2014 NASA/RASC-AL Robo-Ops Competition

Spring Final Presentation

Team 11 Members:

Boris Barreto	-	Electrical and Computer Engineering
Jason Brown	-	Mechanical Engineering
Justin Houdeshell	-	Mechanical Engineering
Linus Nandati	-	Electrical Engineering
Tsung Lun Yang	-	Mechanical Engineering

Team 11 Advisors:

Dr. Jonathan Clark – Mechanical Engineering
Dr. Uwe H. Meyer-Baese – Electrical Engineering

Presentation Outline

- Project Scope
- Overall Design
  - Extraction Module
  - Network and Communication
  - Locomotion and Control
- Project Summary and Future Plans

Project Scope

- **Objectives**
  - Build an innovative rover design capable of competing in the 2014 Robo-Ops competition
  - Selective Competition (8 Teams Nationally Compete)
  - Capable of traversing environments similar to those on Mars
  - Tele-Operated using wireless communications
  - Pick up brightly colored rocks using an extraction unit
- **Areas for development**
  - Sample Extraction Module
    - Manipulator arm
    - End effector
  - Controls
    - Dynamic control
  - Communications
    - Network

NASA Curiosity Rover

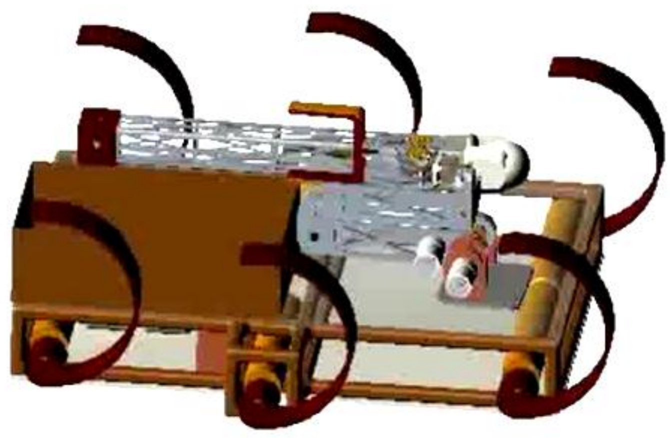
Johnson Space Center Rock Yard

Jason Brown

Project Constraints

- Rover Physical Constraints
  - No larger than 1m x 1m x 0.5m
  - Less than or equal to 45kg.
  - Traverse over obstacles up to 10cm in height.
  - Pick up rocks ranging from 2 to 8 cm in diameter and masses ranging from 20 to 150 g.
  - The rover(s) will be controlled remotely based from the home campus of the university

Overall Design



Research

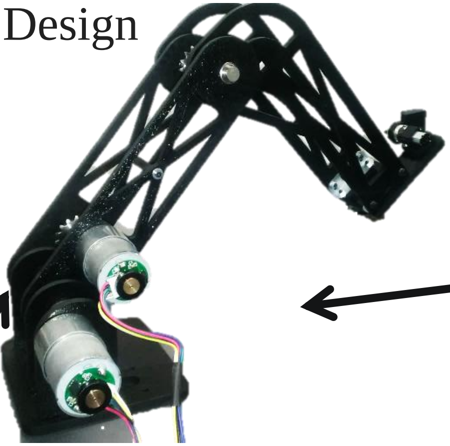
- Studied previous designs from other schools

