FLORIDA A&M UNIVERSITY - FLORIDA STATE UNIVERSITY
COLLEGE OF ENGINEERING

Team 11 – NASA/RASC-AL Robo-Ops

FAMU/FSU College of Engineering

Department of Mechanical Engineering

Deliverable #2 – Project Plan and Product Specifications

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1.0 Introduction

The objective of this project is to build an innovative rover design capable of competing in the 2014 Robo-Ops competition. The robot must be capable of traversing environments similar to those on Mars, it must be teleoperated using wireless communications, and it must be able to selectively pick up brightly colored rocks using an extraction unit.

Our team's goal is to build two smaller rovers, each capable of collecting rock samples. Every team that has competed in the past has used one large robot to collect the samples, mainly because these teams all used wheels and need the large wheel to overcome the obstacles on the environment. Our design would build on the work of last year's platform, which used 6 legs to overcome the obstacles it faced, which from last years' experience and from past research that the legged robot is capable of scaling obstacles larger than the legs.

2.0 Product Specification

Table 1 – Product Specifications

	Mechanical Design		
		Required	Desired
1	Robot dimension	1m x 1m x 0.5m max	
2	Robot Weight	45 kg max	30 kg
3	Leg Loading	45 kg+rocks	150 kg
4	Storage Capacity	5 rocks	30 rocks
5	Terrain Scaling	33% Incline and Decline	
6	Power Source	No internal Combustion Engine	
7	Ride Height	10 cm max obstacle size	
8	Arm/Gripper Requirement	2-8 cm rock size, 20-150g rock weight	
9	Robot Construction	Water resistance, solid underbelly	fully enclosed
	Electronics and Control		
		Required	Desired
10	Battery Life	1 hour	2 hour
11	Telecommunication	3G/4G	
12	Camera		5 Megapixel
13	Leg Control (Buehler Clock)		
14	Arm Control		
15	Water Resistance		
16	GUI/User Interface		
17	Video Streaming	Video must be viewable by parties on Internet	

3.0 Overview

3.1 – Desired Outcomes

There are three outcomes that we will consider based on available funding as well as selection into the competition.

Outcome 1 (Selected to competition with sufficient funds):

The goal of this project is to create something never before seen in competition which is a multiple rover system which each rover is capable of collecting rock samples. With sufficient funds, we will do the following:

1. Design and build 2 smaller rovers capable of walking and running. The design will be a scaled down version of the past year's platform whose locomotion handled the obstacles faced very well.
2. Then to compete in the 2014 Robo-Ops competition with a design that can handle a single rover failure, with the expectation to not only compete, but to be the winning team.

Outcome 2 (Selected to competition with insufficient funds to build multiple rovers):

While the goal is to build multiple platforms, we have a completely functional robotic platform from last year that has significant room for improvement. With these improvements, this rover can also reach the competition. If selected to the competition, we will do the following:

1. Improve the past year's design with an improved arm design, advanced locomotion control, and a more advanced means of controlling the motor temperature.
2. Then to compete in the 2014 Robo-Ops competition with a design that can handle a single rover failure, with the expectation to compete better than last year's team which placed 5th.

Outcome 3 (Not selected to 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 advanced controls of the past year's platform, while working to design and build a single small rover to the specifications of the 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.

4.0 Projected Budget

The budget for this project can vary from a much as $16,250 to $12,250. This flexibility in design will allows us to search for funding and decide which of our outcomes to pursue based on available funding. The project is currently sponsored by The Florida Space Grant Consortium which has pledged $1,000 to the project, and by Misumi which has sponsored us with $2,000 in kind sponsorship. The team is currently contacting various industry contacts to search for the additional funding necessary to complete the project.

