Restated Project Scope and Project Plan

EML 4551C – Senior Design – Spring 2012 Deliverable

Team # 15

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Introduction

This senior design project's purpose is to be entered into the Third Annual NASA Lunabotics Competition. This competition goal is to create a robot capable of operating in a lunar environment, including traversing rough terrain, and collecting lunar soil. After the soil is collected, it will be deposited into the LunaBin. This LunaBin will be located 0.35m from the top of the lunar surface. Research on regolith would help determine the feasibility of lunar inhabitance, which could lead to future scientific breakthroughs. The competition will simulate the lunar environment and the accompanying hazards found on the moon, including craters and obstacles for the robot to traverse. Previous competition teams have succeeded with more traditional wheel based design, but have struggled with navigating the obstacles. This year's team will complete with a hexapedal robot based on the RHex family of robots. The main benefit of this design is the ability to easily overcome various obstacles such as rocks and craters via C-shaped legs. Last year's senior design team began building the Hexcavator platform, but was unable to complete the design. The completed portion of the platform is shown below in Figure 1; the platform has a frame, motors, legs, leg attachments and a few other minor components. It has no control system, power system, wireless communication system or excavation system. These systems will be implemented and tested by the competition date, a detailed time line can be found on page 8.

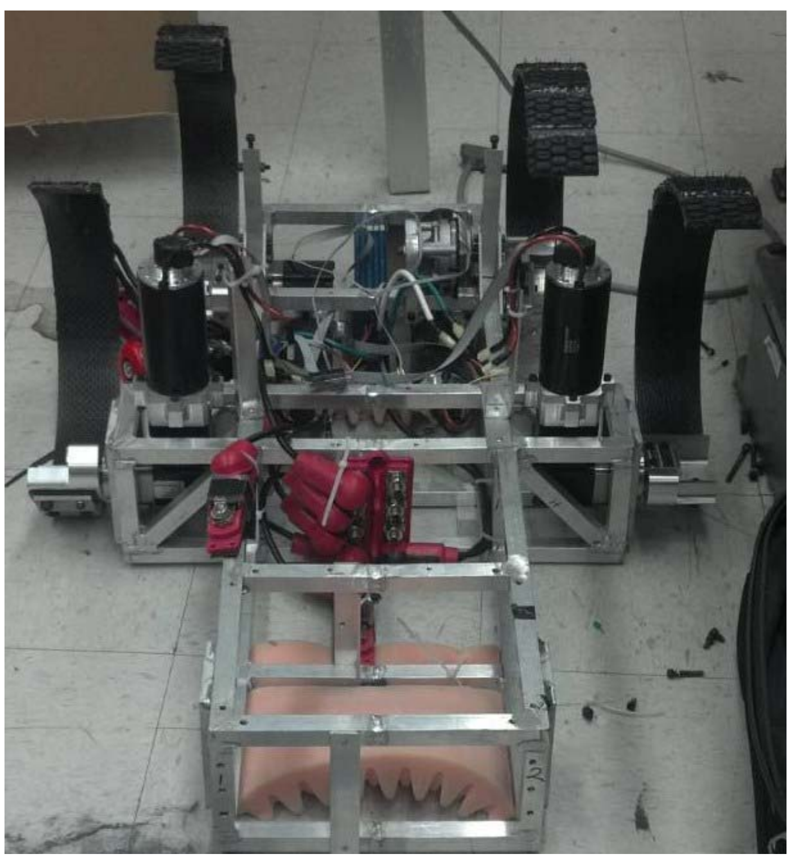


Figure 1: The platform last year's senior design team designed.

Project Specification

The design requirements of the robot are dictated by NASA's Third Annual Lunabotics Mining Competition Rules and Rubrics [1]. Below is a synopsis of these rules.

- The competition will take place on May 21-26, 2012. All teams must arrive at the Competition by noon on May 22, 2012.
- The team will be required to complete two, ten-minute competition attempts using the defined competition area provided by NASA.
- The NASA judges need to be able to send an immediate power-off command to the robot at the end of the ten minute competition attempts.
- The robot must excavate at least 10kg of regolith and deposit it into the LunaBin.
    - The LunaBin will be 0.5m tall and have an opening 1.65m long and 0.48m wide.
- The robot must be able to start from any start position dictated by the judges.
- The robot has a weight maximum of 80kg.
- The robot has a starting height maximum of 0.75m.
- The robot has a starting length maximum of 1.5m.
- The robot has a starting width maximum of 0.75m.
- The complete system must be self-powered.
- The team must have one person on the competition team per 23kg of mass of the robot.
- The team must be capable of setting up the robot in the competition area within ten minutes.
- The robot cannot be anchored to the Luna Surface prior to the competition attempt.
- The robot cannot use the walls as support, or use them to push/scoop regolith.
- The robot is limited to autonomous and telerobotic operations only.
- A red emergency stop button of 5cm diameter is required on the exterior of the robot. IT must act as a kill switch and be a commercially bought product.
- The robot is not allowed to use any fundamental physical processes (e.g. suction or water cooling in the open lunar environment), gases, fluids, or consumables that will not work in a lunar environment.
- The robot cannot cause the regolith to undergo any physical or chemical changes, and it may not be treated as a projectile.
- The robot must be able to overcome simulations of obstacles and craters during locomotion.

