

### Hexcavator



#### Lunar Regolith Excavator Student Competition

Sponsor: Dr. Jonathan E. Clark<sup>1</sup> April 12, 2012

C. Robert Sistare<sup>2</sup>, Devin Walden<sup>2</sup>, James Fadool<sup>1</sup>, McKenzie Reed<sup>1</sup>, Seth Murphy<sup>2</sup>, and Shannon Berger<sup>1</sup>

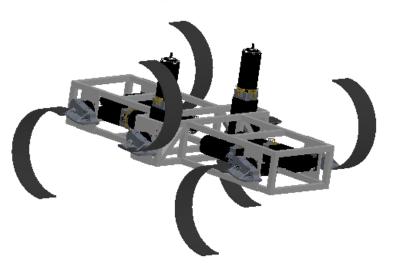
<sup>1</sup>Department of Mechanical Engineering

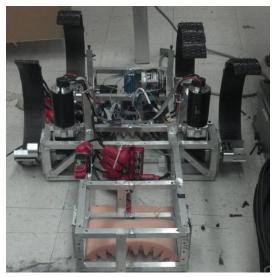
<sup>2</sup>Department of Electrical and Computer Engineering



### Outline

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

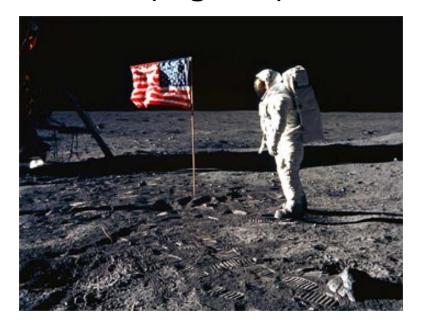






## **Project Inspiration**

- 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





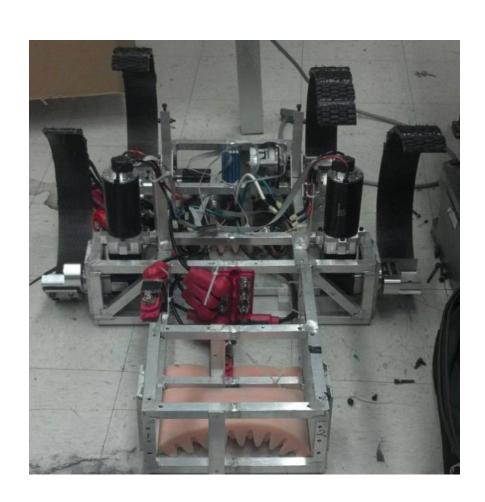
## **Previous Hexcavator Efforts**

#### **Complete:**

- Frame
- Legs
- Motors
- Batteries
- Stop Button

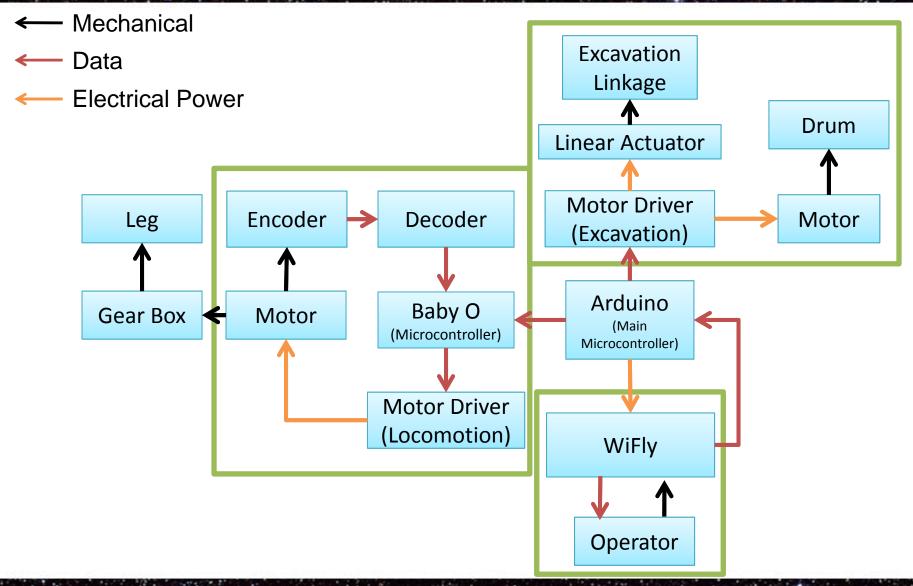
#### **Needs:**

- Excavation
- Controls



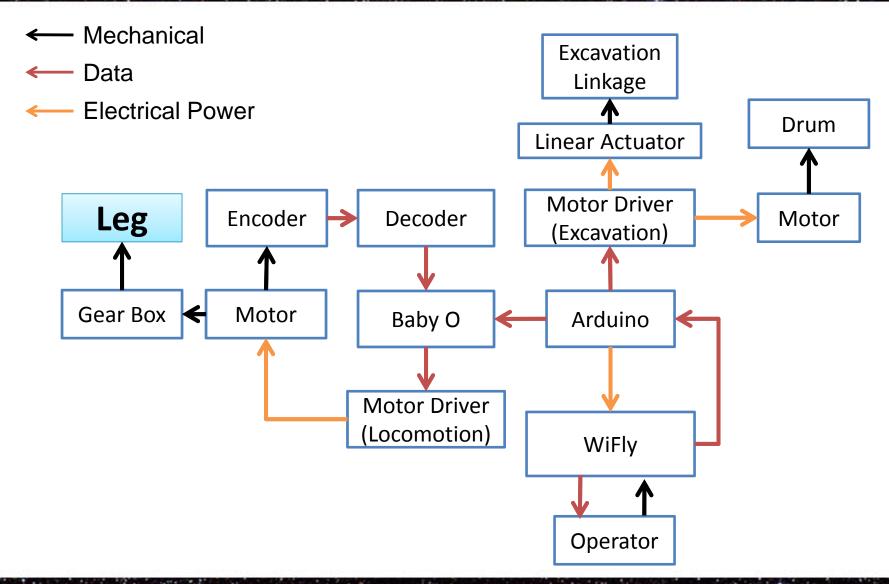


## **Functional Diagram**





## **Functional Diagram**

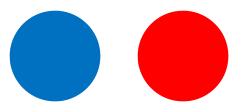


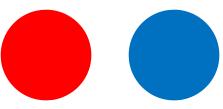


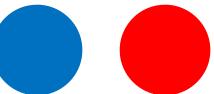
### Locomotion

- 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  $\theta$  = Time of  $\Phi$
  - Need to read position of motor

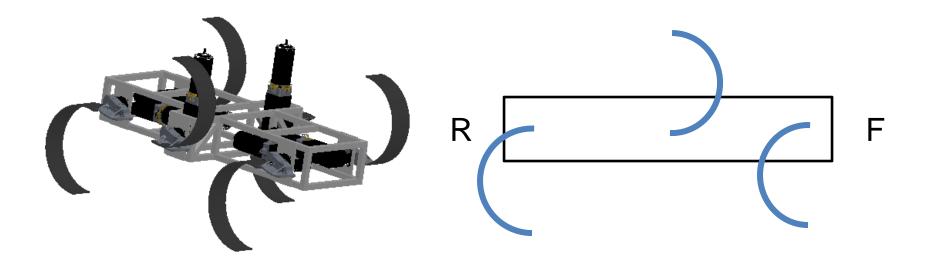
— While leg is in  $\Phi$  angle, the angular velocity is 5 times greater than when in  $\theta$  angle





