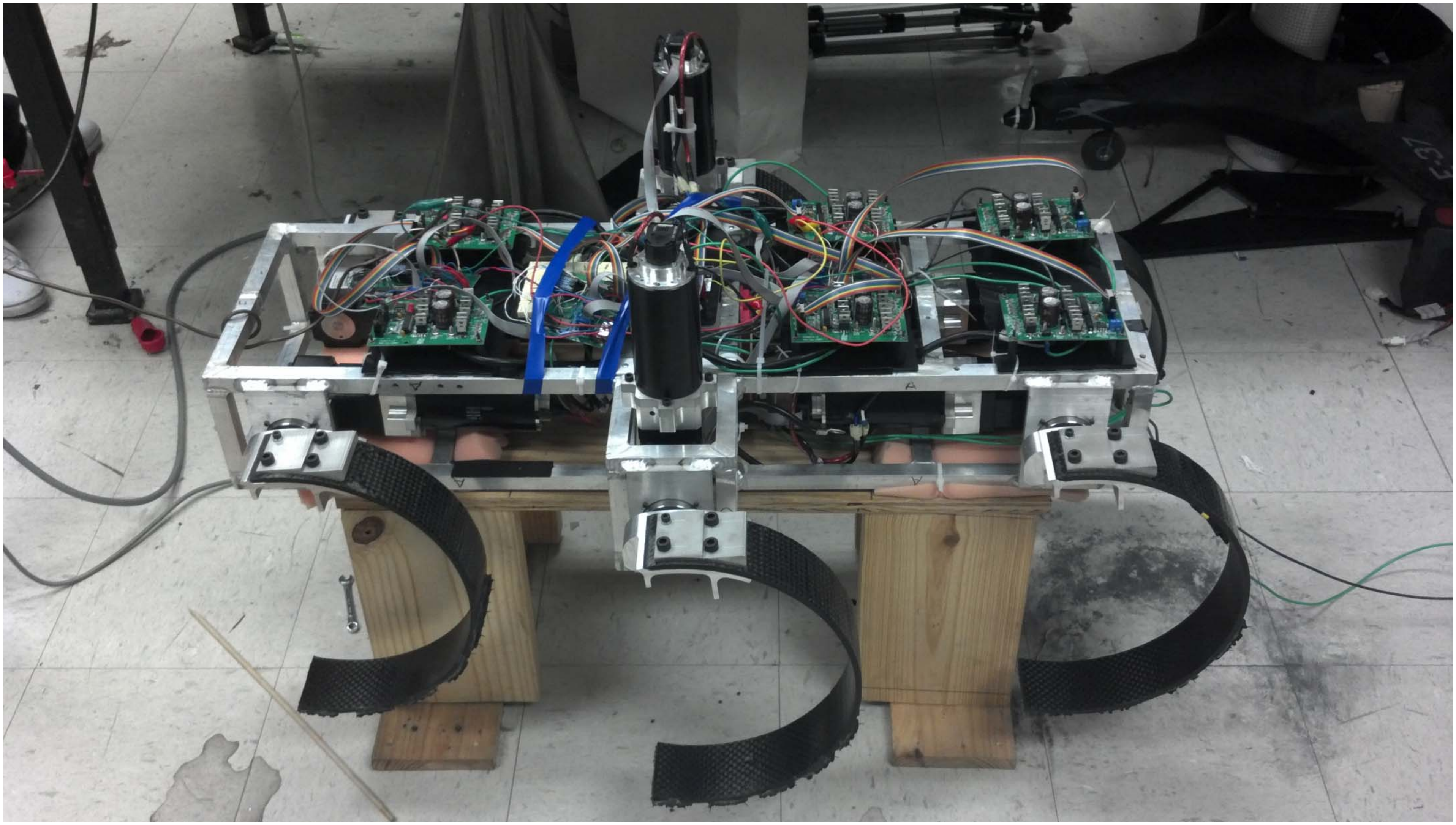
- Able to control two legs with a Bhueler clock
- Prototype on breadboard unstable



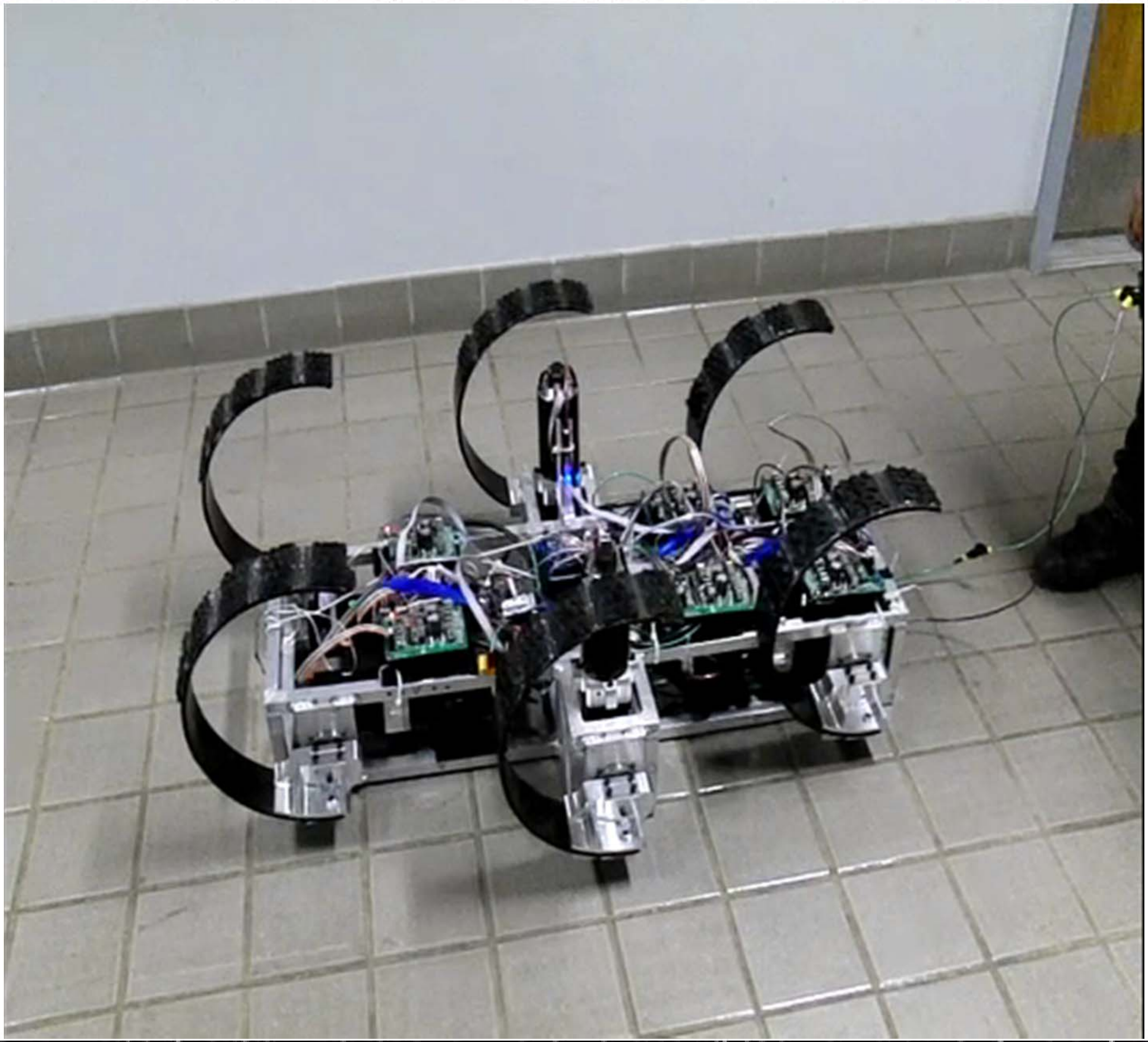
- Made motor control circuit on protoboard