Desired Outcome

The desired outcome for this project is to be able to traverse the simulated moon environment while overcoming obstacles with our Hexcavator Lunabot. Upon reaching the opposite end of the course, the robot will excavate the regolith, store it onboard the robot, and go back across the simulated moon environment. Once the robot reaches the starting area of the course it will deposit the regolith into the repository; at least 10kg of regolith needs to be deposited. During this project we will design a hexapedal robot, named Hexcavator, capable of performing all of the aforementioned tasks while maintaining locomotion.

The competition for this robot is in May 2012, however the first self imposed due date is to have the robot walking by January 31st. Once the robot is walking, we will design and implement an excavation system. After all the systems are integrated and fully functional, we will also develop a wireless communications system as well as we will redesign the frame so that we can make the robot as light as possible. After the robot has been completed, a body will also be designed so that the robot will be dust resistant, lightweight and still sturdy.

Functional Diagram

Below in Figure 2, is the functional diagram, which will be followed to build the robot. It shows how the components of the Hexcavator will work in conjunction with each other. Since this is a hexapedal robot, this process will be iterated in each leg. There is a mechanical connection from the legs to the gear box, the gearbox to the motor, and the motor to the encoder. The encoder then sends data to the decoder, which then sends data to the Micro-Controller, which in turn sends data to the excavation system. Batteries send electrical power to the motor driver, micro controller, communication system and excavation system. The excavation system mechanically acquires regolith. The communication system feeds data back to the Micro-Controller and to the operator. The motor driver sends electrical power to the motor.

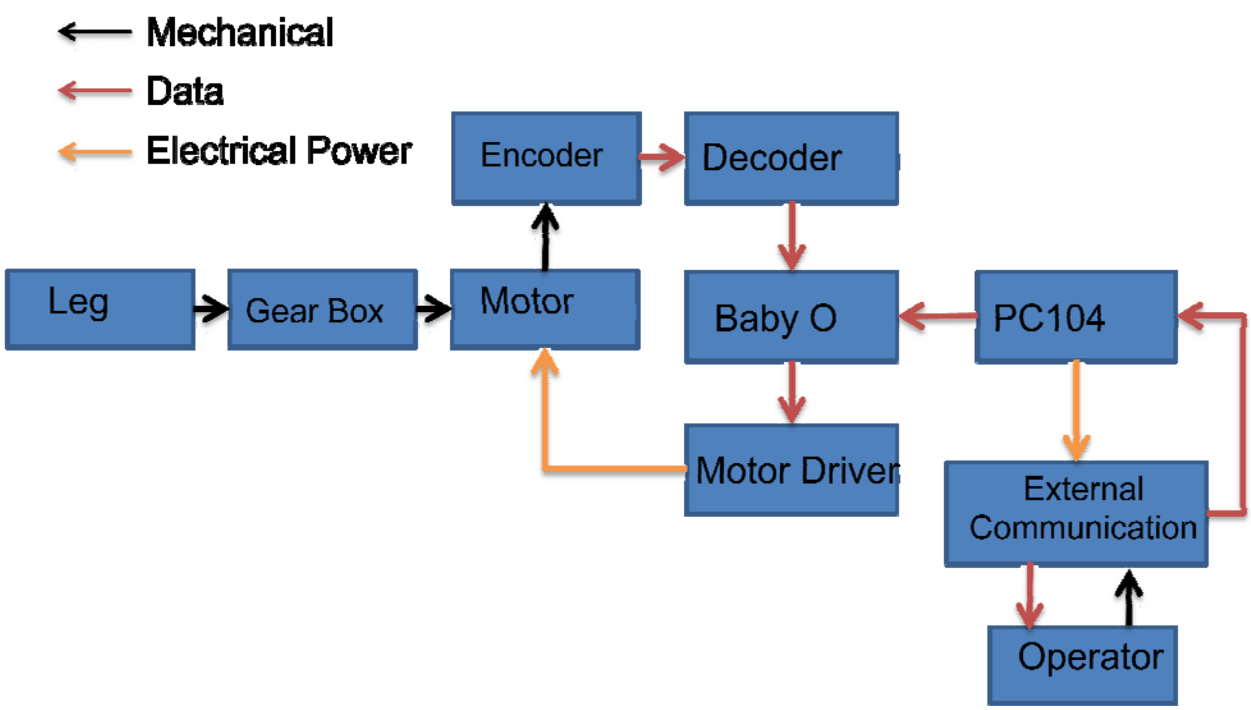


Figure 2: Function diagram of the Hexcavator. This is a hexapedal robot so this process will be iterated in each leg.