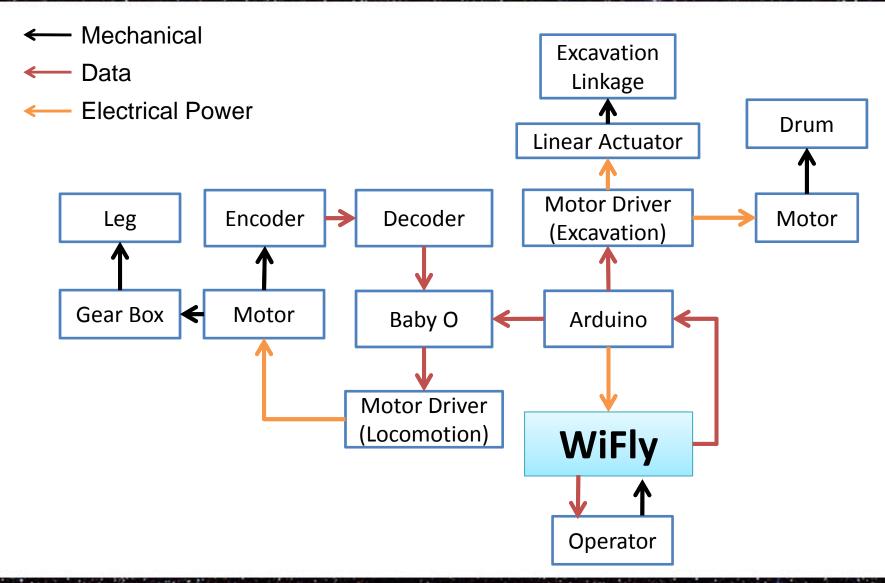
## **Locomotion Control**

#### Side View





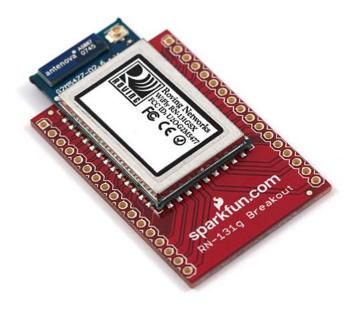
## **Functional Diagram**





## WiFly GSX

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

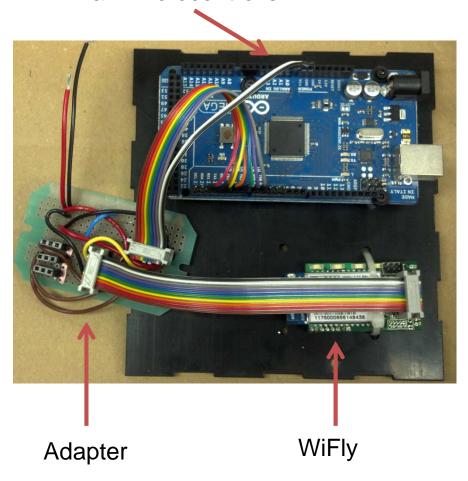




## Interfacing with the WiFly

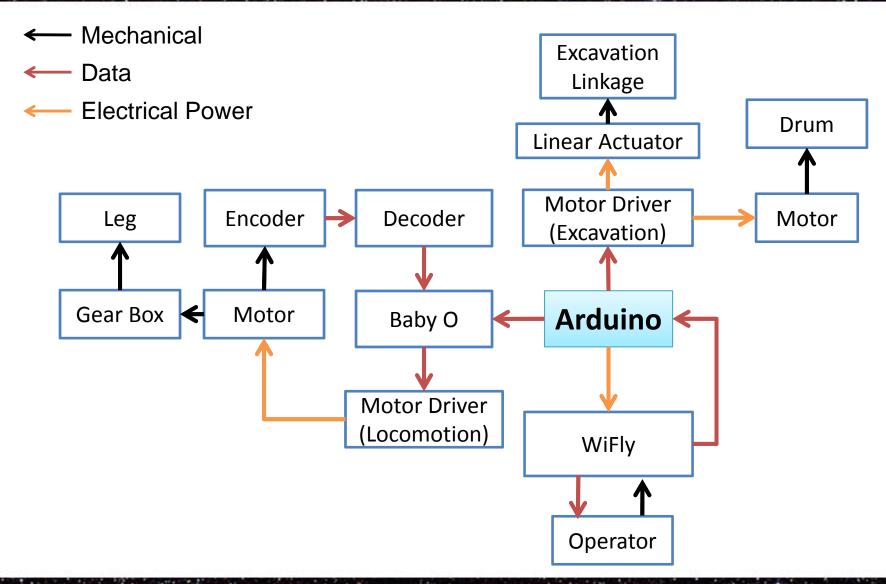
#### Main Microcontroller

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





## **Functional Diagram**





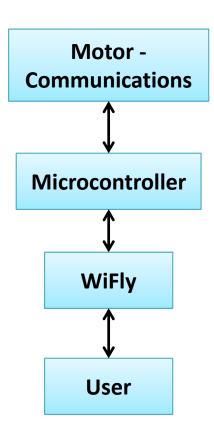
### Microcontroller Selection

#### Requirements

- Multiple serial connections
- Low power

#### **Design Concepts:**

- Netbook
- PC/104
- Arduino Mega 2650





### Netbook

#### • Pros:

- -Components included
- Physically small

#### Cons

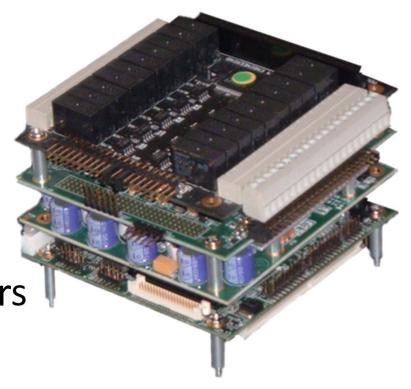
