Final Design

Lunar Regolith Excavator Student Competition

Hexcavator

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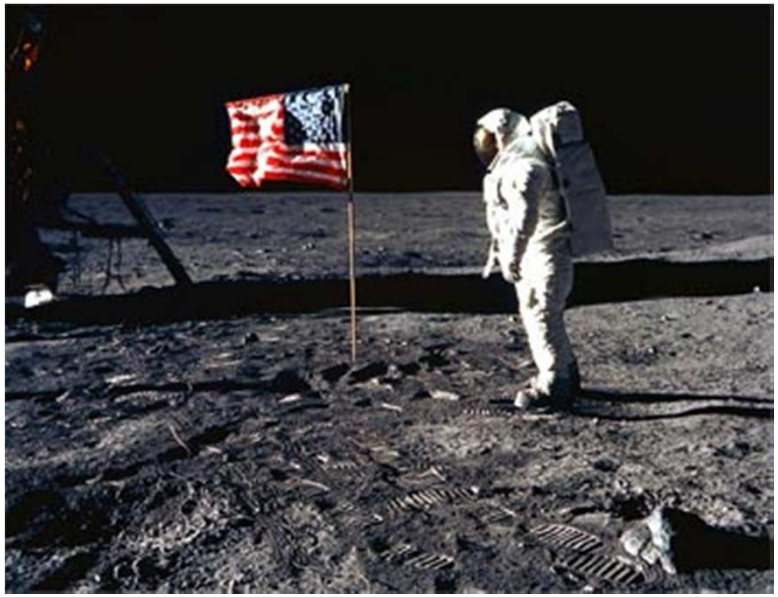
Project Inspiration

- NASA's Third Annual Lunabotics Competition
- Competition Date: May 22, 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

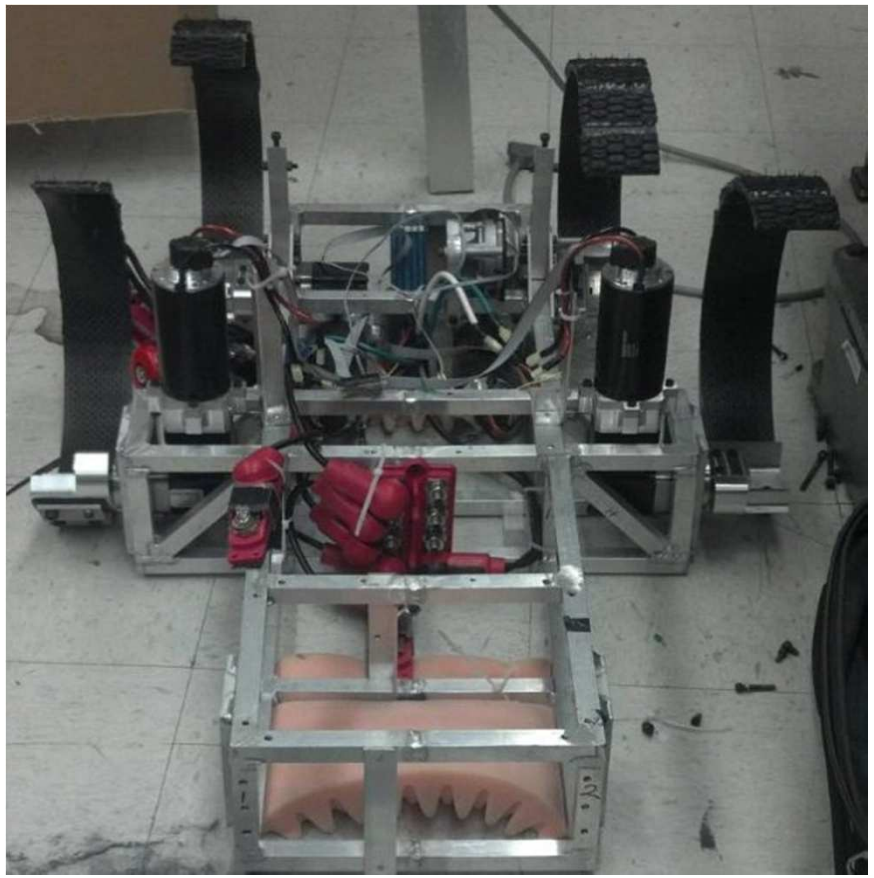
Previous Hexcavator Efforts

Complete:

- Frame
- Legs
- Motors
- Batteries
- Stop Button

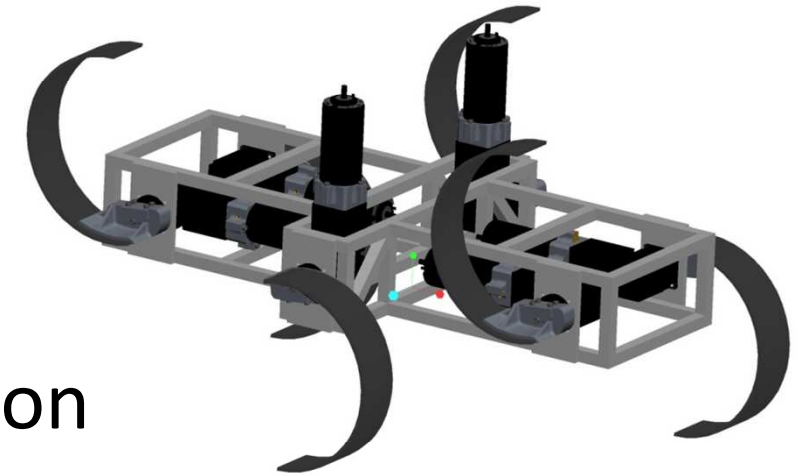
Needs:

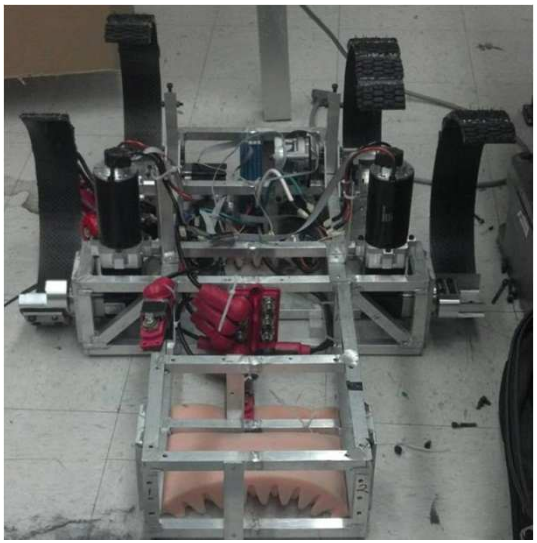
- Excavation
- Controls



Approach

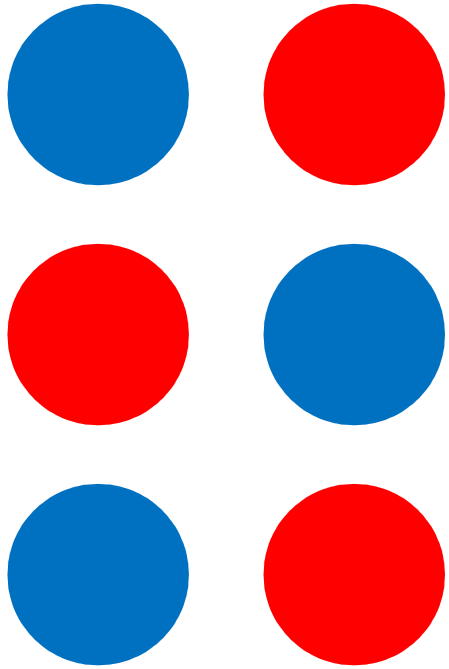
- Locomotion Scheme
- Wireless Communication
- MicroController
- Inter-robotic communication
- Power System
- Excavation Design
- Cost Analysis
- Time Line





Locomotion

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



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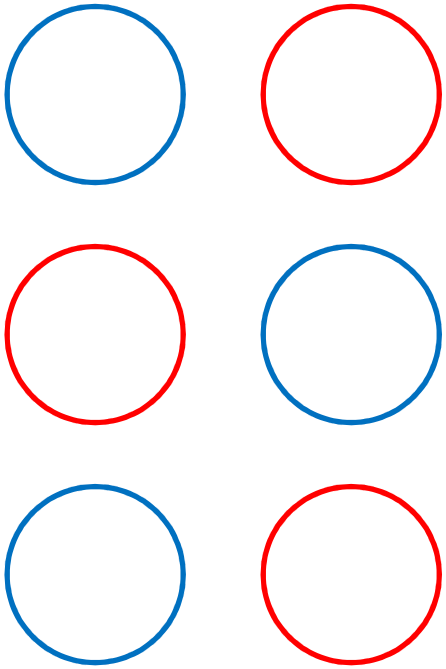
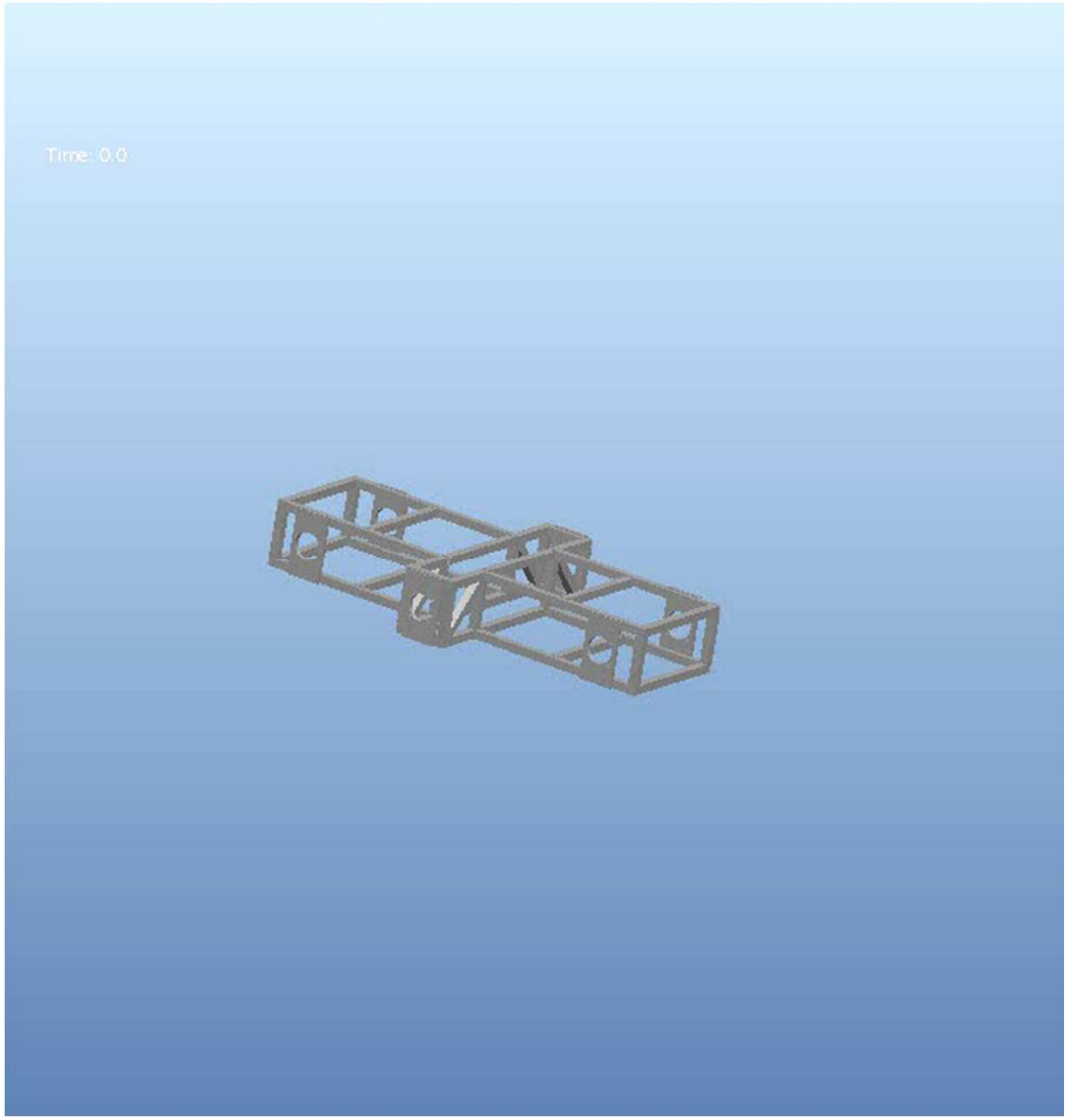
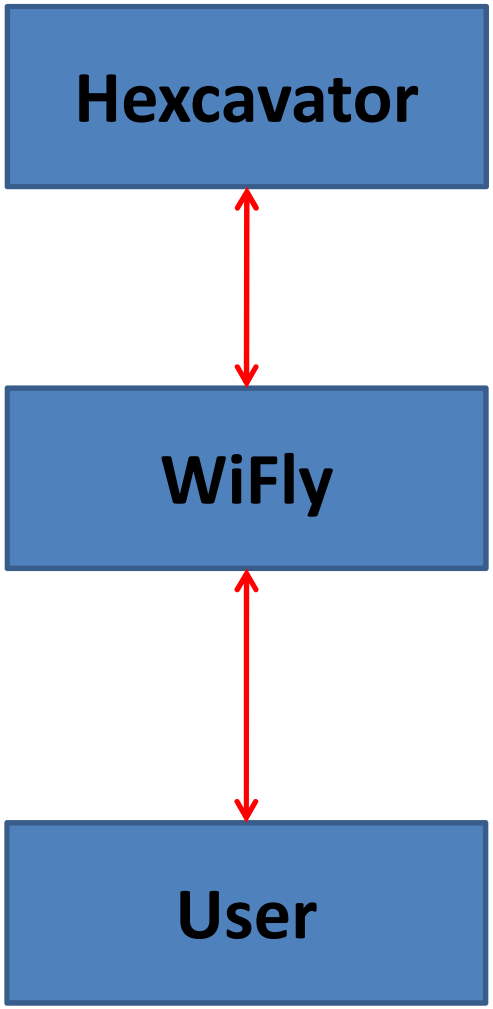