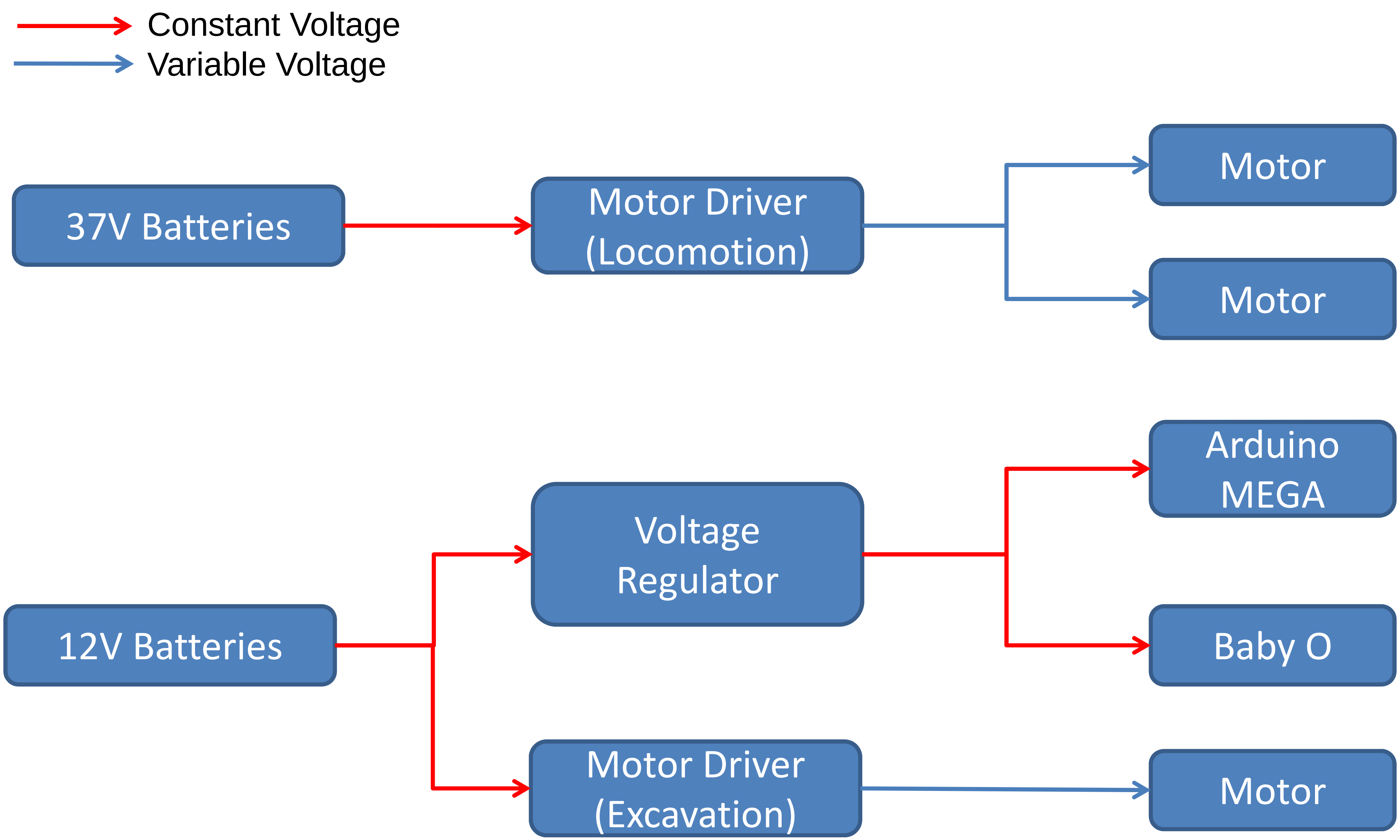
Testing Platform



Hexcavator Walking



Power Flow Chart



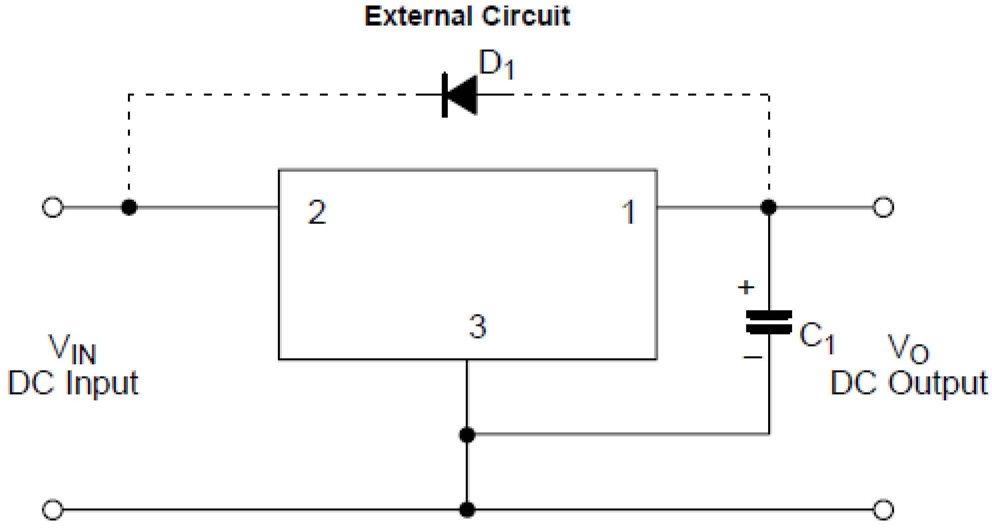
Batteries

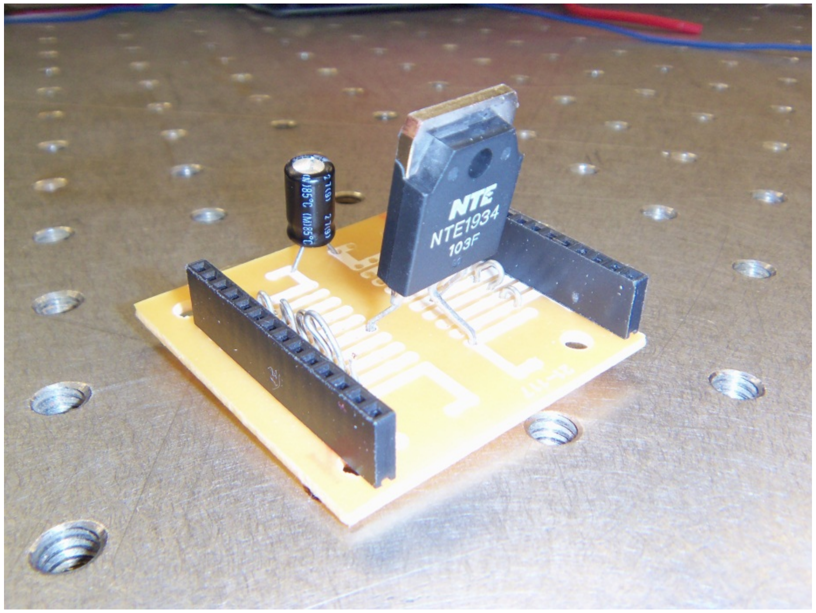
- Rated for 37V
- Actual output about 42V
- Run in Parallel for 37V potential and double current

- Rated for 12.8V
- Used for excavation system and onboard electronics

Voltage Regulator

- Power supply for electronics
- Provides consistent 5V
- Breadboard holes for GND and +5V
- Capacitor across regulated voltage to compensate for ripple voltage





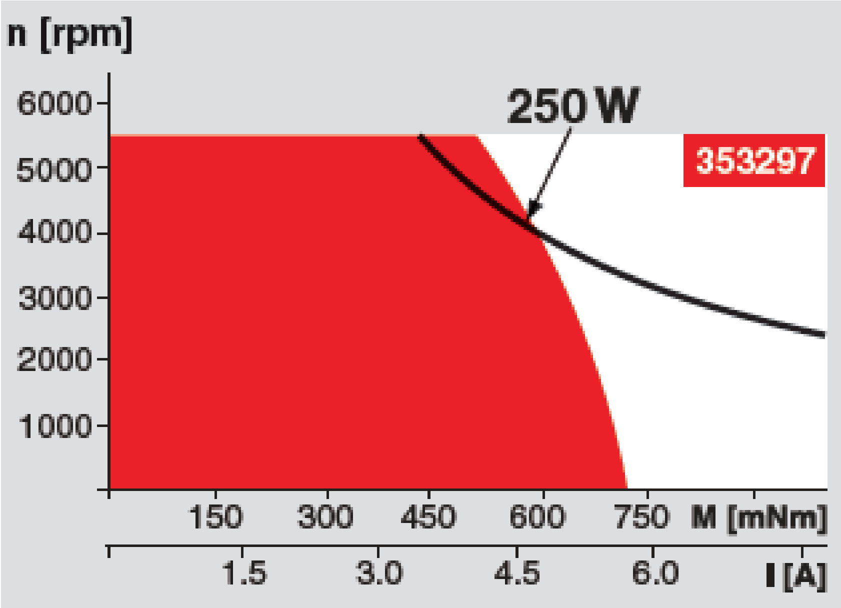
Part No: NTE1934

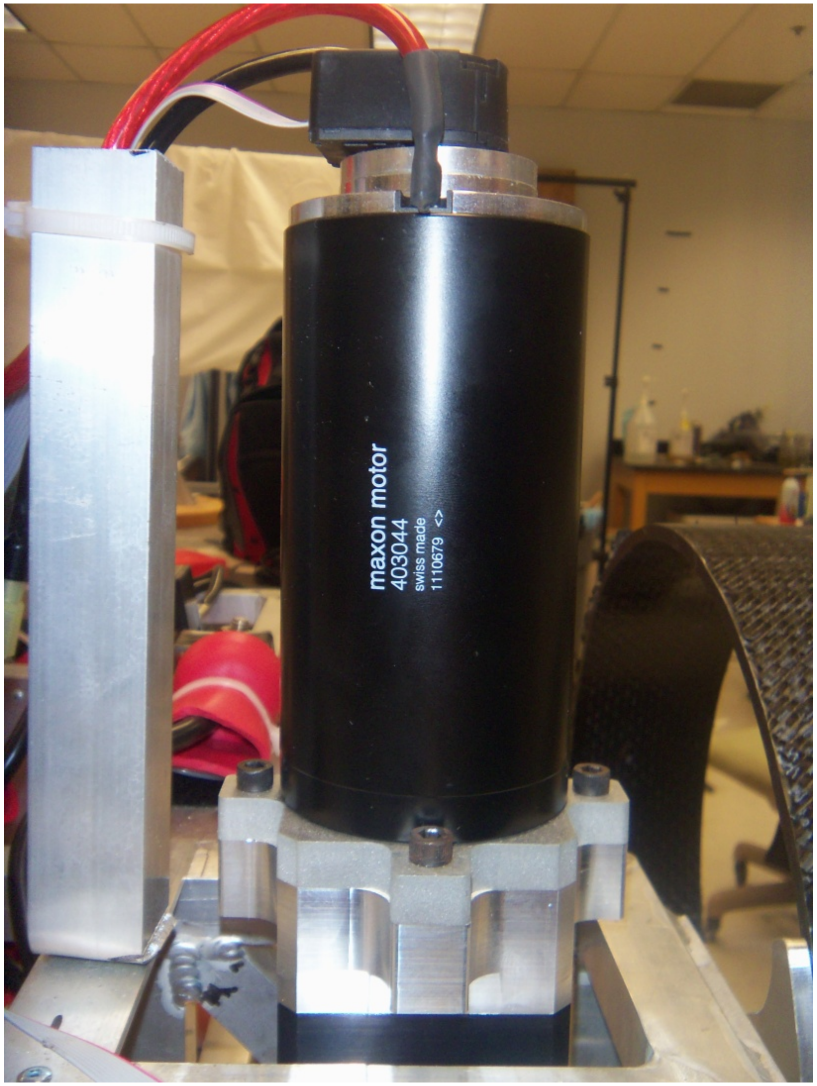
I_o = 0 to 2.0A
V_{in} = 8V to 45V
V_o = 5V