- High bandwidth usage
- -Superfluous ports
- -Limited low level customization





## Microcontroller (PC/104)

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





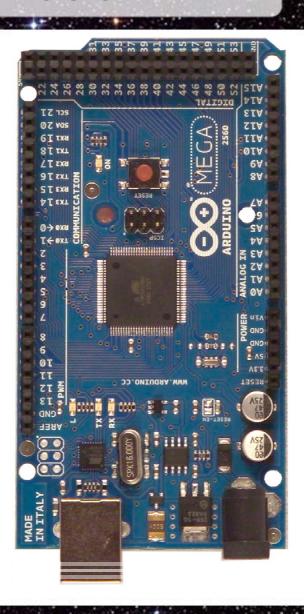
### Arduino MEGA 2650

#### Pros

- Inexpensive
- Easy to use
- Four serial connections
- Low bandwidth usage

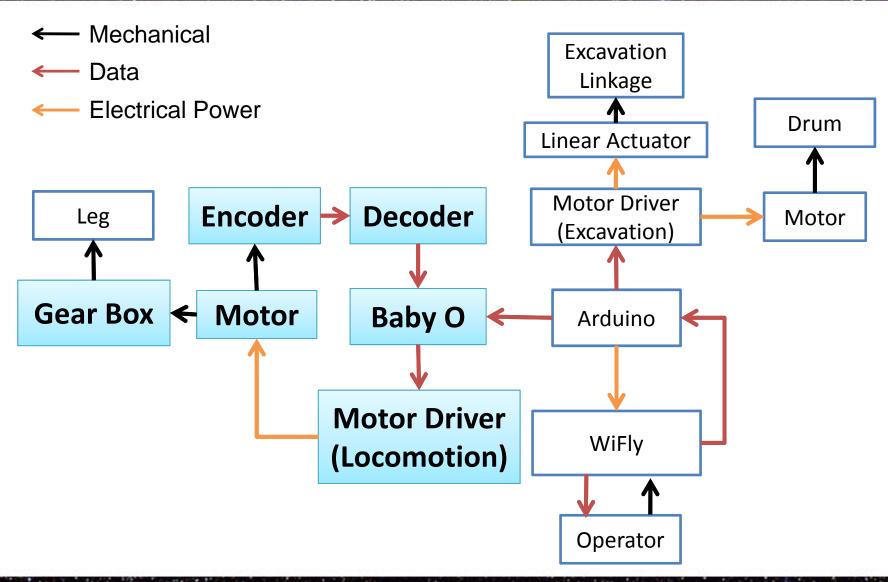
#### Cons

- Limited lower level control
- Slow processor





## **Functional Diagram**





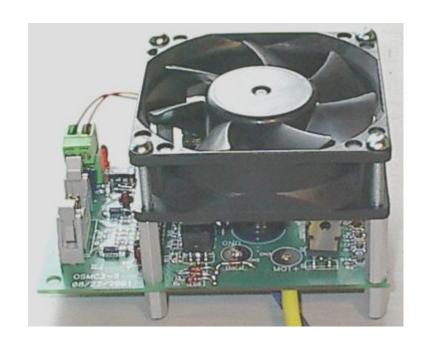
### Custom Motor-Controller

Mechanical **Analog Signal**  Components Digital Signal Motor-driver Decoder Motor-driver Micro-controller Micro-controller (OSMC) (Baby-O) Encoder **Gear Box** Motor Decoder (UT 90-50:1) (Maxon 35) (HEDL 5540) (HTCL2023)