Alternating Tri-Pod Gait



Wireless Communication

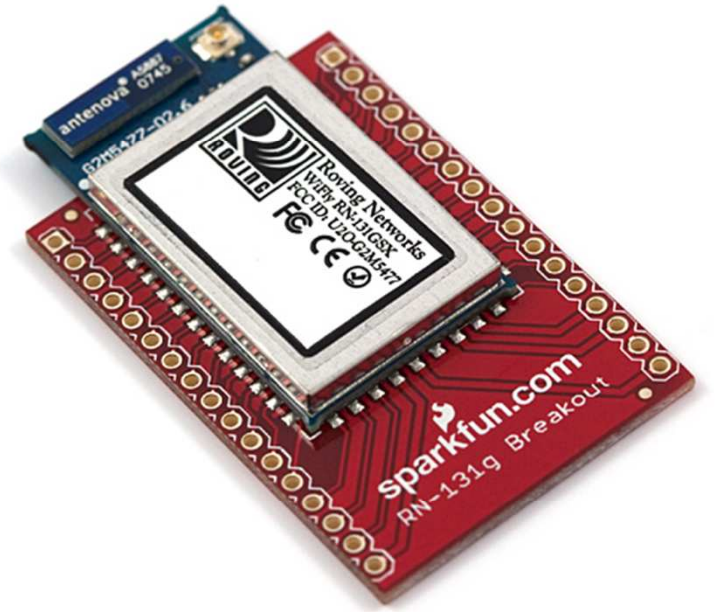


Requirements

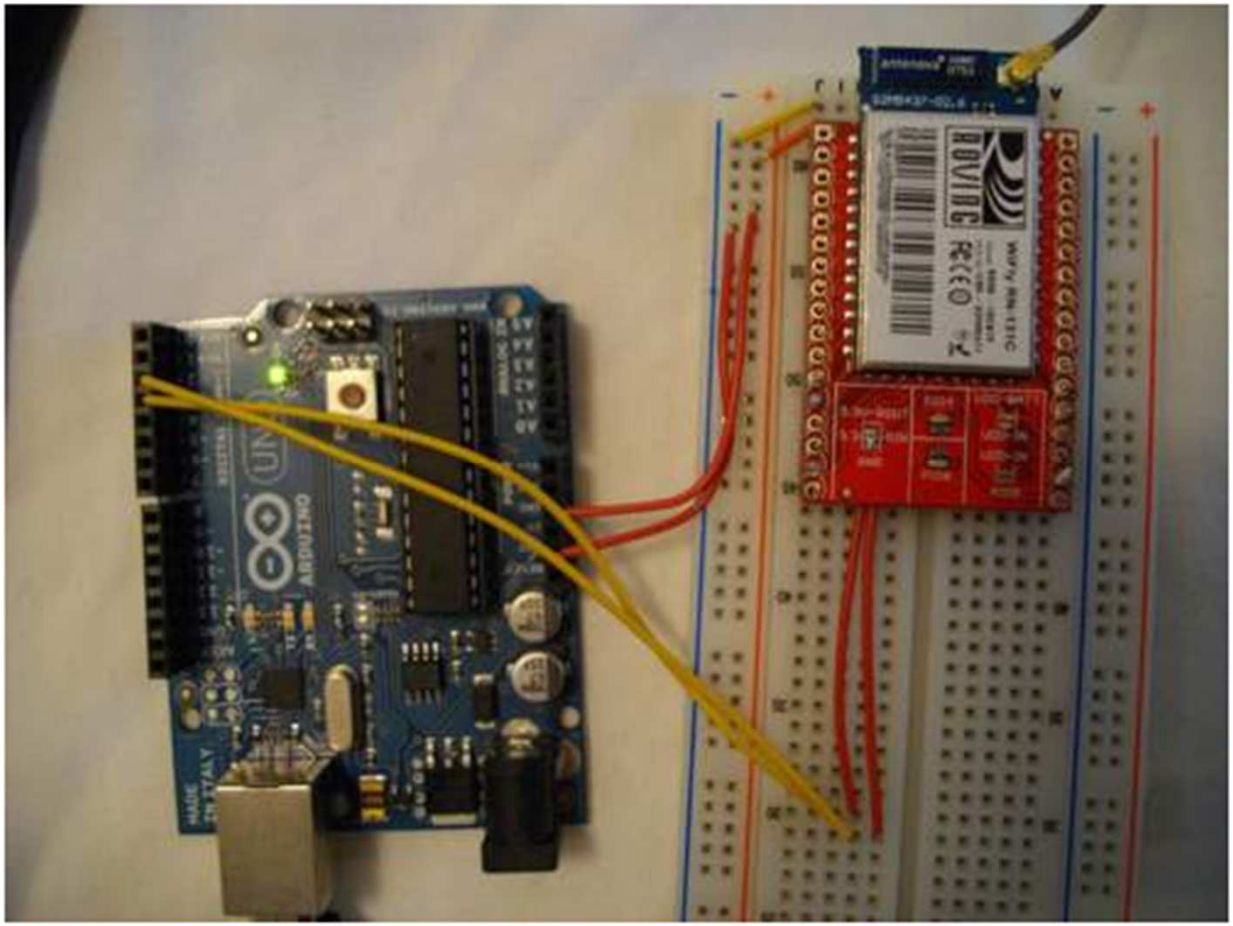
- WiFi
- Minimum bandwidth usage

WiFly GSX

- Standalone Wireless LAN
- Works within requirements
- Wireless UART connection
- IEEE 802.11 b/g
- Bandwidth Constraints
- $84.95

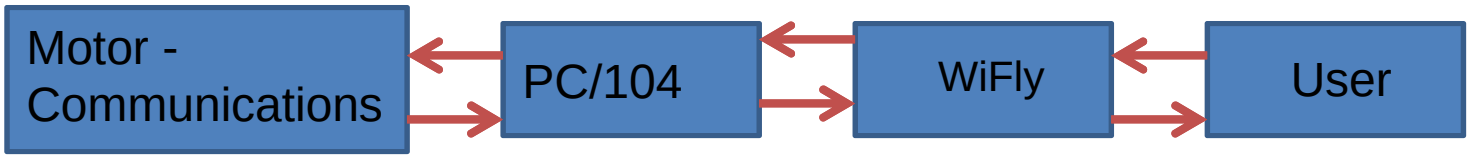


Prototype of the WiFly GSX



Main Micro-controller

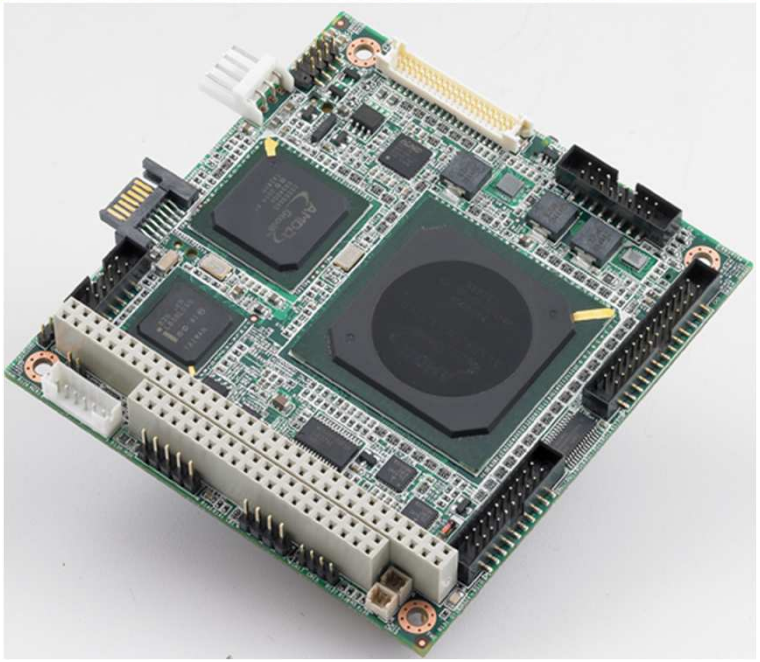
- Distribute User's Commands to Robot



PC/104

- Stacks required
  - CPU Stack (PC/104)
  - Serial Port Stack (RS232 and RS485)
  - Digital Input/Output Stack

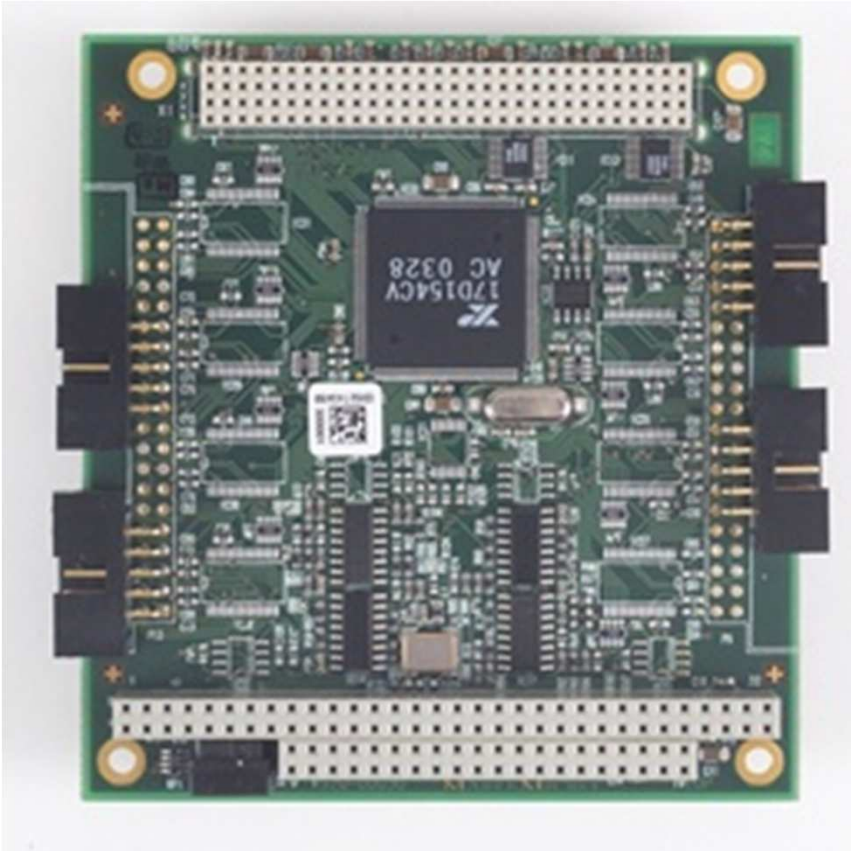
PC/104



- CPU Stack
  - Advantech PCM-3355
  - Cost: $247.00
  - CPU: AMD LX800 500MHz
  - Ports: 2 USB, 2 RS-232,
    1 RS-485
  - Operating System: Windows CE 6.0 Pro Embedded

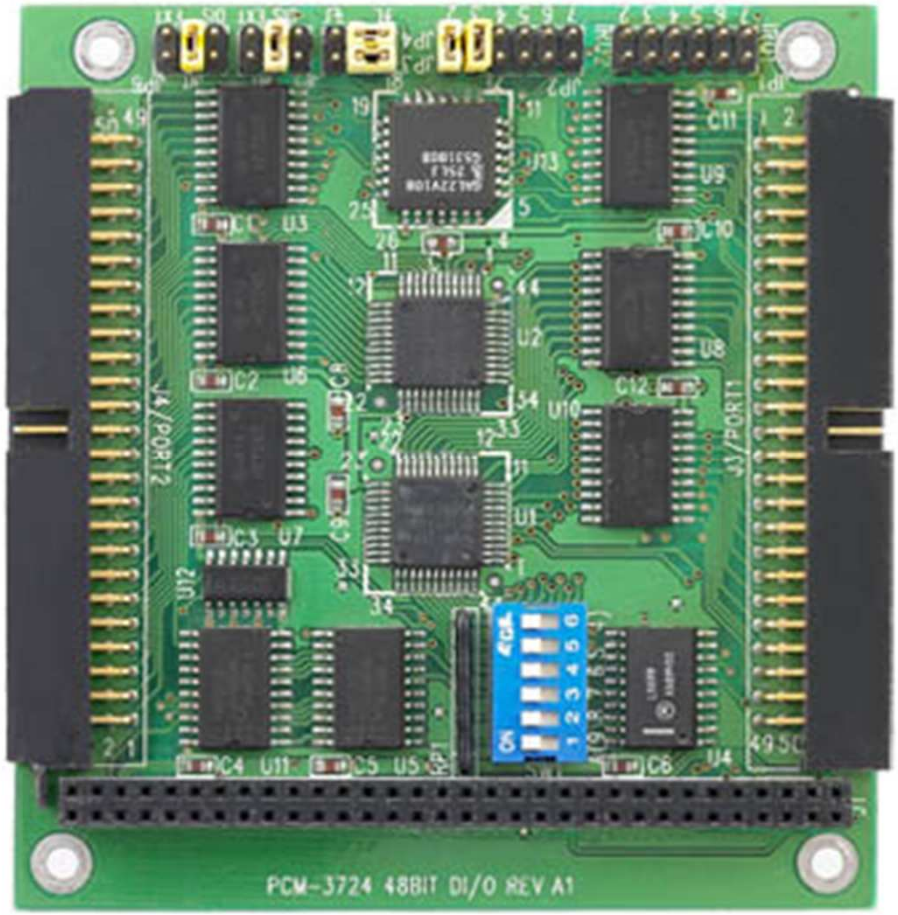
PC/104

- Serial Port Stack
  - Advantech PCM-3644
  - Costs: $144.00
  - Ports: 8 RS-232



PC/104

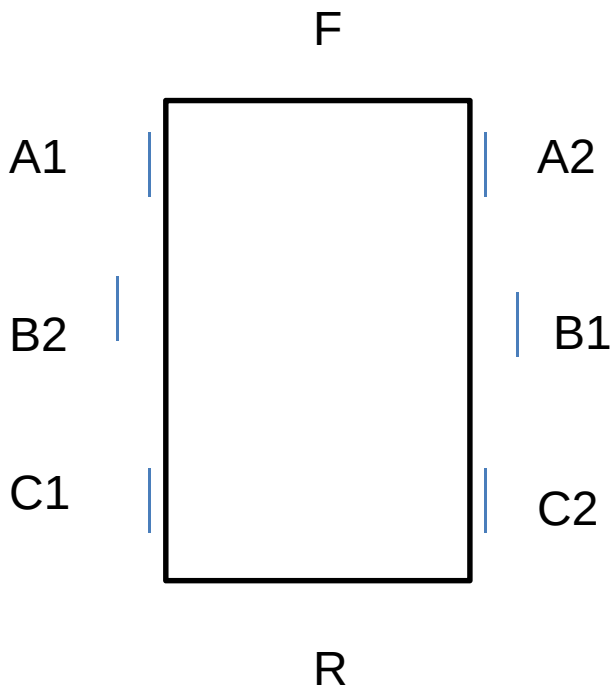
- Digital I/O Stack
  - Advantech PCM-3724
  - Cost: $79.00
  - Ports 48 I/O ports
    - All configurable
  - Logic: 5V TTL