Locomotion Motor

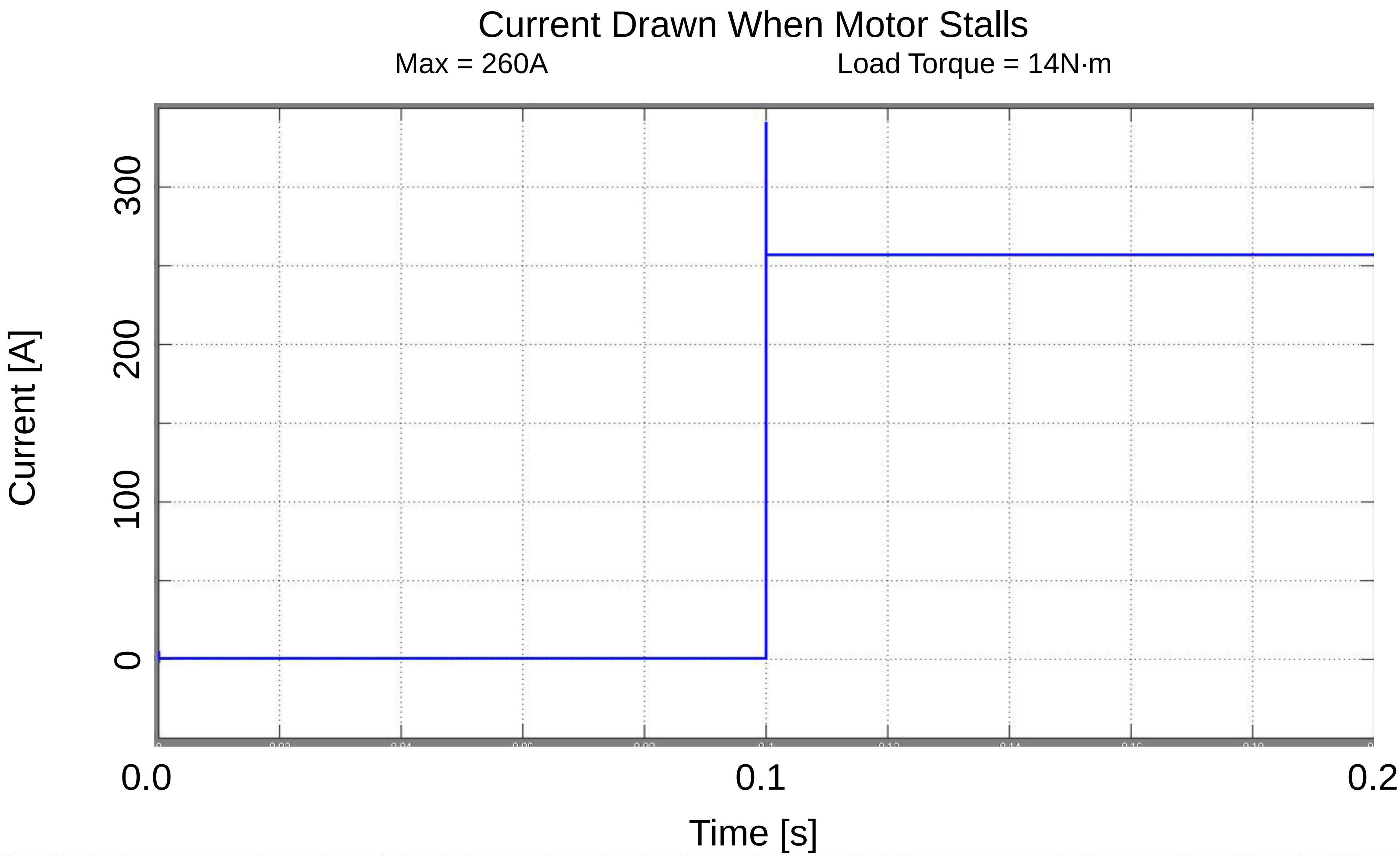
Gearbox: 50:1

Nominal voltage = 18V
Nominal torque = 442mN·m
Nominal current = 10A
Stall torque = 14 N·m
Starting current = 296A
Nominal speed = 3,150rpm