Table 2. Project Budget Breakdown

	Item	Vendor	Part Number	Cost	Quantity	Total
Chasis	Carbon Fiber Roll	US Composites	FG-PW5750	$430	3	$ 1290
	Carbon Fiber Resin	US Composites	FASC-11025	$21.25	4	$ 85.00
	Driving Motors	Maxon Motors	397172	$119.38	7	$ 835.66
	Gearbox	Maxon Motors	326661	$182.25	7	$ 1275.75
	Encoders	Maxon Motors	110512	$131.50	7	$ 920.50
	Sabertooth Motor Drivers	Robot Shop	RB-Dim-44	$189.99	3	$ 569.97
	Aluminum Square Tubing	McMaster Carr	88875K31	$13.15	5	$ 65.75
	Battery Pack	Battery Space	CU-J167	$ 339.50	3	$ 1018.50
	Subtotal					$6,061.13
Arm	Raspberry Pi B 512MB	Amazon		$42.36	1	$ 42.36
	Aluminum Sheet	McMaster Carr	9008K23	$10.58	3	$ 31.74
	HiTec Servos	Robot Shop	RB-Hit-148	$89.99	7	$ 629.93
	Subtotal					$ 754.03
Electronics	TP-Link N Type Wireless Router	Amazon		$129.99	1	$ 129.99
	TP-Link Cameras	Amazon		74.99	6	$ 449.94
	Cooling Fans	Amazon		$12.16	2	$ 24.32
	Subtotal					$604.25
	Miscellaneous					$ 1,000
	Subtotal					$ 1,000

Table 3. Budget for Each of the Desired Outcomes

Two Robots		Single Robot		Improving Old Robot	
2 x Chasis's	$ 12,122.62	Chasis	$ 6061.31	Improved Chasis	$ 1375.00
2 x Arm's	$ 1,508.06	Arm	$ 754.03	Arm	$ 754.03
Electronics Set	$ 604.25	Electronics Set	$ 604.25	Electronics Set	$ 604.25
Other	$ 2,000.00	Other	$ 1,000	Other	$ 1,000
Total Cost	$ 16,234.93	Total Cost	$ 8,595	Total Cost	$ 3733.28

5.0 Concept Generation Strategy

One of the major focuses of the RASC-AL Robo-Ops Competition is to search for innovative and clever engineering solutions to solve out of this world problems from students around the country. Team SpaceHex brought the first ever legged robotic rover to the competition in last year's competition and won praises from many. With innovation being the strength of the team, concept generation process is especially important as it is essential for the team to head towards the right direction and continues come up with groundbreaking designs to build a superior robot.

5.1 – Background Research

Before the team begins to generate new designs, it is imperative to gather as much information about the constraints the competition imposes to form a clear picture of the limits of our potential creativity. The team looked to the official RASC-AL website to gather the requirements about the competition itself such as project weight and size requirements as well as other various constraints placed on the robotic rover. The result of this background research is displayed in the table in section 2.0 of this deliverable.

After the team understands constraints, the next step is to research the solutions previous team implemented as well as industry developments related to the area. The research for the state of the art robotics rover platforms from the past competition serves as an ideal glimpse of the standards set by the past teams and a survey of various design and mechanisms to prevent the team from reinventing the wheel. By comparing the designs with the competition results, it also allows the team to evaluate which types of systems have a higher chance of being successful.