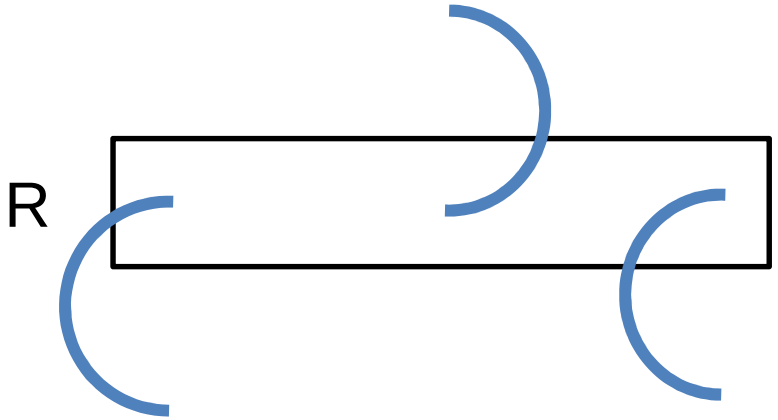


PC/104

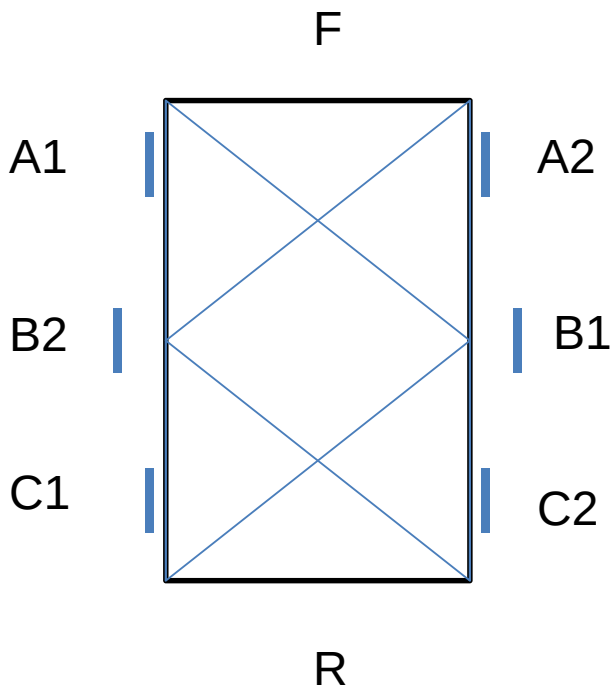
- Testing Procedure
  - Communicate with PC/104 with WiFly
  - Control motor with PC/104
  - Incorporate all three devices
- Motor control mechanism
  - Difficulties due to legged robot

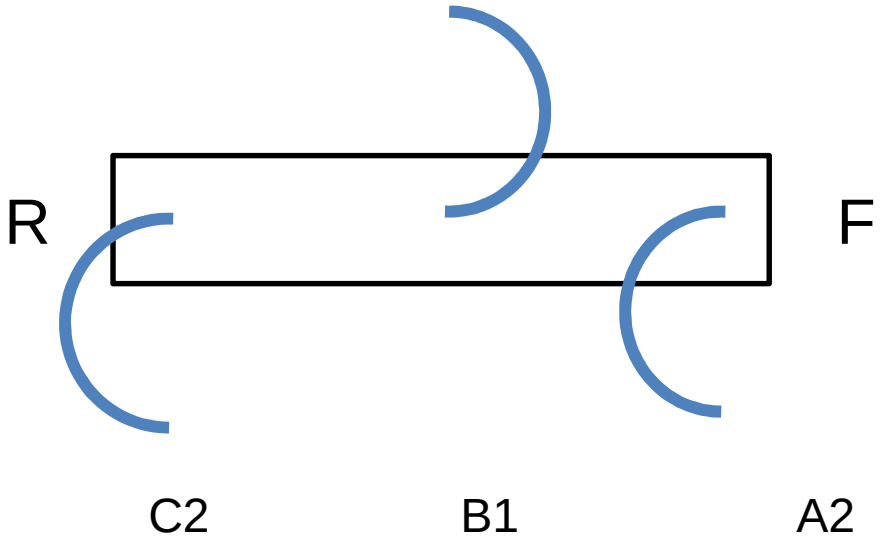
Locomotion Control





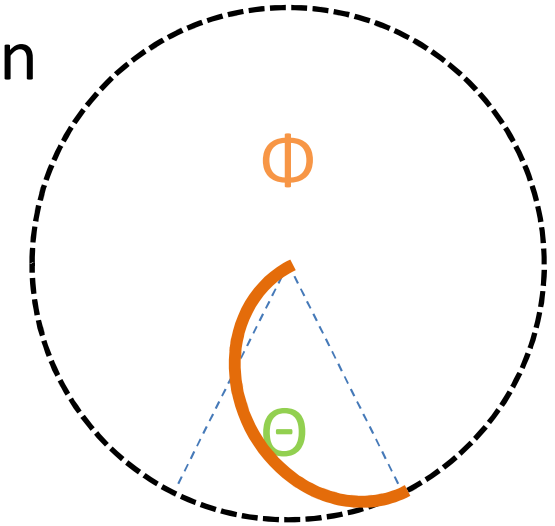
Locomotion Control





Locomotion Control

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



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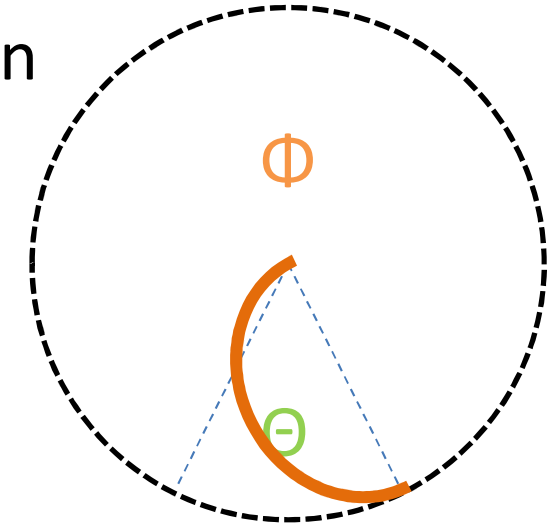
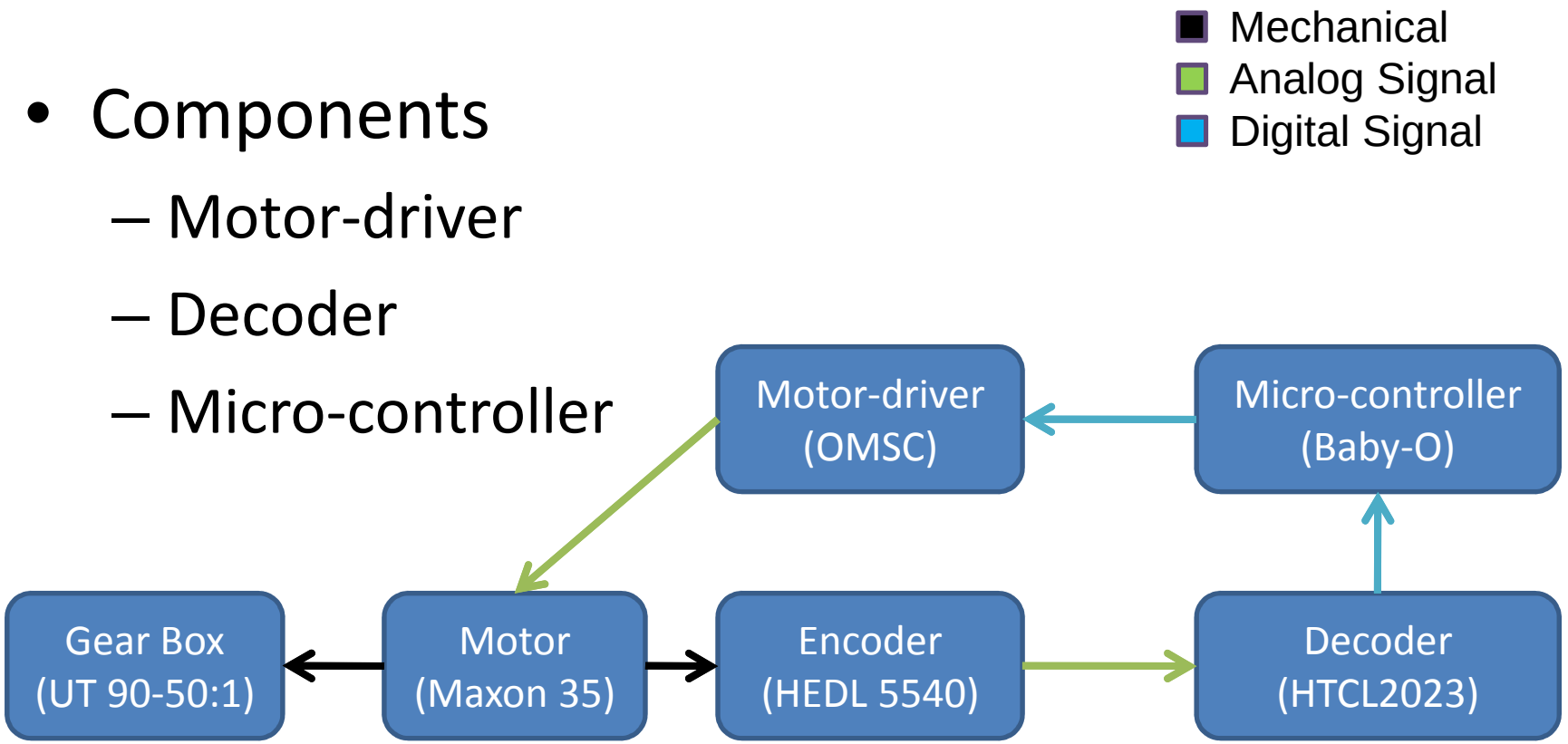


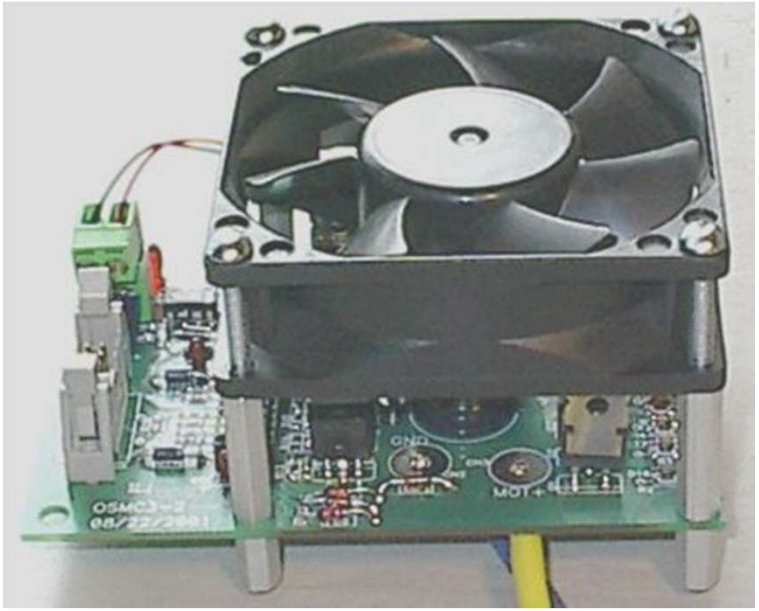
Custom Motor-Controller

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



Motor-Driver

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



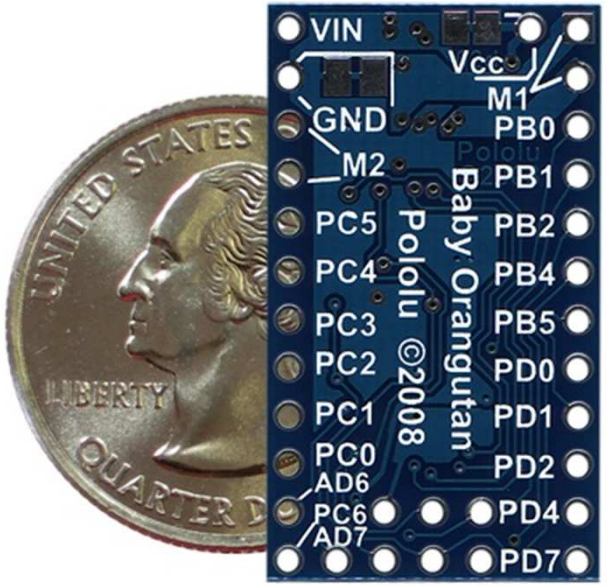
Decoder Chip

- HCTL2023-SC
- 102,400 counts per revolution
- 32bit
  - Used to track multiple revoultions
- Single Byte Read

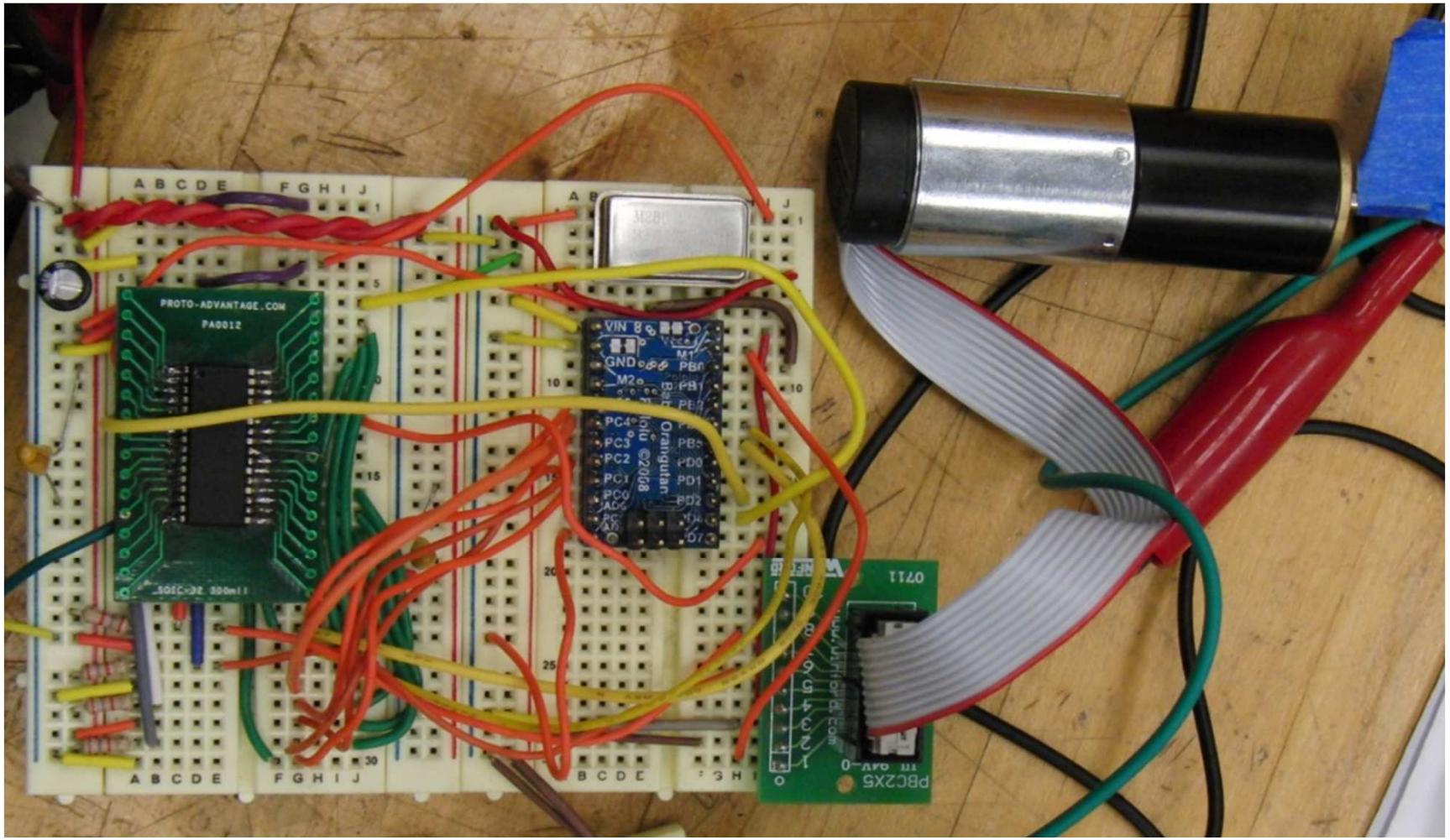
		BYTE SELECTED			
SEL1	SEL2	MSB	2ND	3RD	LSB
0	1	D4			
1	1		D3		
0	0			D2	
1	0				D1