Budget

In Figure 29, the breakdown of final cost estimates for individual components are given. Our total budget amounts to $9000. We received $2000 from FAMU/FSU College of Engineering, $4000 from National Space Grant and $3000 from Northrop Grumman. Our final cost estimate is $5451.77 which is within our budget. The rest of the budget will be reserved for unanticipated costs that may arise during construction.

Components	Cost	Quantity	Total Cost
Bushings	$0.64	24	$15.36
PC104	$ 691.00	1	$691.00
Aluminum (Excavation)	$600.00	1	$600.00
ABS Plastic (Excavation)	$30.00	1	$30.00
Steel Shafts	$40.00	1	$40.00
CirClips (Pack of 10)	$8.09	3	$24.27
Motor for Excavation	$359.34	1	$359.34
WiFly	$84.95	1	$84.95
Baby O	$19.00	5	$95.00
Motor Drivers	$220.00	4	$880.00
Voltage Regulators	$6.00	5	$30.00
Decoders	$8.00	5	$40.00
Clocks	$3.00	7	$21.00
Copper Sheet	$60.00	1	$60.00
Travel Expenses (Estimated)	$2,480.85	1	$ 2,480.85
Total			$ 5,451.77

Figure 3: Breakdown of the final cost estimates for the Hexcavator.

Gantt Chart

The team has come up with their own internal goals, which can be seen in the gray rows of the Gantt Chart. They are further explained below:

Research
Completion: Week 5

The team has performed an in-depth analysis of the former year's robot to determine which components can be utilized again for this year (discussed above in the budgeting section). Locomotion schemes, controls and different methods of excavation were reserached. The team agreed on a micro controller and motor controllers, and met with a technical expert, Dr. Camillo Ordonez, to verify that our selected components were suitable.

Prototype 1a: Walking Platform
Intended Completion Date: Week 17

By the end of week 17, the group would like to have a functional walking hexapedial platform. Achieving this will entail acquisition of needed electrical components, installation, programming and testing of the drive system.

Even though the long term goal is for the robot to be controlled via WiFi, an umbilical tether will be used initially for simplicity. Once the robot is mobile, it will be tested indoors. The next step is to test Hexcavator in an outdoor sand pit. This will test Hexcavator's capabilities on non-consistent surface. After testing Hexcavator's ability to go forwards and backwards, the robot will need to be programmed to make turns within the confinements of the competition arena.

Initial Prototype of Excavation
Completion Date: Week 12.

The production of the excavation system will be a multistep process involving design, integration, and improvement. The team developed a six-bar linkage which can be mounted on the existing frame. An excavating drum was also designed as a method of actually excavating the regolith. This design has been prototyped from ABS plastic, and appears to be fully functional.

