Product Specification and Project Plan

Team 11 – NASA/RASC-AL Robo-Ops

EMEL4551 – Senior Design - Fall

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1.0 Introduction

The objective of this project is to design and build a robot that can traverse terrain similar to that found on the moon and Mars. The robot must have an appendage capable of picking up rocks and a place to store the rocks. All control of the robot during the competition must be done remotely from the campus of the university, with the competition itself taking place at the NASA Johnson Space Center in Houston, Texas.

We will build upon efforts of past years' senior design teams which designed and built a hexapedal robot for the purpose of competing in the NASA Lunabotics competition. The intent of this project is to build an entirely new robotic platform for our competition. However, if we are not selected for the competition (only 8 teams are selected), our contingency plan is to adapt the existing robotic platform to the requirements of this competition and perform a mock run of the competition before the end of spring semester, paving the way for a team to build upon our efforts and make an even stronger case for entry into the competition next year.

2.0 Product Specification

Competition Requirements:

Maximum Weight:	45kg
Maximum Dimensions:	1m x 1m x 0.5m
Storage Capacity:	5 Rocks (minimum), 30 Rocks (maximum)
Claw/Arm payload	2-8 cm diameter rocks, 30-150 grams each
Ground Clearance:	10 cm (minimum)
Terrain:	33% maximum up/down slope, flat sand for 20 ft.
Environment:	Light rain, high ambient temperatures
Battery Life:	1 hour minimum
Control:	3G/4G wireless control from a distance of ~700 miles
Video Quality:	Must be able to distinguish between 6 colors
Video Streaming:	Video must be viewable by outside parties on web
Power Source:	No internal-combustion engines

Repair: One ten minute repair window during the competition

Desired Outcomes

There are two possible sets of project outcomes, which occurs is contingent upon selection of this design to compete by the competition steering committee.

Case 1 – Selected for the competition

If the project is selected to be one of the 8 competing teams, the desired outcomes will be as follows:

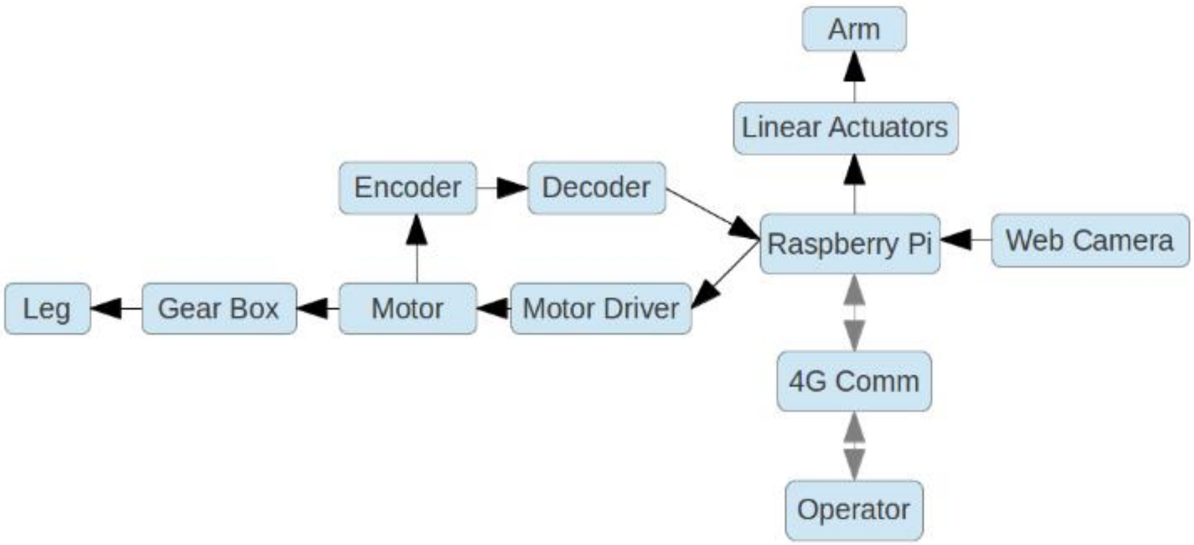
1. Design and construction of a walking, remote controlled hexapedal robot with video streaming capability and an appendage for picking up rocks as per the competition guidelines.
2. Participation in the competition, expectations will be set in regards to the robot's performance as there are too many uncontrollable factors.