### **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**

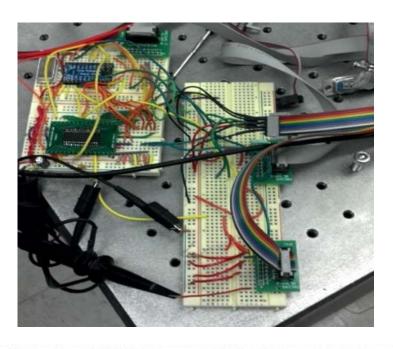
- Atmega 328P
- 20MHz
- 18 I/O lines
- 1.2" x 0.7"
- 1.5g



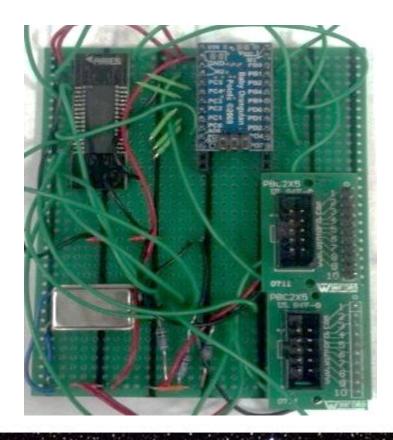


## Prototyping of Motor Controller

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

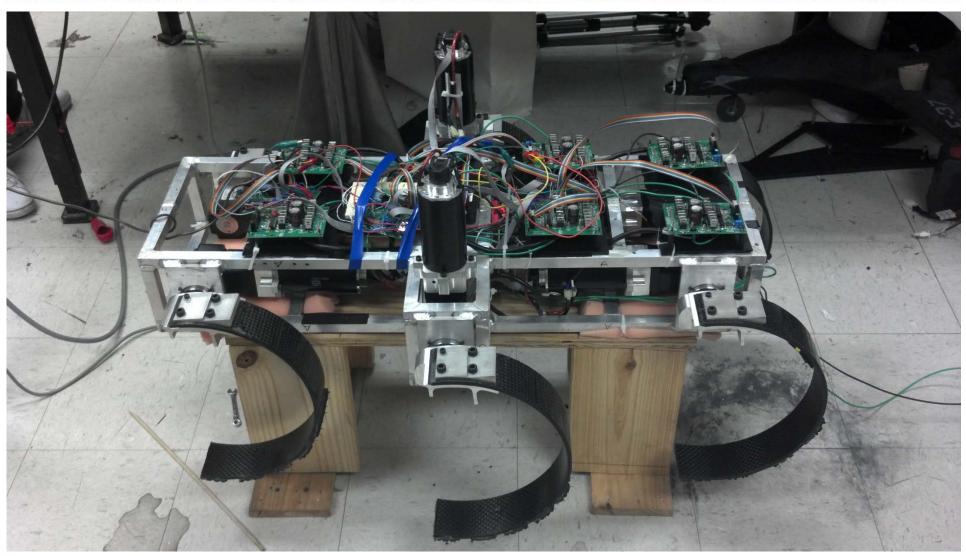


 Made motor control circuit on protoboard



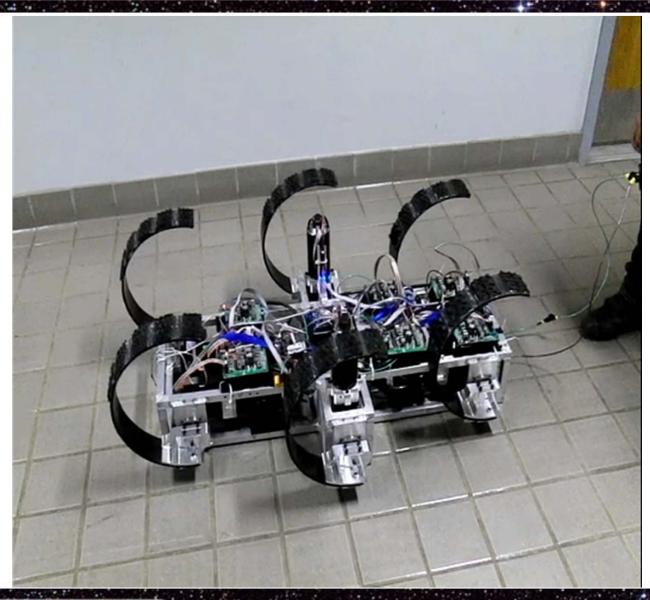


# **Testing Platform**



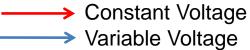


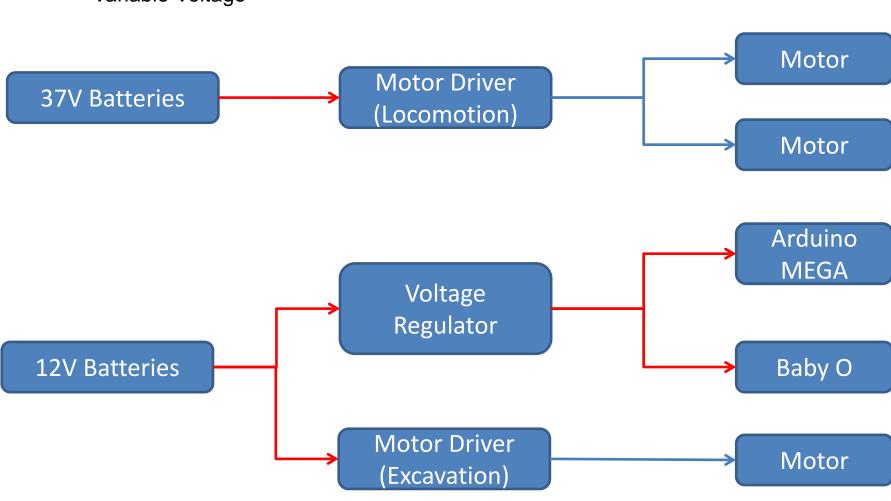
# Hexcavator Walking





#### **Power Flow Chart**







### **Batteries**





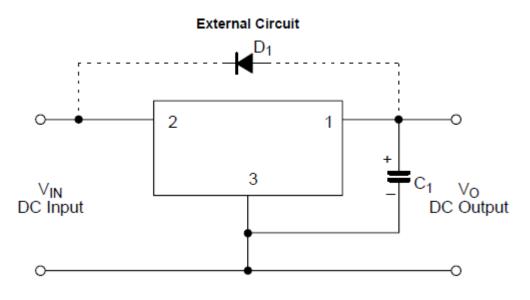
- Rated for 37V
- Actual output about 42V
- Run in Parallel for 37V potential and double current