Baby Orangutan

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



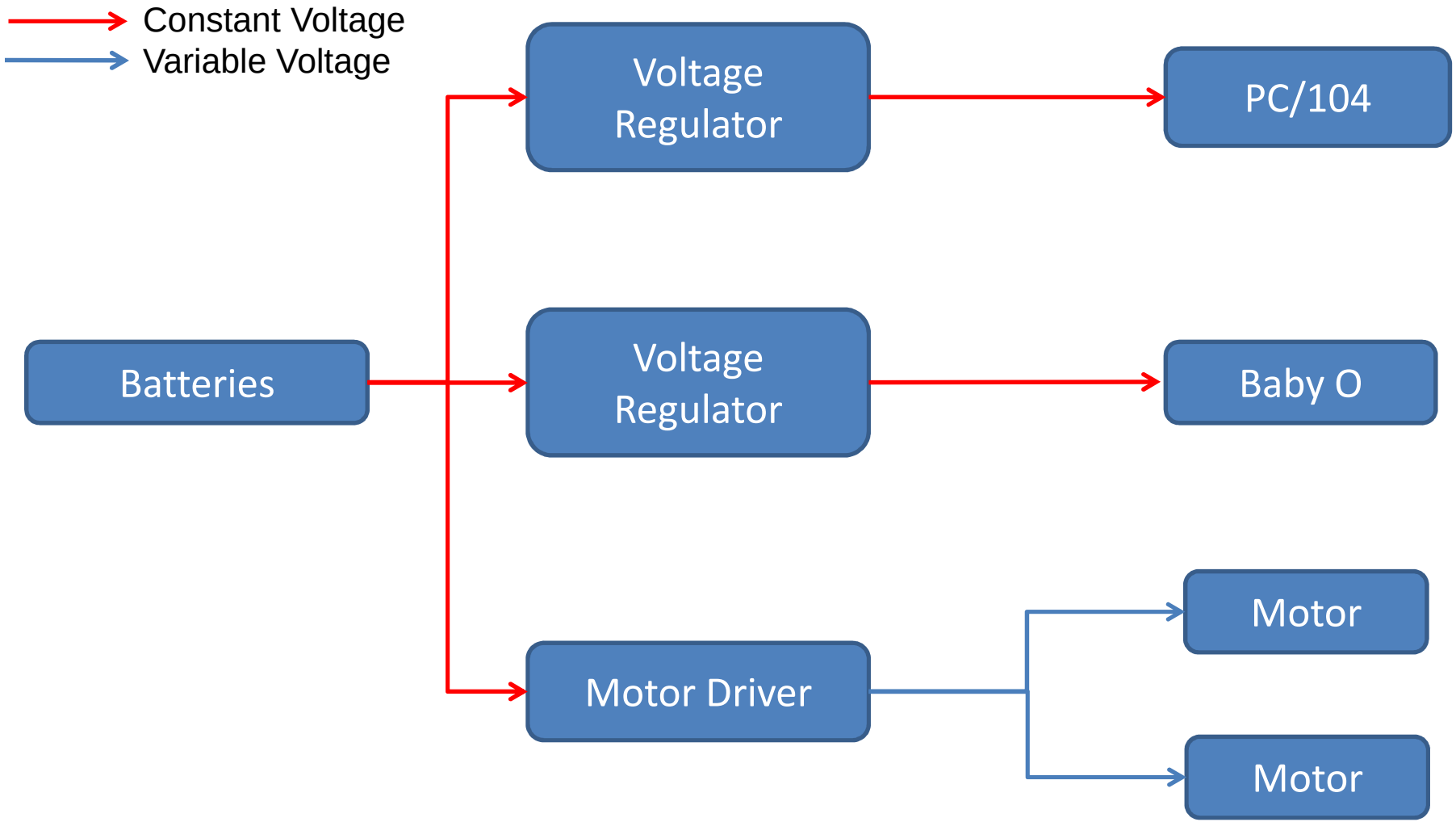
Prototype Motor-Controller



Small Motor Buhler Clock

Hexcavator Moving Leg

Power Flow Chart



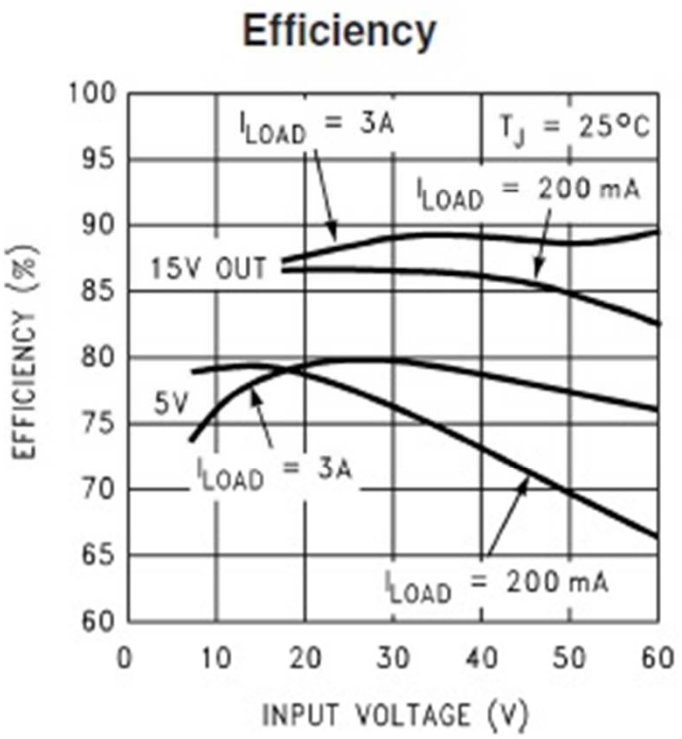
Batteries

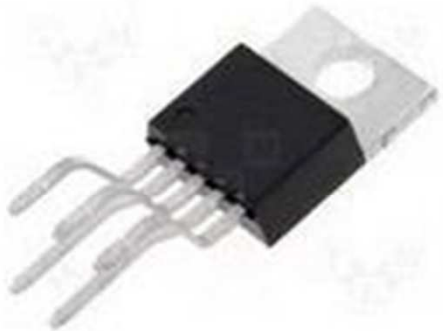
- Rated for 37V
- Actual output about 42V
- Run in Parallel for 37V potential and double current

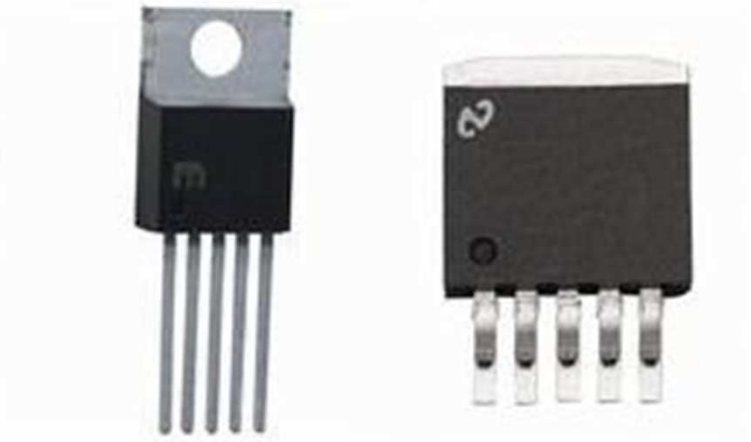
Voltage Regulator

Part No: LM2576HV-5.0

I_o = 0.5 to 3.0 A
V_{in} = 8V to 60V
V_o = 5V

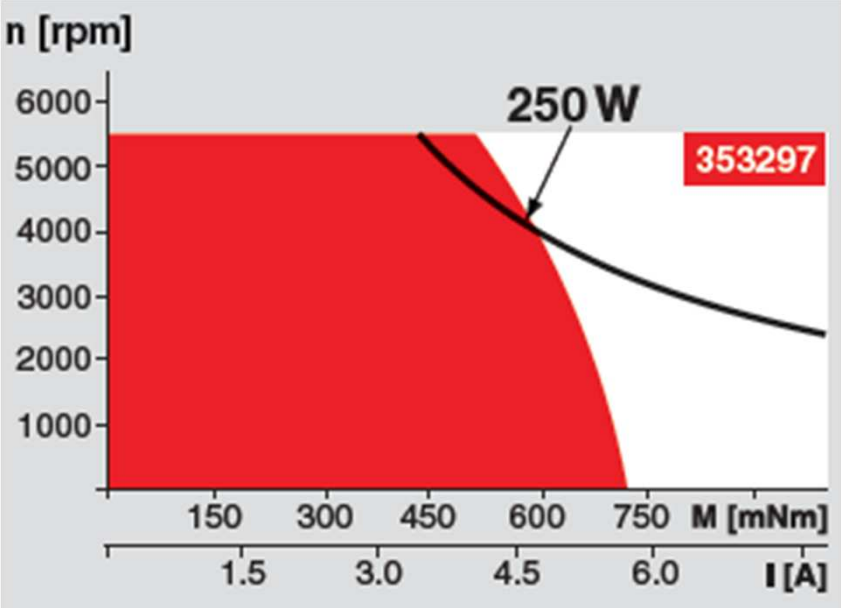




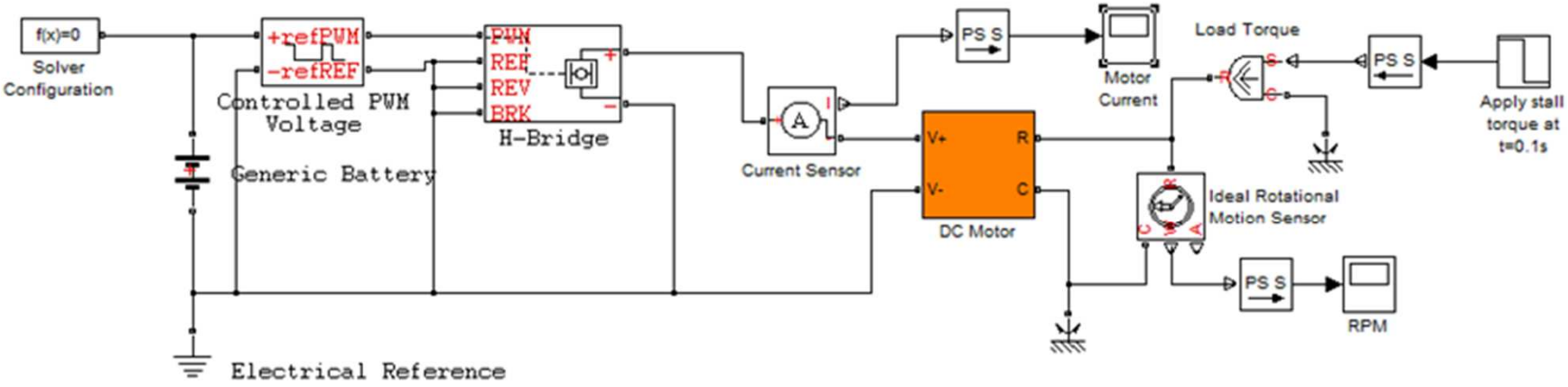


Motor

Nominal voltage = 18V
Nominal torque = 442mNm
Nominal current = 10A
Stall torque = 14 Nm
Starting current = 296A
Nominal speed = 3,150rpm