Case 2 – Not selected for the competition

In the event that the project is not one of the 8 teams selected, our desired outcomes will shift as follows:

1. Implementation of a robotic appendage, vision system and remote telecommunications system on the existing hexapedal platform developed for last years' NASA Lunabotics competition.
2. Completion of a "mock competition" using this adapted robotic platform that will represent the actual competition as closely as possible.
3. Emphasis will be placed on fully documenting all systems so that a team can re-attempt entry into the competition next year armed with the lessons that are learned during this project.

3.0 Functional Diagram



The center of the functional diagram is the Raspberry Pi, which is a small credit card-sized Linux based computer. It is responsible for handling all 4g communications and streaming a web cam feed. The Raspberry Pi will control the motor drivers and read the current motor position through general purpose IO pins available on board. The decoder – motor driver loop is used to run the Buehler Clock (variable leg speed algorithm) as our control algorithm depends highly on motor position and timing. The Raspberry Pi will also control the linear actuators that move the robotic arm.

4.0 Project Budget

Category	Description	Vendor	Part Number	QTY	Cost	Total	Will be Purchased	Additional Needed
Motor	Drive Motors for Legs and Arm	Maxon Motors	218011	10	$496.25	$4,962.50	1	$4,962.50
	Gearbox	Maxon Motors	203124	8	$359.75	$2,878.00	1	$2,878.00
	Encoder	Maxon Motors	110512	10	$131.50	$1,315.00	1	$1,315.00
Batteries	36 Volt LiPo Battery			2		$0.00	0	$0.00
Electronics	Motor controller			1	$600.00	$600.00	0	$0.00
	Sensors (Camera, Infrared, Accelerometer, etc.)			1	$600.00	$600.00	1	$600.00
	Sharx Security Wireless Camera	Sharx Security	SCNC2606	1	$199.95	$199.95	1	$199.95
	High Current Motor Drivers			10	$200.00	$2,000.00	Need only 4 more	$800.00
	4G LTE Mobile Hotspot	Verizon	4620L	1	$269.99	$269.99	1	$269.99
	4g Monthly Plan	Verizon		9	$60.00	$540.00	1	$540.00
	Voltage Regulators			3	$25.00	$75.00	0	$0.00
	Miscellaneous Wires and Connectors			1	$200.00	$200.00	1	$200.00
Arm/Grabber	Linear Actuator (12")	McMaster Carr	6530K118	1	$422.56	$422.56	0	$0.00
	Miscellaneous (Gears, Hardware, etc.)			1	$500.00	$500.00	1	$500.00
Raw Materials	Aluminum (For Arm, Mounts, etc.)			1	$400.00	$400.00	1	$400.00
	ABS Plastic			1	$200.00	$200.00	1	$200.00
	Aluminum Square Tubing (3/4" x 3/4" x 45 ft)	McMaster Carr	88875K31	9	$13.15	$118.35	1	$118.35
	Hardware (Screws, Bolts, etc.)			1	$200.00	$200.00	1	$200.00
	Carbon Fiber			1	$500.00	$500.00	1	$500.00
Outreach	Lego Mind Storm	Lego	8547	2	$279.99	$559.98	1	$559.98
					Totals	$16,541.33		$14,243.77

The approximate expected budget for this project is $14,244. A portion of this amount is expected to be supplied by The Florida Space Grant Consortium in an amount of up to $4,000. Due to recent budget cuts within The Florida Space Grand Consortium, the team has yet to be notified of an exact amount. The team is also currently seeking industry sponsors who will donate in the form of monetary or materials contributions. A portion of the items needed for this project will be reused from the previous year's Lunabotics Competition project. The detailed preliminary budget is detailed above. The column labeled "Additional Needed" indicates additional costs.