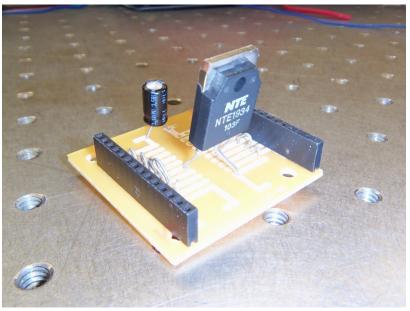
- •Rated for 12.8V
- Used for excavation system and onboard electronics



## 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

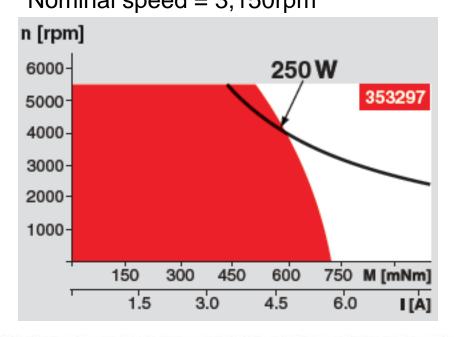
$$I_o = 0$$
 to 2.0A  
 $V_{in} = 8V$  to 45V  
 $V_o = 5V$ 



### **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





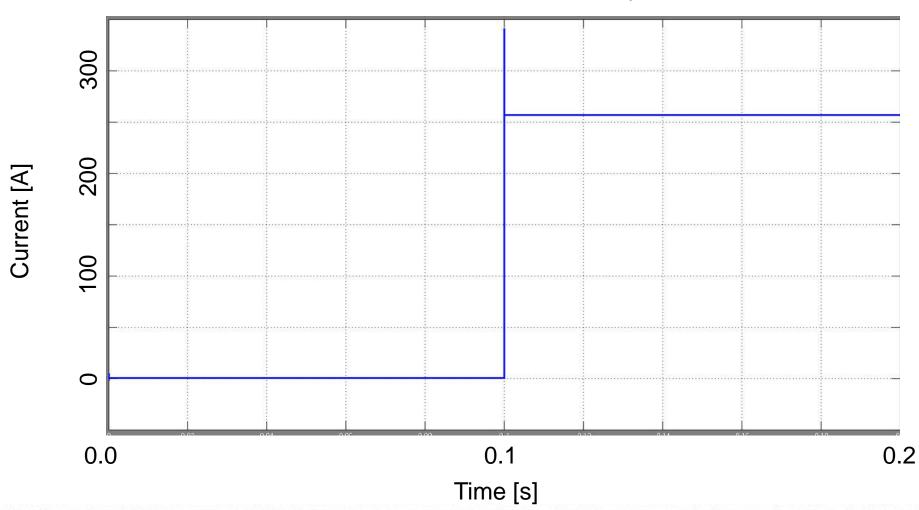


## **Motor Stall Current**

#### **Current Drawn When Motor Stalls**

Max = 260A

Load Torque = 14N⋅m





## Fuses and Safety Switch

100A Fuse Rating



ED252L Locking safety switch

Maximum Voltage: 96V Maximum Current: 250A

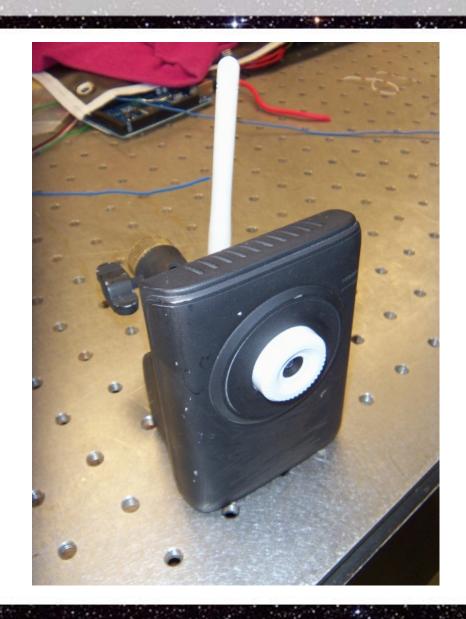