- Worchester Polytechnic Institute

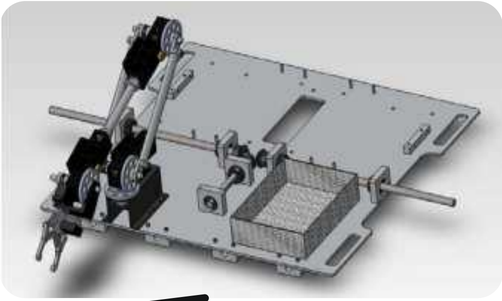
2 Degrees of Freedom

Our Design

4 Degrees of Freedom



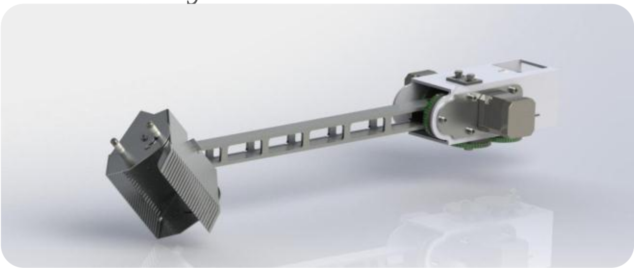
- California Institute of Technology



7 Degrees of Freedom

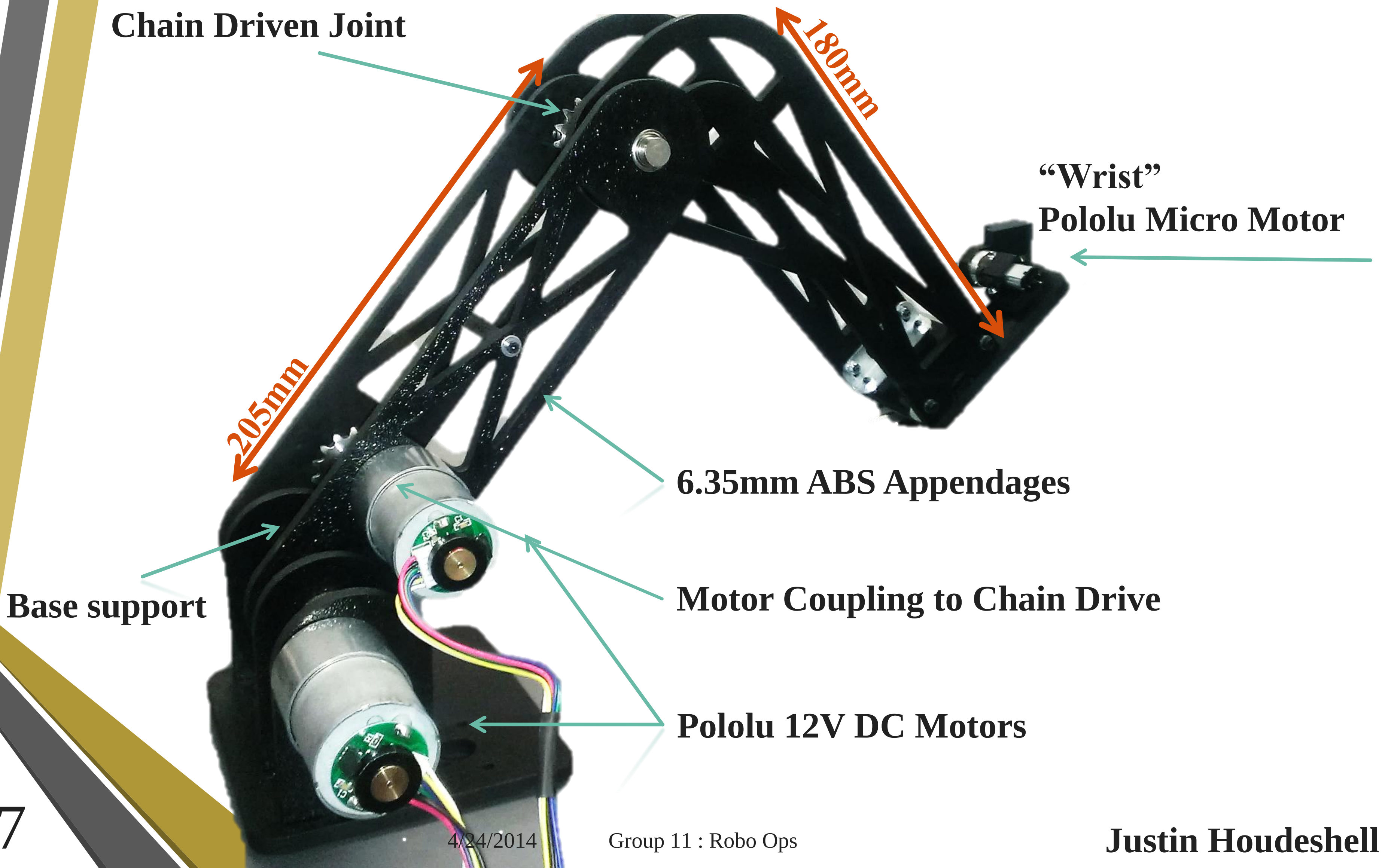
- University of Massachusetts Lowell

2 Degrees of Freedom



Justin Houdeshell

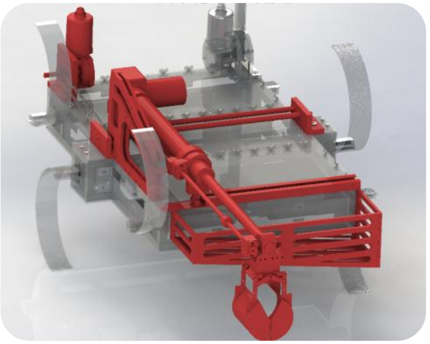
Extraction Arm

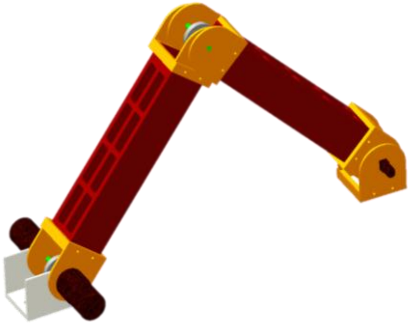


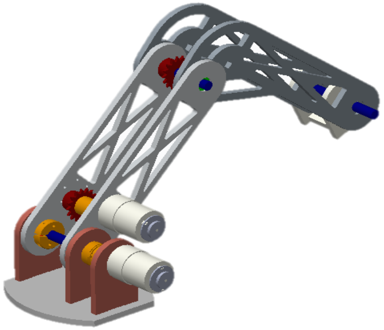
Justin Houdeshell

Extraction Arm

	2013 Design	Fall Design	Spring Design
Drive Motors	McMaster Carr Linear Actuator	Maxon Motor with 113:1 Gearbox	Pololu 12V 100:1 DC motors