5.0 Project Structure

The next several sections will detail the various phases of our fall semester project plan.

5.1 Planning and Research

Team Planning and Role Establishment

Early in the project, the team established three weekly meeting times. The frequent meetings ensure the team continues to move forward while having little to no down time between project phases. Team member roles were established in a code of conduct which was signed by all team members. The code of conduct allows each team member to know their duties as well as serving as a guideline for harmonic team collaboration.

Competition and Prior Work Research

The governing rules and guidelines for the competition were researched intensively as they will restrict the design of the robotic platform. Due to the guidelines of the competition, it was decided that the robot "Hexcavator" cannot be readily adapted to meet the specifications needed due to weight and size constraints. The hexapedal walking robotic platform concept used by the previous year's team suits the needs for the competition and will solve obstacle avoidance issues that may arise. Based on the hexapedal design, a preliminary budget was compiled and a funding proposal has been drafted and will be presented to prospective industry sponsors.

Project Planning

A preliminary project schedule has been created to serve as a guideline for completing individual portions of the project in a timely manner. The team will abide by the schedule as closely as possible to avoid delays in progress.

Telecommunications Research

A major concern for the project is developing the telecommunications to communicate with the robot. Various methods of implementation of telecommunication on the robot are being researched to ensure the least time intensive and most reliable method is selected. Correspondences with the competition steering committee have led to information as to which methods of communication are acceptable.

Outreach Planning

Community outreach is a large part of the score for the competition. Throughout this semester, the team will be planning events aimed to get the community and grade school children excited about the field of space and planetary exploration as well as STEM education (Science, Technology, Engineering, and Mathematics). Planning participating in events such as demonstrations at the Challenger Learning Center volunteering to work on educational programs with local elementary and middle schools will be the focus of the team's community outreach this semester.

5.2 Concept Generation and Design Selection

Concept generation and selection – Locomotion Method

At the onset of the project, an early decision had to be as to whether our robot would build upon the leg driven design of past years or if we would switch to a more traditional wheeled configuration. The primary criteria for this decision was originality because only 8 teams are selected for the competition and a design which stands out is likely to stick in the minds of the steering committee members. Because this decision has already been made, the table below is included and outlines our comparison between a wheeled and legged design.

Criteria	Wheeled Robot	Legged Robot
Originality		++
Speed		+
Prior Work		+
Weight	+	
Complexity	+	
Traction		+
Clearance		+
Stability	+	
TOTAL	**3**	**6**

Table 1 - Relative comparison between legged and wheeled robots

Concept generation and selection – Robotic Arm and Claw

This phase is underway and involves generating several concepts for an end effector that will allow our robot to pick up rocks and move them to a storage bin on board. Several designs have been proposed and rough prototypes are currently being built to help gage their feasibility and effectiveness. Weighted criteria have been established and will be used to objectively judge the merit of each design and aid in selection. The details of these designs and our selection process will be outlined in the next deliverable and presentation.

Concept generation and selection – Vision System

This phase has also begun and involves selecting the camera(s) to be used, detailing their placement, and deciding if an extendable boom is needed to extend the robot's range of vision. Design and selection of a vision system will be performed based on qualitative evaluation methods, hardware cost, and testing; further details will be given in the next deliverable.