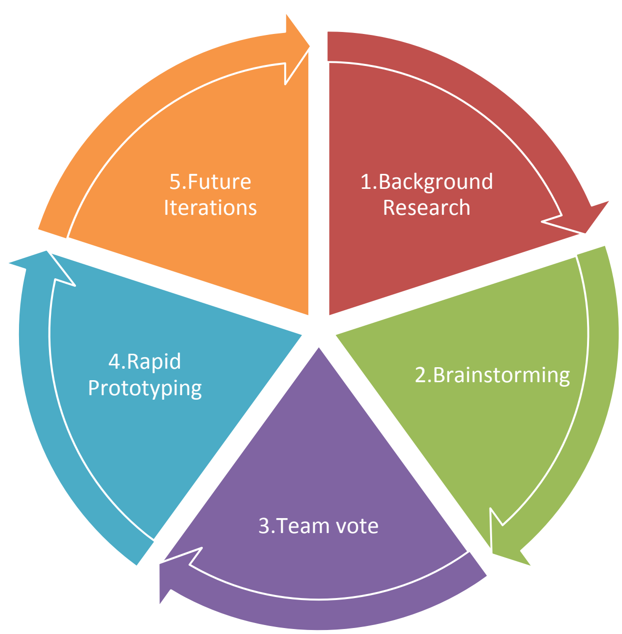

Figure 1. Concept Generation Process

5.2 – Concept Development and Design Selection

Following the background research by the team, several brainstorming sessions were conducted to generate potential designs for implementation on the rover. The team chose to conduct the brainstorming sessions in a non-judgmental and free flowing environment to encourage the generation of wild, viable ideas for potential refinement and adjustment. Soon after the brainstorming sessions, a team vote was conducted to decide which designs deemed desirable, viable, and feasible by all of the team members. The team is then grouped into two sub-teams to produce a rough prototype from the finalist ideas. Rapid prototyping is especially important for this project due to the heavy funding and time constraints placed by the competition. The team utilizes the prototypes to evaluate the practicalities of various designs to improve future iterations.

5.3 – Example of Team Concept Generation

Example process

The team begins with several presentations from the background research to ensure all of the team members begin brainstorming with a similar knowledge level on the subject. The team then briefly discusses the presentation to ensure the concepts are understood. After discussion, the team brainstorms to generate possible ideas for the project. The ideas are drawn on paper and presented immediately to the team during the brainstorming session. Any critique is deferred and save for the discussion after the brainstorming session.

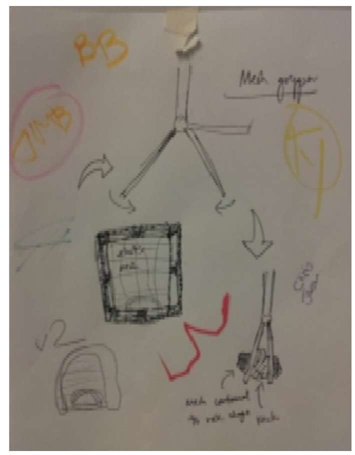

Figure 2. Design from brainstorming session

Figure 2 is an example of one of the design from the brainstorming session. Each member was asked to put their initials on the paper to show their vote for the design.

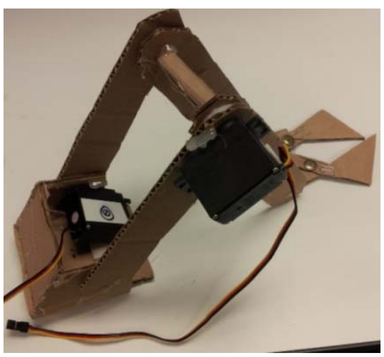

Figure 3. Rough prototype of robotic arm

The team quickly constructed several prototypes based on the voted designs to evaluate the physical practicality and viability. Figure 3 shows the first generation prototype produced for the arm mechanism. Once the team agreed upon the adjustments that should be made on the design, next iteration of the prototype were made to continue the design cycle.

Figure 4. Second generation gripper prototype

Figure 4 demonstrates a second generation gripper prototype utilizing the elastic mesh end effector.

6.0 Proposed Design

6.1 – Arm Design

The old design

The arm mechanism developed the previous year was designed to lift larger rocks than the competition uses. Because of its robust design, the thickness of metal used and size of motors pushed the overall weight of the robot to the maximum 45kg. This design will also be scrapped due to its limited degree of freedom. Another large problem with this design is the claw itself, which has designed to be extremely robust, but had limited view of the rock. This arm is slower, heavier, and not as precise required for the type of robot platform.

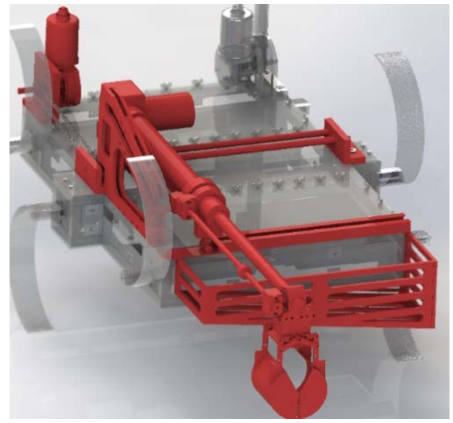

Figure 5. Last Year's Extraction Module

New Arm Ideas

Pitch Shovel - The first idea we discussed was a robot with a bulldozer shovel on the front to quickly scoop up rocks that are laying out in the open. This design would be simple, it would be fast and effective at obtaining easy rocks saving us valuable time. A problem arose was that if our chassis is on the ground, we can't move as the legs are in the air. We solved that by angling the arms which attach to the shovel's head up towards the frame which stays flat on level surfaces. A spindle has been discussed to help pull the rocks onto the shovel so we don't just push the rock away. Another problem would be digging, another simple solution was presented, similar to another idea that was presented during brainstorming, a pitchfork like rake will scoop up objects that are large (rocks) and small objects will flow through (sand, dirt, gravel). This dozer would function as a secondary arm as it cannot reach difficult rocks which may be inlaid in a rock yard.