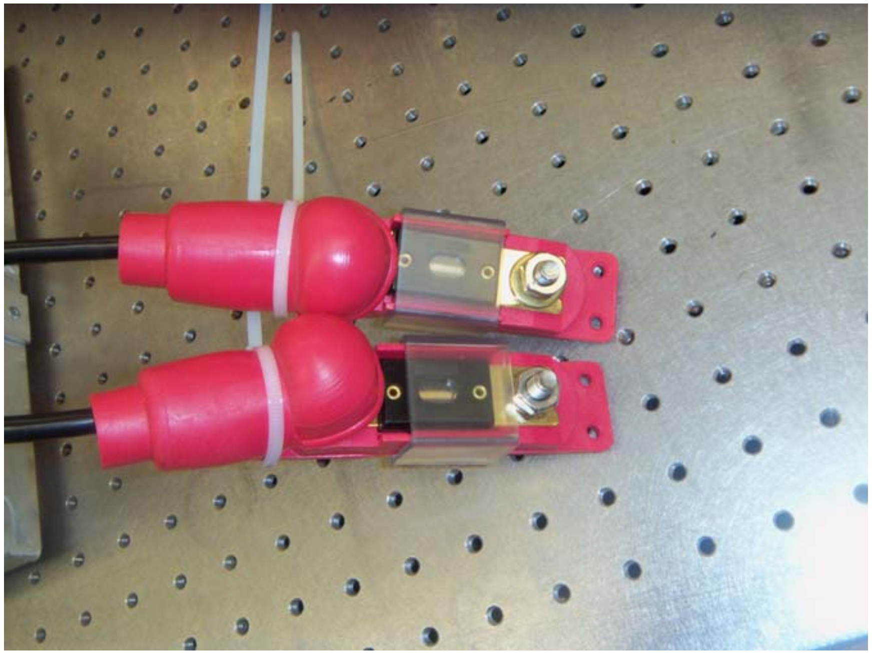


Motor Stall Current



Fuses and Safety Switch

100A Fuse Rating



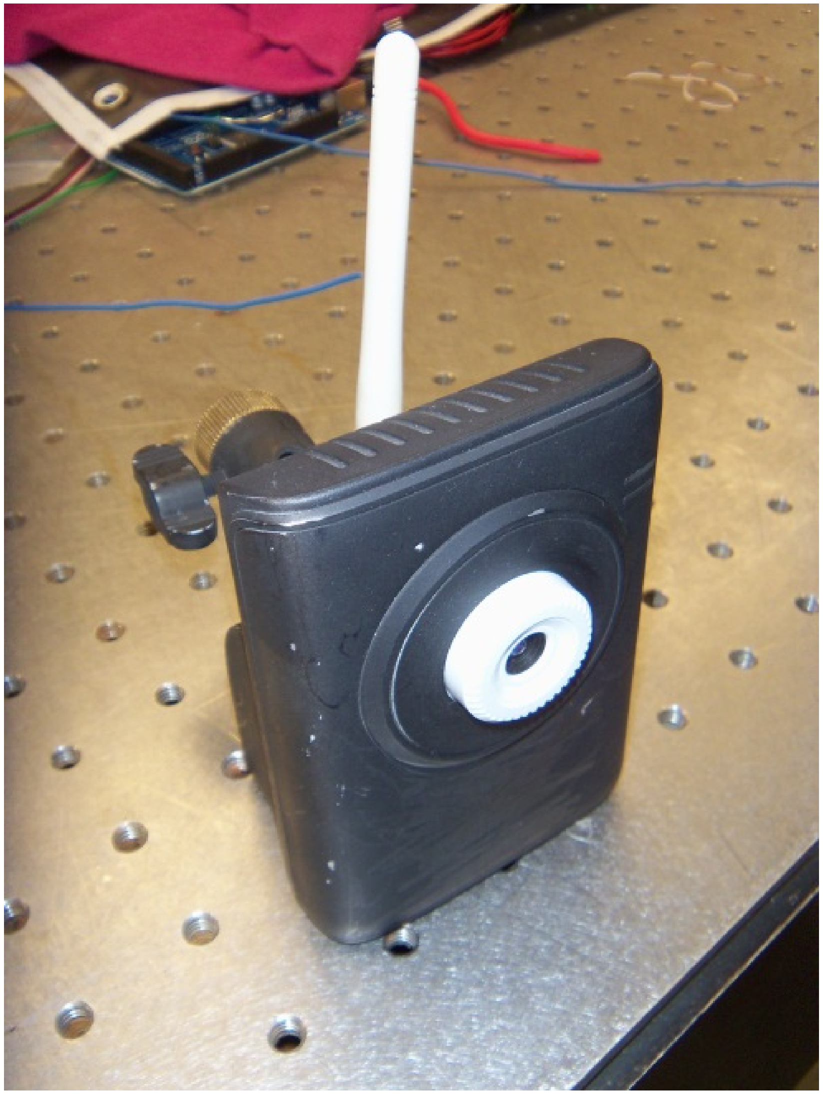
ED252L Locking safety switch

Maximum Voltage: 96V
Maximum Current: 250A

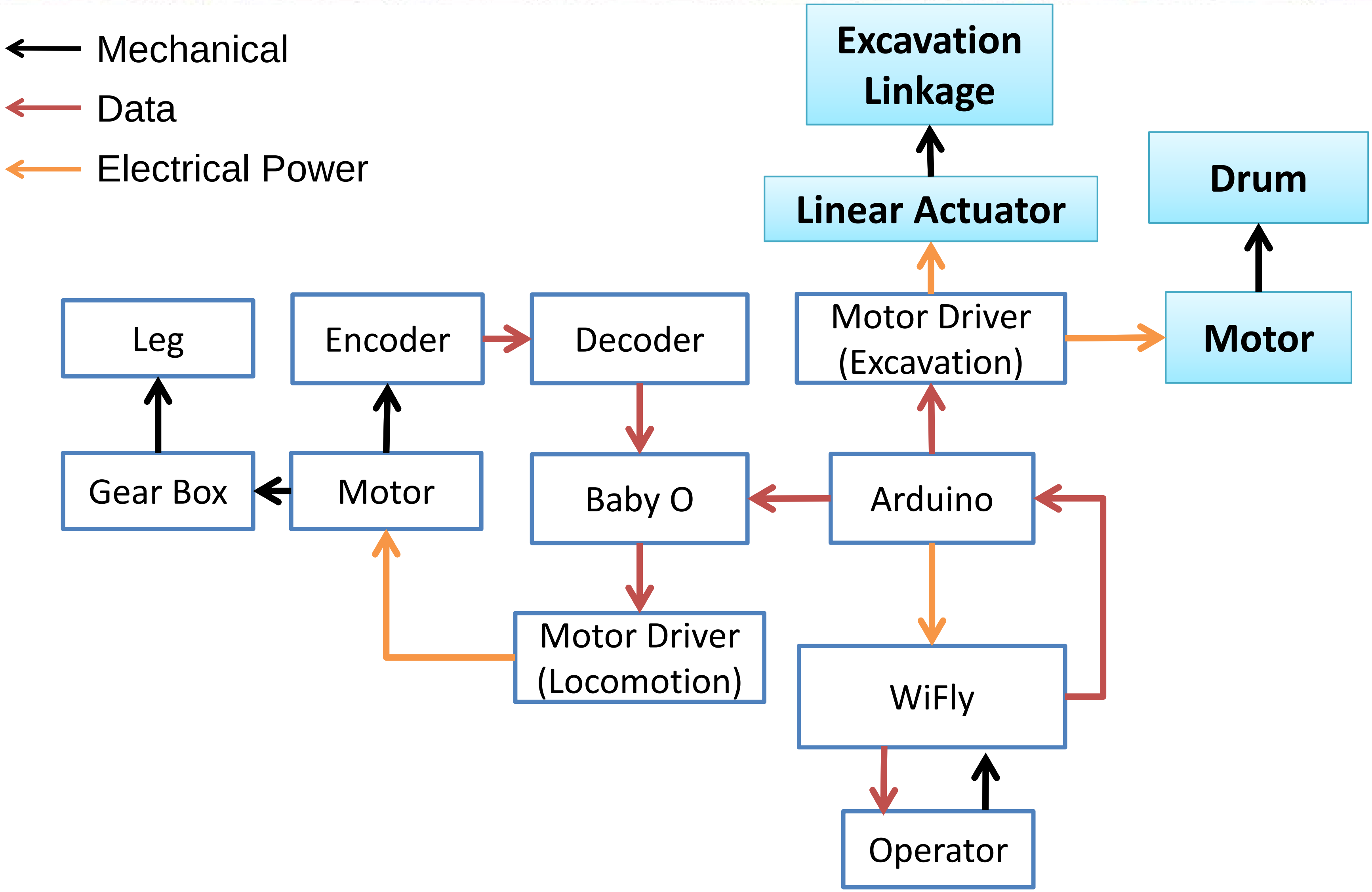
Wireless Camera

TRENDnet
TV-IP110W/A

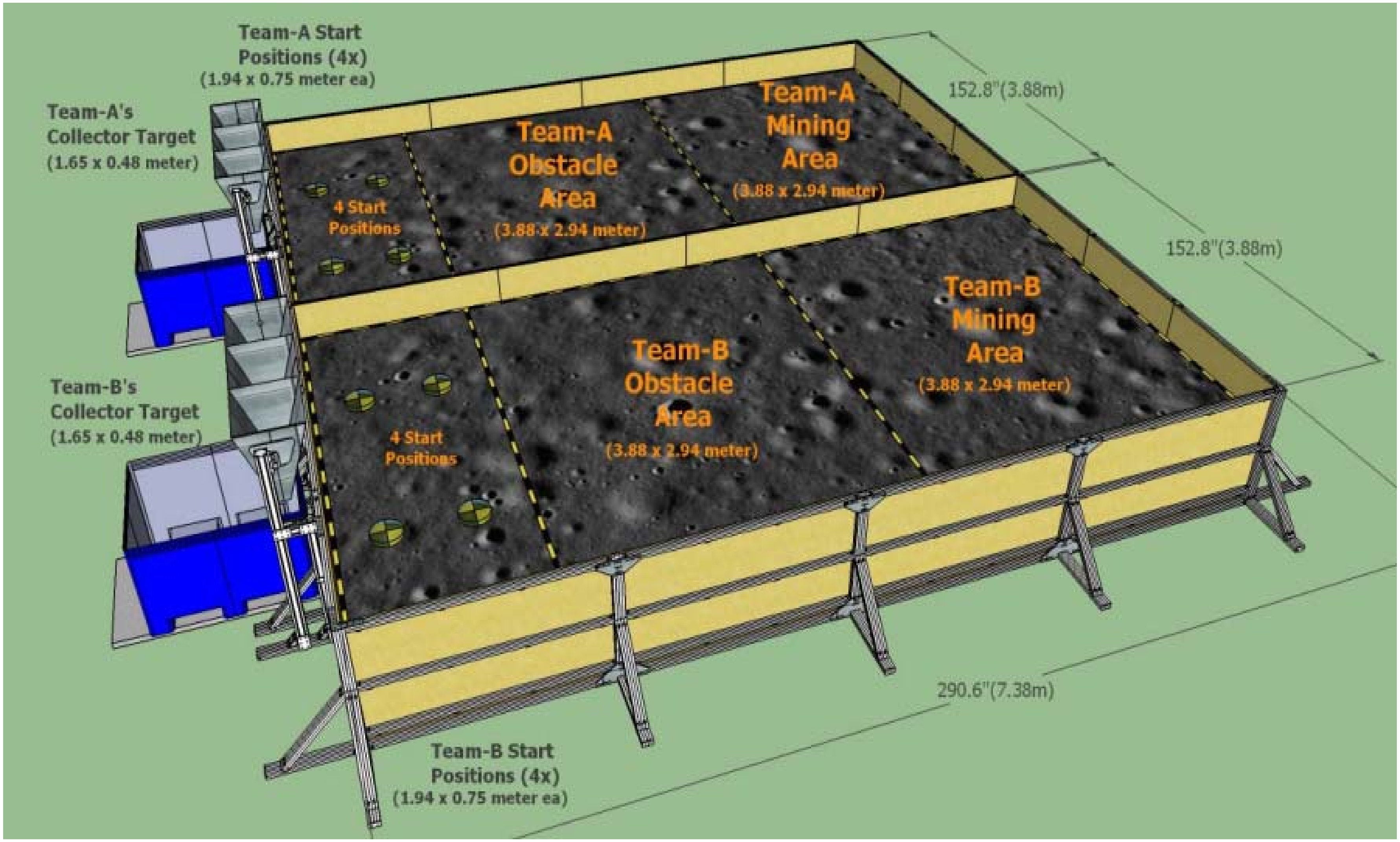
- Wi-Fi communication
- Fast Setup/Configuration
- Limited visibility provided



