TEMPLE UNIVERSITY NASA LUNABOTICS 2014 ELECTRICAL TEAM

Senior Design 2 Presentation: Saturday, May 5, 2013

Mark Halberstadt, Eric Schisselbauer, John Morris
Team: Lunabotics Electrical 2014
Advisor: Dr. John Helferty
College of Engineering
Temple University

Agenda:

1. Team
2. Motivation
3. Problem Statement
4. Design Constraints
    a. Functional Constraints
    b. Non-functional Constraints
5. Approach
6. Final Design
7. Cost Analysis
8. Next Steps

Abstract:

On May 19 through May 23, 2014, NASA will be hosting the 5th Annual Lunabotics Mining Competition. This is a collegiate level competition where teams from across the world design robots capable of navigating a simulated lunar environment, excavating simulated lunar regolith, and depositing the excavated regolith into a collection bin.

Scoring for the competition is based on a point system where seven separate criteria are used to award points.

The elecrical team will build power and control systems capable of driving the robot through the simulated lunar environment. The control system of the robot will have both manual and autonomous modes of operation. By default, the robot will be controlled autonomously unless a user overides to the backup manual control system.

Team:

Mark Halberstadt (ECE)
Team Leader
Autonomous Systems
Control Systems

Eric Schisselbauer (ECE)
Computer Architecture
Control Systems
Autonomous Systems

John Morris (EE)
Power Electronics
Power Monitoring Systems
Electrical Circuit Design and Testing

John Helferty, Ph.D.
Electrical and Computer Engineering
Advising Professor

Motivation:

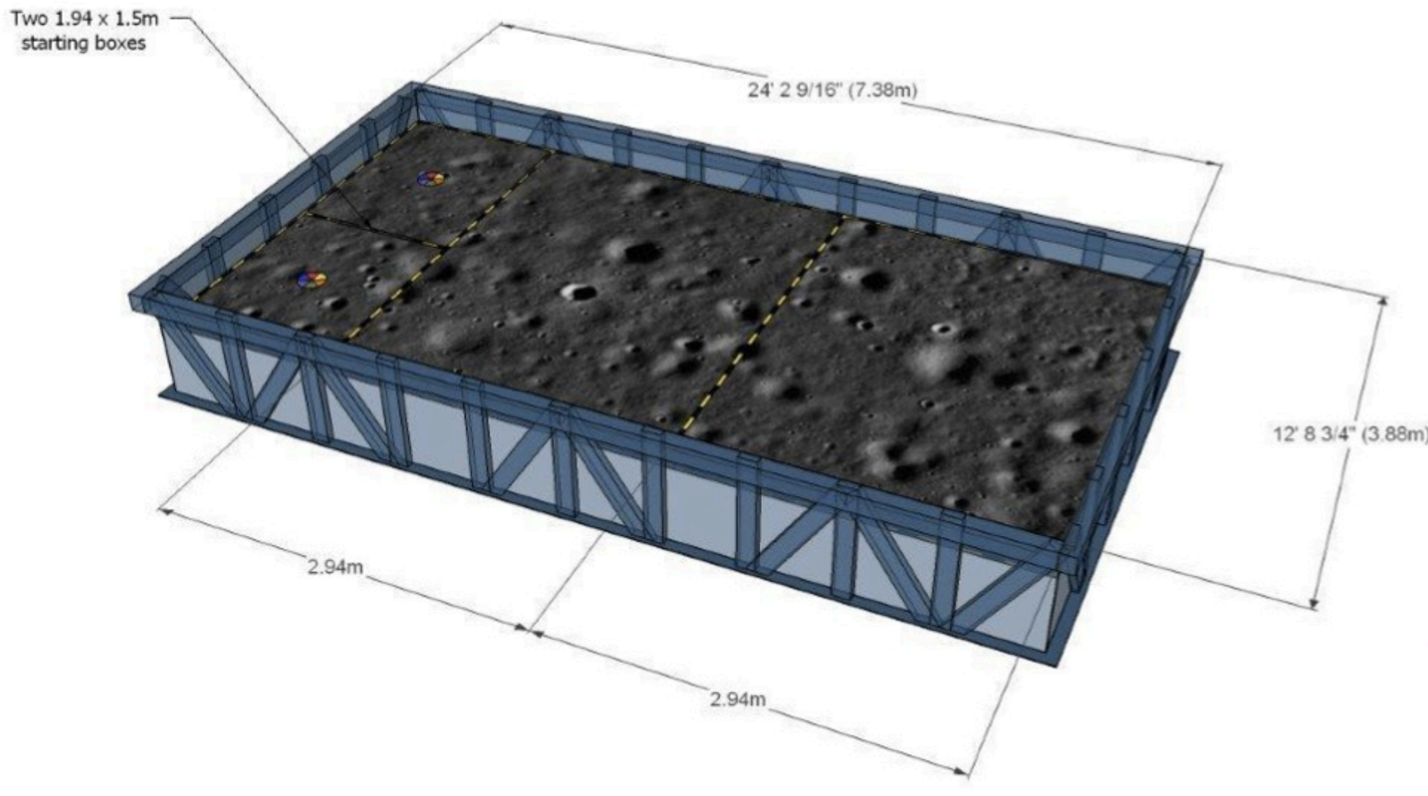
- NASA’s Fifth Annual Robotic Mining Competition
  - University-level competition
  - Teams design and build robots capable of traversing simulated lunar soil, excavating regolith, and depositing excavated regolith into collection bin

Problem Statement:

1. Design and build power, control, and communication systems capable of driving a mining vehicle through a harsh lunar environment
2. Complete autonomous functionality of the mining vehicle
3. Increased power efficiency of system in order to reduce size and weight of system

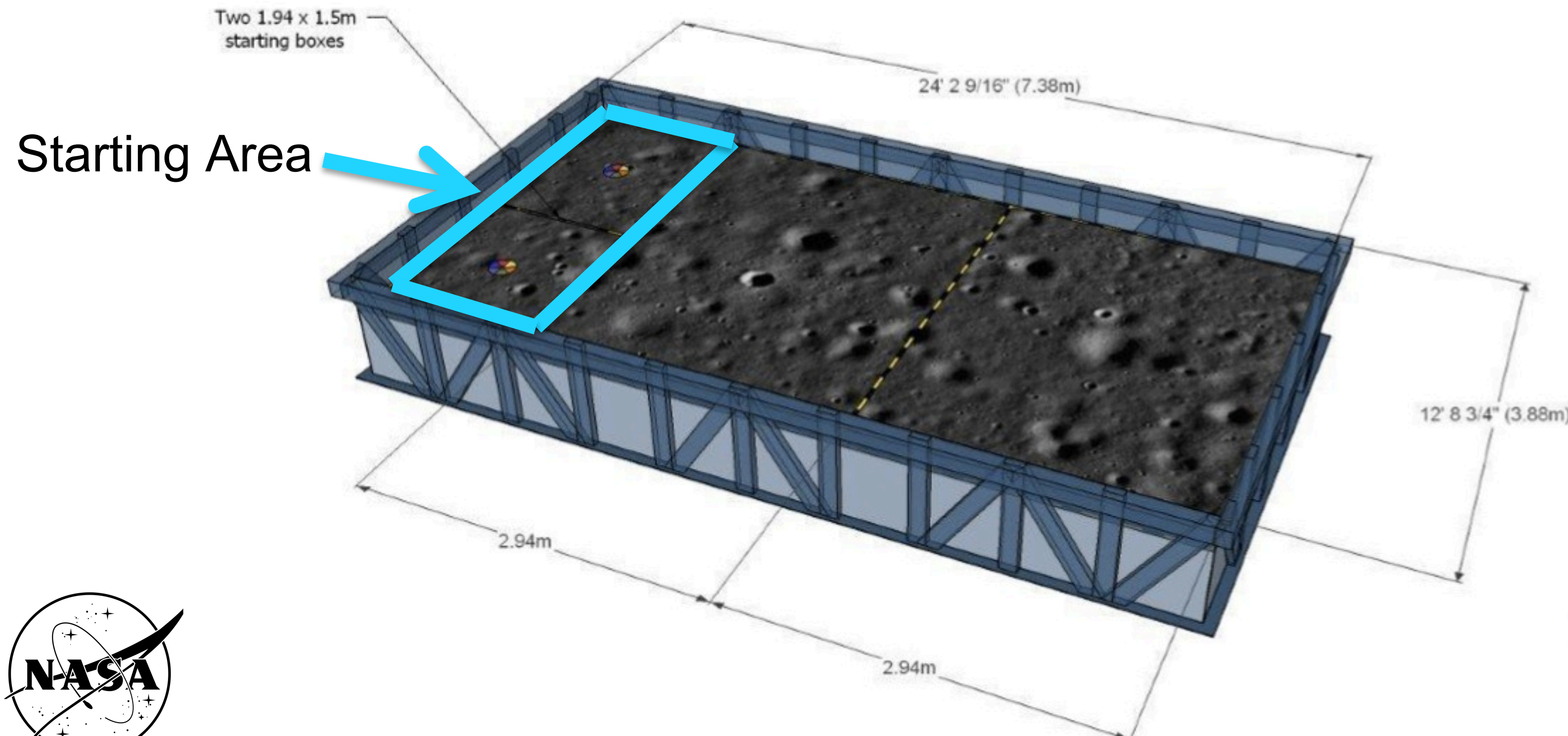
Problem Statement:

- Simulated Lunar Surface
  - BP-1 Soil
  - 7.38 meters by 3.88 meters



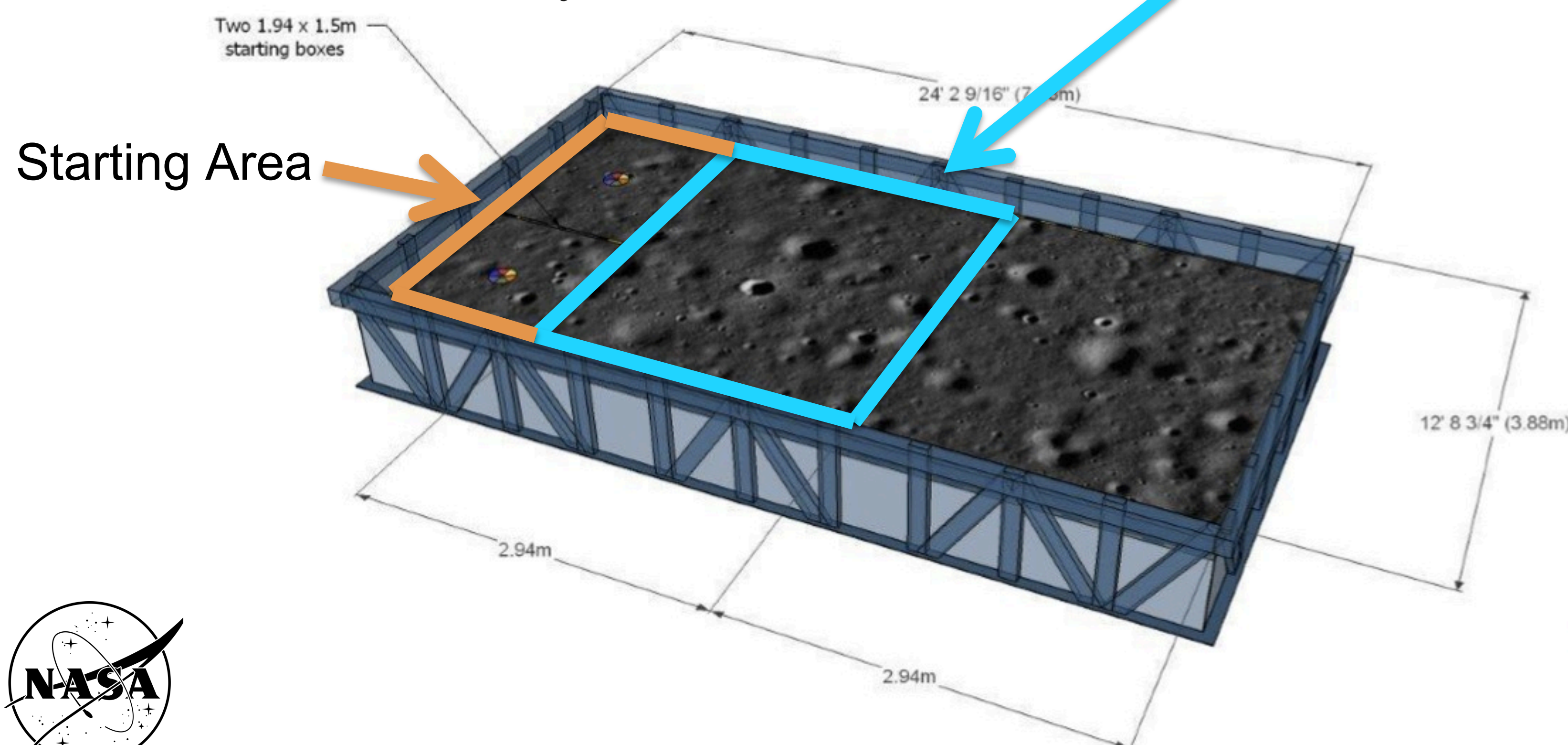
Problem Statement:

- Simulated Lunar Surface
  - BP-1 Soil
  - 7.38 meters by 3.88 meters



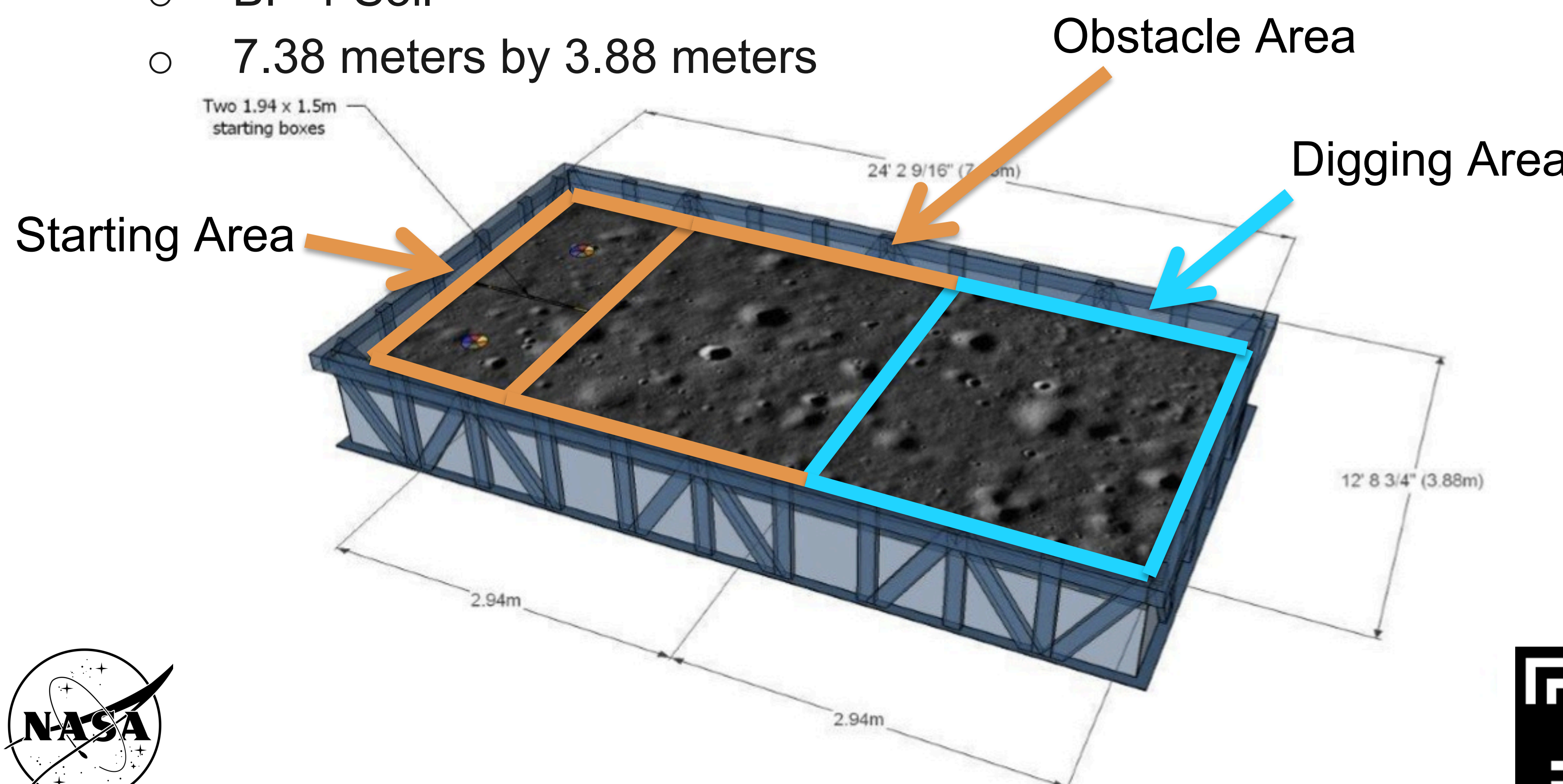
Problem Statement:

- Simulated Lunar Surface
  - BP-1 Soil
  - 7.38 meters by 3.88 meters



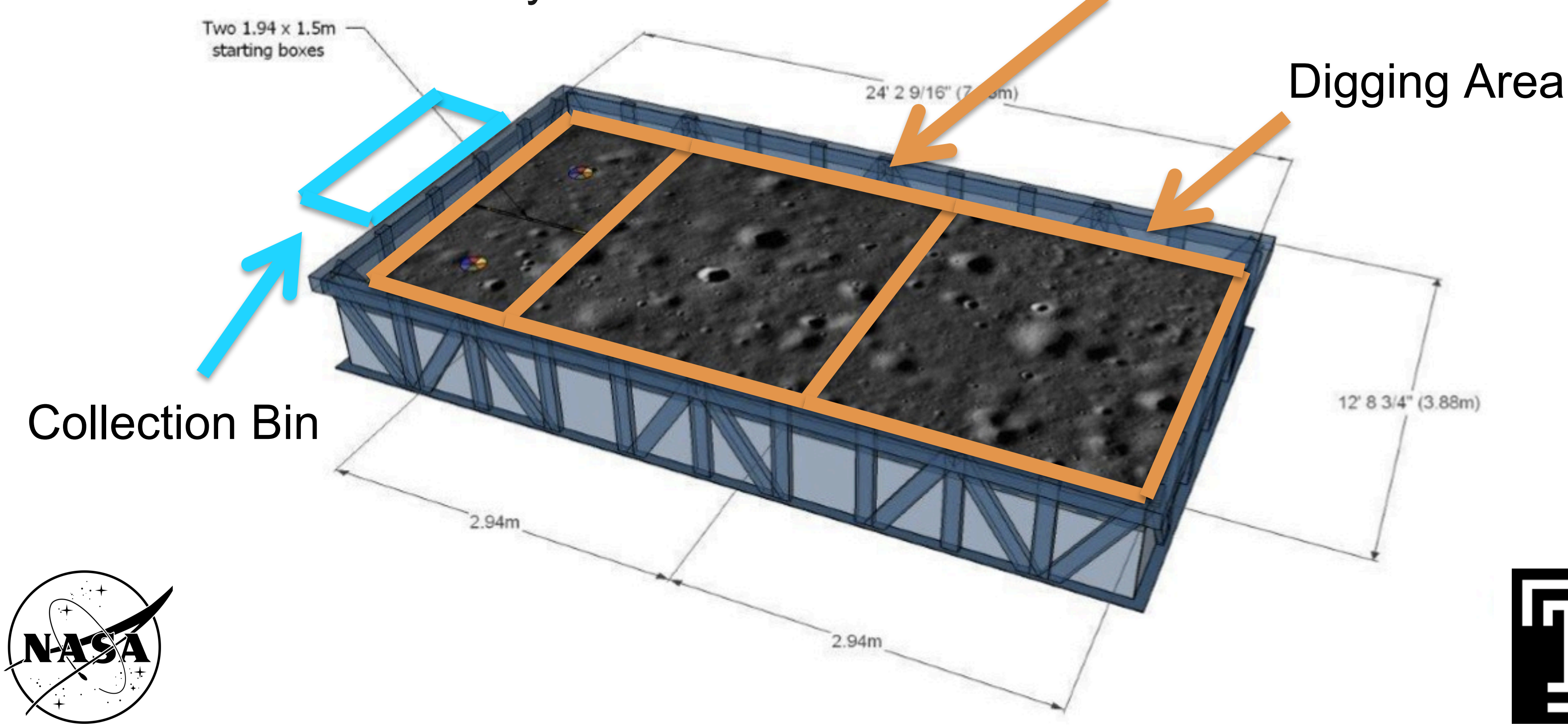
Problem Statement:

- Simulated Lunar Surface
  - BP-1 Soil
  - 7.38 meters by 3.88 meters



Problem Statement:

- Simulated Lunar Surface
  - BP-1 Soil
  - 7.38 meters by 3.88 meters



Problem Statement:

Mining Category Elements	Specific Points	Actual	Units	Mining points
Pass Inspections				1000
BP-1 over 10 kg	+3/kg	110	kg	+300
Average Bandwidth	-1/50kb/sec	5000	kb/sec	-100
Mining Robot Mass	-8/kg	80	kg	-640
Report Energy Consumed	+20	1	1= Achieved 0= Not Achieved	+20
Dust Tolerant Design (30%) & Dust Free Operation (70%)	0 to +100	70	Judges' Decision	+70
Autonomy	50, 150, 250 or 500	150		+150
Total				800

- Competition points awarded on robot mass, mass of mined regolith, average bandwidth, reporting of energy consumption, dust-tolerant design, and autonomous operation
- Goal to earn 800 points or greater