Arm and Wrist – To grab the hard to reach rocks, a multi degree of freedom arm has been derived. It would sit atop the robot and be comprised of several servos. The first servo would allow it to spin left and right, the next would angle it up and down, the third will be an extension that also angles up and down, the fourth servo rotates as a "wrist" so the "hand" and orient itself in a certain situation.

Figure 6. 6 DOF Robotic Arm

Pronged Fingers – Finger grippers need to be precise in their implementation. They are practical as they can reach and grab items in confined spaces, however there is less forgiveness if we are off by anything more than a centimeter. Opposed to a scooper or last year's claw which can get grab a rock within a larger area. There are a few finger ideas on the board, 2 pronged, which is small and can reach most everything but needs to squeeze the rock and get a good grip as it's only touching the rock in two places, or 3 pronged, which would hold the rock very stable but may not be able to get access to 3 different sides of the rock. The FESTO Fin Adaptive Finger (right) has gained our curiosity as its shape conforms to object it is grabbing and is delicate enough to pick up an egg. The second idea for fingers are rake-like, skinny tendrils on the fingers allow the fingers to close around the rocks shape to have greater contact area.

Figure 7. Compliant Fingers

Mesh Fingers – This idea has been improving in design at each meeting and proving an innovative possibility. Presented during brainstorming as two clamps that have a mesh screen in their center, then became an elastic mesh grip which will be more versatile and have a higher friction coefficient. The lower support was removed to create an upside-down U structure so we can get the mesh as close to the ground as possible. This mesh gripper clamps onto the rock and it's form is conformed into the material providing optimum grip. This design will be used with the Arm and Wrist.

6.2 – Locomotion Design

The proposed leg design is unique and has never been attempted by another school for this competition. There will be six legs, all of which are in a 'C' shape, lining up with three to the left side of the robot (parallel to the robot) and three to the right side of the robot (also parallel to the robot). The legs will only be on one axis of freedom, meaning they can only rotate forward or backwards, but not pivot. This makes turning the robot much more thought intensive than a normal car's tires, which just pivot to the side to turn.

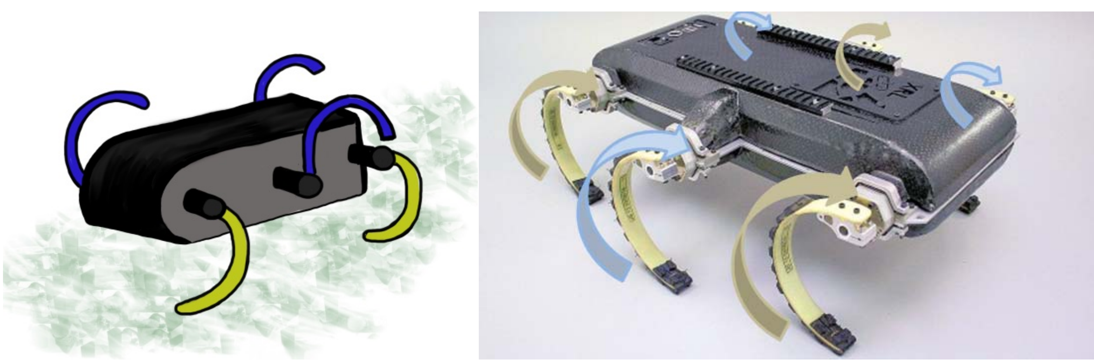

Figure 8. Examples of Locomotion System Utilized

There are plenty of reasons for the chosen design, which will be more difficult to implement but hopefully more rewarding as well. In the competition at hand, there will be rocks which are taller than our rover, unsteady terrain such as sand and gravel, and steep hills to climb. All of these are *avoidable* by a rover which moves with tires, but they are *manageable* with a rover which has legs. A normal rover will roll up to a rock and crash into it but the legs are able to climb the rock and gain a better vantage point over the rest of the field. Differing terrains should cause no problem since legs are able to get very good traction on each point that they stand as opposed to a rover which will roll and skid.