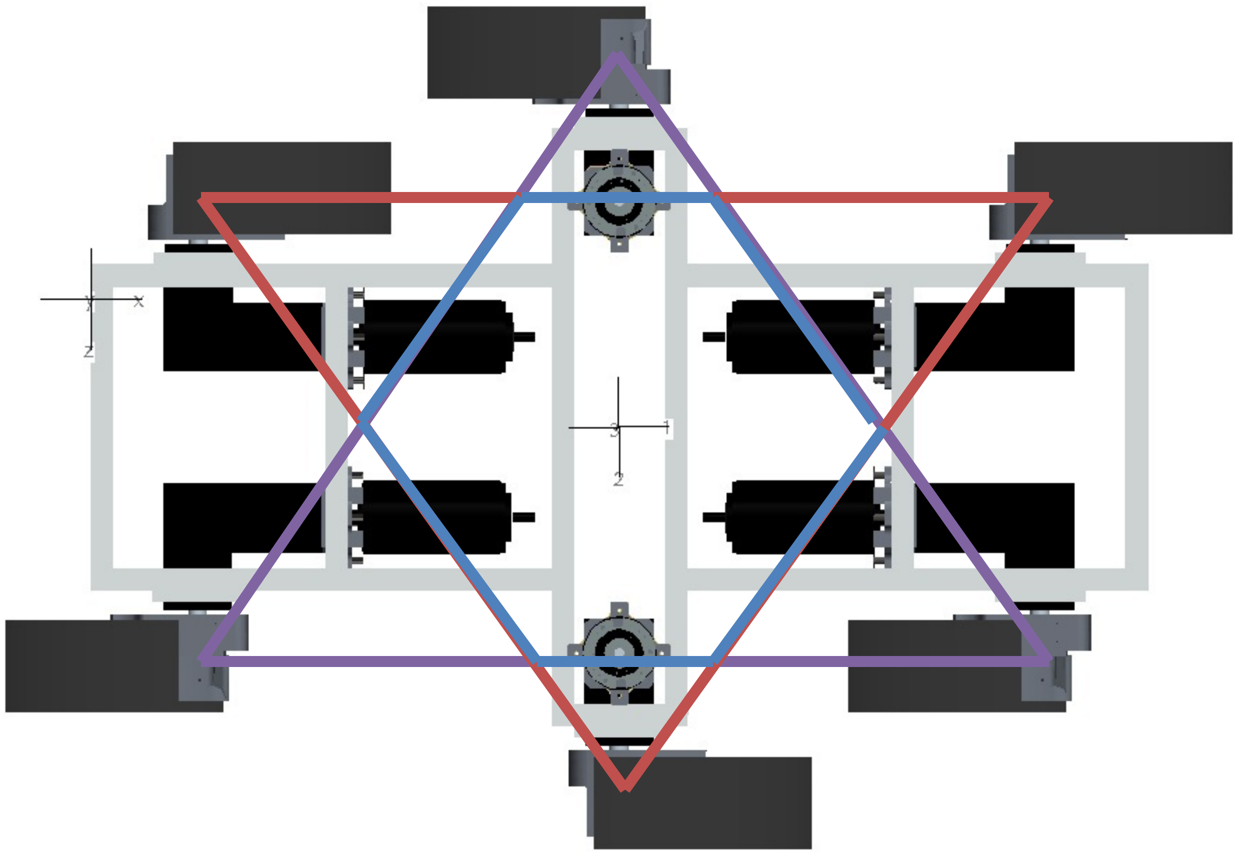
Functional Diagram



Competition Area



Center of Mass



Four Bar Design

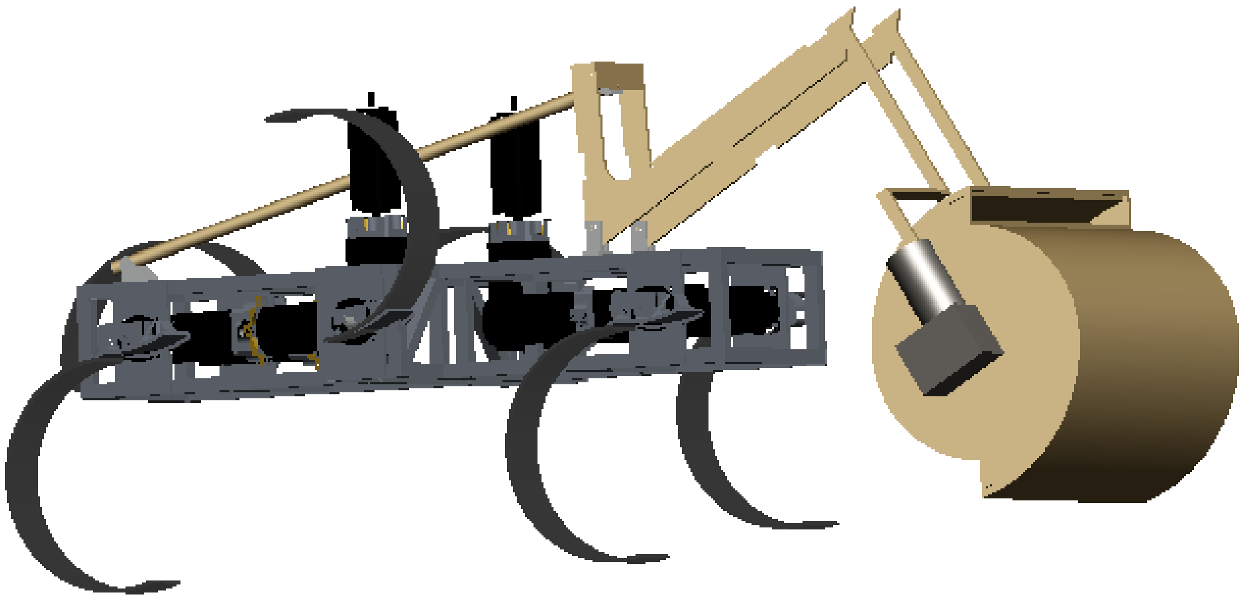
Uses linear actuator to extend and retract drum

Advantages

- Simple design
- Stable
- Better weight distribution

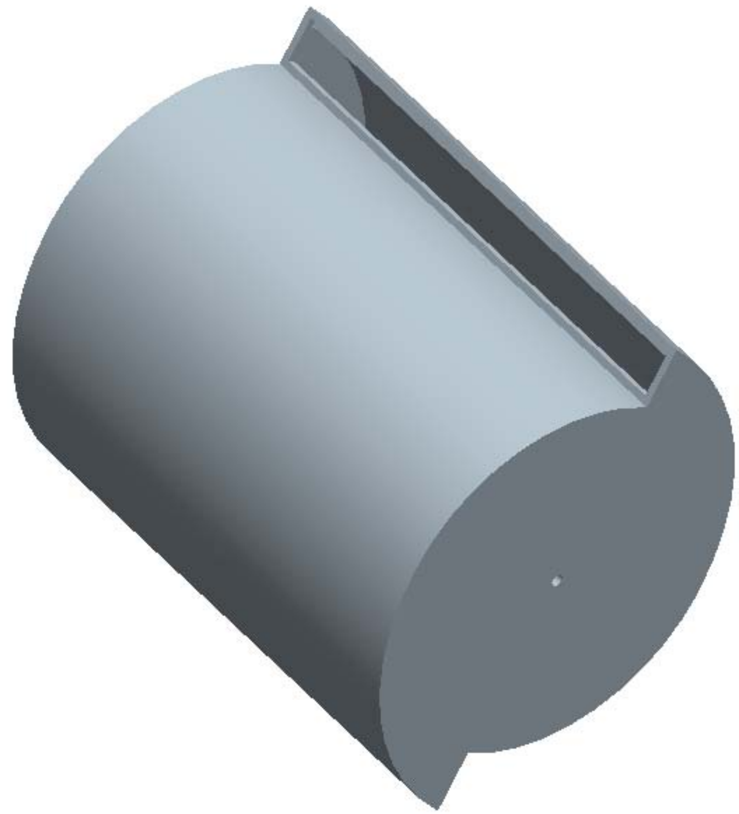
Disadvantages

- Welded



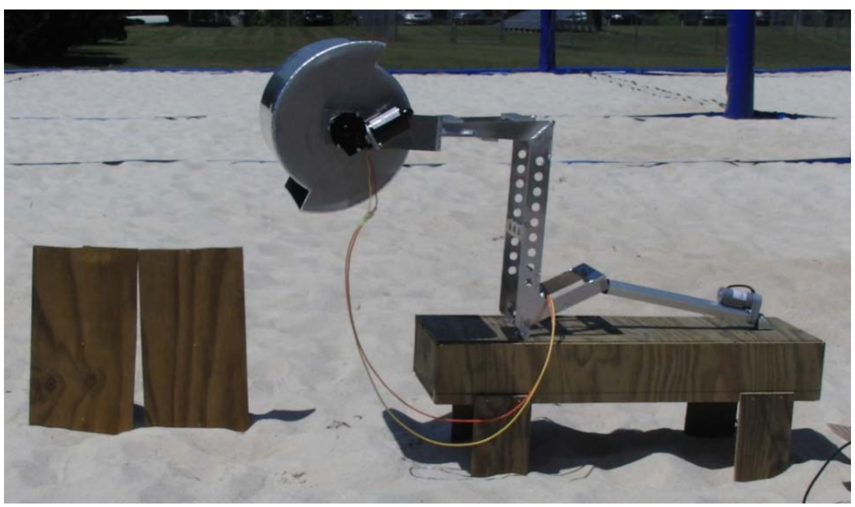
Rotating Drum

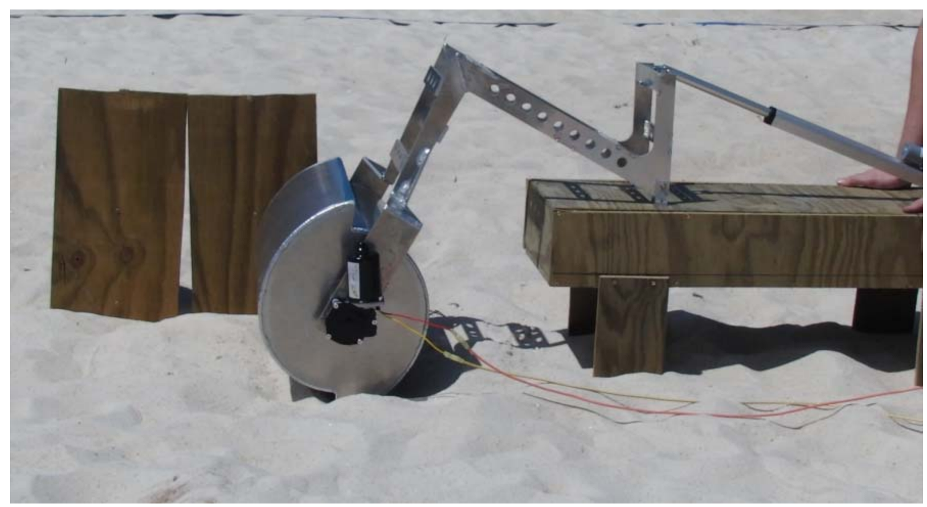
- Material: Aluminum 6061
- Density of Regolith: 1500kg/m^3
- Payload Ability: 48kg
- Motor Driven
  - Must handle up to 33.9N·m torque