Link Material	6063 Aluminum	6063 Aluminum	ABS Plastic
Overall Reach	320 mm	660 mm	385 mm
Estimated Weight	10 kg	6 kg	3 kg
Advantages	Simple Control Scheme Stable Platform	Large Workspace	Lightweight Moderate Reach
Disadvantages	Limited Workspace	High Torque Requirements	Deflection





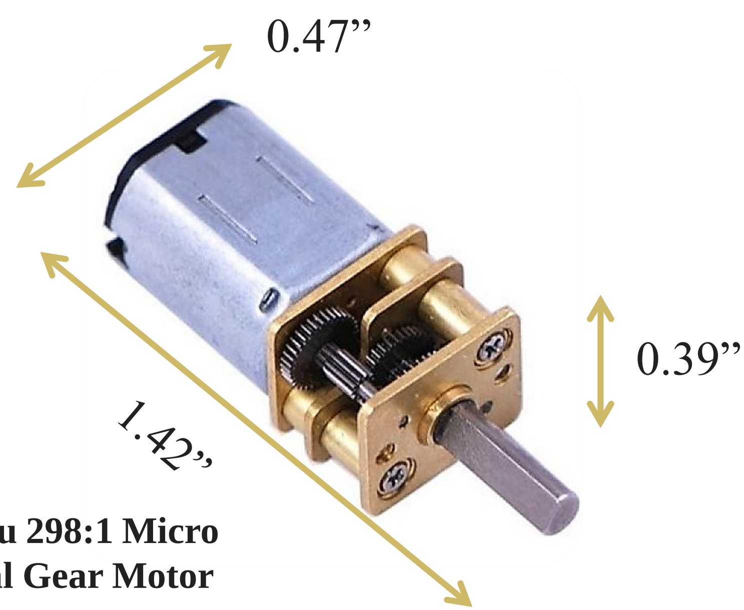


Justin Houdeshell

Motor Selection for Arm

- Used Torque Calculations from Matlab to determine Motors
  - Determined Max Torque of 10.2 kg cm
  - Pololu 12V 100:1 Motor
    - 15.8 kg cm of Torque
    - Weight: 223 grams per motor
  - Selected Pololu 298:1 Micro Metal Gearmotor for wrist and gripper actuation
    - Weight: 10 grams
    - Torque: 6.5 kg-cm
    - 1.42" x 0.39" x 0.47"