### Wireless Camera

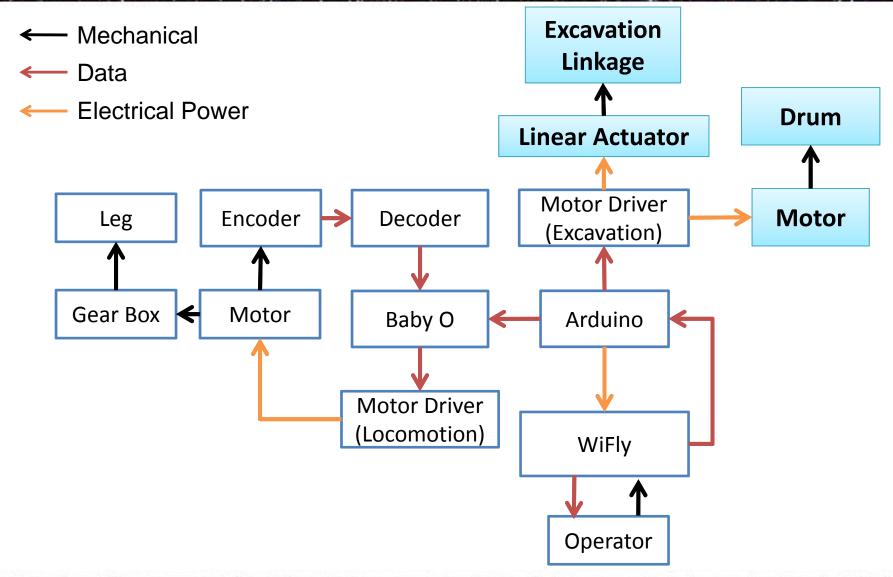
# TRENDnet TV-IP110W/A

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



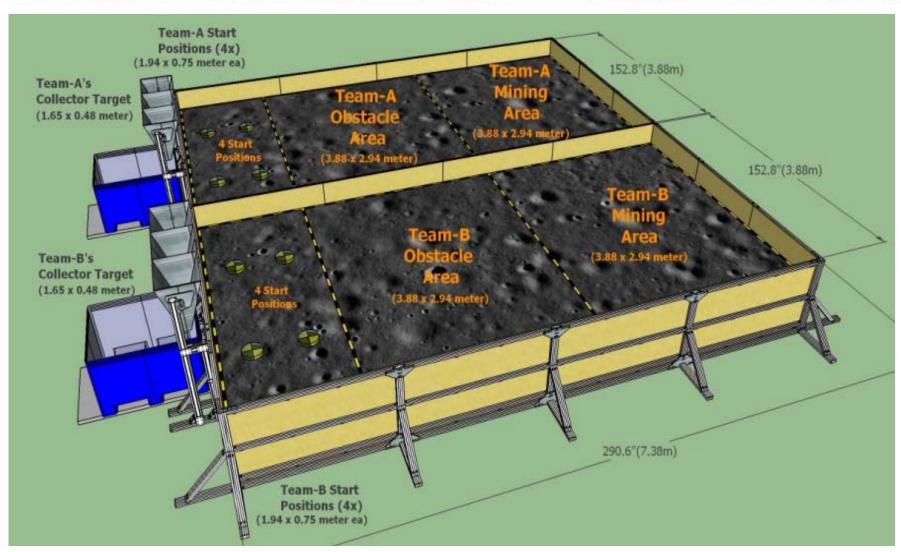


## **Functional Diagram**



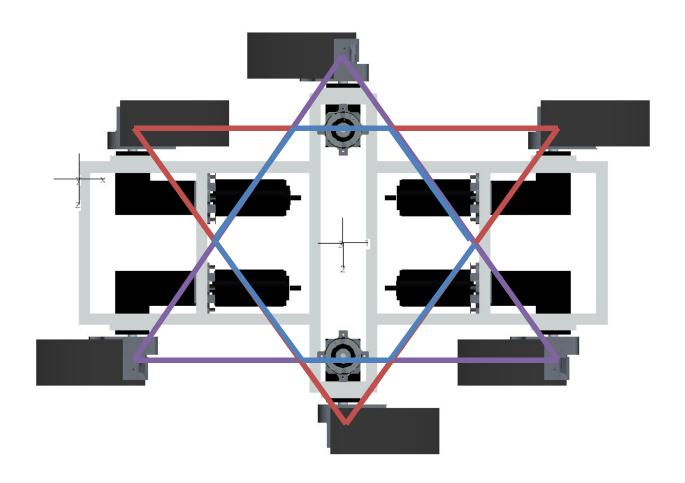


# **Competition Area**





## Center of Mass





### Four Bar Design

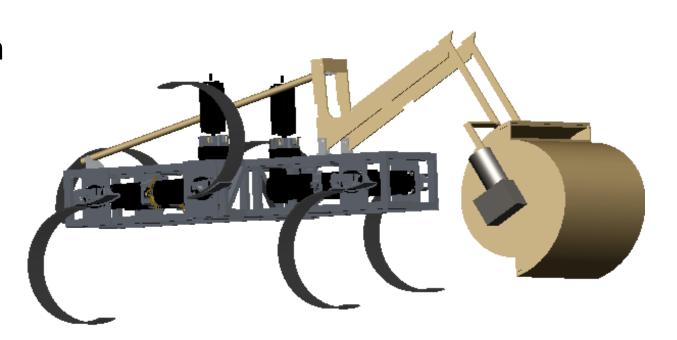
Uses linear actuator to extend and retract drum

### Advantages

- Simple design
- Stable
- Better weight distribution

### Disadvantages

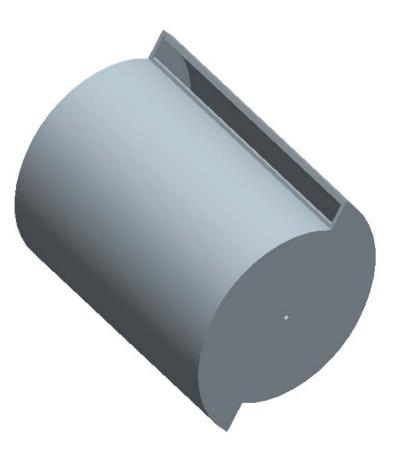
Welded





### **Rotating Drum**

- Material: Aluminum 6061
- Density of Regolith: 1500kg/m³
- 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