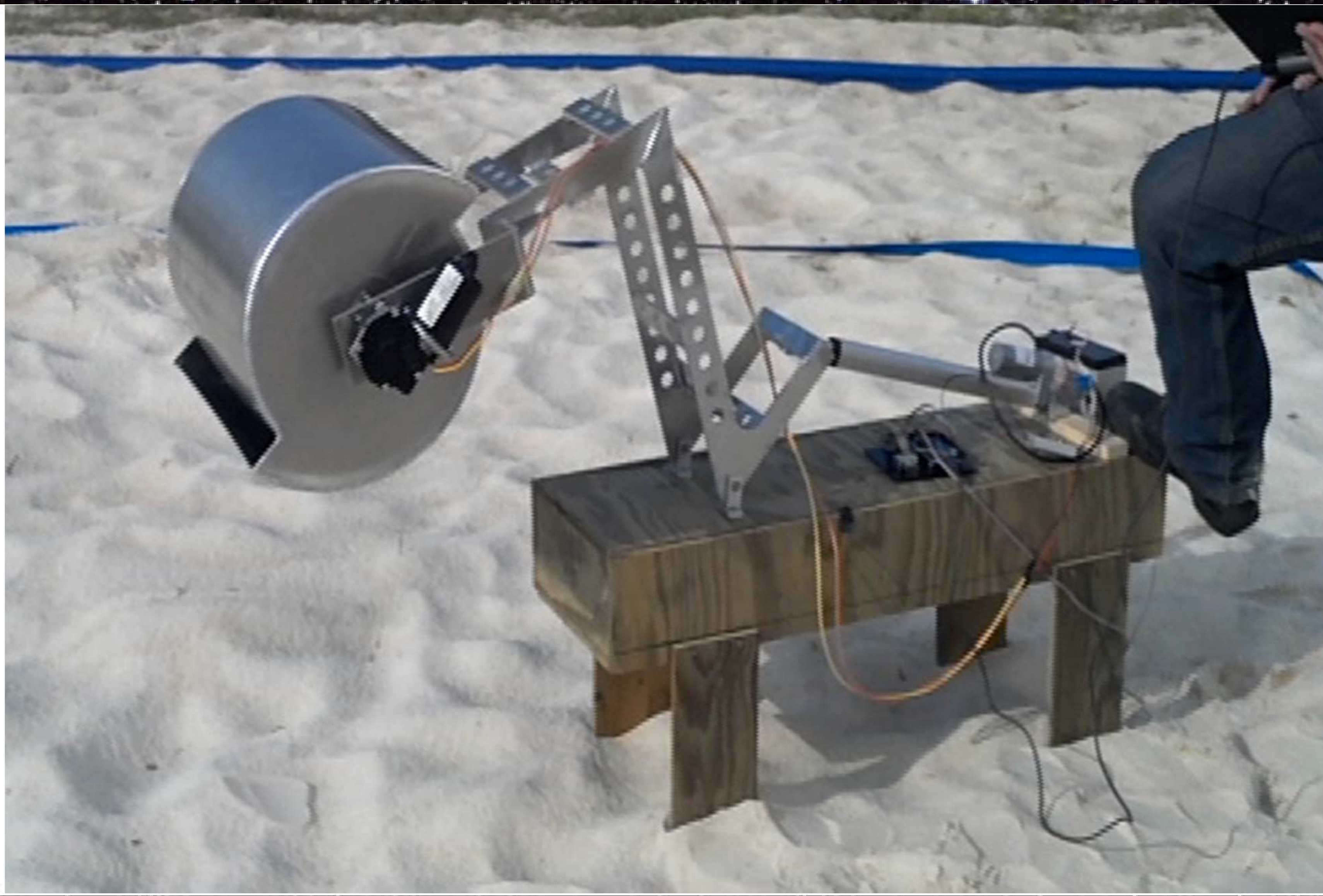
Implementing Four Bar

- Attached to wooden to-scale body of Hexcavator
- Tested in sand pit
- Performs necessary motions
- Batteries used to counter balance robot





Excavation Testing



Excavation Motors

Linear Actuator

- 12inch stroke length
- Load capacity: 890N
- 12V DC
- 5A at maximum

Drum Motor

- 96RPM at no load
- Maximum torque: 36.7N·m
- 12V DC
- 68A at Stall

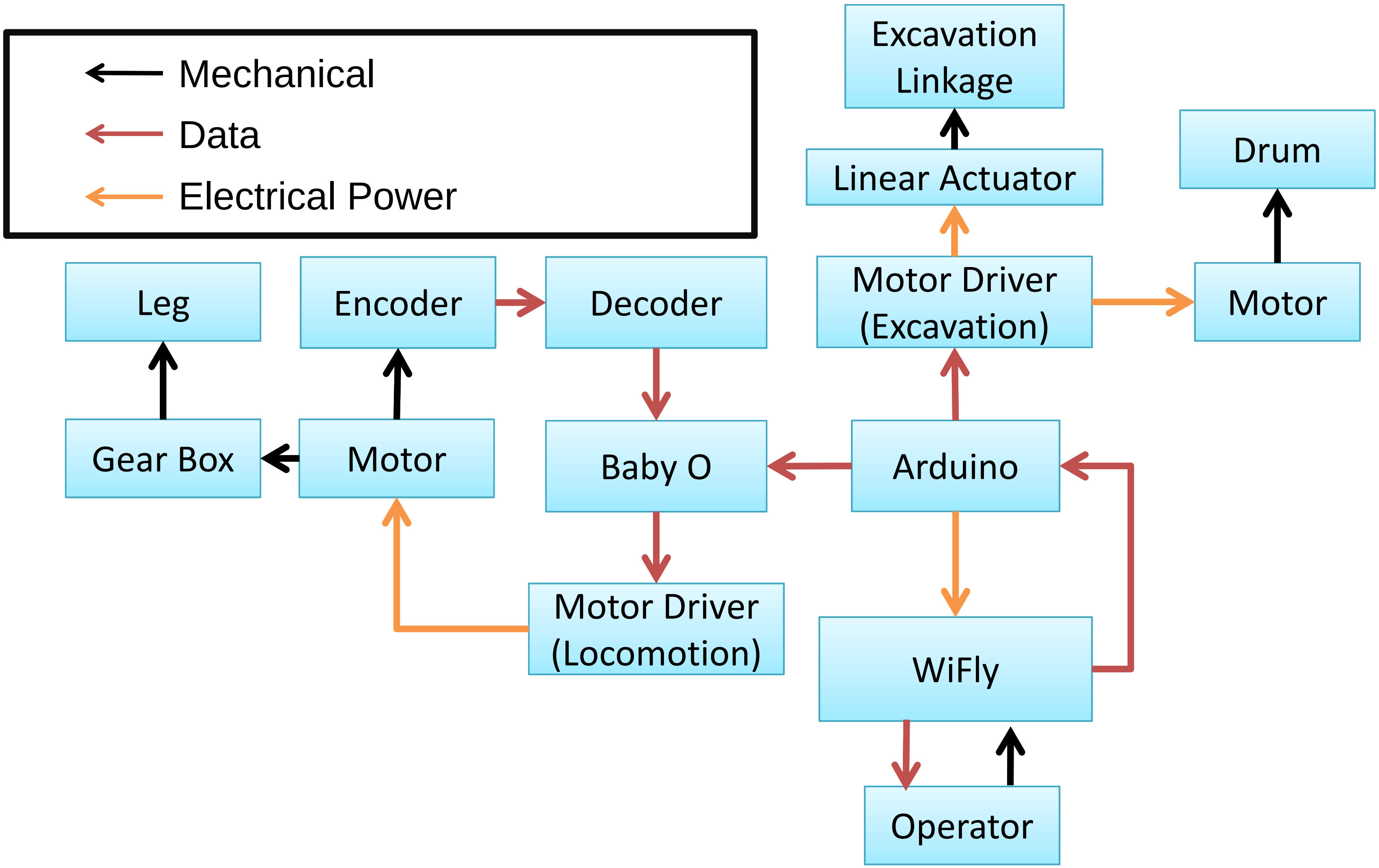
Cost Analysis

Expense:	Amount:
Electronics	$2,802.13
Excavation	$1,536.74
Hardware	$274.81
Travel	$1,880.85
TOTAL:	**$6,494.53**

Total Budget: $10,000

- FAMU/FSU College of Engineering: $2000
- National Space Grant: $ 5000
- Northrop Grumman $3000

Functional Diagram



Questions?

References

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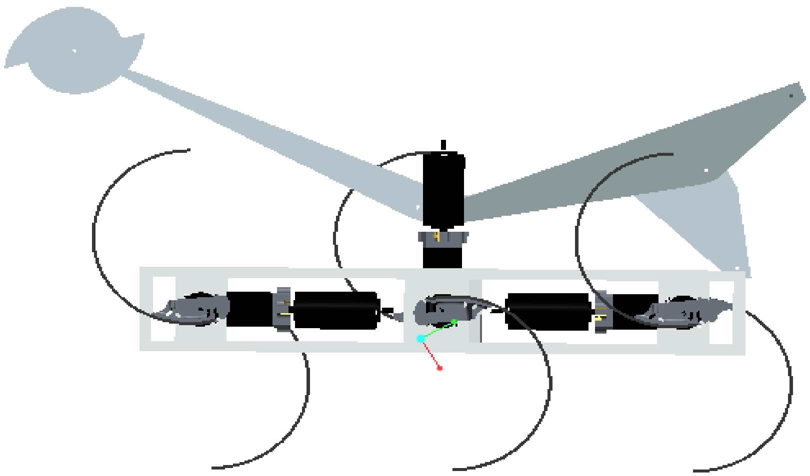
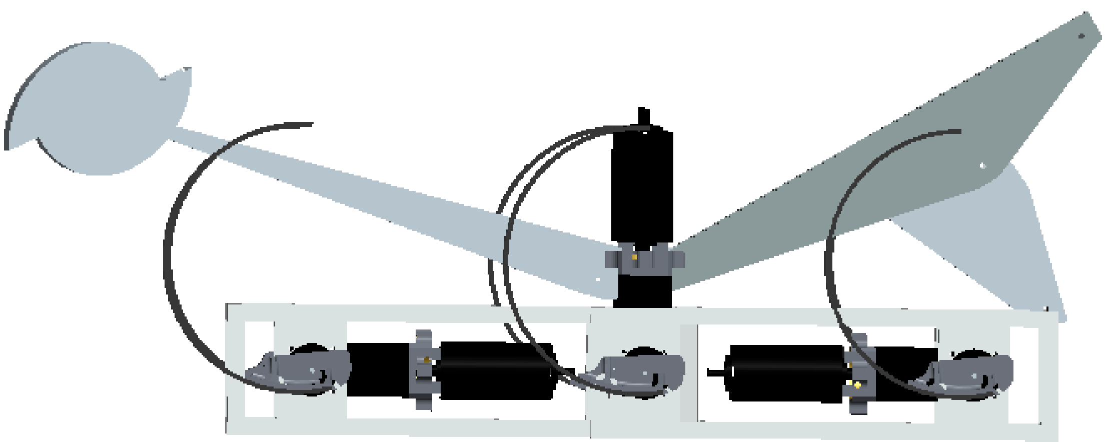
Six-Bar Excavation Design