Pololu 100:1 12V DC Motor



Pololu 298:1 Micro Metal Gear Motor

Justin Houdeshell

Extraction Arm Control

Potentiometer model

Read differential voltage from potentiometer

Converted analog signal to digital signal via MCU

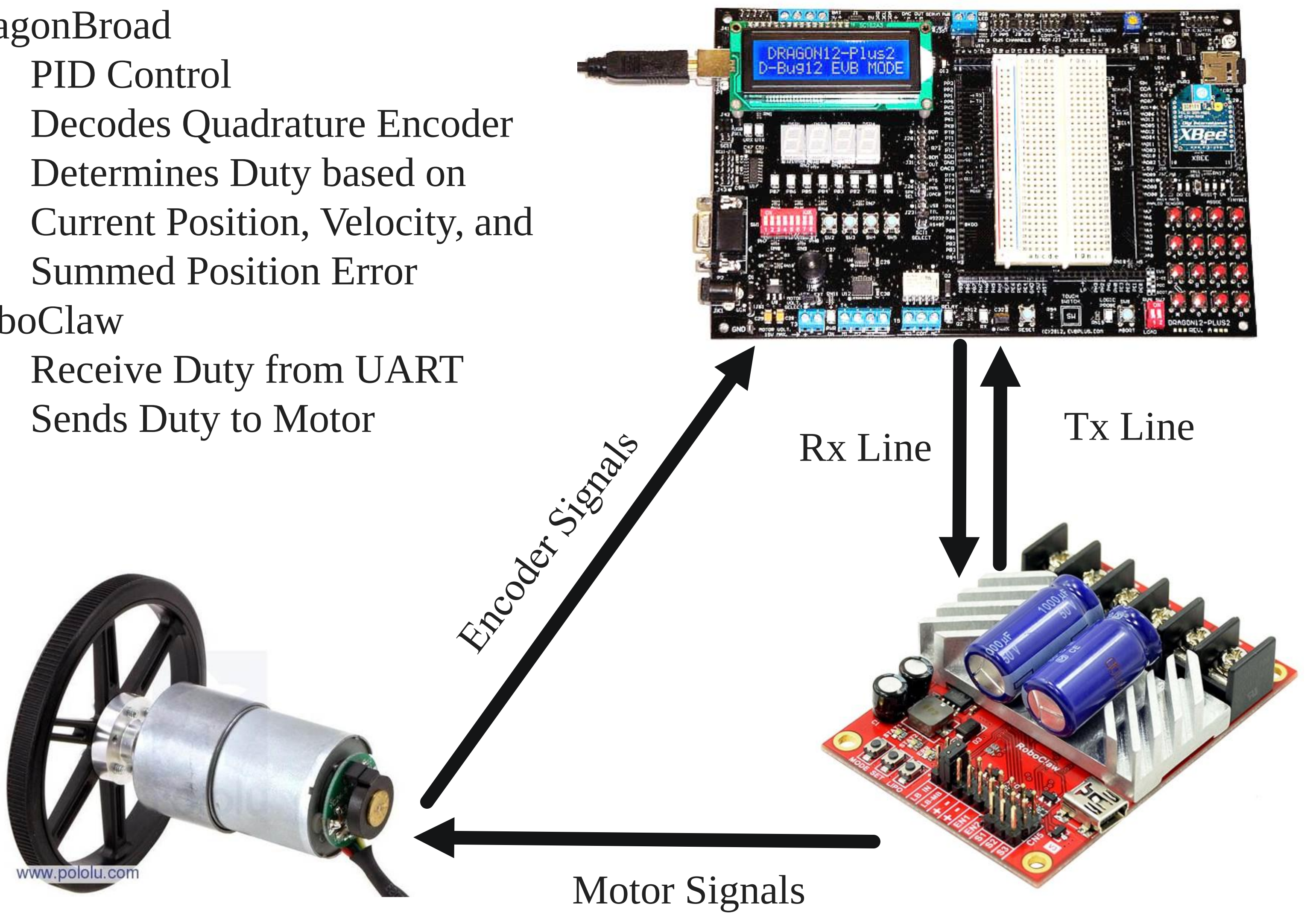
Map digital signal to motor position

Complete integration of mechatronic system

Jason Brown

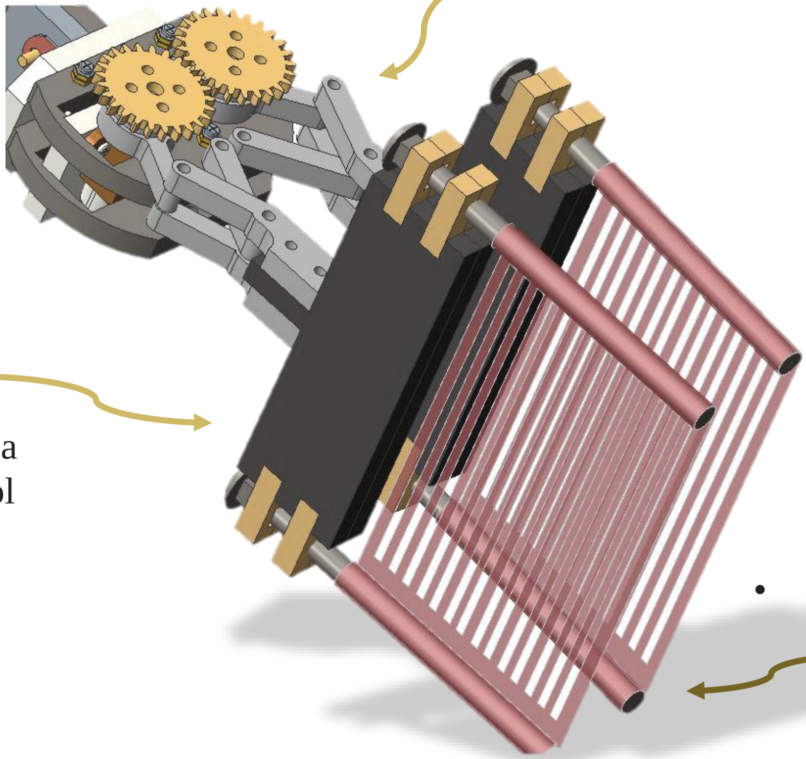
Extraction Arm Control

- DragonBroad
  - PID Control
  - Decodes Quadrature Encoder
  - Determines Duty based on Current Position, Velocity, and Summed Position Error
- RoboClaw
  - Receive Duty from UART
  - Sends Duty to Motor



Extraction End Effector

- **Scooper Design**
  - Large contact area
  - Simplified control



- **Two-prong pincher Design**
  - Precision

- **Elastic Jamming Design**
  - Strong shape/orientation tolerance

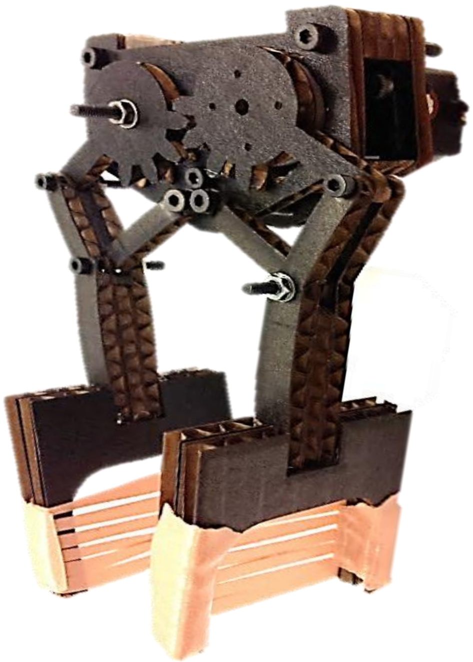
Tsung Lun "Chris" Yang

Extraction End Effector

1st Generation Prototype

- Elastic mechanism viable
- Improve linkage mechanism for precision

2nd Generation Prototype



- Testing elastic material: First Aid tape