Table 4. Decision Matrix to Keep with Legged Motion

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

The proposed 6 legged rover is extremely unique in its motions and therefore is much more difficult to implement than a standard tire. Where most tires simply spin and turn, this robot has to use differentiating leg directions and speeds to achieve simple motions such as “turn”. The proposed design which was used, but not perfected, last year is the Buehler clock. The idea behind it is to speed up the legs while they are in the air so that they can complete the ~270 degree cycle at the same time that the opposing three legs are completing a ~90 degree cycle on the ground. For operations such as “turn while walking,” these speeds will have to be adjusted in order to get the right tires moving at a faster pace than the left tires (thus moving the rover slightly in that direction) and vice versa. Each function (including stand) is coded individually as opposed to a tire which will stand on its own even with no coding. While this design is much more difficult to implement, we feel the rewards will be worth the work and our rover will be able to outperform the competition.

Last year’s team left us with both a very good platform and reusable code. They currently have a rover which stands on command, walks on command, turns on command, and lays down on command. While this may not seem like a big step, it is enough to move the rover anywhere, although it is very bulky. The problems with the design right now are that the robot is not very agile, the motors are overheating, and the GUI environment is not user friendly and extremely counter intuitive.

This year, we have a plan to correct each issue from last year’s team. The two separate rovers will be much more agile and cover a lot more ground than the single rover. The motors will be equipped with a water cooled system to ensure that they don’t rise too high in temperature. And the robot’s control module will be an Xbox controller. Putting a controller on a robot poses a couple of extra challenges. Because the rover isn’t being told what to do one command at a time, it must be much more dynamic in its programming. This will require it to be able to change commands on the fly. For instance, if the rover is going forward and then someone decides to make it turn instead, it must be able to change to the turn function almost immediately (from the regular walking function). The current version of the code does not have a working turn while walking function, which would be extremely handy with an Xbox controller. This will also be implemented, along with maybe a leap function, and any other functional locomotion functions which we encounter in the transition from GUI to controller.

6.3 – Telecommunication Design

Graphical User Interface

The Graphical User Interface (GUI) is a custom computer application which aims to greatly simplify the operation of the rover through integration of information display, in the form of video feeds and sensor data, and rover control. In essence, it gives the user a tool for controlling the rover.

In last year's design, the GUI was written in the C# program language. Below is an image of the objective of the design:

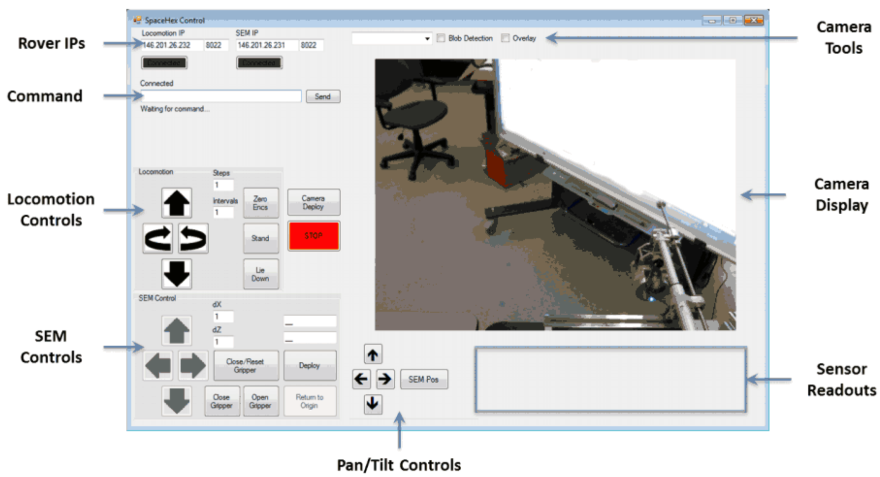

Figure 9. Previous Year's GUI

The GUI was operational, but many aspects will be changed in order to make the GUI more user friendly. For one thing, the user would have to input the number of steps and the direction that the rover should proceed. The process was very cumbersome, especially if the user needed the rover to move to a specific spot. As the rover will be competing with other rovers to pick up the most rocks, creating a GUI that allows the user to interact more freely with the rover would be much more efficient. There were also locomotion concerns, as was discussed earlier, as the rover could not turn while walking. So the GUI only has the controls Forward, Reverse, turn-Left, and turn-Right. Our goal is to implement an Xbox or Playstation controller allowing the user 360 degrees of control, with the ability to change direction while moving. We wish to eliminate the need to enter the number of steps prior to moving. A simple push of the joystick will command the rover to move.

Communications and Networking

To establish communication between the cameras and computing systems on the rover and the Mission Control server located at the college detailed networking protocol is desired The figure below displays the design of the network. The blocks on the right represent the rover arm, locomotion and cameras.

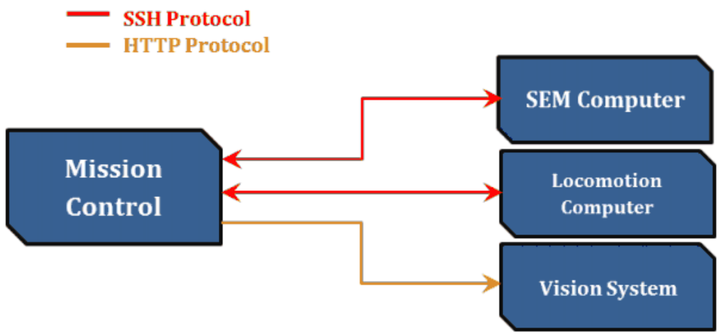

Figure 10. Communication Block Diagram

As the above figure shows, communications via SSH (Secure Shell) were established between the on-rover computers and the mission control computer; communication via HTTP (Hypertext Transfer Protocol) was used to link the cameras to mission control. In last year's case, both the mission control computer and networked hardware on the rover are behind NAT (Network Address Translation) firewalls. The NAT firewall prevents all incoming connections to all the devices.

In last year's design, the communications system was put together in more haste than what would have been ideal. For one, the mission control operated from a student's apartment. Also, the on-rover router used was a G-type router leading to limited bandwidth. Looking at last year's issues, a lack of bandwidth may have contributed to the issues of last year's team, such as lagging and dropped communications. Additionally, the blob-detection would be impaired by a low-resolution video feed, which normally would be used in cases where the bandwidth was limited. To counteract these issues, a higher grade router will be used. Last year's router, the TP-Link TL-MR3430 (pictured below) was a fine router for home usage, but a higher grade router would do the project well.

Figure 11. Left: Type G router   Right: Type N Router

The TP-LINK SafeStream TL-ER6020 Gigabit Dual-WAN VPN Router (pictured below) is an ideal router. It is a next generation, the N-type. It creates a VPN (Virtual Private Network) thus adding more security by securing an IP address, and preventing interference from other addresses. Additionally, the router is much more powerful, with enough bandwidth to spare.

Additionally, this year’s team will make the mission control router the DNS-enabled router. Last year, the team did not take care to make sure only one router was DNS-enabled. Also, some issues arose that were out of the control of the team. The team relied on Verizon’s 3G network as there was a tower near the site. Ironically, the 3G network had issues on the day of the competition. Since, Houston is a major city, using another network as a backup, such as Cisco or AT&T, will be the way to go.

7.0 Project Deliverables

Deliverables for EML 4551

The Fall 2013 semester of Senior Design Class has the following deliverables.

- Code of Conduct – October 3,2013
- Needs Assessment – September 27,2013
- Project Plan and Product Spec – October 11, 2013
- Midterm Report I – October 25, 2013
- Team Evaluation – October 29, 2013
- Final Report – December 6, 2013

These deliverables are required to complete the class and will be used to demonstrate the engineering process the team will use to accomplish the project. The reports will include detailed plans and Gantt Charts to outline the schedule for our project.