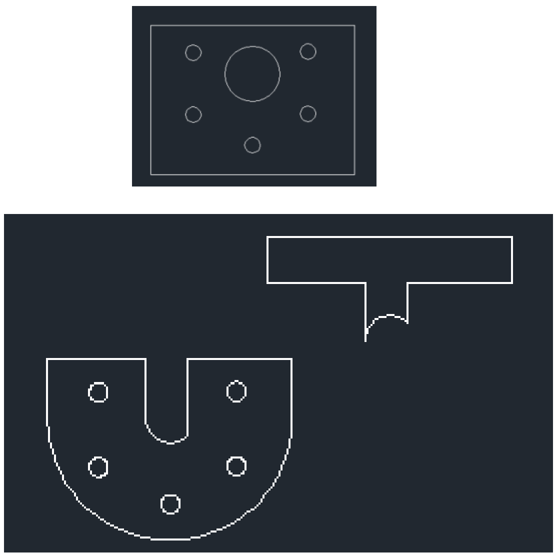


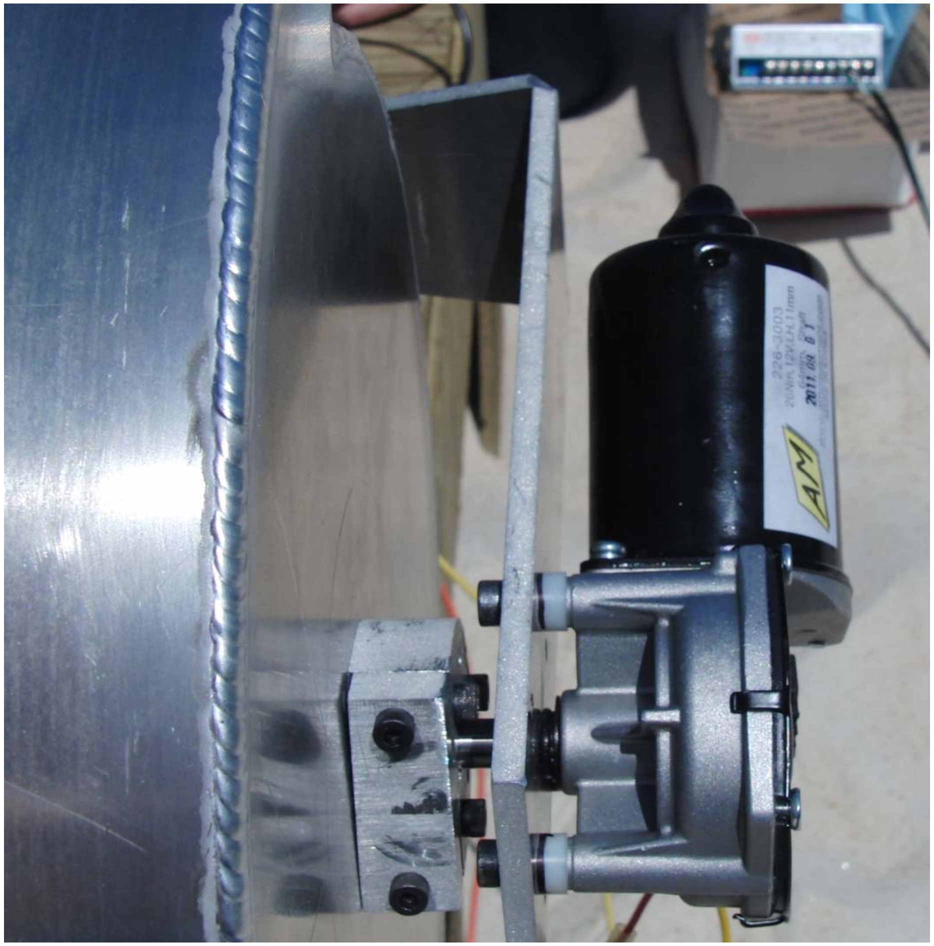


Advantages:
- Compact initial dimensions: 0.39m x 1.23m x 0.75m
- Robot never required to turn around

Disadvantages
- Very complex
- Unstable

Motor Mount

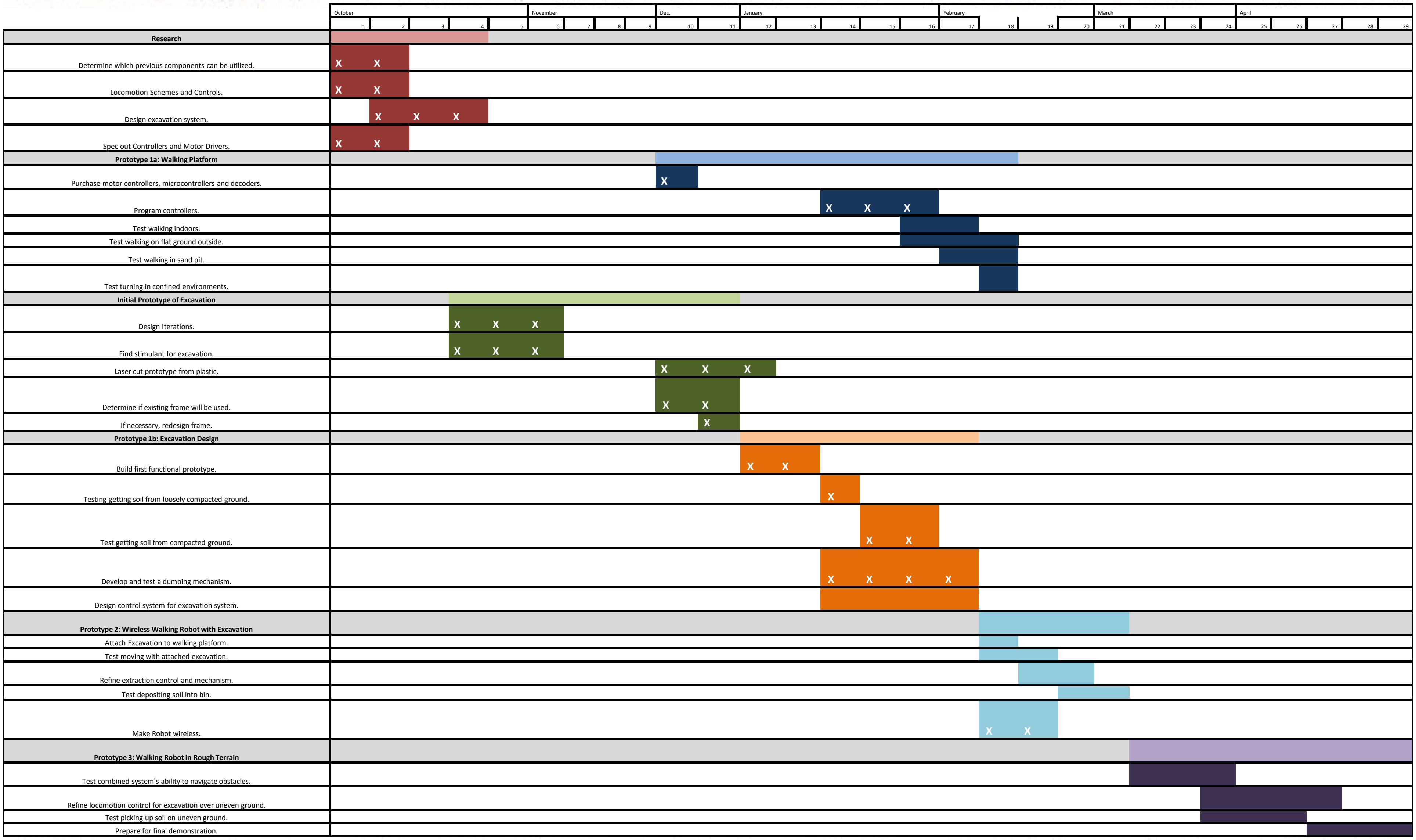




PC/104

- Windows CE 6.0 Pro Embedded
  – Costs: $18.00
  – Requirements: 1GB on storage
  – Restrictions: 512 MB RAM
    - Restricted by OS
  – Benefits: Advantech Software
    - Not compatible with Linux
    - Costs $20.00
    - Makes interfacing with stacks easier