- Need to increase elastic surface area

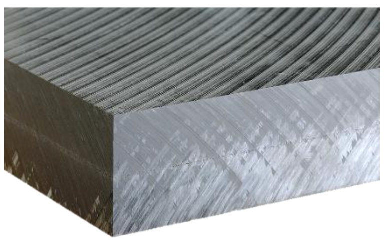
3rd Generation Prototype

- Mars suitable elastic material finalized: Silicone Rubber
  - Temperature range: -120C to 300C

Tsung Lun “Chris” Yang

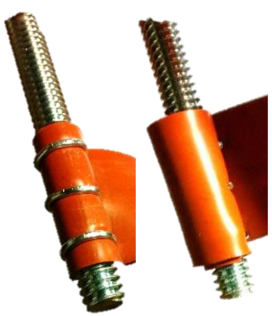
Extraction End Effector

Acrylonitrile
Butadiene Styrene
(ABS) Plastic



298:1 Pololu Motor

Silicon Rubber



Adjustable tension control

Tsung Lun "Chris" Yang

Extraction End Effector

Sample Extraction Module Future Plans

- The complete system have reduced weight by 60% compared to previous design, further weight reduction possible.

- Upgrade hardware to achieve robust manipulator arm and gripper control
  - Higher grade DC motor
  - Fully incorporate RoboClaw motor controller
    - Dedicated decoder
    - Build-in PID routine

Tsung Lun "Chris" Yang

Communications

Last Year's Issues:

-dropped coverage

-lagging video/ relay of commands

Lessons Learned:

-needed larger bandwidth

-secure specified IP addressed for teams use

-needed to be exclusive and secure from eavesdroppers

Communications
What We Have Done:

-Update from 3G to 4G Verizon service

  -Service speeds 8x faster

  -New 4G USB modem

-IP addressing from No-IP.com

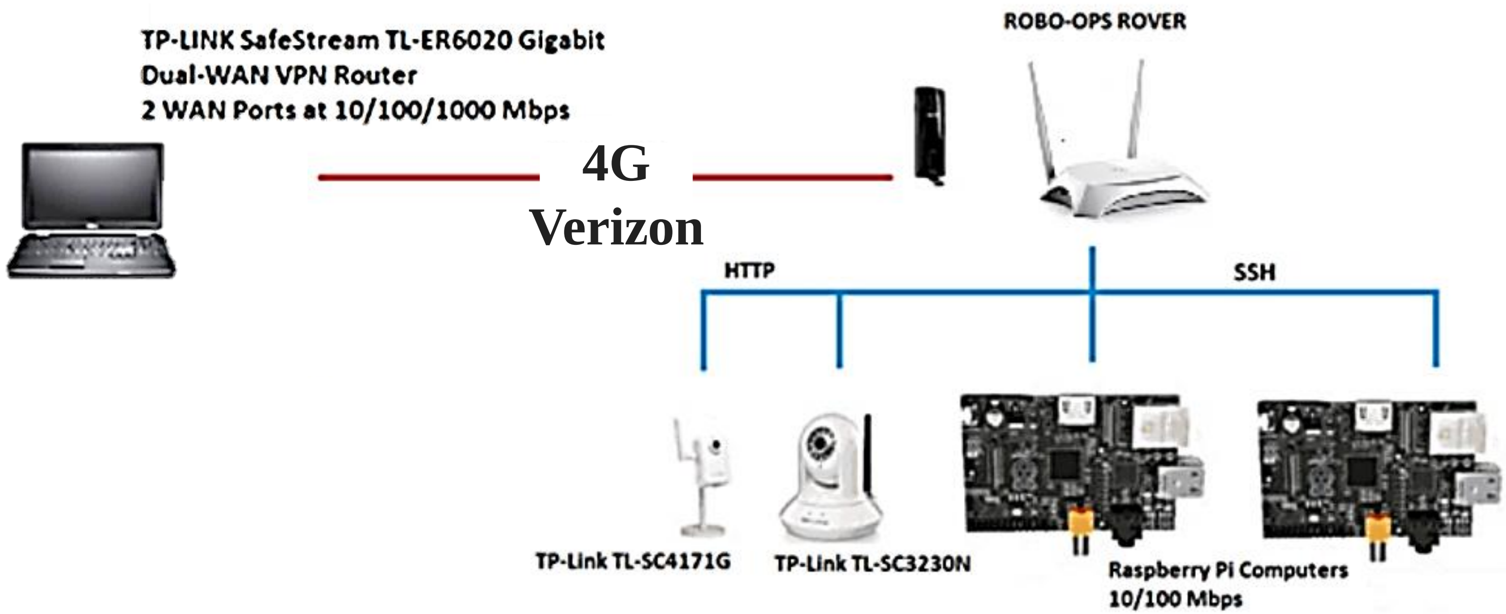
  -pool of IP addresses supplied for modem

  -allows for IP address to be dynamic

    -Static was giving problems with the USB modem

    -no need to constantly sniff for specific IP

Planned Design



- Communicate with USB modem
  - IP Address Pool supplied by No-IP.com
- Data packets processed and transferred between two LANs via WAN
  - Think of a smartphone and the rate at which it can access data

Communications Future Plans

-Secure Bandwidth for Multiple Cameras

-Incorporate AT&T (split BW demands)

-Dynamically be able to switch between networks

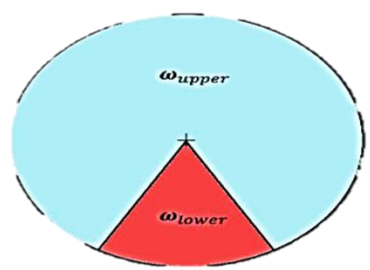
- -This is done Through Script Writing
- -Utilize all the Bandwidth
- -Open source software is needed, complex idea

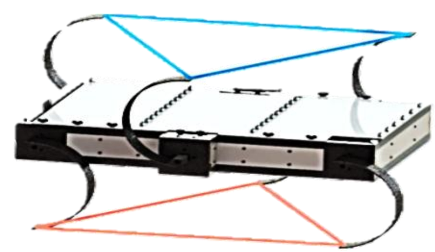
Controls Motivation

Boris Barreto

Existing Locomotion Gaits

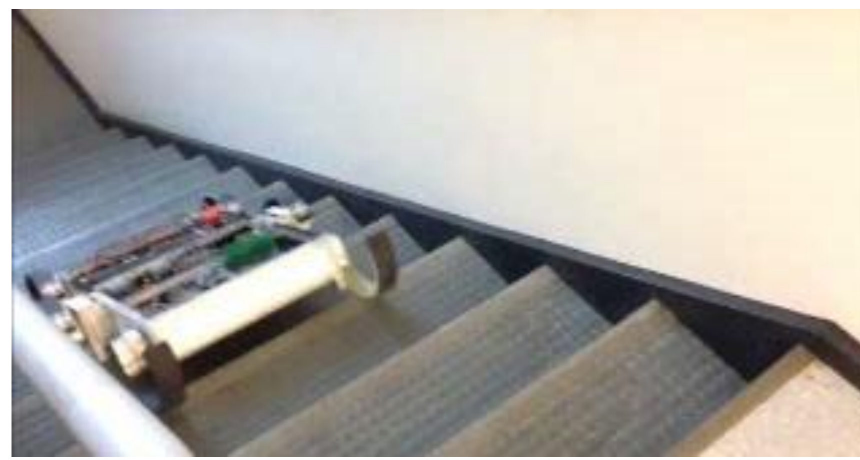
- Calibrate
- Forward Walk
- Backward Walk
- Turn-In-Place
- Lay Down
- Stand Up
- Hill Climb