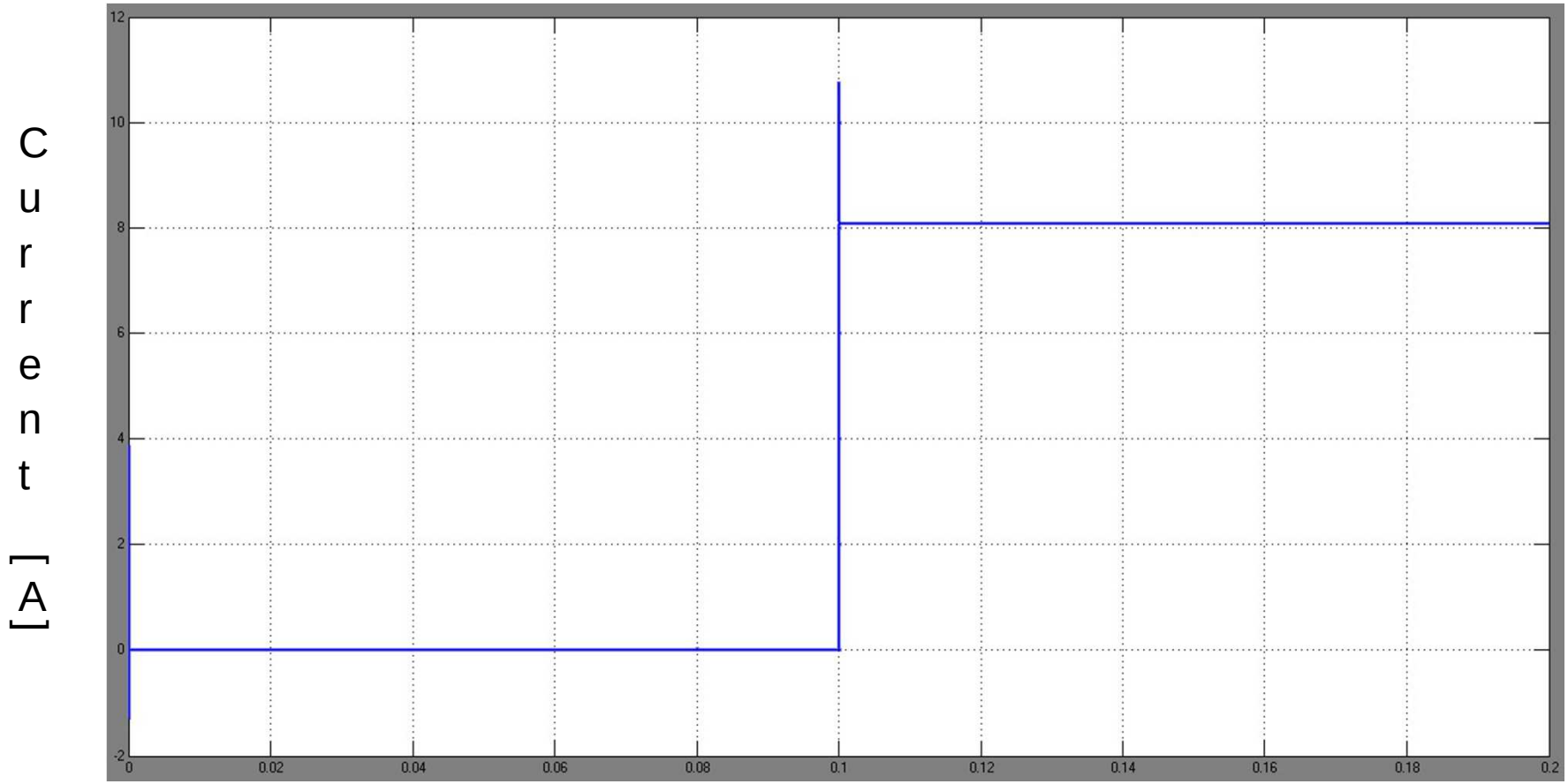
Simulation Circuit



Nominal Speed

Current Drawn When Motor Running at Nominal Speed

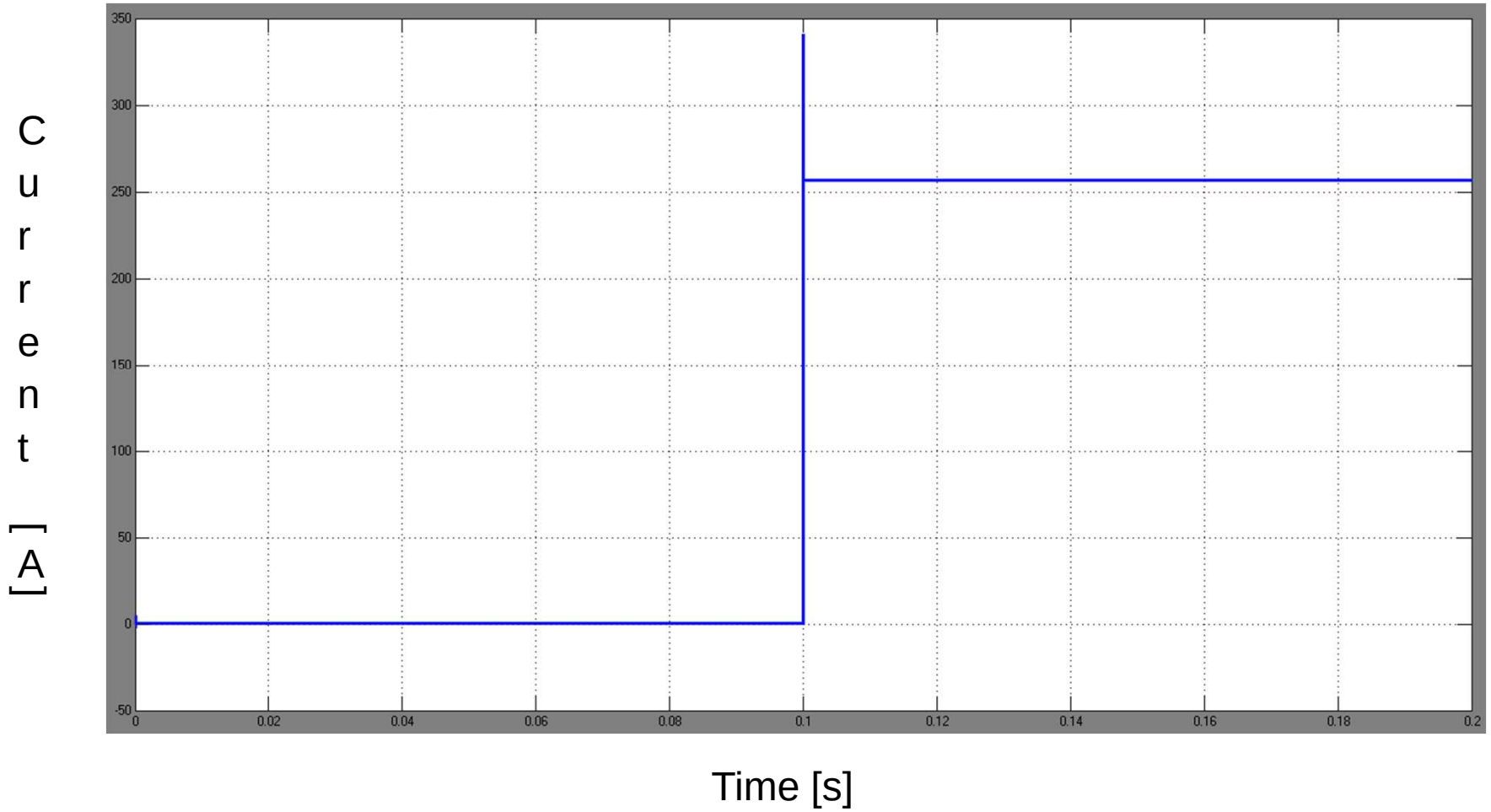
Max = 8.1 Amps (rated for 10A) Load Torque = 0.442 N*m



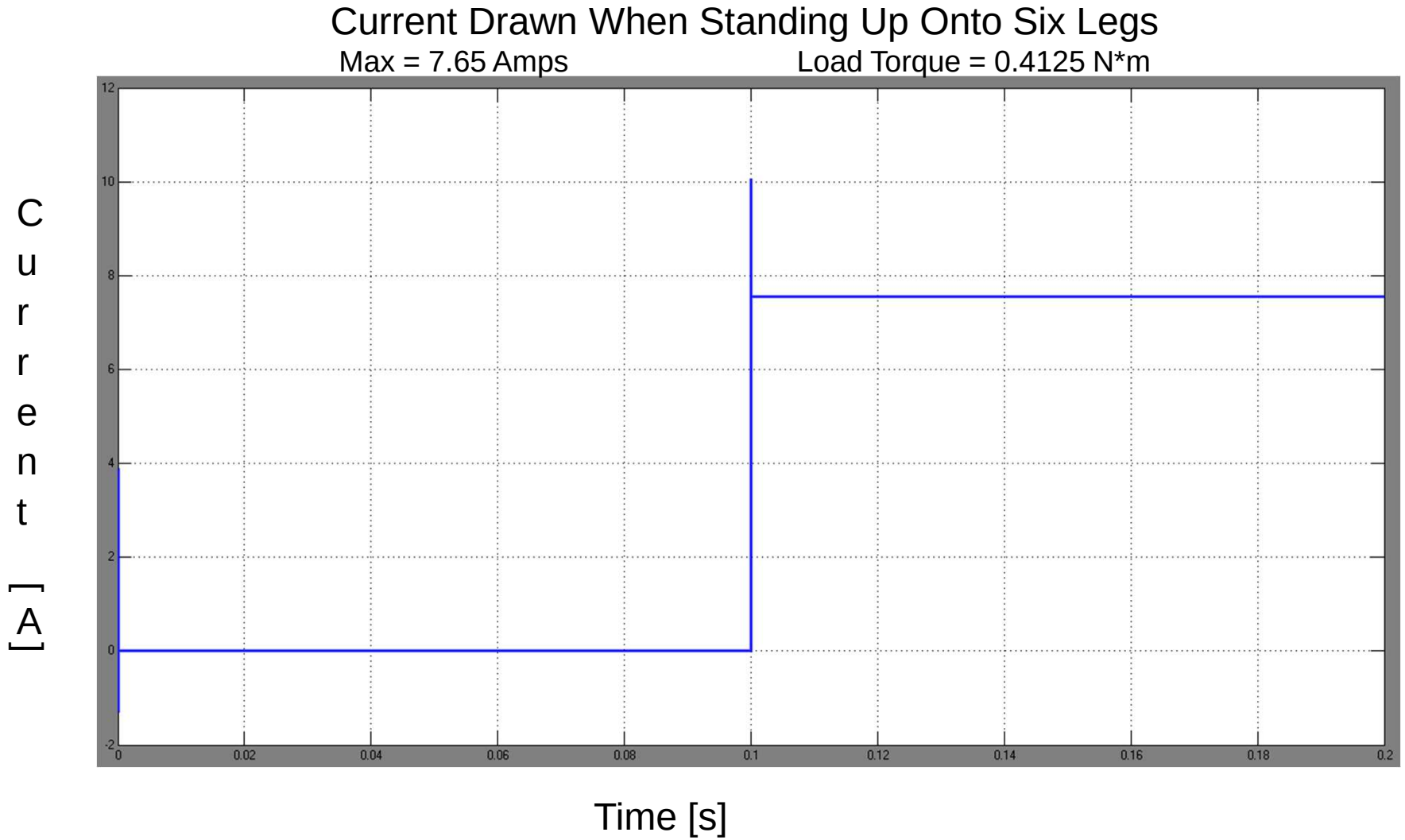
Motor Stall Current

Current Drawn When Motor Stalls

Max = 260 Amps Load Torque = 14 N*m



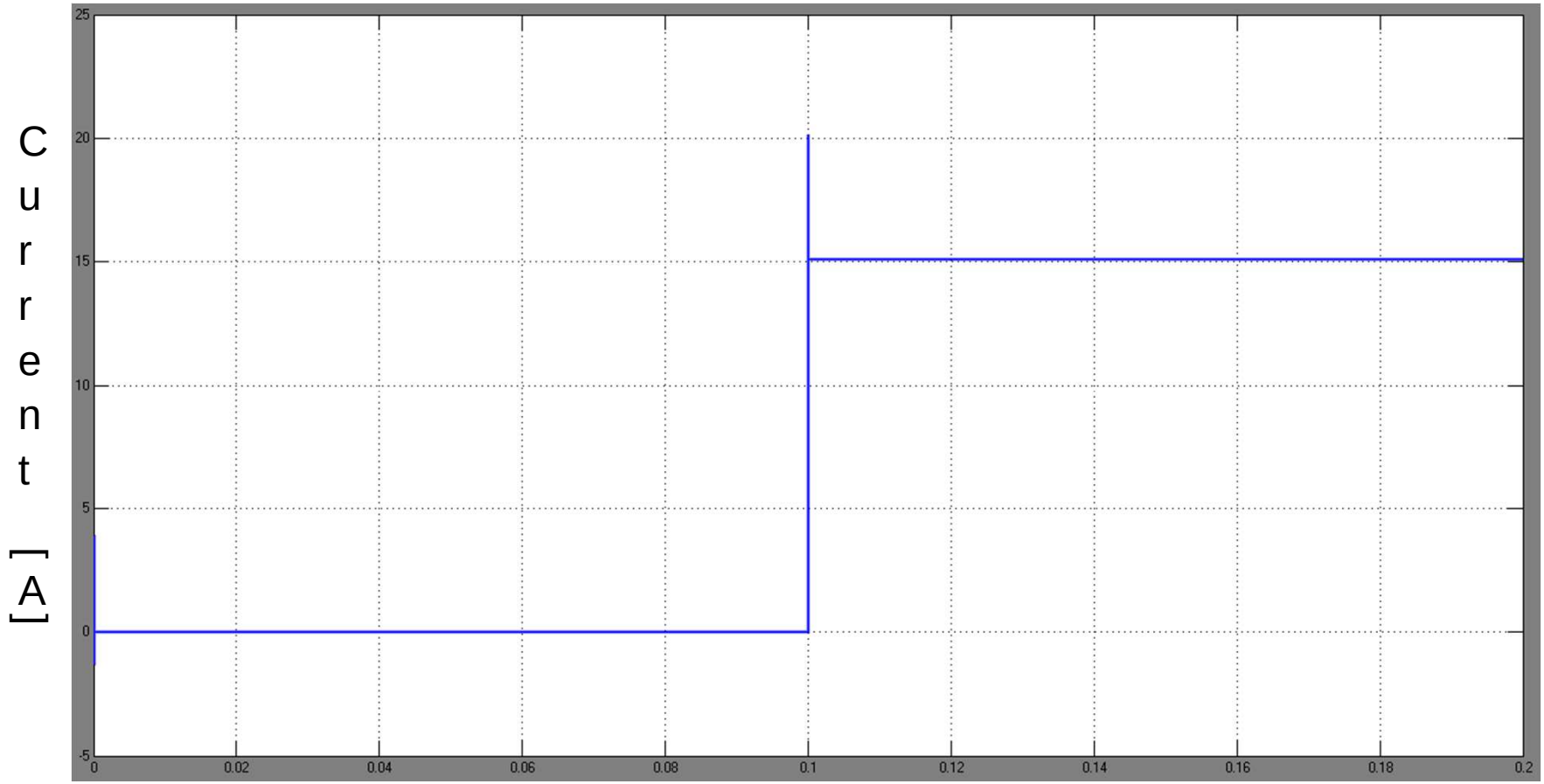
Current Drawn When Standing Up



Standing on Three Legs

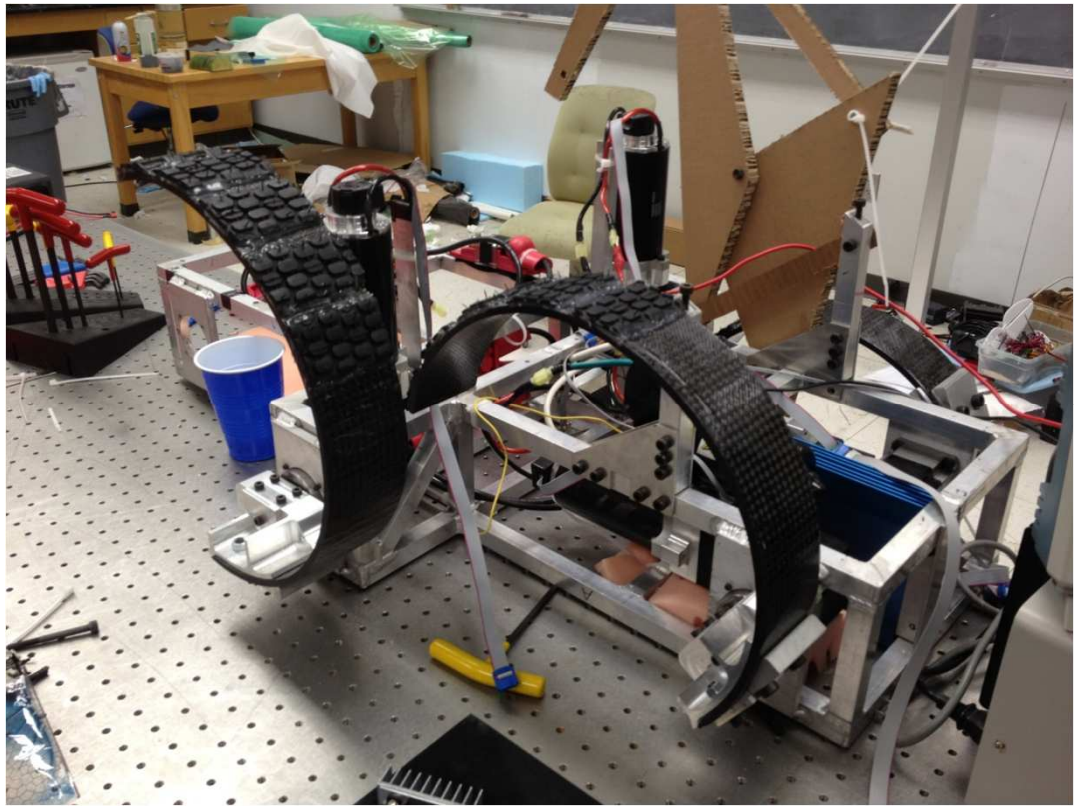
Current Drawn When Hexcavator is Standing on Three Legs