Complete Gantt Chart



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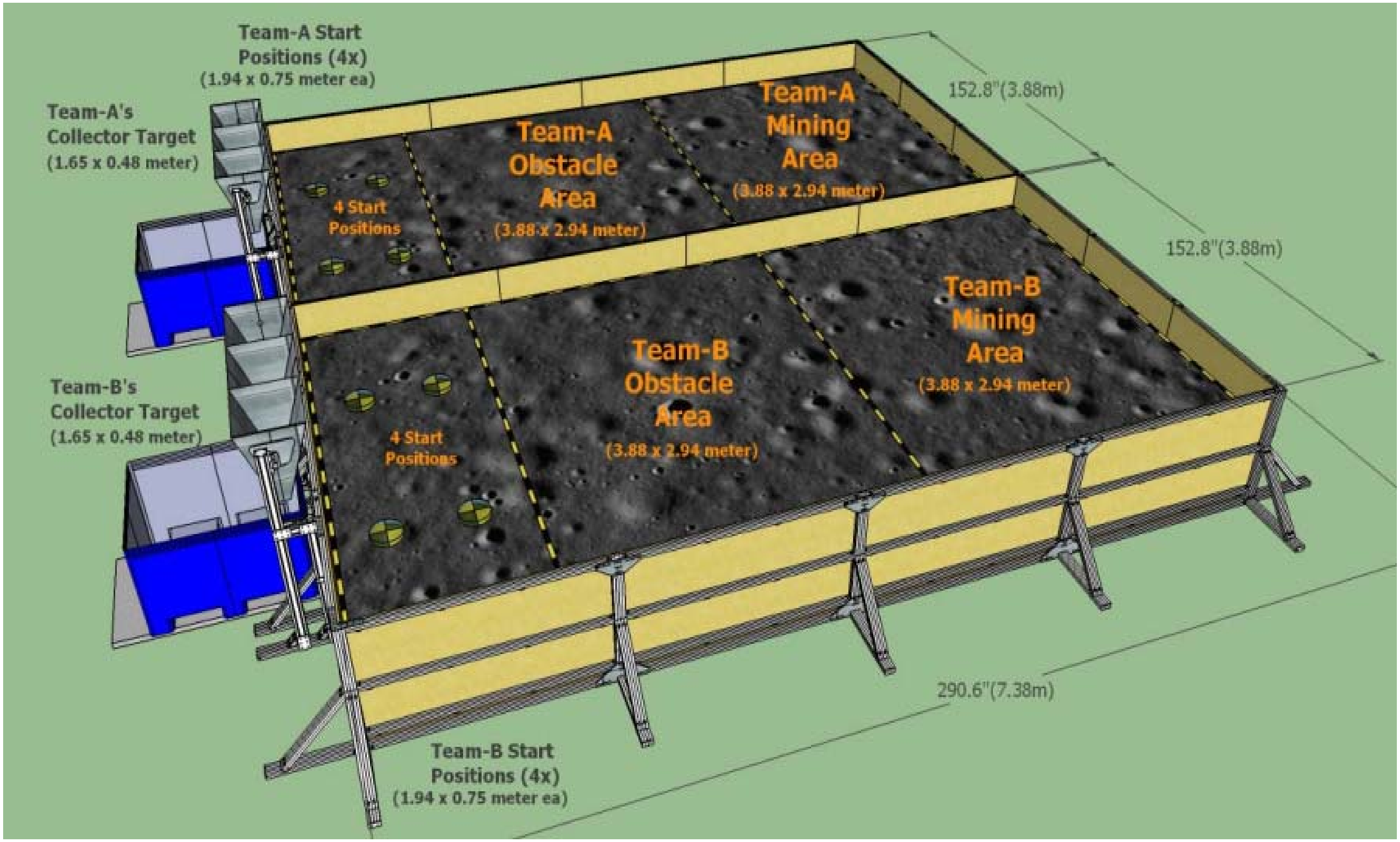
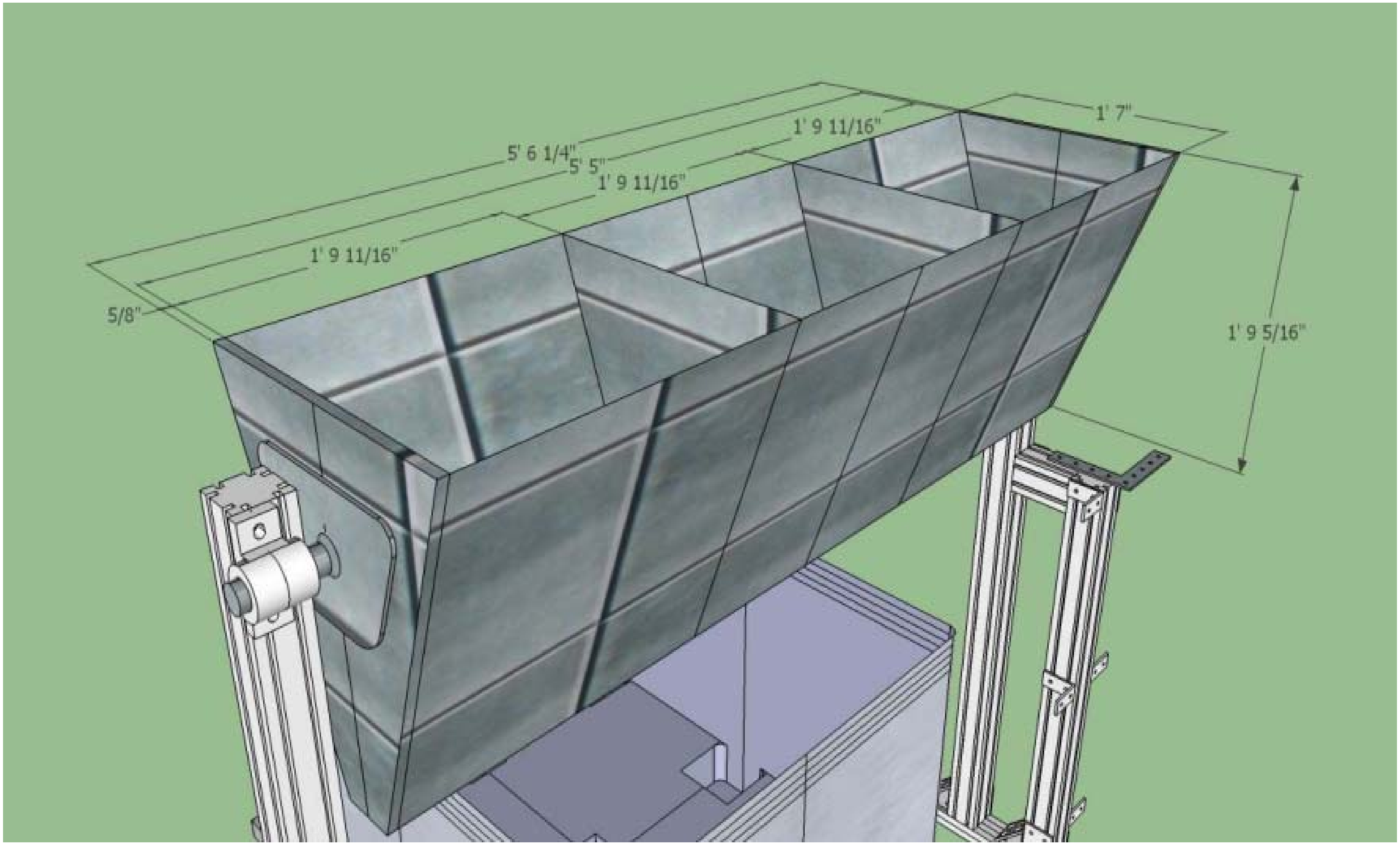
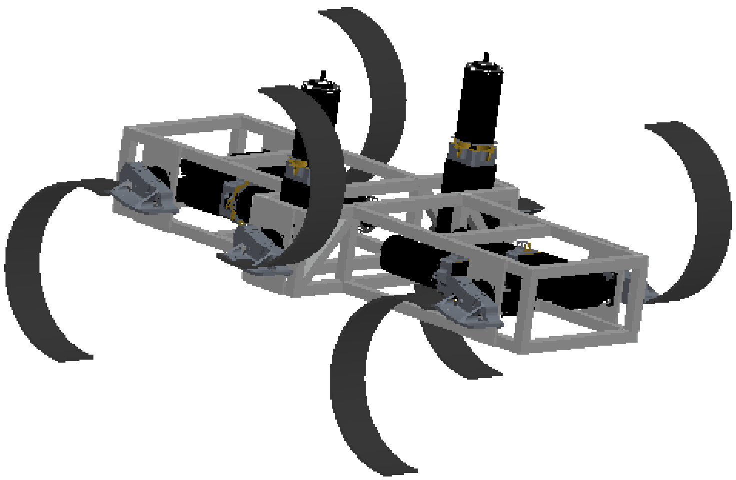


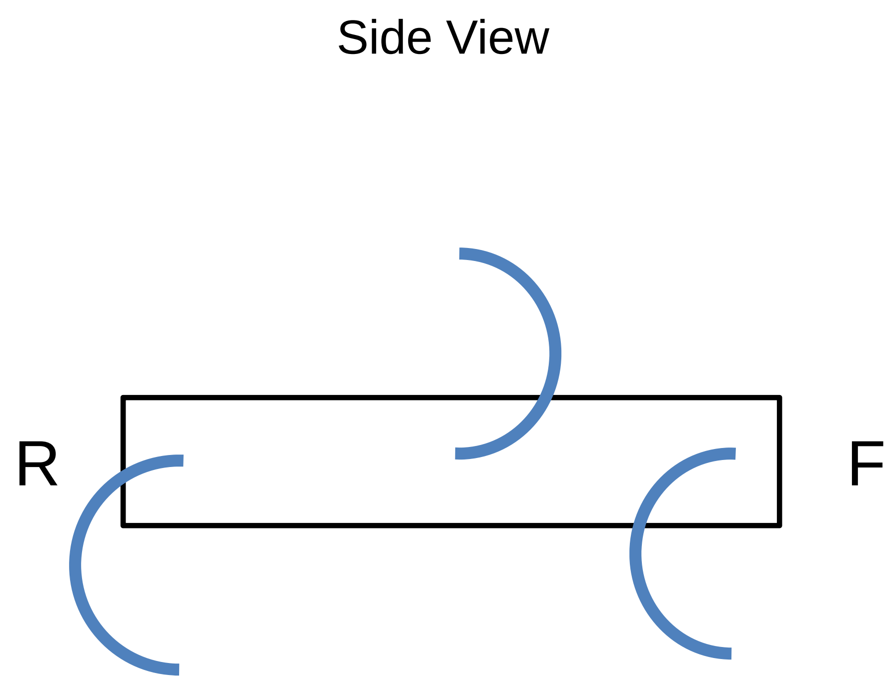
LunaBin




Hexcavator
WiFly
User

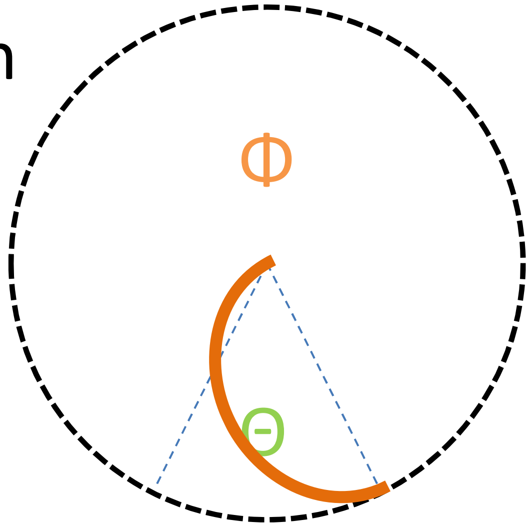
Locomotion Control





Locomotion Control

- Solution: Buehler Clock
  - Speed varies depending on position
    - Time of θ = Time of Φ
  - Need to read position of motor



  - While leg is in Φ angle, the angular velocity is 5 times greater than when in θ angle