User Interface

Locomotion Types	Status
Turn While Walking	Complete
Stair Climbing	Prototype Complete



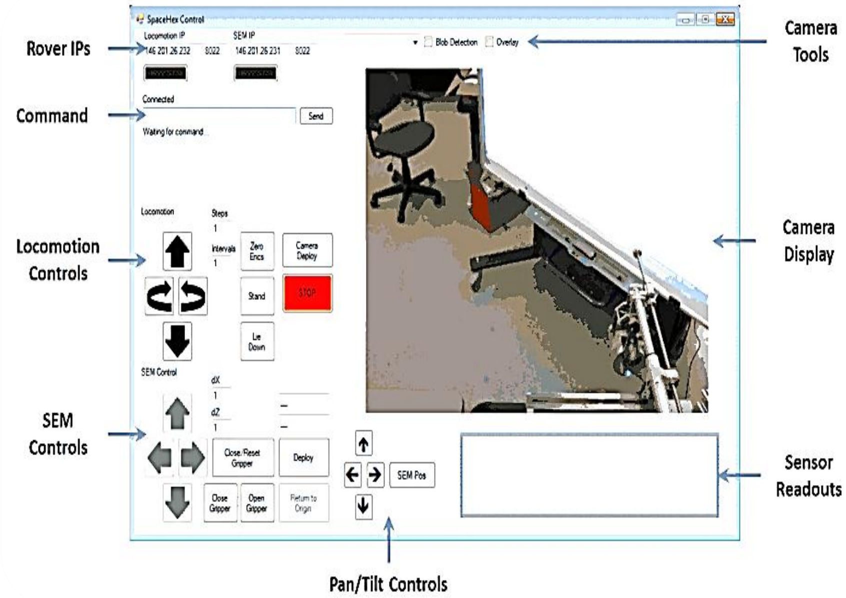
Boris Barreto

User Interface

- Old GUI
  - Video Feed
  - Temperature sensors
  - Connection indicators

  - Not User-Friendly
  - Slow

- XBOX Controller
  - Comfortable Environment
  - Fast
- SDL
- Curses



Boris Barreto

Dynamic Switching

Static Control

Dynamic Control

Videos Played at 2x Speed

Boris Barreto

Locomotion Future Plans

- Develop Additional Gaits
  - Turn While Climbing
  - Small Angle Turning
  - Refine Stair Climbing

- Reduce Delay Switch Between Gaits
  - Currently 500 ms delay between gaits
  - Smoother and more rapid transition between gaits

- Utilize more Functionality of Xbox Controller
  - Vibrate Functionality
  - Use Wireless Remote
  - Develop Supplementary GUI

Boris Barreto

Project Procurement

	Item	Vendor	Part Number	Cost	Quantity	**Total**
Arm	Pololu 12V Motors with Encoders	Pololu	397172	$39.95	3	**$120**
	Encoders	Pololu	110512	$8.95	4	**$36**
	Pololu 298:1 Micro Metal Gear Motor	Pololu		$16.95	4	**$68**
	Shafts, Bearings, Chain, Sprocket and Misc. Hardward	Misumi	Various	$270	1	**$270**
	¼ " ABS Plastic	Interstate Plastics		$15.00	4	**$60**
Communications	Verizon Wireless Service	Florida State University IT Services		$60.00 /month	3 months	**$180**
TOTAL						**$734**

PROJECT SUMMARY

Competition Status	Not selected to participate 2014 Robo-Ops competition
	Switch to back up plan
Extraction Module	Created a 4 DOF Robotic Arm with simple Haptic Control
	Created Elastically Compliant Gripper
Communication	Established Stable Connection with single network
	Upgraded Bandwidth with Verizon 4G Network
Rover Locomotion	Improved locomotion control (turn while walking/Stair climbing)
	Dynamic control (Xpadder/getch())
Future plans	Further Integration and Debugging of all Components
	Create formal recommendations for future team