Max = 15 Amps Load Torque on Motor = 0.825 N*m



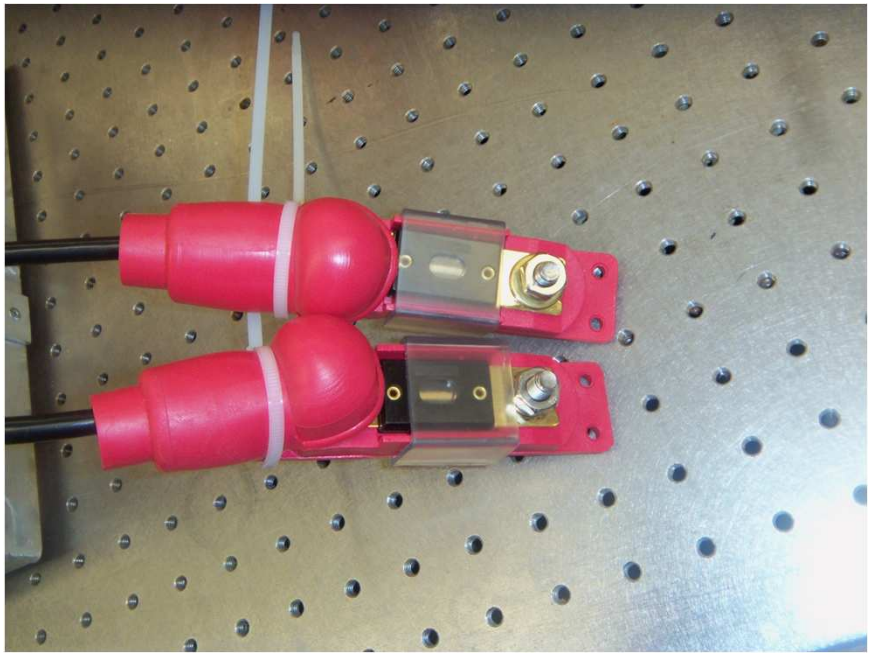
Power Simulation Conclusion

- Current batteries more than sufficient
- On board electronics draw negligible current
- Worst-case-scenario are well within the discharge capacity of two batteries in parallel



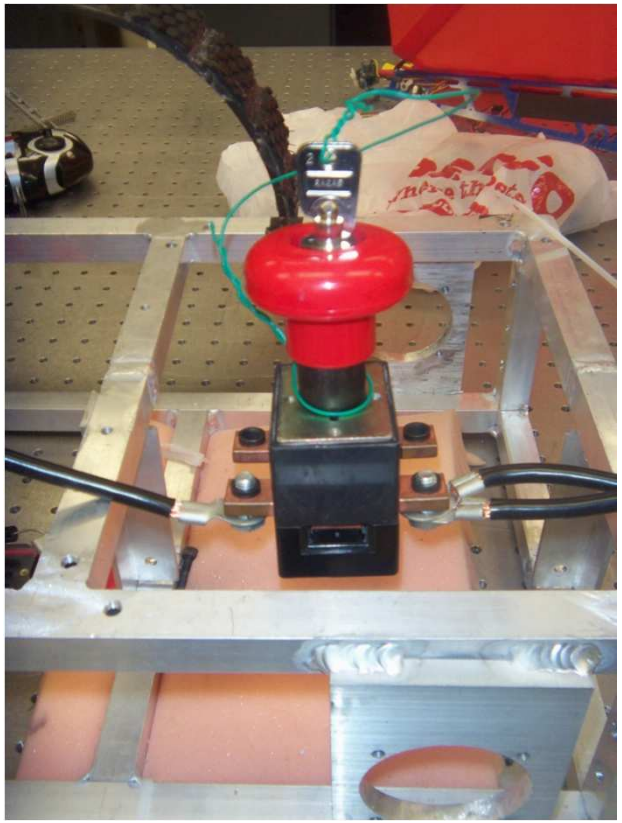
Fuses and Safety Switch

100A Fuse Rating

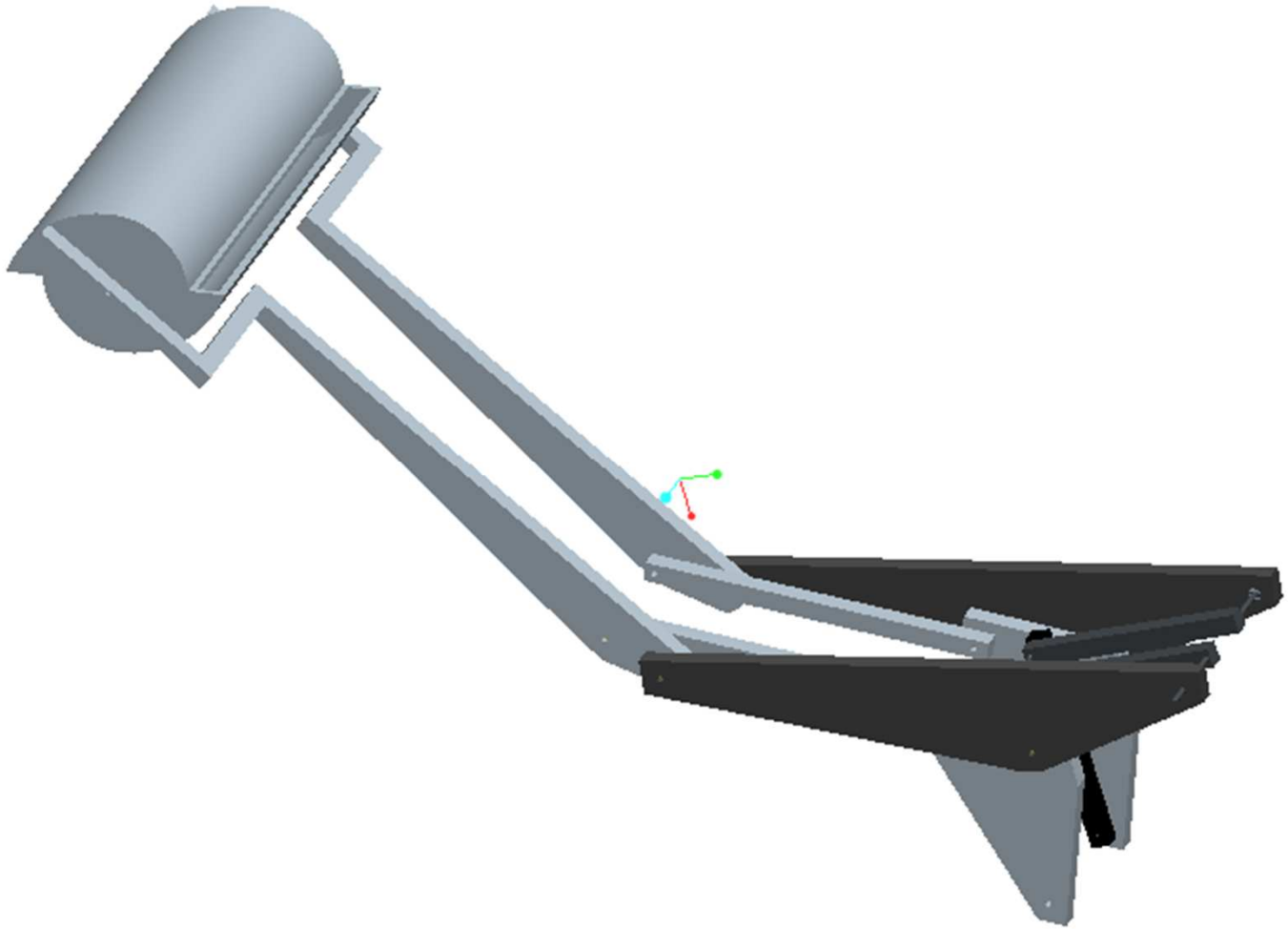


ED252L Locking safety switch

Maximum Voltage: 96V
Maximum Current: 250A

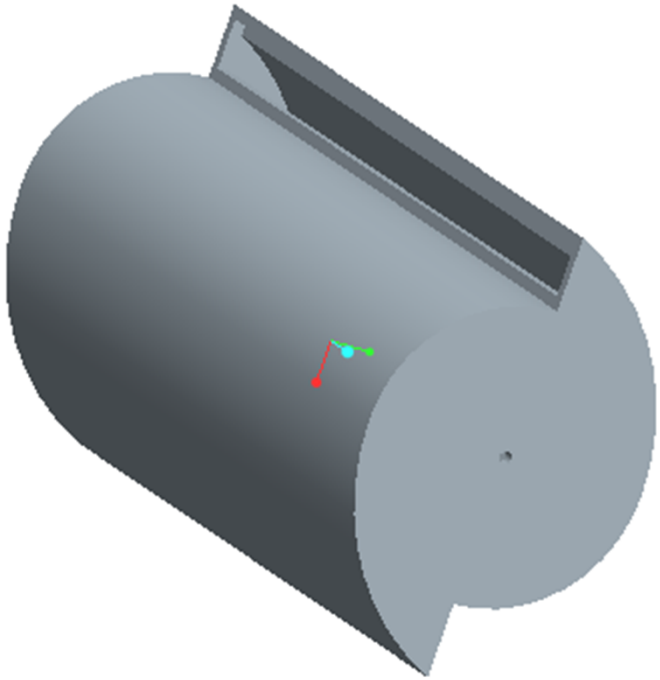


Excavation Analysis

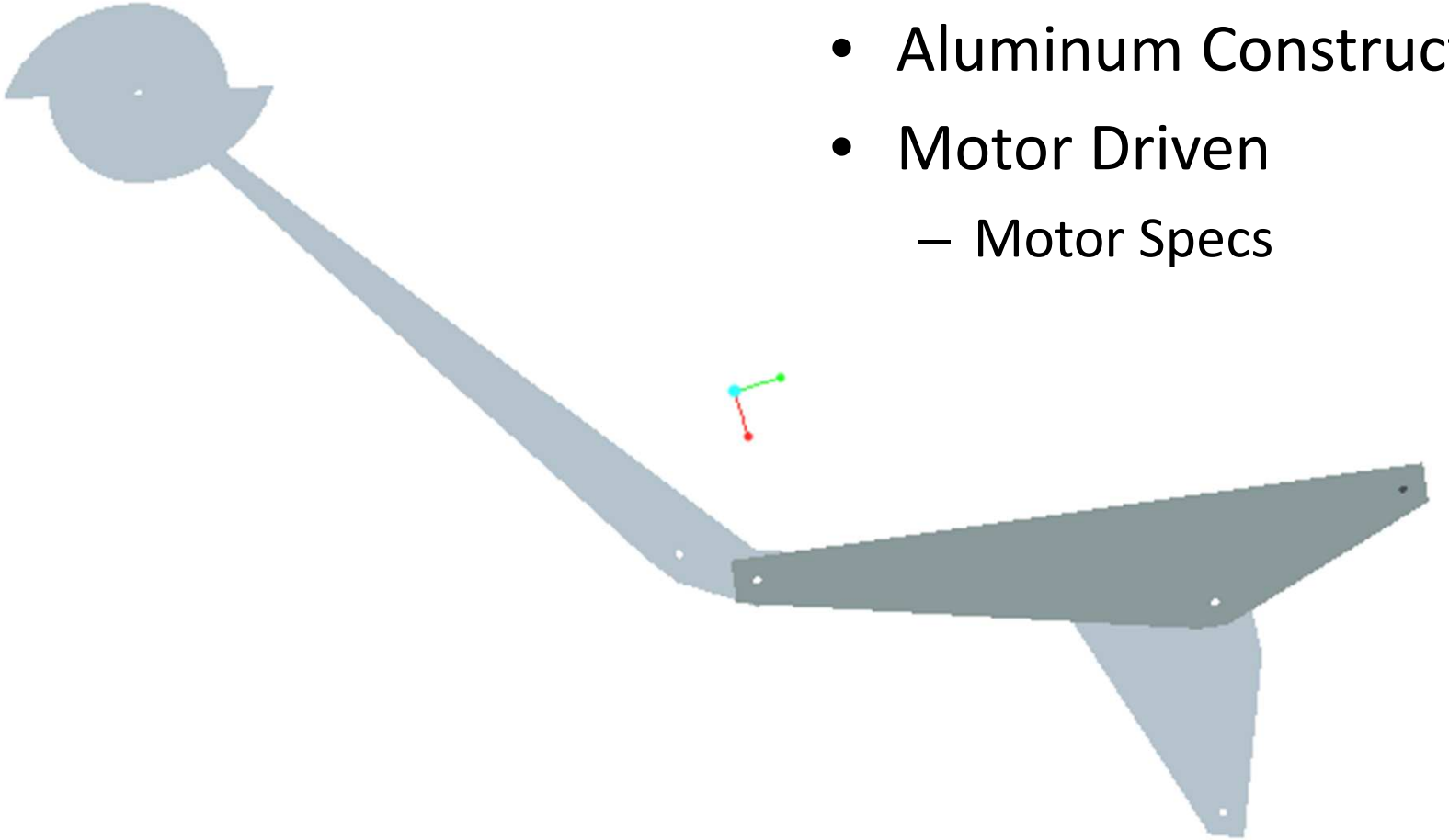


Rotating Drum

- Material: Aluminum 6061
- Density of Regolith: 1.5g/cm^3
- Payload Ability: 9.761kg
- Motor Driven
  - Must handle up to 33.9N*m torque



Six-Bar Arm Linkage



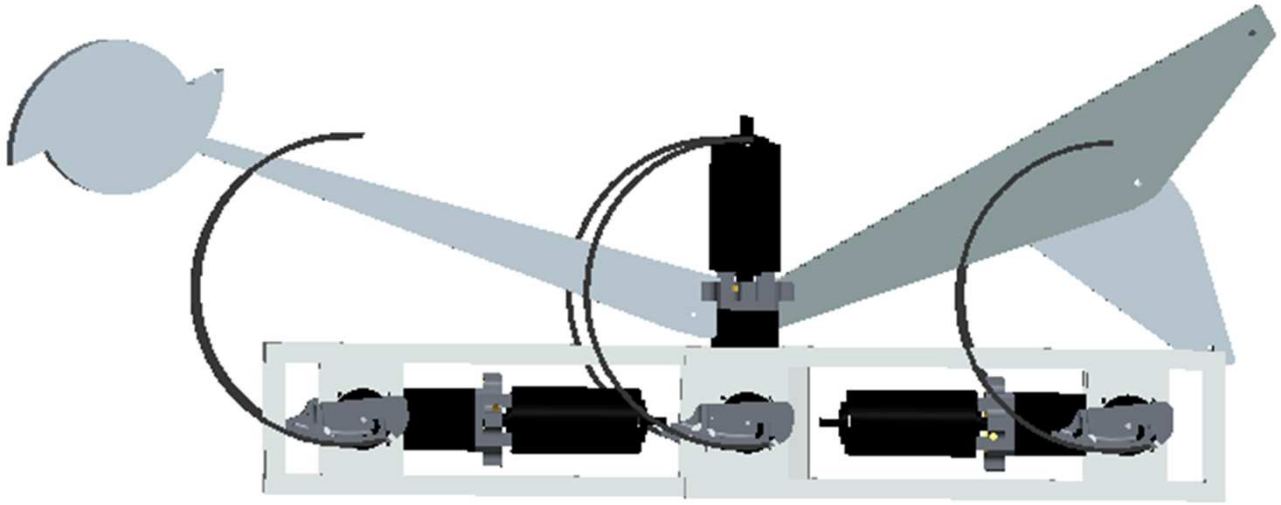
- Aluminum Construction
- Motor Driven
  - Motor Specs