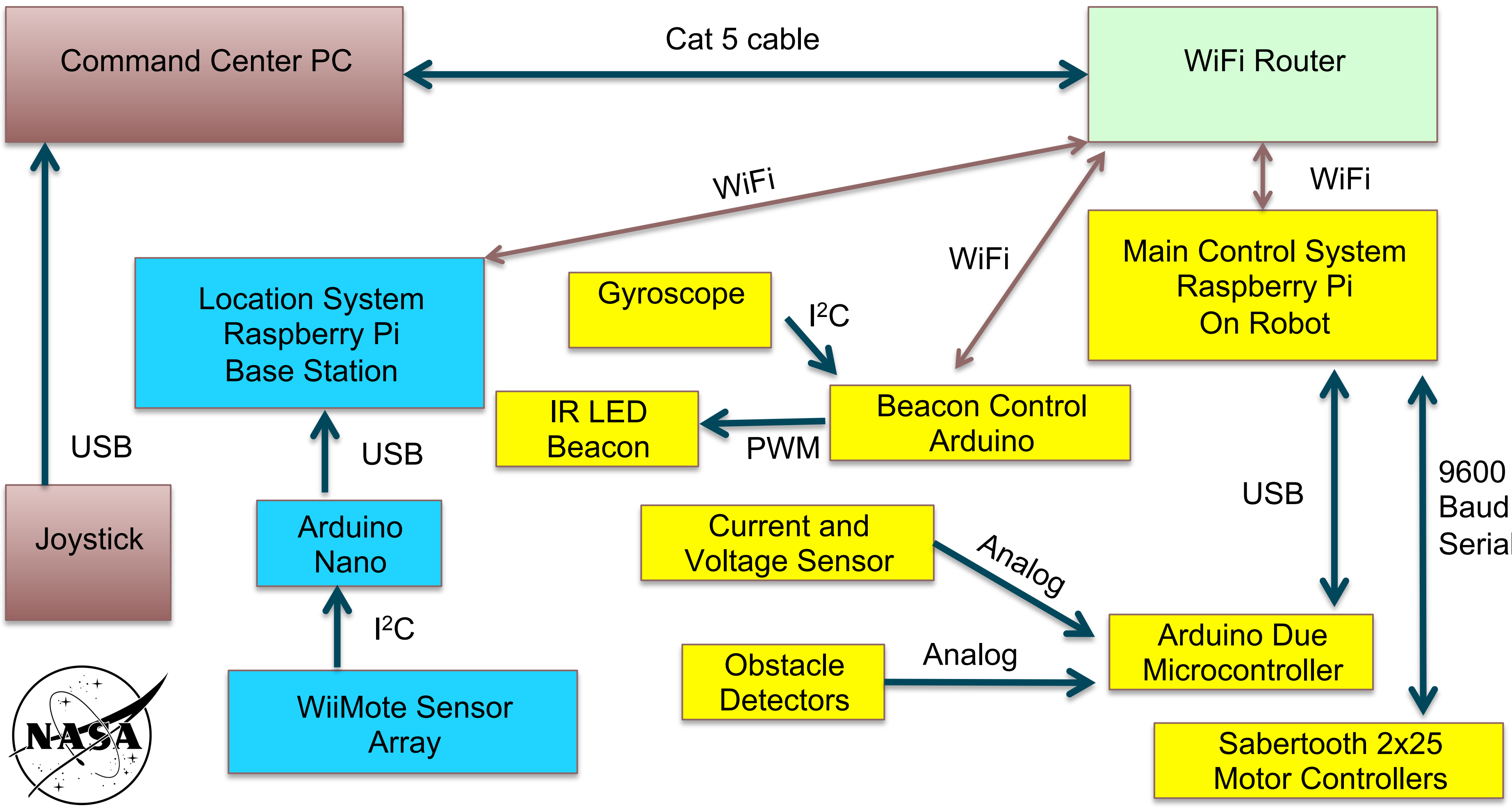
Functional Constraints:

Name	Description
Battery Performance	The Battery system of the robot will be able to supply adequate power to all systems and sub-systems of the robot for a minimum of 30 minutes. Recharging of the battery system should take no more than two hours to complete.
Obstacle Avoidance	Autonomous system shall be able to successfully detect and navigate vehicle around rocks of 30 cm diameter and craters with 30 cm diameter and 30 cm depth.
Speed	The robot must be capable of completing a minimum of 2 complete excavation cycles within a 10-minute competition time.
Size	All components designed by the electrical team must fit into the enclosures provided by the mechanical team. Proper cooling of all electronics must be achieved.
Global Location	The robot must be able to locate itself in the arena without human operator intervention.

Non-Functional Constraints:

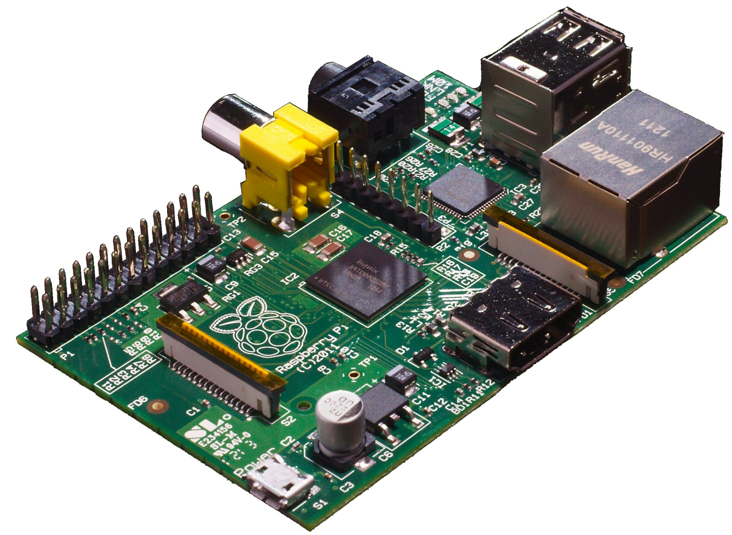
Type	Name	Description
Economic	Cost	The cost for purchasing and assembling parts may not exceed \$5,000
Environmental	Dust Tolerance	All components used for the robot must be able to operate as specified in the harsh, dusty environment of the simulated lunar arena.
Sustainability	Reliability	In order to accept the design, the autonomous system must complete a minimum of 20 simulated 10-minute competition rounds.
Manufacturability	Modularity	All components must be modularly connected with standard components thereby aiding transportation and maintenance.
Health and Safety	Safety	A commercial off-the shelf (COTS) red button must be used as an emergency stop switch. All electrical wiring must conform to NFPA 70 NEC standards.

Approach:


Command Center PC
Cat 5 cable
WiFi Router
WiFi
WiFi
WiFi
Main Control System
Raspberry Pi
On Robot
Location System
Raspberry Pi
Base Station
Gyroscope
I²C
Beacon Control
Arduino
IR LED
Beacon
PWM
USB
USB
Joystick
Arduino
Nano
I²C
WiiMote Sensor
Array
Current and
Voltage Sensor
Analog
Obstacle
Detectors
Analog
Arduino Due
Microcontroller
USB
9600
Baud
Serial
Sabertooth 2x25
Motor Controllers

Approach:

- Main Control System and Location System
  - Raspberry Pi
    - 32-bit ARM-based Linux Computer
    - Raspbian OS
    - 700 MHz clock
    - Oracle Java 7 JDK



Approach: Network

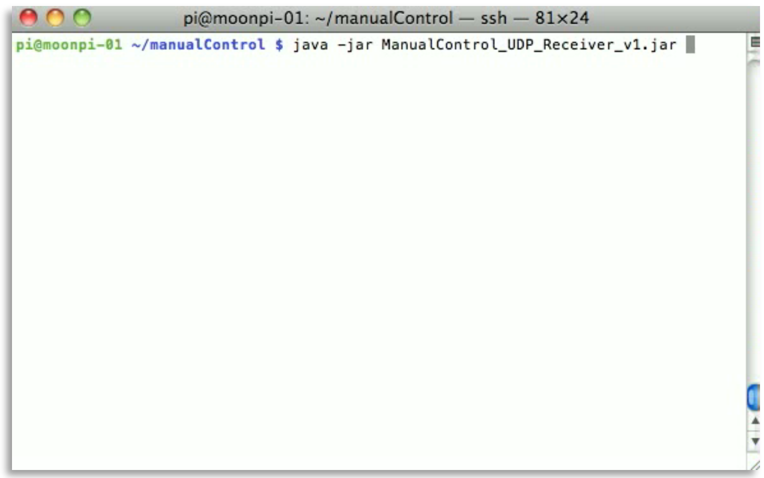
- Command Center to Lunarena
  - IEEE 802.3 100 Base-T Ethernet (5 Mb/s limit)
- Wireless
  - IEEE 802.11 b/g, Channel 1
- Lunarena
  - Main router to robot router: WIFI network bridge
  - Robot router flashed with DD-WRT
  - Antennas extended via coaxial cable to outside of robot