References

- http://www.maxonmotorusa.com/maxon/view/product/motor/dcmotor/re/re40/148867
- http://www.robotshop.com/en/pololu-298-to-1-micro-gear-motor-hp.html
- http://www.tp-link.us/products/details/?categoryid=1678&model=TL-ER6020
- http://www.britannica.com/EBchecked/topic/182081/elastomer#ref625240
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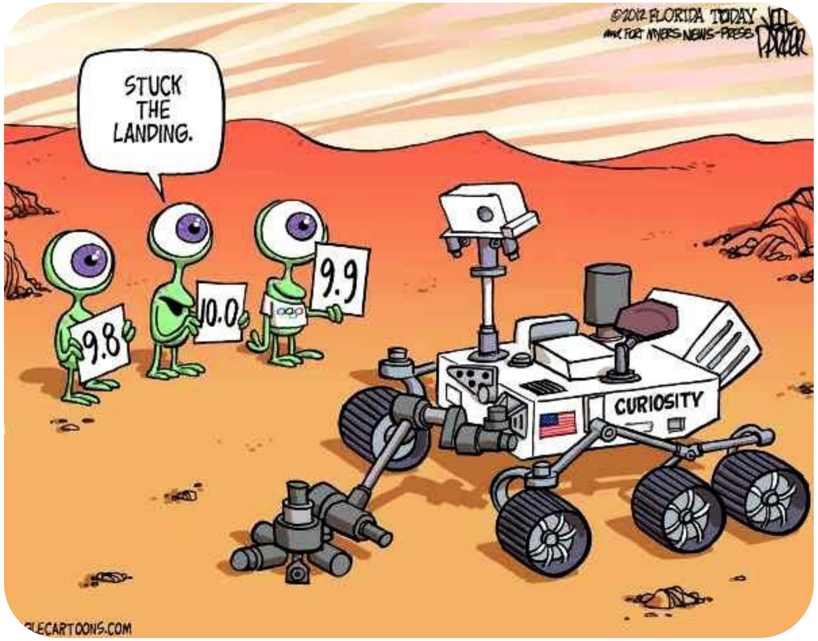
- http://www.tp-link.us/products/details/?categoryid=1678&model=TL-ER6020
- http://raspberrypi.stackexchange.com/questions/1976/alternatives-to-raspberry-pi
- http://www.tp-link.us/products/?categoryid=202
- http://www.raspberrypi.org/

Question/Comment?



Project Schedule

Task Name	Start	Finish
Fundrasing	Fri 9/20/13	Fri 5/2/14
Locomotion Controls	Mon 9/23/13	Fri 2/28/14
Turn While Walking	Mon 9/23/13	Fri 2/28/14
Turning while climbing	Mon 9/23/13	Fri 2/28/14
Control with and Xbox	Fri 10/25/13	Fri 2/28/14
Sample Extraction Module	Mon 9/23/13	Mon 3/24/14
Gripper	Mon 9/23/13	Mon 3/24/14
Brainstorming	Mon 9/23/13	Fri 9/27/13
Prototyping – Cardboard Stage	Mon 9/30/13	Fri 10/25/13
Selection of Final Design	Mon 10/21/13	Fri 10/25/13
Determine Parts Necessary	Mon 10/28/13	Fri 11/22/13
Complete CAD Model	Mon 10/28/13	Fri 11/22/13
Construction	Mon 11/25/13	Mon 1/20/14
Attachment to Arm	Mon 2/24/14	Mon 2/24/14
Testing Gripper	Tue 2/25/14	Mon 3/24/14
SEM Mechanism	Mon 9/23/13	Fri 3/21/14
Brainstorming	Mon 9/23/13	Fri 9/27/13
Prototyping – Cardboard Stage	Mon 9/30/13	Fri 10/25/13
Selection of Final Design	Mon 10/21/13	Fri 10/25/13
Determine Parts Necessary	Mon 10/28/13	Fri 11/22/13
Complete CAD Model	Mon 10/28/13	Mon 1/20/14
Construction	Tue 1/21/14	Fri 2/21/14
Testing SEM System	Mon 2/24/14	Fri 3/21/14
Communication	Mon 9/23/13	Mon 3/17/14
Develop Communications Design	Mon 9/23/13	Fri 10/18/13
Determine Necessary Components	Mon 10/21/13	Fri 11/8/13
Acquire Necessary Components	Wed 1/15/14	Tue 1/28/14
Build Communication System	Wed 1/29/14	Mon 2/17/14
Test and Debug Communications	Tue 2/18/14	Mon 3/17/14
Complete System Integration – '	Tue 3/25/14	Mon 5/19/14