5.3 Vision and Telecommunication Development

Select Telecommunications Hardware

The robot must be controlled via the 3G or 4G network offered by any of the major wireless providers such as Verizon or AT&T. Wireless data plan pricing and flexibility with the project schedule will decide the carrier chosen but it is noted that Verizon is recommended in competition documentation. Connection to the carrier's network will require a device, such as a mobile hotspot or a USB modem, which will allow some computer on the robot to receive instructions from the user. A mobile hotspot would not require any extra hardware on the robot since it is already WiFi enabled; on the other hand, the USB modem may require additional hardware for interface with the main microcontroller. In any case, the device will need data rates fast enough to handle streaming video live to the user.

Select Vision System Hardware

Vision systems play a significant role in the successful control of the robot since it will be the controller's only eyes on the ground. A camera is the obvious choice for this system. Video recorded by the camera will need to be compressed and encoded prior to transmission. Many cameras on the market, mainly those used for security purposes, are suited for this purpose with little work required on image processing. Another solution would be to have a webcam with an onboard computer to perform then encoding. The group would need to make sure that the computer operating system could interface with the webcam (i.e. drivers are available for the operating system). Either solution will require the main focus to be on the actual streaming of the video. This will require a web server of any live stream website or of the groups' own setup.

Select Software Platform

A user interface that gives direct access to the robot's controller and video is desirable. Whatever software interface chosen should be able to send commands to the robot and receive information from the sensors that are on the robot; possibly including the video stream.

5.4 Design of New Robotic Platform

Size Robot

The sizing of the robot will be based off of the aspect ratio of a hexapedal robot (XRL) that STRIDe lab is currently utilizing. This model is known to work and can run at speeds greater than those required by our group despite its smaller size. In order to clear obstacles greater than 10 centimeters, it will be necessary to scale up the platform. This will also allow for the frame to be large enough to enclose the motors and other electronics to protect them from contaminants.

Image I: XRL hexapedal robot, created by University of Pennsylvania and STRIDe Lab

Select Motors

The motors will be decided upon once the final weight of the robot can be accurately approximated. Using XRL as a basis, we will use continuous output torque to weight ratio for the existing platform and apply it to our new platform.

Materials Selection

Since our competition has a maximum weight regulation, material selection will have to be a careful process. Our group will have to try to use as little material as possible and run finite element analysis to ensure that the proper thickness material is used and we do not have extremely large or too small of a factor of safety for any given component.

Dynamic Modeling

Currently, all dynamic modeling is research-based. The plan is to review the functionality and control of the inherited platform and asses the problems encountered to generate viable solutions. Also, research will be conducted to investigate research and development on the XRL platform to aid in updating the inherited platform with sound control schemes.

Detailed Design of robotic arm and claw

This process entails generating concepts and prototypes to determine their effectiveness and efficiency. As gathering rocks is a major source of points for our assessment from the competition, this process has to be well thought out so that it will be reliable and allow the team to pick up as many rocks as possible. Once the prototypes are generated and tested, the team will use a decision matrix to select the best method for the competition.

Component Layout

The goal of the component layout design is to enclose all electrical components into the frame. This will aid in keeping a lower center of gravity as well as protecting them from the elements of the test arena. Due the team's decision to use a walking robot, the legs may throw sand and gravel during the robot's running motions.

Packaging

Compact packaging the robot is also a constraint of the competition guidelines. The robot has to start in a configuration no larger than 1 meter wide by 1 meter long by .5 meters high. This means the frame, legs, arm mechanism and rock storage bin have to be able to compactly store away. Arm storage also factors in the robot's stability while running. All of this will be tested on the prototype platform as well as in CAD software.

Complete CAD Model Package

To get a better idea of how all parts of the project will come together, one CAD model will be made and all major components of the robot will be included. This will help with determining key dimensions of the platform such as the weight, packaging constraints and will aid in accurate simulations.