Six-Bar Mechanism

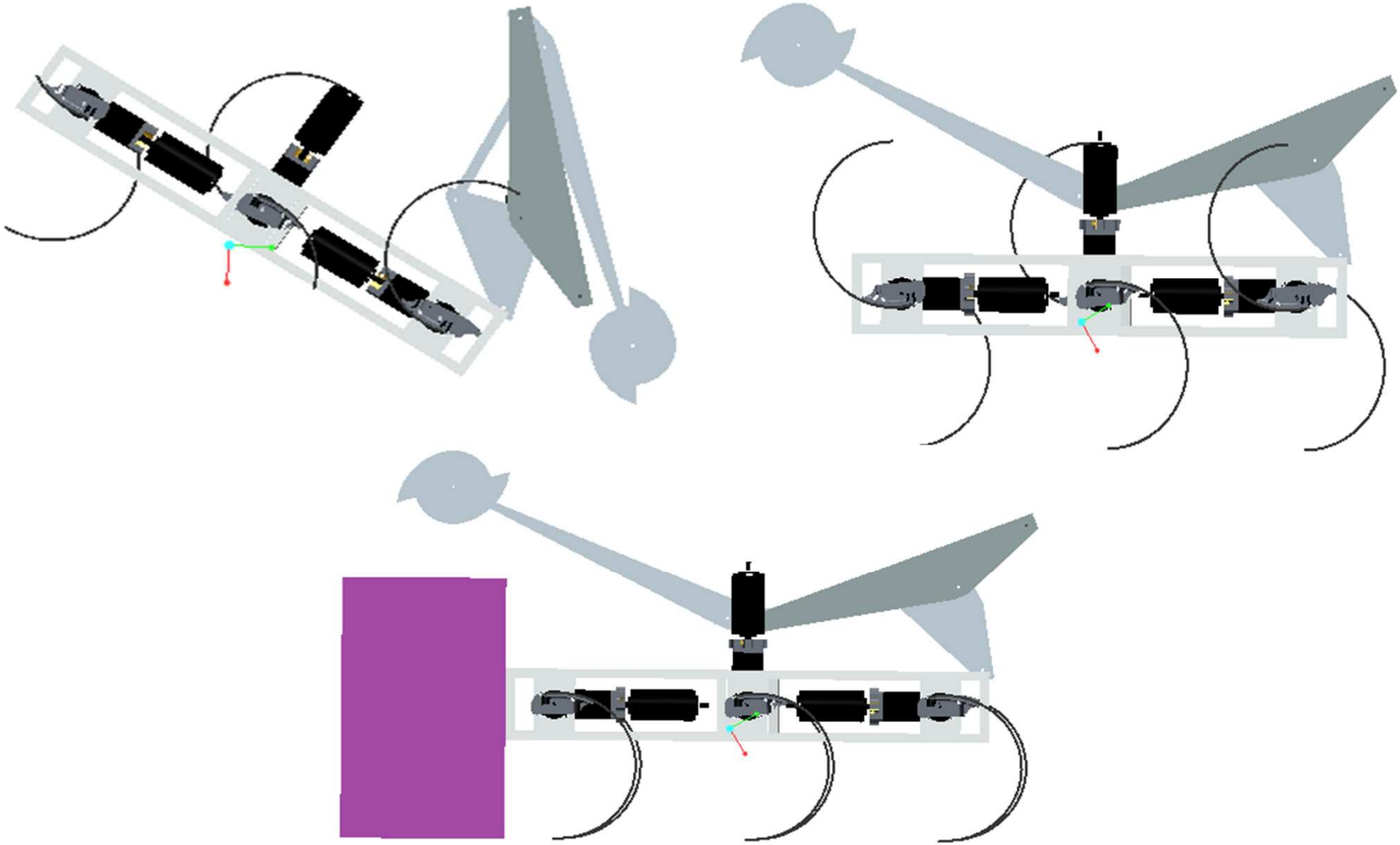
Excavation Conditions

- Hexcavator initial dimensions:
  - 38.97cm x 123.01cm x 75cm
  - Mass: 67kg
- Measured while sitting

- Dimensions of Lunarena:
  - 7.38m x 3.88m x 0.62m

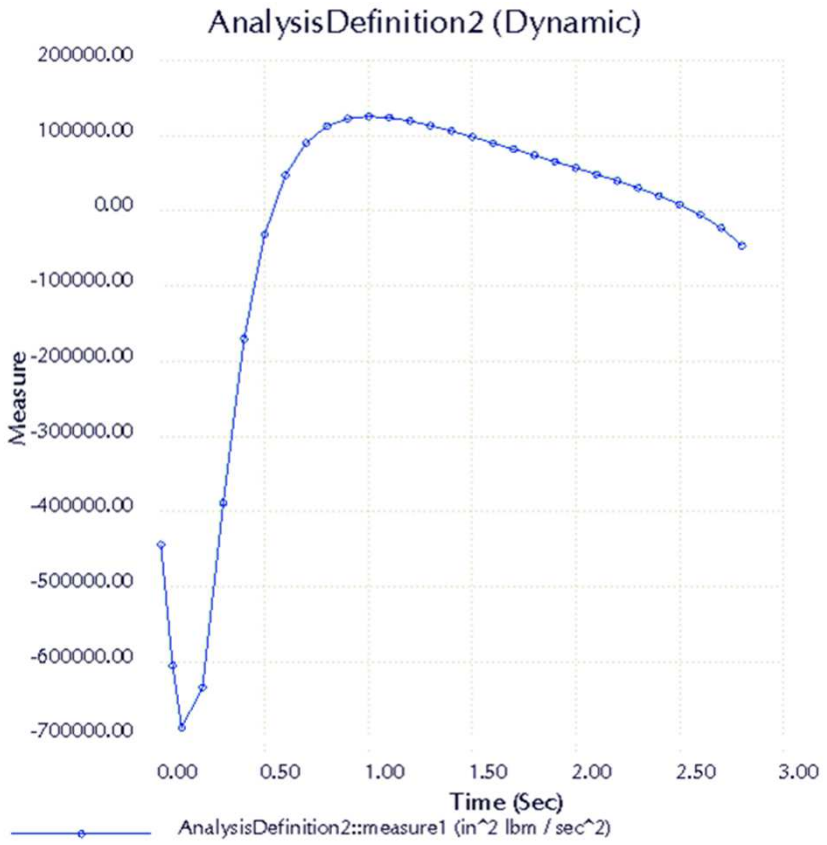


Major Positions



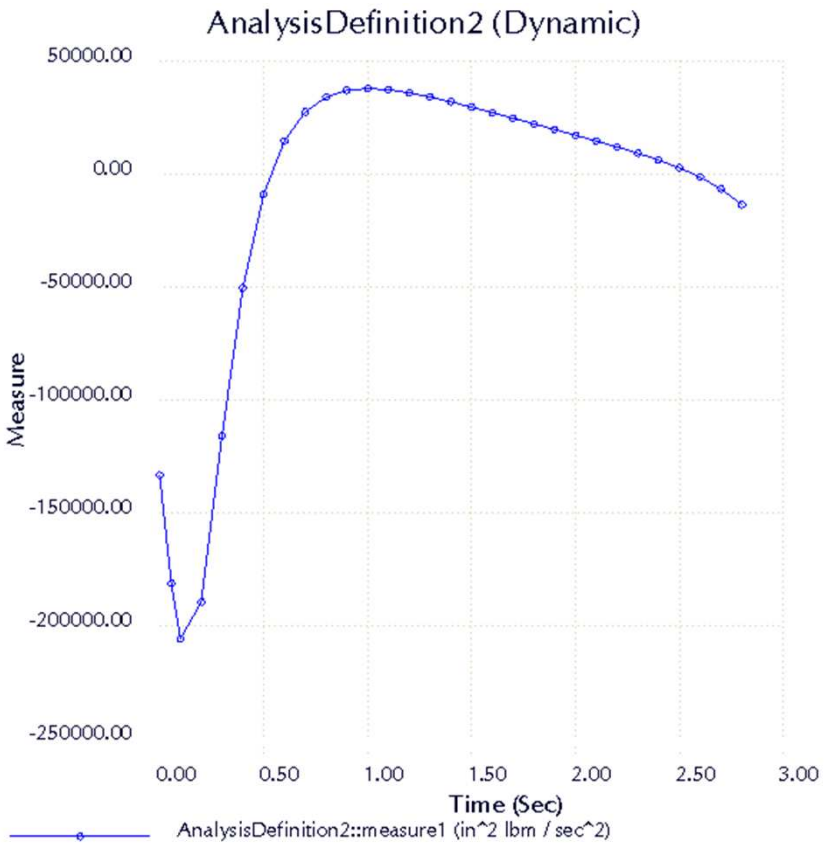
Sixbar Torque Analysis

- Empty Drum Torque Analysis
  - Converted using Mathcad
    - 38 N*m torque maximum

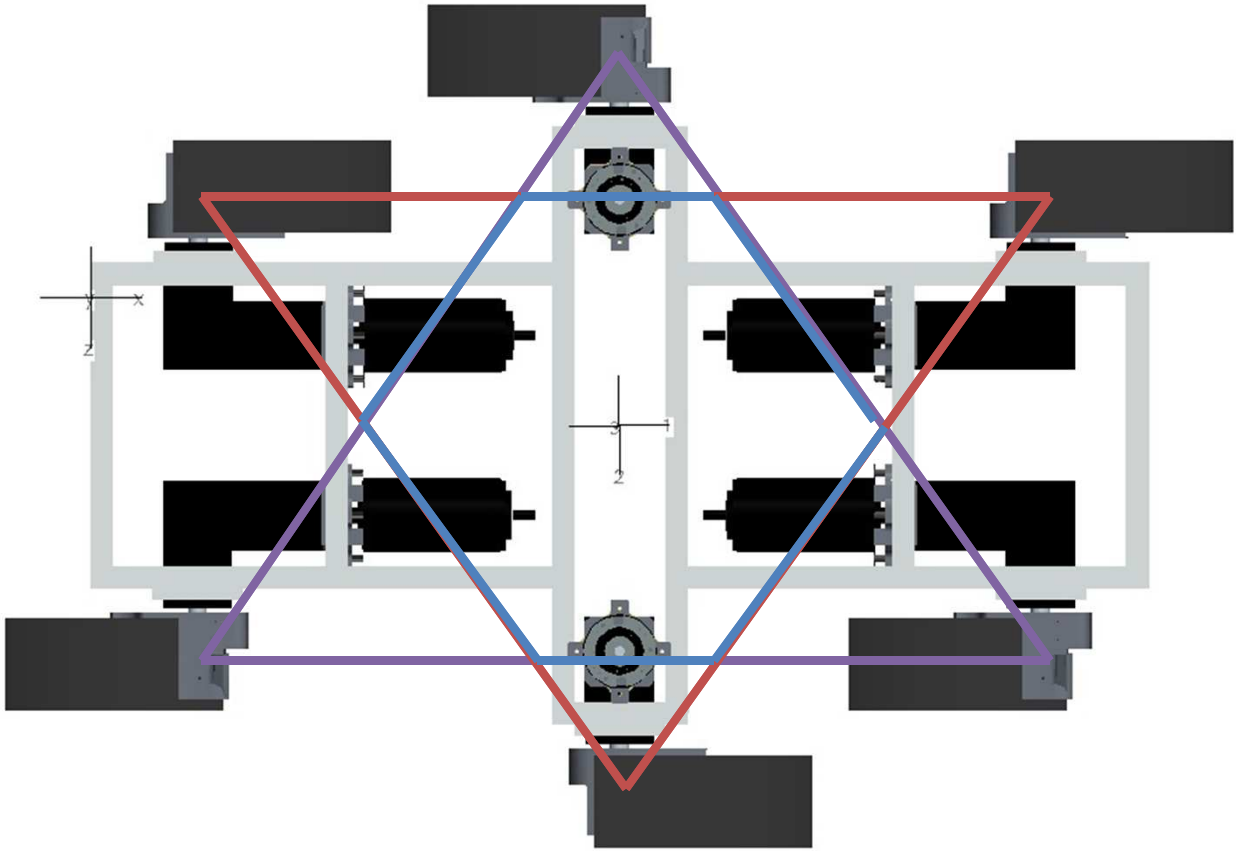


Sixbar Torque Analysis

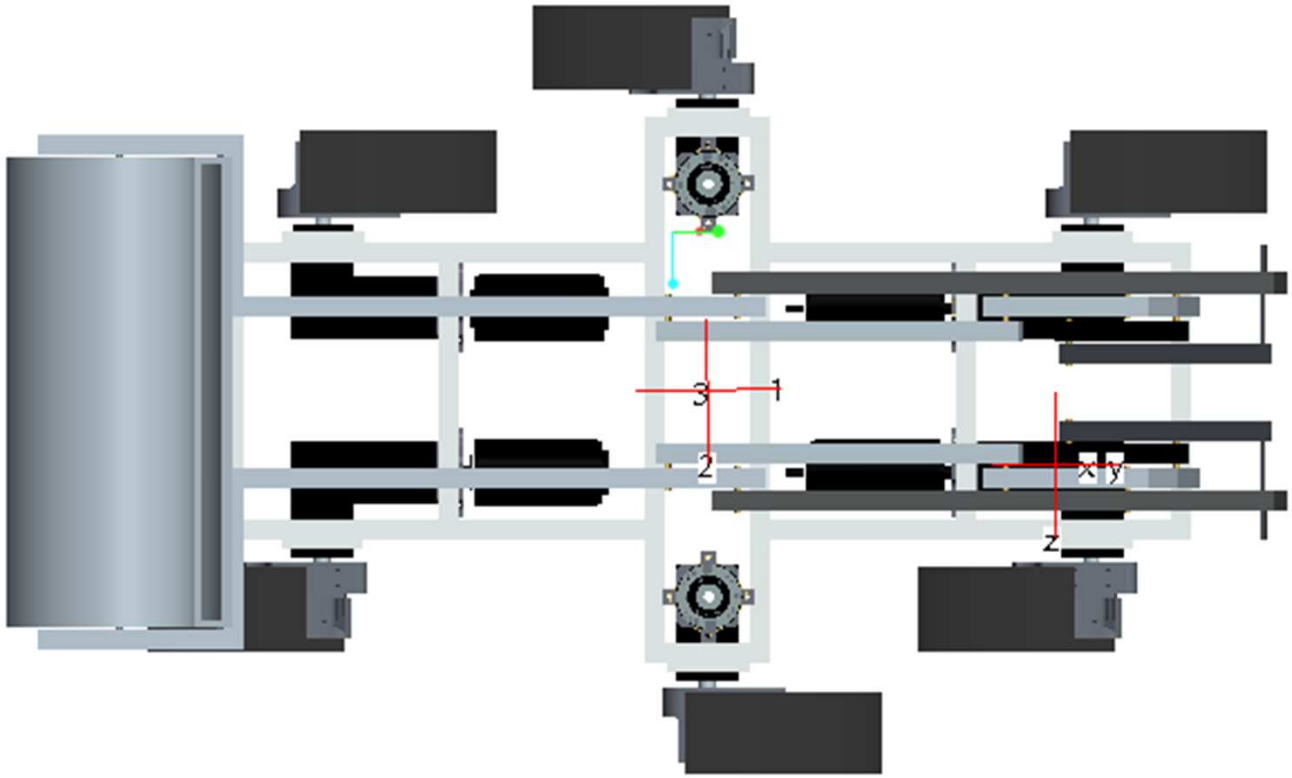
- Full Drum Torque Analysis
  - Conversion Factor using Mathcad
    - 61 N*m torque maximum