Deliverables for RASC-AL Robo-Ops Competition

There are three major reports due for the RASC-AL Robo-Ops Competition. The first is a Notice of Intent which is due November 15, 2013. This report is not required to be selected for the competition, but is strongly encouraged and will therefore be completed. The first required deliverable is the Project Plan Proposal which is due on December 8 ,2013 and is used to select the 8 teams which compete in the competition and receive a $10,000 grant from NASA. If selected to the competition, a Mid-Project Review must be submitted by March 17, 2014 and is required to receive the full $10,000.

8.0 Project Schedule

In order to complete the project in the timeframe for the competition, the team needs to aggressively complete the design and implementation of the rover platform. The next page details the schedule the team has developed. Each member of the team is responsible for a specific portion of the project. The breakdown of these responsibilities is as follows

Boris – Locomotion Controls

Chris – Gripper Design and SEM testing

Linus – Communications

Jason – SEM Mechanism and Thermal Fluid System

Justin – Fundraising and Thermal Fluid System

8.1 Gantt Chart

ID	Task Name	Start	Finish
1	**Fund rasing**	**Fri 9/20/13**	**Fri 5/2/14**
2	Complete Funding Proposal	Fri 9/20/13	Tue 9/24/13
3	Engineering Day Presentation	Fri 9/20/13	Mon 9/23/13
4	Contact Individuals we know	Wed 9/25/13	Tue 10/8/13
5	Pray For Money	Mon 9/23/13	Fri 5/2/14
6	**Locomotion Controls**	**Mon 9/23/13**	**Fri 2/28/14**
7	Turn While Walking	Mon 9/23/13	Fri 2/28/14
8	Finer Turning Motions	Mon 9/23/13	Fri 2/28/14
9	Turning while climbing	Mon 9/23/13	Fri 2/28/14
10	Control with and Xbox	Fri 10/25/13	Fri 2/28/14
11	**Sample Extraction Module**	**Mon 9/23/13**	**Mon 12/30/13**
12	**Gripper**	**Mon 9/23/13**	**Mon 12/30/13**
13	Brainstorming	Mon 9/23/13	Fri 9/27/13
14	Prototyping – Cardboard Stage	Mon 9/30/13	Fri 10/25/13
15	Selection of Final Design	Mon 10/21/13	Fri 10/25/13
16	Determine Parts Necessary	Mon 10/28/13	Fri 11/1/13
17	Complete CAD Model	Mon 10/28/13	Fri 11/1/13
18	Construction	Mon 11/4/13	Fri 11/29/13
19	Attachment to Arm	Mon 12/2/13	Mon 12/2/13
20	Testing Gripper	Tue 12/3/13	Mon 12/30/13
21	**SEM Mechanism**	**Mon 9/23/13**	**Fri 12/27/13**
22	Brainstorming	Mon 9/23/13	Fri 9/27/13
23	Prototyping – Cardboard Stage	Mon 9/30/13	Fri 10/25/13
24	Selection of Final Design	Mon 10/21/13	Fri 10/25/13
25	Determine Parts Necessary	Mon 10/28/13	Fri 11/1/13
26	Complete CAD Model	Mon 10/28/13	Fri 11/1/13
27	Construction	Mon 11/4/13	Fri 11/29/13
28	Testing SEM System	Mon 12/2/13	Fri 12/27/13
29	**Communication**	**Mon 9/23/13**	**Fri 2/21/14**
30	Develop Communications Design	Mon 9/23/13	Fri 10/18/13
31	Determine Necessary Components	Mon 10/21/13	Fri 11/8/13
32	Acquire Necessary Components	Mon 11/11/13	Fri 12/6/13
33	Build Communication System	Tue 12/10/13	Fri 1/24/14
34	Test and Debug Communications	Mon 1/27/14	Fri 2/21/14
35	**Thermal Fluid System**	**Mon 9/30/13**	**Fri 12/20/13**
36	Concept Generation	Mon 9/30/13	Fri 10/4/13
37	Concept Selection	Mon 10/7/13	Fri 10/11/13
38	CAD Model	Mon 10/14/13	Fri 10/25/13
39	Determine Components	Mon 10/14/13	Fri 10/25/13
40	Construction	Mon 10/28/13	Fri 11/22/13
41	Testing Thermal System	Mon 11/25/13	Fri 12/20/13
42	**Complete System Integration --**	Mon 3/3/14	Fri 4/25/14