5.5 Project Deliverables

Deliverables for EML 4551

The following reports are currently due for the Fall 2012 semester Senior Design Class. The Code of Conduct was due on September 20, 2012. It outlined the organization and function of our team, detailing the responsibilities of specific roles within our group. The Needs Assessment was due September 27, 2012, and outlined the requirements for the project as specified by the primary customer/sponsor. We are required to submit Bi-Weekly Progress Reports at every staff meeting outlining accomplishments and milestones achieved over a two week period that spans the time between meetings. The Project Plan/Product Specs report is due October 11, 2012, and is a plan of action for the project for the Fall 2012 semester. It also details measurable specifications for the product. A Team Evaluation report is due November 1, 2012. An Interim Design Review discussing changes made to the product design since last defining the product specifications is due November 13, 2012. Lastly, a Final Deliverable Package is due December 4, 2012 detailing the finalized product concept with CAD images of components, schematics of systems, and a plan of action for constructing, testing and implementing the product.

Deliverables for RASC-AL Robo-Ops Competition

Two major reports are due for the RASC-AL Robo-Ops Competition. A Project Plan Proposal is due December 9, 2012, and will determine whether or not the team will be one of eight teams selected to participate in the competition and receive a $10,000 grant from NASA to complete the project. The project plan must outline the proposed system's ability to meet the competition requirements, the capabilities and experience of team members, and the physical and functional qualities of the proposed rover. If our team is selected to participate in the competition and be awarded the grant money from NASA, a Mid-Project Review must be submitted by March 15, 2012. Teams are given half of the NASA grant money upon being selected. The second half is allotted to teams after submitting a two part report that demonstrates rover functionality. The first part is a video demonstrating the rover's functional and communicative systems. The second part is a two to five page written document that describes development progress, and confidence in completing by the 2013 Robo-Ops Competition.

6.0 Project Schedule

The major fall-semester project components outlined in the previous section will be performed over a 16-week period defined as follows:

	Start	End
Week 1	**8/26**	**9/1**
Week 2	**9/2**	**9/8**
Week 3	**9/9**	**9/15**
Week 4	**9/16**	**9/22**
Week 5	**9/23**	**9/29**
Week 6	**9/30**	**10/6**
Week 7	**10/7**	**10/13**
Week 8	**10/14**	**10/20**
Week 9	**10/21**	**10/27**
Week 10	**10/28**	**11/3**
Week 11	**11/4**	**11/10**
Week 12	**11/11**	**11/17**
Week 13	**11/18**	**11/24**
Week 14	**11/25**	**12/1**
Week 15	**12/2**	**12/8**
Week 16	**12/9**	**12/15**

6.1 Gantt Chart

	Fall Semester																		
Project Phase		September					October				November				December				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Planning and Research																			
Establish meeting schedule																			
Establish team member roles, code of conduct																			
Research competition rules, previous work																			
Develop preliminary project budget																			
Develop preliminary project schedule																			
Telecommunications research																			
Plan community outreach efforts																			
Concept Generation and Design Selection Phase																			
Selection of locomotion method																			
Concept generation for robotic arm and claw																			
Selection of telecommunications system																			
Design selection for robotic arm and claw																			
Concept generation for vision system																			
Design selection for vision system																			
Control Development on Existing Robotic Platform																			
Single motor control with Buehler Clock																			
Multiple motor control with Buehler Clock																			
Establish locomotion with wired control																			
Establish locomotion with wireless control																			
Vision and Telecommunications System Development																			
Establish BOM for telecommunications system																			
Establish BOM for vision system																			
Select software platform for telecomm interface																			

	Fall Semester			
Project Phase	September	October	November	December
Design of New Robotic Platform				
Size robot (aspect ratio, frame dimensions)				
Select motors				
Materials Selection				
Dynamic modeling				
Detailed design of robotic arm and claw				
Component Layout				
Packaging (Stowed/Un-stowed)				
Complete Cad model package				
Project Deliverables				
Code of Conduct				
Needs Assessment				
Product Spec and Project Plan				
Conceptual design review and presentation				
Team evaluation report				
Interim design review presentation and report				
Final design review presentation and report				
Submit project proposal to competition hosts				