Center of Mass



Center of Gravity Analysis



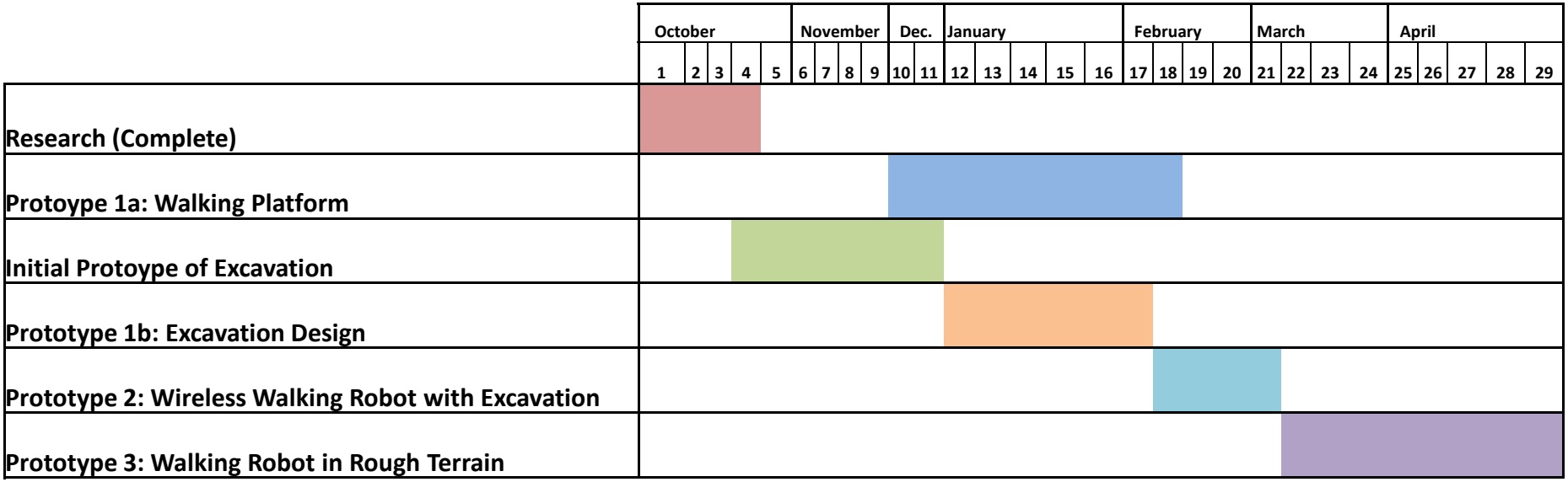
Cost Analysis

Components	Cost	Quantity	Total Cost
Bushings	$ 0.64	24	$ 15.36
PC104	$ 691.00	1	$ 691.00
Aluminumn (Excavation)	$600.00	1	$ 600.00
ABS Plastic (Excavation)	$30.00	1	$ 30.00
Steel Shafts	$ 40.00	1	$ 40.00
CirClips (Pack of 10)	$ 8.09	3	$ 24.27
Motor for Excavation			$ 359.34
WiFly	$ 84.95	1	$ 84.95
Baby O	$ 19.00	5	$ 95.00
Motor Drivers	$ 220.00	4	$ 880.00
Voltage Regulators	$6.00	5	$ 30.00
Decoders	$8.00	5	$ 40.00
Clocks	$3.00	7	$ 21.00
Copper Sheet	$60.00	1	$ 60.00
Travel Expenses (Estimated)	$2,480.85	1	$ 2,480.85
Total			**$ 5,451.77**

Total Budget: $6000

- FAMU/FSU College of Engineering: $2000
- National Space Grant: $ 4000

Gantt Chart


October
November
Dec.
January
February
March
April
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Research (Complete)
Protoype 1a: Walking Platform
Initial Protoype of Excavation
Prototype 1b: Excavation Design
Prototype 2: Wireless Walking Robot with Excavation
Prototype 3: Walking Robot in Rough Terrain

Questions?

References

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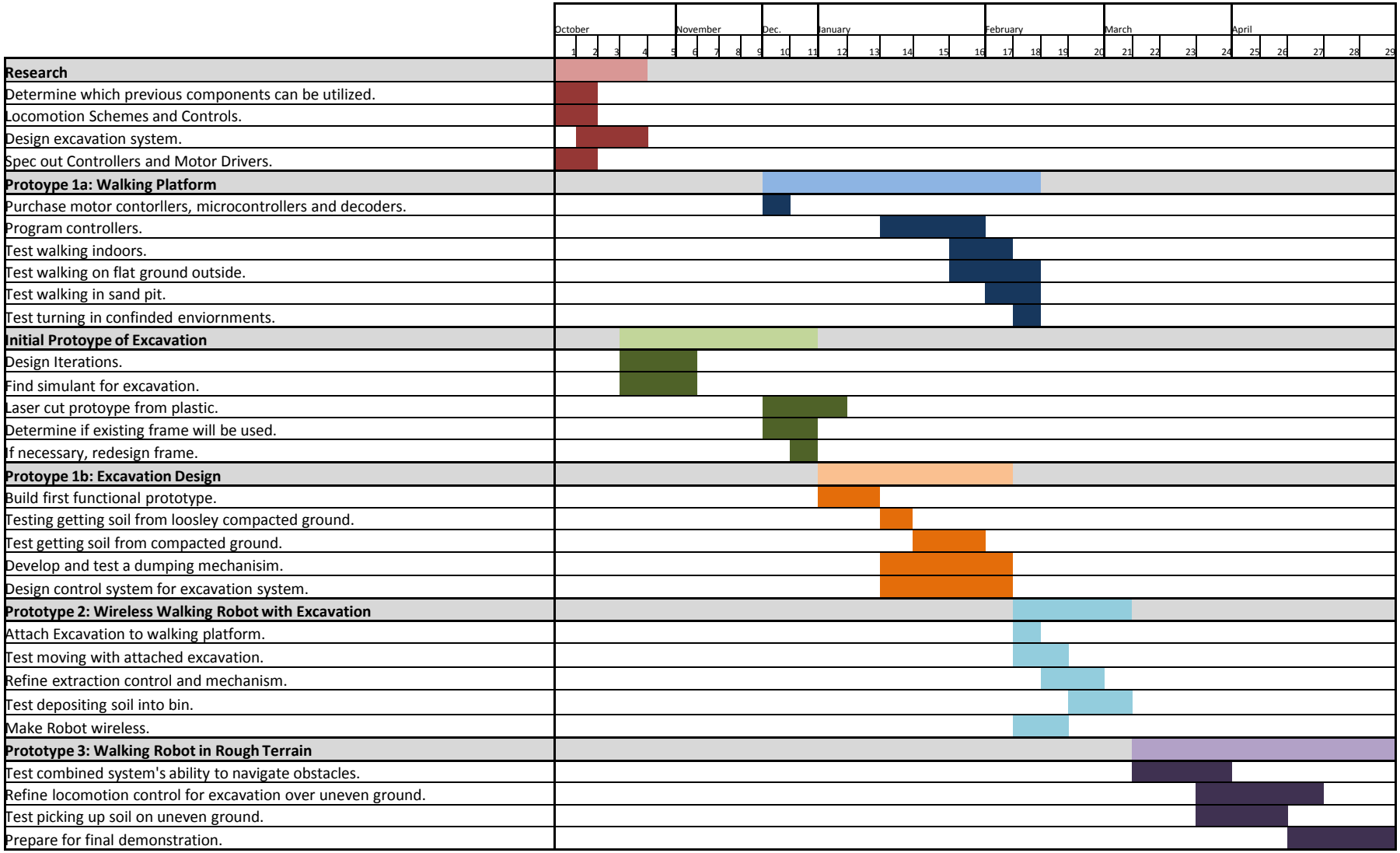
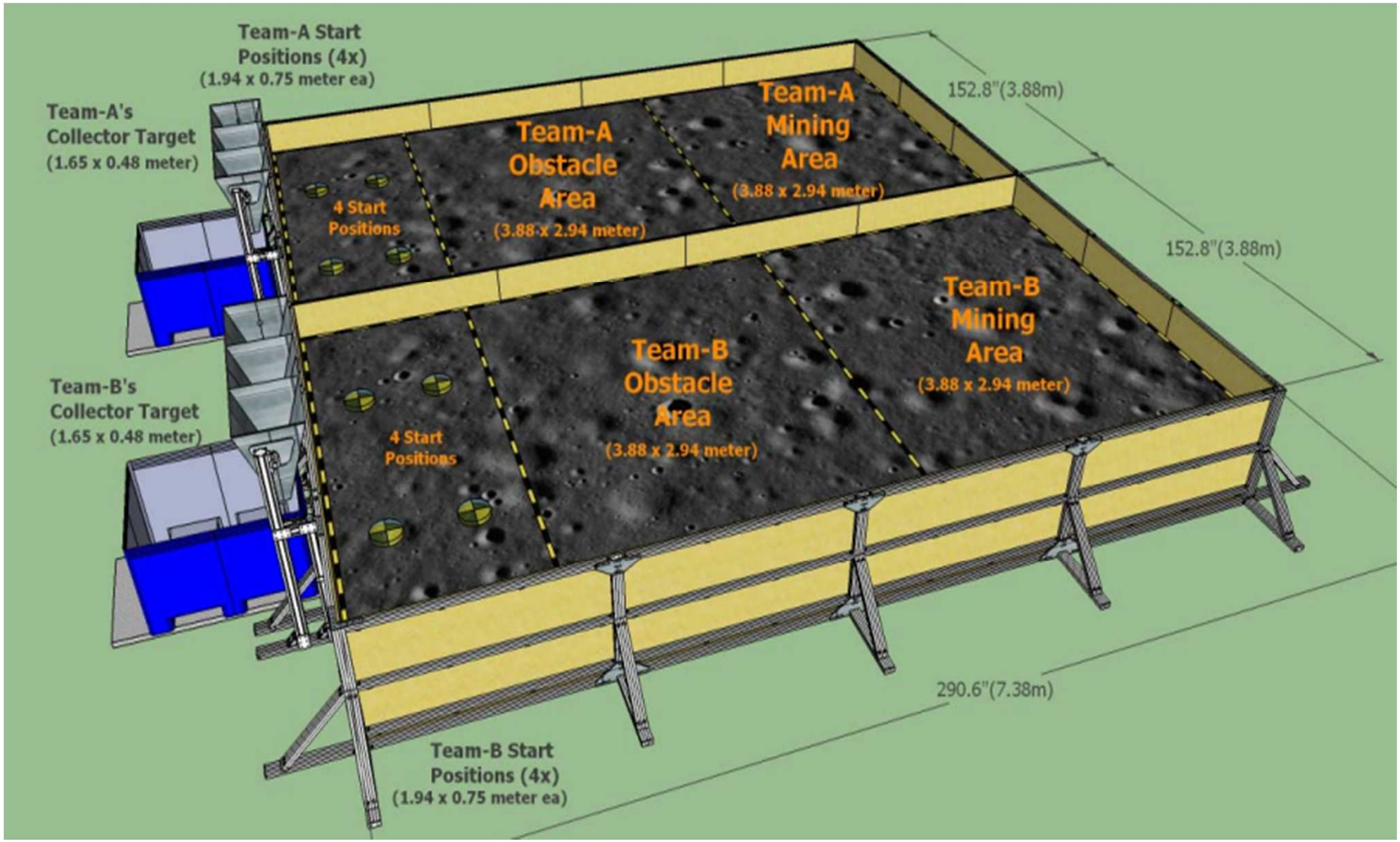
PC/104

- 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

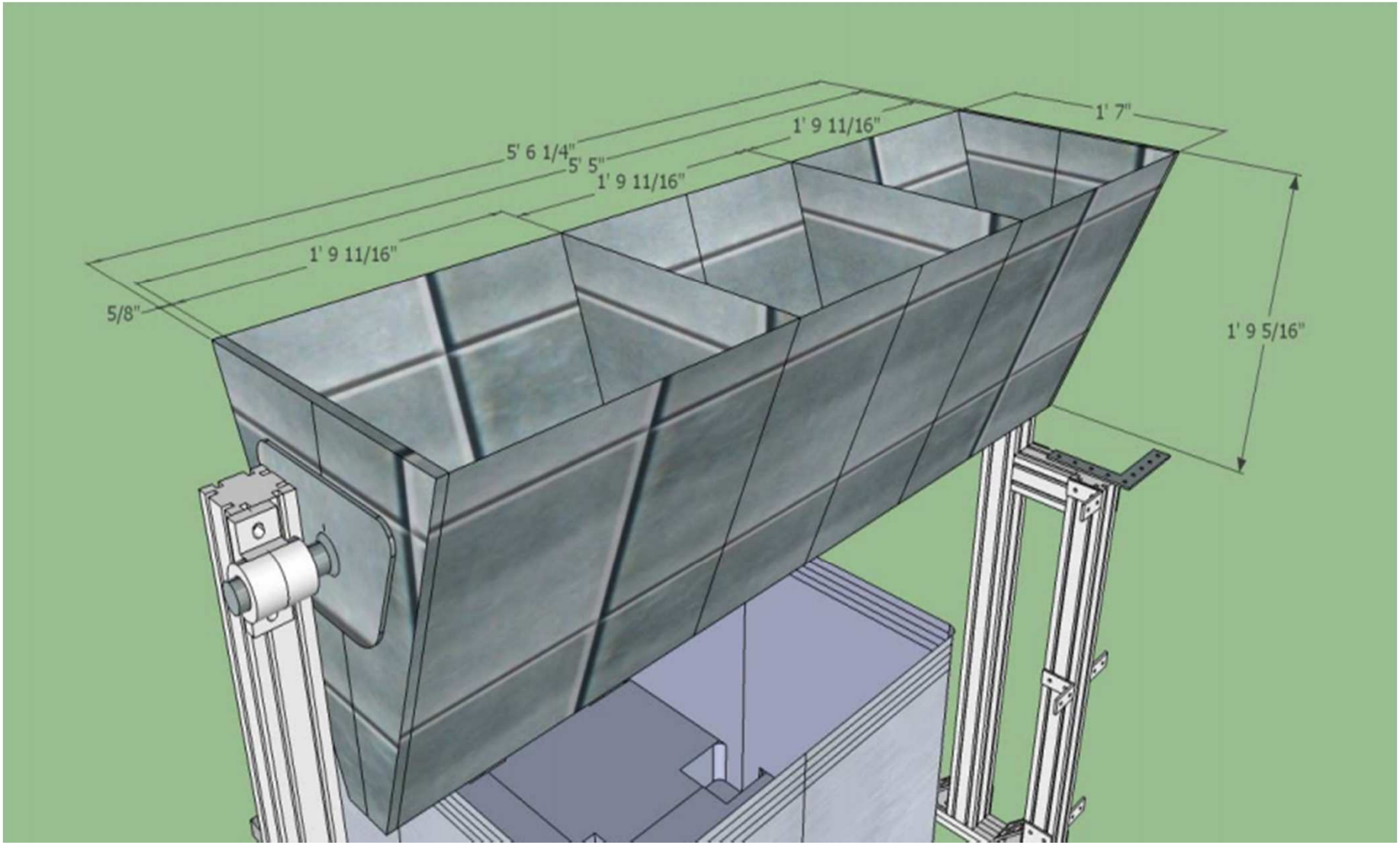
Complete Gantt Chart



Competition Area



LunaBin




Hexcavator
WiFly
User