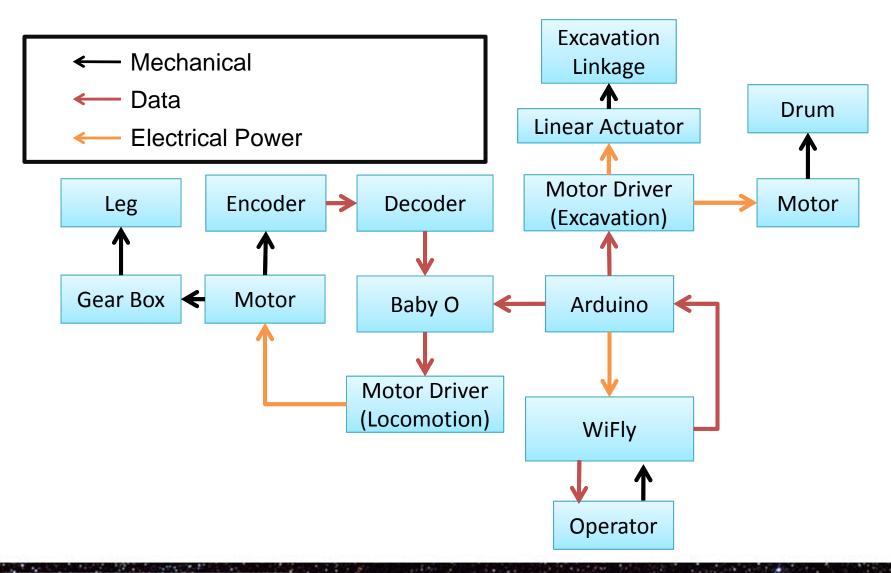
Engineering: \$2000

• National Space Grant: \$ 5000

• Northrop Grumman \$3000



## **Functional Diagram**





## Questions?









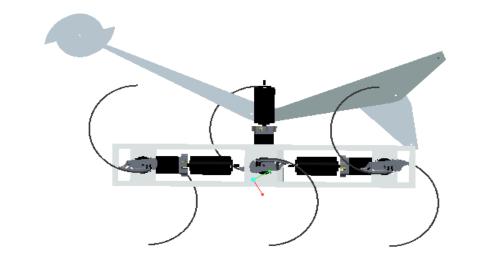
### References

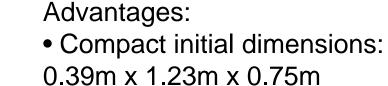
- U. Saranli, M. Buehler and D. E. Koditschek, "RHex: A Simple and Highly Mobile Hexapod Robot", International Journal of Robotics Research, vol. 20, no. 7, pp. 616-631, 2001
- http://hekilledmywire.wordpress.com/2011/08/03/introduction-to-pwm-part-7/
- http://www.signal11.us/io.html
- http://www.buynetbookcomputer.com/best-netbook-to-buy.php
- www.sparkfun.com
- Texas Instruments. Slts098. 30 June 2000. PDF.
- Roboteq. Hdc2450\_datasheet. 20 July 2010. PDF.
- Maxon Motors. RE-65-353294\_11\_EN\_084. May 2011. PDF.
- "Robot Power Products Open Source Motor Control (OSMC)." Robot Power. Web.
   04 Dec. 2011. <a href="http://www.robotpower.com/products/osmc\_info.html">http://www.robotpower.com/products/osmc\_info.html</a>.
- Lloyd, Sonny, Matt McFadden, Don Jennings, and Robert L. Doerr.
   Osmc\_project\_documentation\_v4\_21. 24 Dec. 2001. PDF.
- http://www.firgelliauto.com/default.php?cPath=90
- http://www.robotcombat.com/products/AME-226-3003.html