Approach: Network

- Protocols in use
  - UDP
    - Beacon control
    - Manual control
    - Data exchange
  - TCP
    - SSH: remote system control, failure recovery, debug
    - Prototype code for manual control and data exchange

Approach: Network

- Rationale for UDP
  - Connectionless
  - Minimal setup/ maintenance
  - More efficient data transmission than TCP/ IP
  - Implemented basic stop-and-wait mechanism



Approach: Network

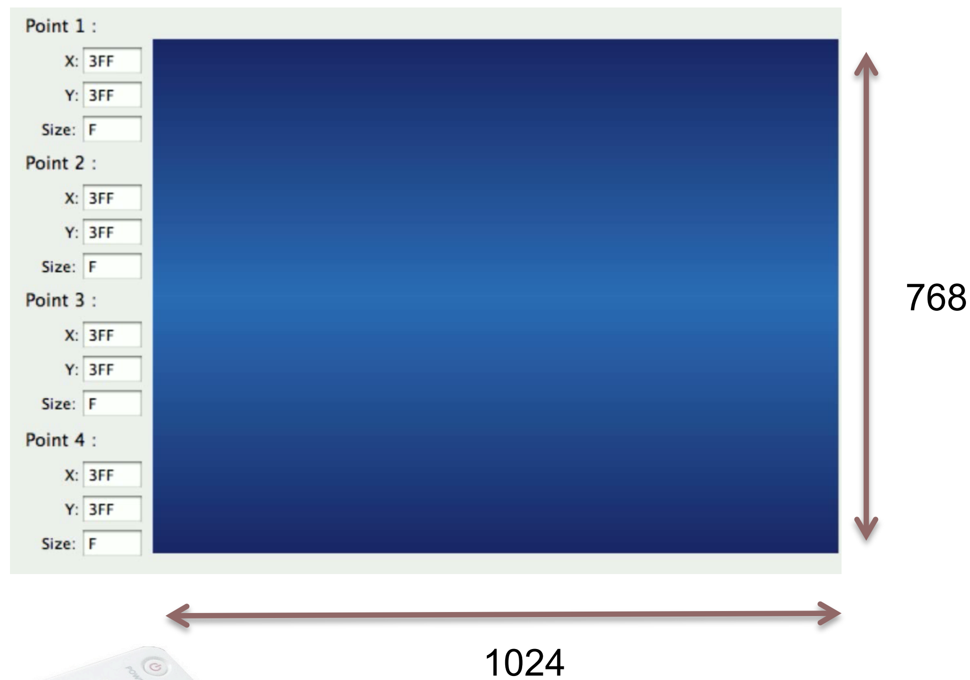
- General Data Format
  - Javastruct Library used
  - Sends C-types in network byte order over the network
  - Easily compatible with virtually all programming languages

Approach:

- Autonomous System
  - Location
    - Use WiiMote system to determine location of vehicle in arena
  - Obstacle Detection
    - Detect obstacles within arena
  - Navigation
    - Use A-star algorithm to compute path
    - Use Bresenham’s Line Algorithm to simplify path
  - Actuator Control
    - Control motor systems to drive vehicle

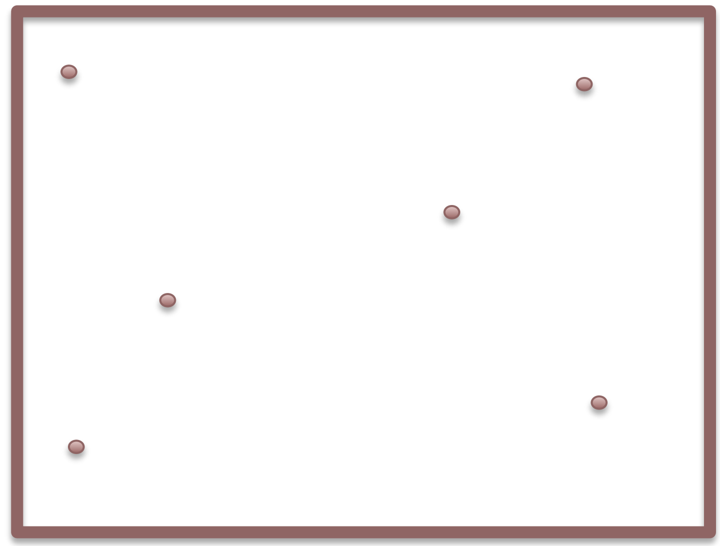
Approach:

- WiiMote Location System
  - I^2C communication
  - 100 frames / second
  - 1024 x 768
  - Reports angle at which IR LED beacon on robot is seen



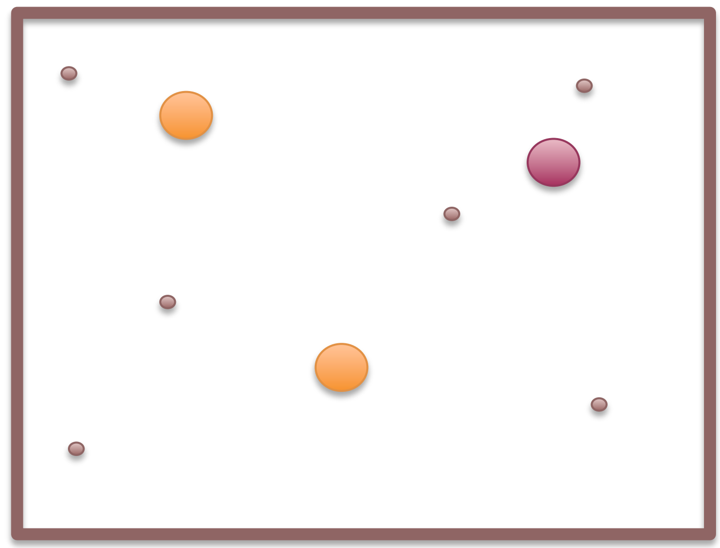
Approach:

- WiiMote Data Particle Filter
    1. Randomly distribute 100 particles in viewable area of wiimote



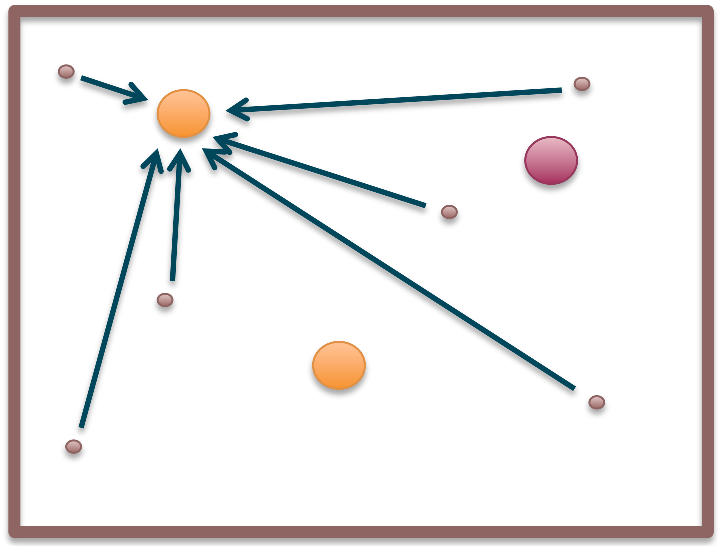
Approach:

- WiiMote Data Particle Filter
  2. Turn beacon on and sample data



Approach:

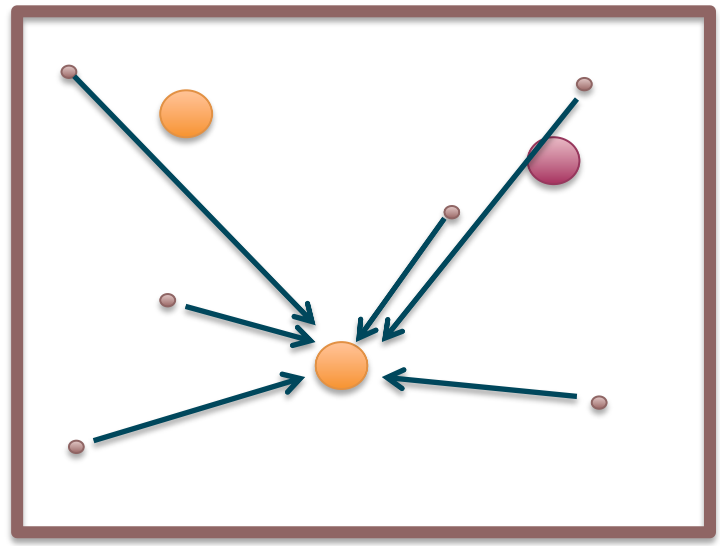
- WiiMote Data Particle Filter
  3. Sum up the distances to each IR Blob for every particle



Particle Score = $d_1 + d_2 + d_3$

Approach:

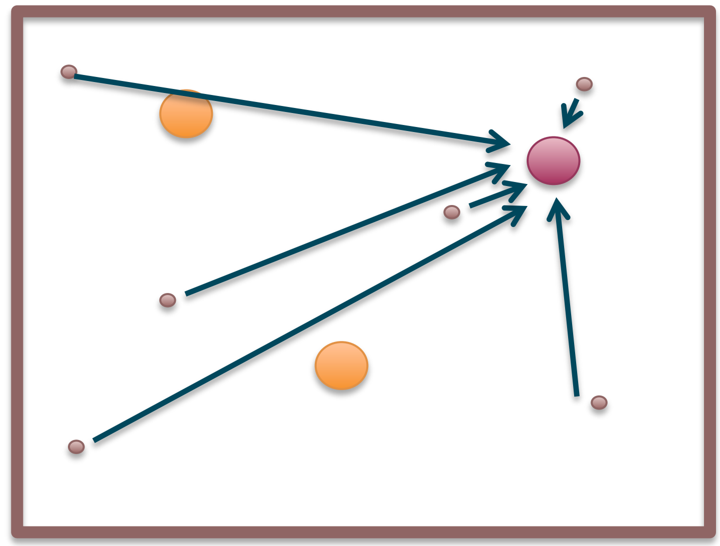
- WiiMote Data Particle Filter
  3. Sum up the distances to each IR Blob for every particle



Particle Score = $d_1 + d_2 + d_3$

Approach:

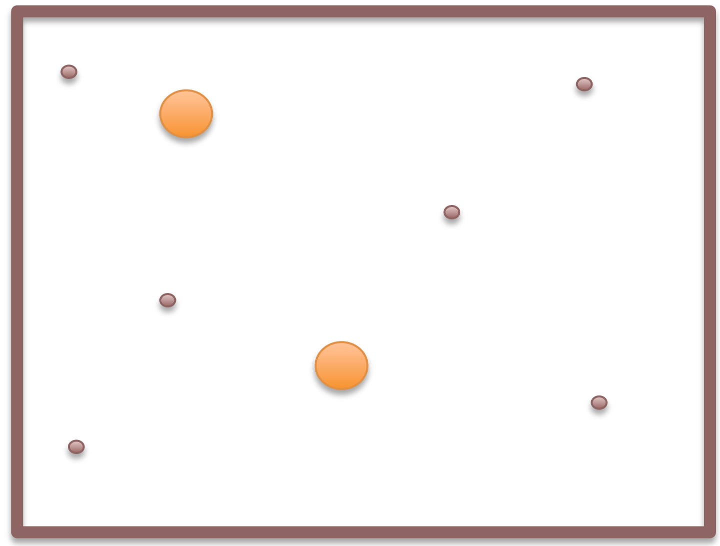
- WiiMote Data Particle Filter
  3. Sum up the distances to each IR Blob for every particle



Particle Score = $d_1 + d_2 + d_3$

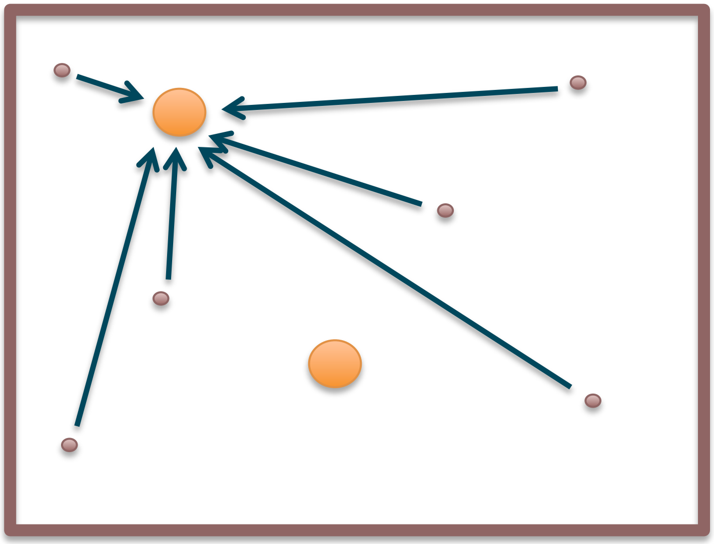
Approach:

- WiiMote Data Particle Filter
    4. Turn beacon off and sample data again



Approach:

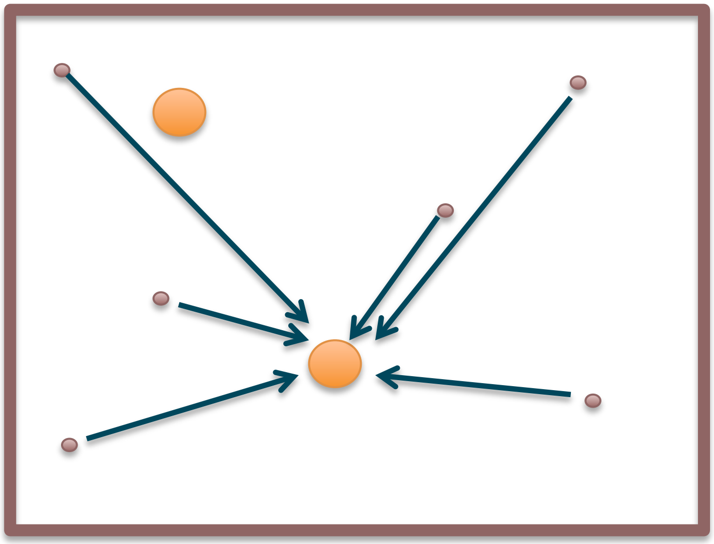
- WiiMote Data Particle Filter
  5. Subtract the distances to each IR blob for every particle



Particle Score = (old particle score) - d_1 - d_2

Approach:

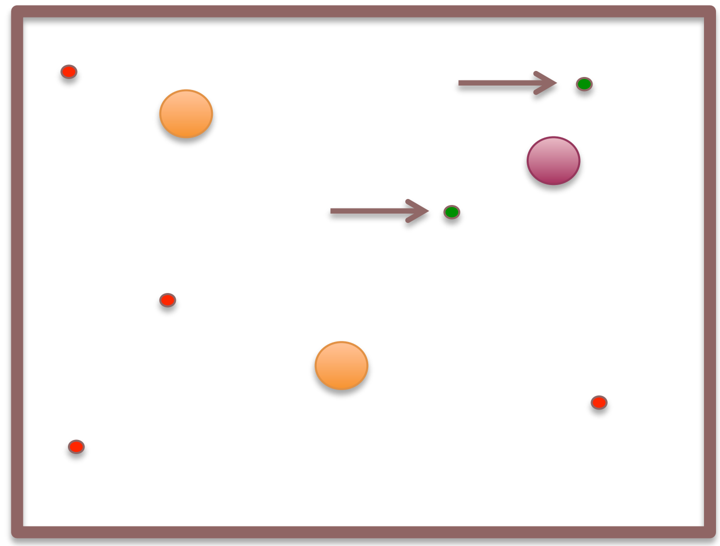
- WiiMote Data Particle Filter
  5. Subtract the distances to each IR blob for every particle



Particle Score = (old particle score) - d_1 - d_2

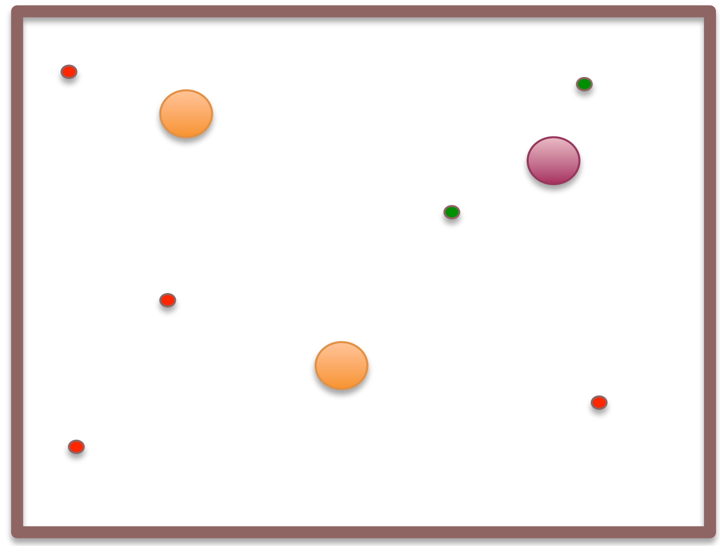
Approach:

- WiiMote Data Particle Filter
  6. Identify the 40 particles with the 40 lowest scores. Keep these particles for next iteration



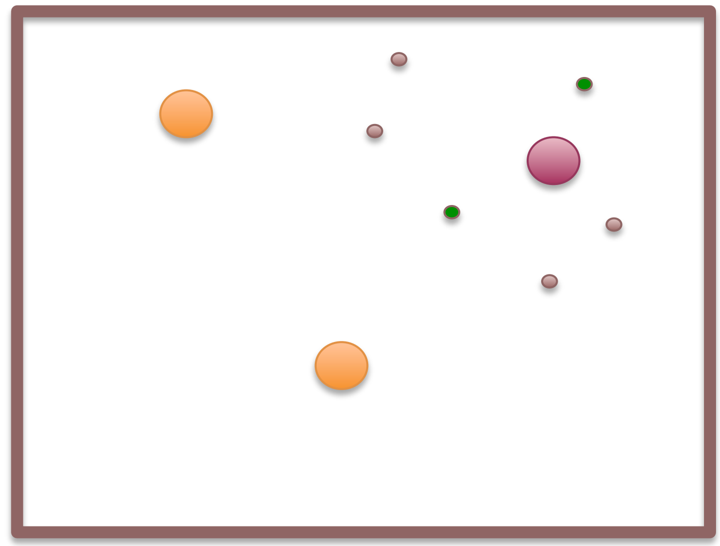
Approach:

- WiiMote Data Particle Filter
    7. Regenerate 60 other particles closer to the good particles.

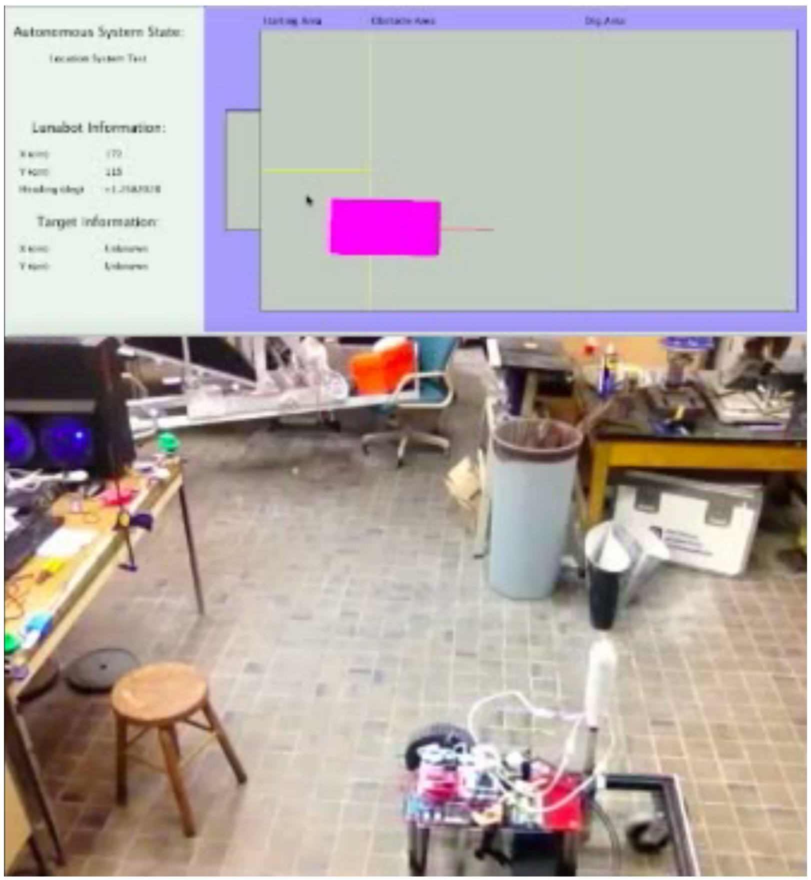


Approach:

- WiiMote Data Particle Filter
  7. Regenerate 60 other particles closer to the good particles.
  8. Repeat the algorithm



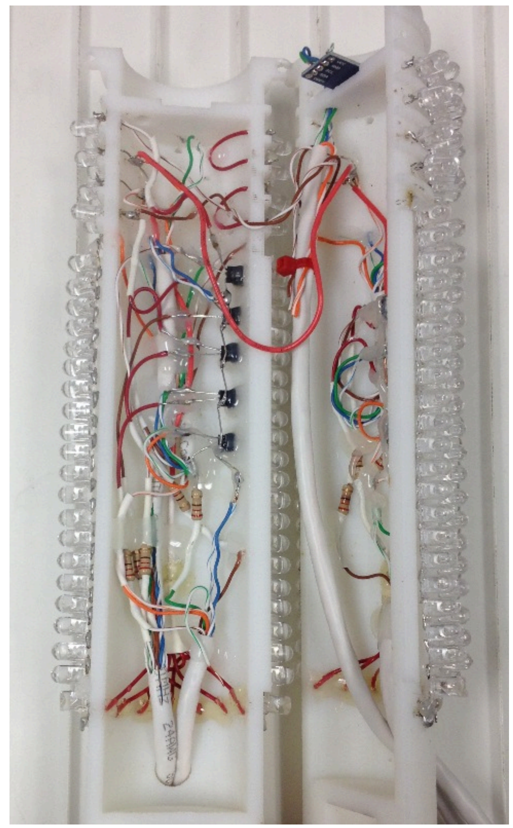
Final Design:

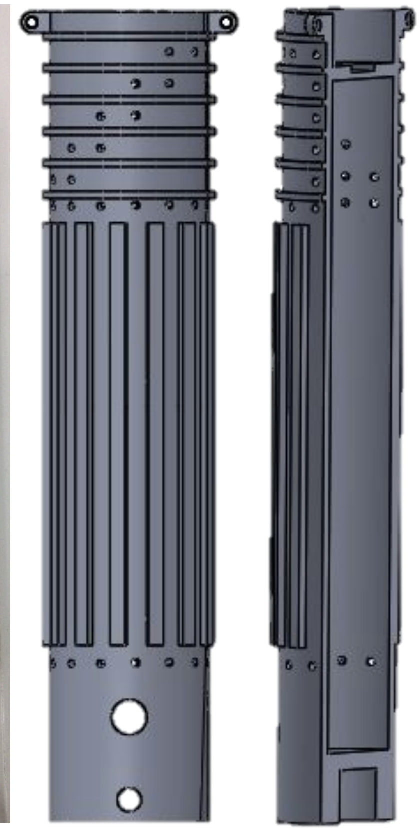


- WiiMote Location System Final Design
  - Programmed in Java for code portability
  - WiiMote IR Sensors mounted on Parallax Standard Servos

Final Design:

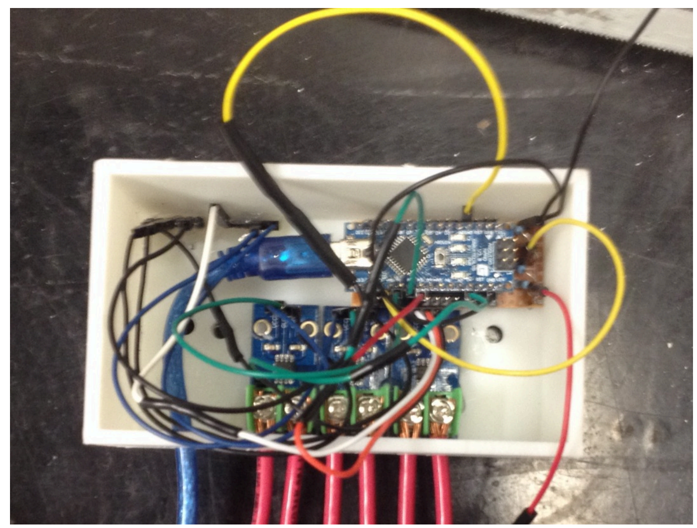
- Beacon
  - 3D Printed
  - Designed for Repair and Manufacturing
  - 362 IR LEDs (940 nm)
  - 16 Red Visible-Light LEDs





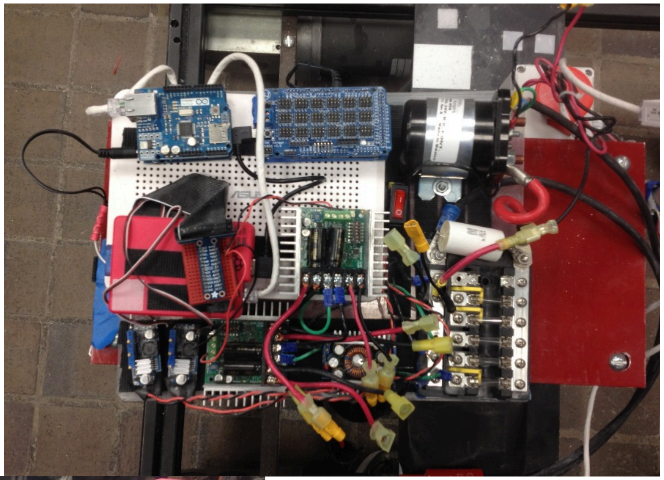
Final Design:

- Power Measurement System
  - 3 Current Sensors
    - Main drive motors
    - Collection and Dump motors
    - Control system
  - LCD Display showing live power consumption
  - Power Consumption Data logged to Java Program



Final Design:

- Electrical Box
  - Modular design
  - 2 Motor controllers
  - 3 Buck converters
    - 12V control
    - 12V motor controller
    - 5V control
  - Fuses for protection
  - 24V relay connected to emergency stop



Cost Analysis:

Item	Quantity	Unit Price ($)	Total Price ($)
25.9V 40Ah LiPo Battery	2	1,434.95	2,869.90
Current Sensor	3	7.00	21.00
Gyroscope	1	34.99	34.99
IR LEDs (LTE-5208A)	500	0.16560	82.80
RocketBrand WiiMote Sensor	4	~ 40.00	~160.00
Raspberry Pi	2	42.00	84.00
IR Range Sensors	8	14.95	119.60
Parallax Standard Servo	2	12.99	25.98
Arduino Due	1	49.95	49.95
Motor Controllers	2	124.99	249.98
Arduino Nano	3	10.00	30.00
WiFi Router	2	82.99	165.98
Wiring and Lab Supplies	1	256.99	256.99
		Total:	**4,151.17**

Next Steps:

- Schedule:
  - May 4, 2014 – May 17, 2014
    - Final testing of design
  - May 17, 2014
    - Leave Temple University for Kennedy Space Center
  - May 19, 2014 – May 23, 2014
    - Competition

Acknowledgements:

- Dr. John Helferty
- Dr. Shriram Pillapakkam
- Temple Lunabotics Mechanical Team
- George Gower (Refractory Minerals Co.)
- Chris Yatsco (Triumph Engineering Group)
- Rhett Hockenbury
- All Student Space Lab Participants

References:

Cowen, R. (2006). Lunar outpost: NASA unveils plans for a return to the moon. *Science News, 170*(24), 373-373. doi: 10.2307/4017381

DiGiuseppe, M., Pirich, R., & Kraut, V. (2009). Lunar regolith control and resource utilization. Paper presented at the *Systems, Applications and Technology Conference, 2009. LISAT '09. IEEE Long Island,* 1-5. doi:10.1109/LISAT.2009.5031560

Hua Han, Yongsheng Ding, & Kuangrong Hao. (2010). A new immune particle filter algorithm for tracking a moving target. Paper presented at the *Natural Computation (ICNC), 2010 Sixth International Conference on, , 6* 3248-3252. doi:10.1109/ICNC.2010.5582619

Jansma, P. A., & Means, E. K. (2012). Developing the NASA systems engineering body of knowledge. Paper presented at the *Aerospace Conference, 2012 IEEE,* 1-17. doi:10.1109/AERO.2012.6187426

Neale, A. M., Mare, J., Chiappero, J., & Makopo, M. W. (2012). Capabilities required to apply lunar regolith excavators terrestrially. Paper presented at the *Robotics and Mechatronics Conference of South Africa (ROBOMECH), 2012 5th,* 1-5. doi:10.1109/ROBOMECH.2012.6558454

Petrič, T., Gams, A., Ude, A., & Žlajpah, L. (2010). Real-time 3D marker tracking with a WIIMOTE stereo vision system: Application to robotic throwing. Paper presented at the *Robotics in Alpe-Adria-Danube Region (RAAD), 2010 IEEE 19th International Workshop on,* 357-362. doi:10.1109/RAAD.2010.5524560

Rhaman, M. K., Hasan, S. I., Hossain, M. J., Anik, K. M. R., Oyon, M. H., Bhuian, B. H., & Rahman, M. M. (2012). A simple tele-robotic lunar excavator. Paper presented at the *Advanced Computer Science Applications and Technologies (ACSAT), 2012 International Conference on,* 31-36. doi:10.1109/ACSAT.2012.99

Schwandt, C., Hamilton, J. A., Fray, D. J., & Crawford, I. A. (2012). The production of oxygen and metal from lunar regolith. *Planetary and Space Science, 74*(1), 49-56. doi:http://dx.doi.org/10.1016/j.pss.2012.06.011

QUESTIONS?