## Six-Bar Excavation Design

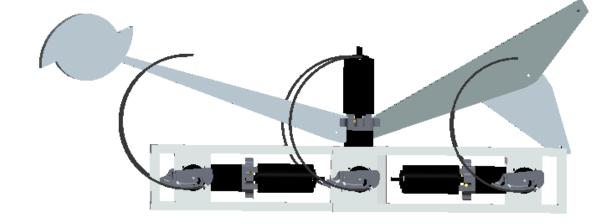




Robot never required to turn around

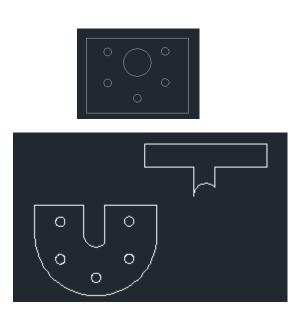
### Disadvantages

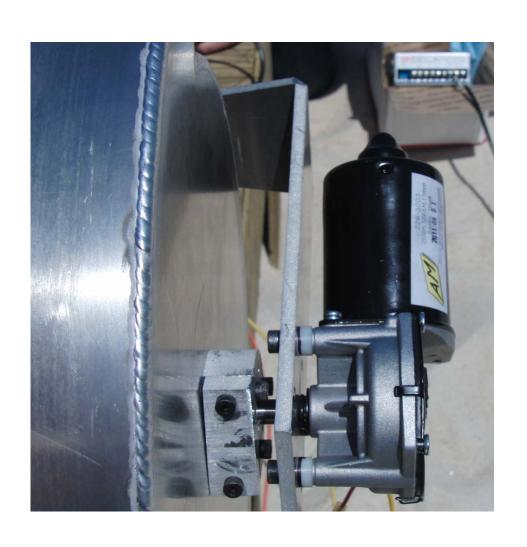
- Very complex
- Unstable





### 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

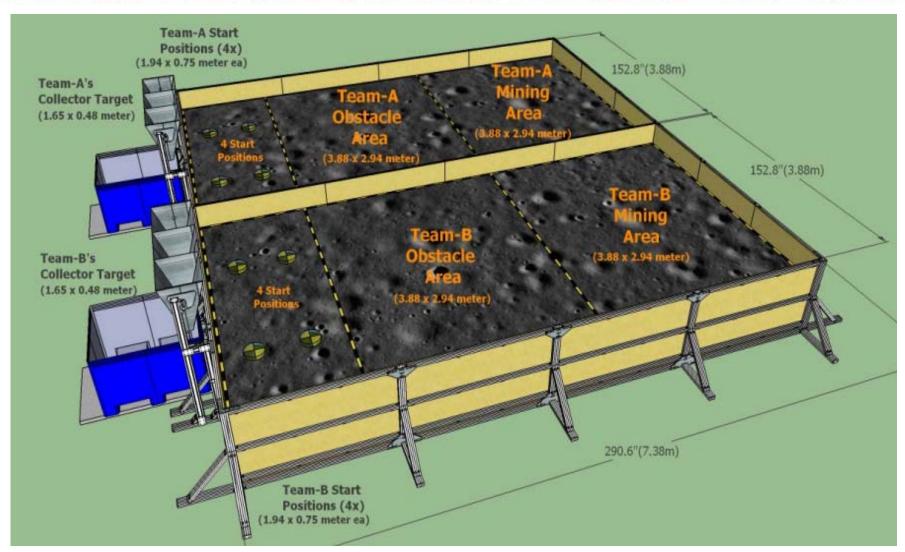


# Complete Gantt Chart

STATE OF THE PARTY	
	Color November Occ. Imany Tetrany Much March Ageil
Research	
Determine which previous components can be utilized.	x x
	x x
Locomotion Schemes and Controls.	
Design excavation system.	X X X
Spec out Controllers and Motor Drivers.	х х
Prototype 1a: Walking Platform	
Purchase motor controllers, microcontrollers and decoders.	X and the state of
Program controllers.	x x x
Test walking indoors.	
Test walking on flat ground outside.	
Test walking in sand pit.	
Test turning in confined environments.	
Initial Prototype of Excavation	
Design Iterations.	x x x
Find stimulant for excavation.	x x x
	x x x
Laser cut prototype from plastic.	
Determine if existing frame will be used.	X X
If necessary, redesign frame.	x
Prototype 1b: Excavation Design	
Build first functional prototype.	x x
	l
Testing getting soil from loosely compacted ground.	X
Test getting soil from compacted ground.	x x
Develop and test a dumping mechanism.	x x x x
peverup and test d dumping methanism.	
Design control system for excavation system.	
Prototype 2: Wireless Walking Robot with Excavation	
Attach Excavation to walking platform.	
Test moving with attached excavation.	
Refine extraction control and mechanism.	
Test depositing soil into bin.	
Make Robot wireless.	X X
Prototype 3: Walking Robot in Rough Terrain	
Test combined system's ability to navigate obstacles.	
Refine locomotion control for excavation over uneven ground.	
Test picking up soil on uneven ground.  Prepare for final demonstration.	
Prepare for final demonstration.	

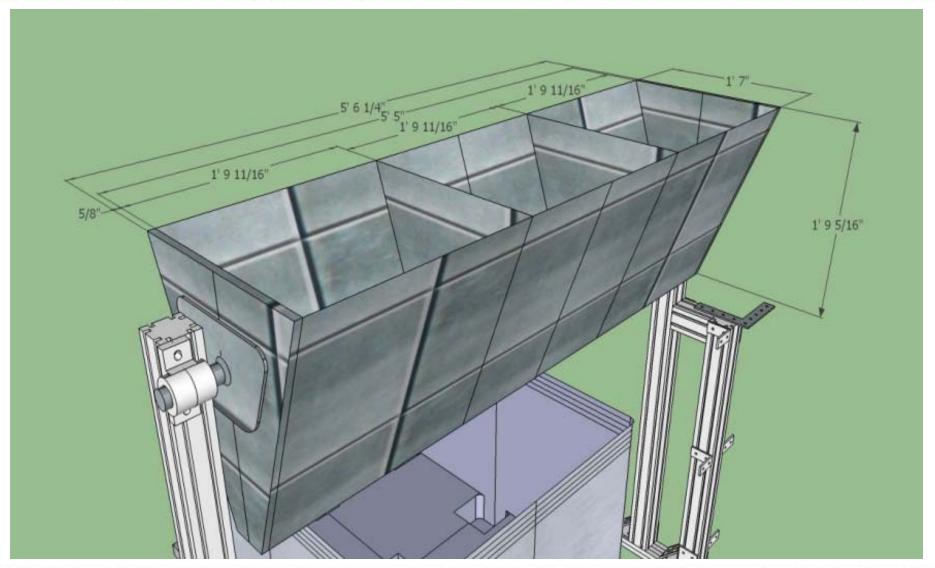


# **Competition Area**





### LunaBin



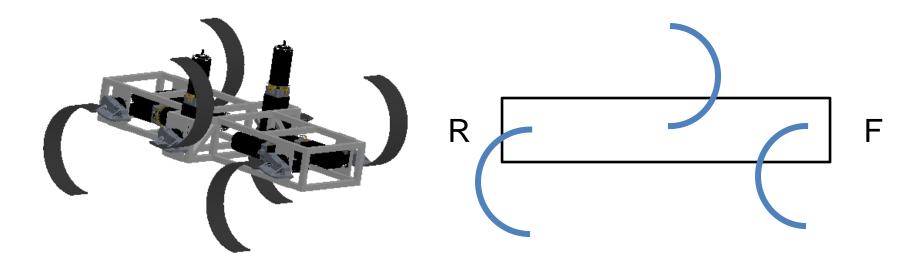






### **Locomotion Control**

#### Side View





### **Locomotion Control**

- Solution: Buehler Clock
  - Speed varies depending on position
    - Time of  $\theta$  = Time of  $\Phi$
  - Need to read position of motor

— While leg is in  $\Phi$  angle, the angular velocity is 5 times greater than when in  $\theta$  angle