Prototype 1b: Excavation Design
Intended Completion Date: Week 17

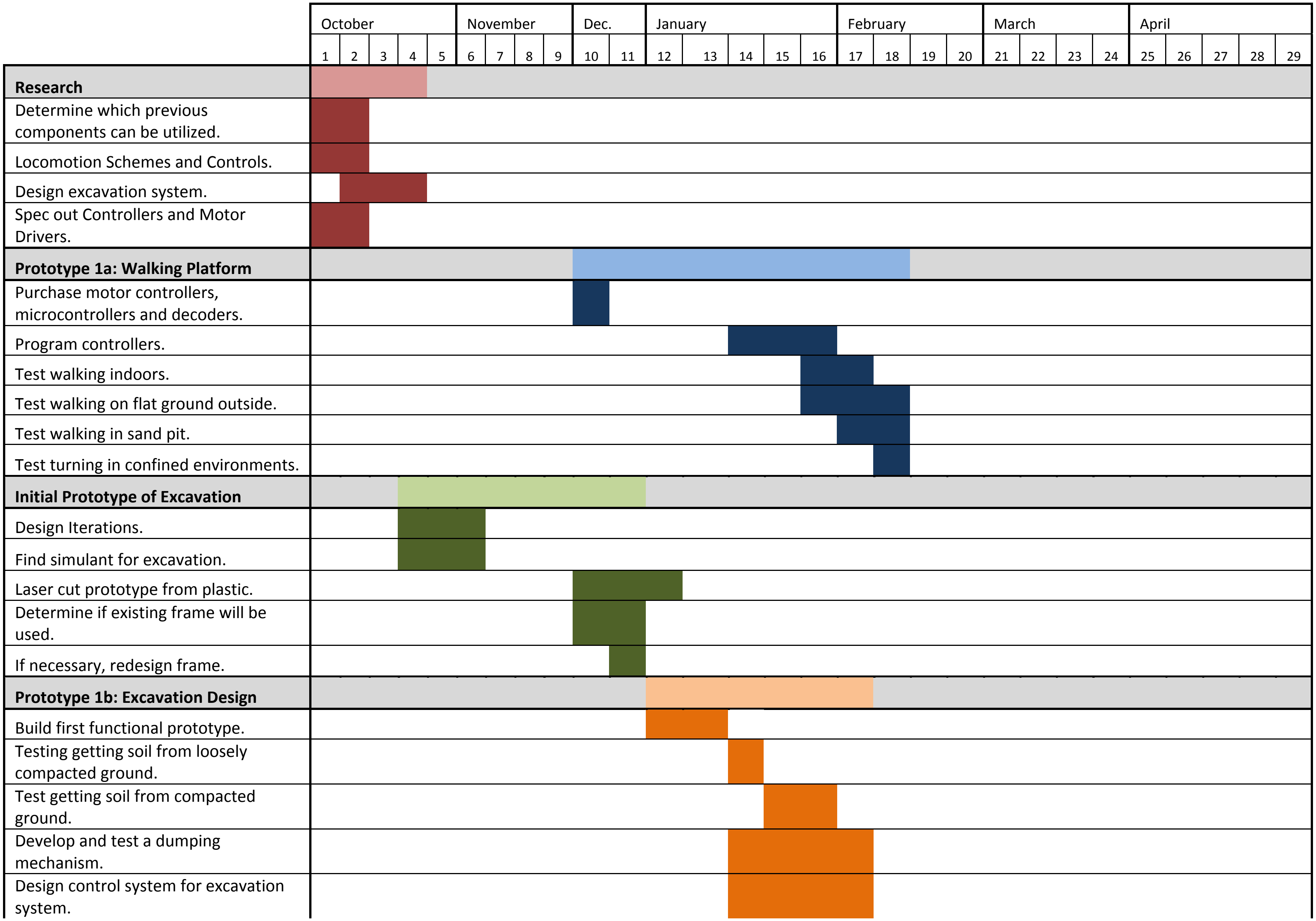
Since the excavation design has been prototyped the design will be now be machined from Al6061. It will then be mounted to the existing Hexcavator frame (using the mounts constructed by last year's team). The next step will be to implement the motors and a controls scheme onto the excavation system. Then tests will be conducted in soil to verify that it the design works. The key here is the strength of the excavation system and its ability to dig into the compacted ground. By the conclusion of week 17, the excavation system will be extracting both soft and compacted soil from the ground and will be depositing it into a test bin. Then the

<u>Prototype 2: Wireless Walking Robot with Excavation</u>
Intended Completion Date: Week 22

The Hexcavator will have considerably more mass above the top of the robot when the excavation system is attached. Hexcavator will need to undergo testing and control refinement to maintain its locomotion capabilities. The system will also need to be tested to see if it is still capable of picking up soil. Additional testing will be performed to see how Hexcavator's locomotion is impacted when the excavation system is carrying the regolith. Depositing the regolith simulant will also need to be tested so that the maximum amount will be deposited. Navigating over obstacles will also need to be tested with the additional weight of the excavation system, with and without regolith. During these testing phases a wireless communications system will be implemented so that the robot will not need its umbilical tether.

<u>Prototype 3: Walking Robot in Rough Terrain</u>
Intended Completion Date: Week 29

The final steps that will be tested and practiced on the Hexcavator system will to making sure that the complete system is working correctly and efficiently. This will include navigating all obstacles, such as rocks, craters, and rough terrain. Also, the entire system will need to be capable of collecting soil and traversing a practice course to deposit into a practice bin. The excavation system at this point should be collecting the simulated regolith without hindering locomotion. It will then traverse the practice course to successfully deposit said substitute material into a practice bin that will simulate the LunaBin that will be used during competition. At the end of this deliverable, the team will participate in NASA's competition at Kennedy Space Center on May 23.


October
November
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January
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Research
Determine which previous components can be utilized.
Locomotion Schemes and Controls.
Design excavation system.
Spec out Controllers and Motor Drivers.
Prototype 1a: Walking Platform
Purchase motor controllers, microcontrollers and decoders.
Program controllers.
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.
Find simulant for excavation.
Laser cut prototype from plastic.
Determine if existing frame will be used.
If necessary, redesign frame.
Prototype 1b: Excavation Design
Build first functional prototype.
Testing getting soil from loosely compacted ground.
Test getting soil from compacted ground.
Develop and test a dumping mechanism.
Design control system for excavation system.

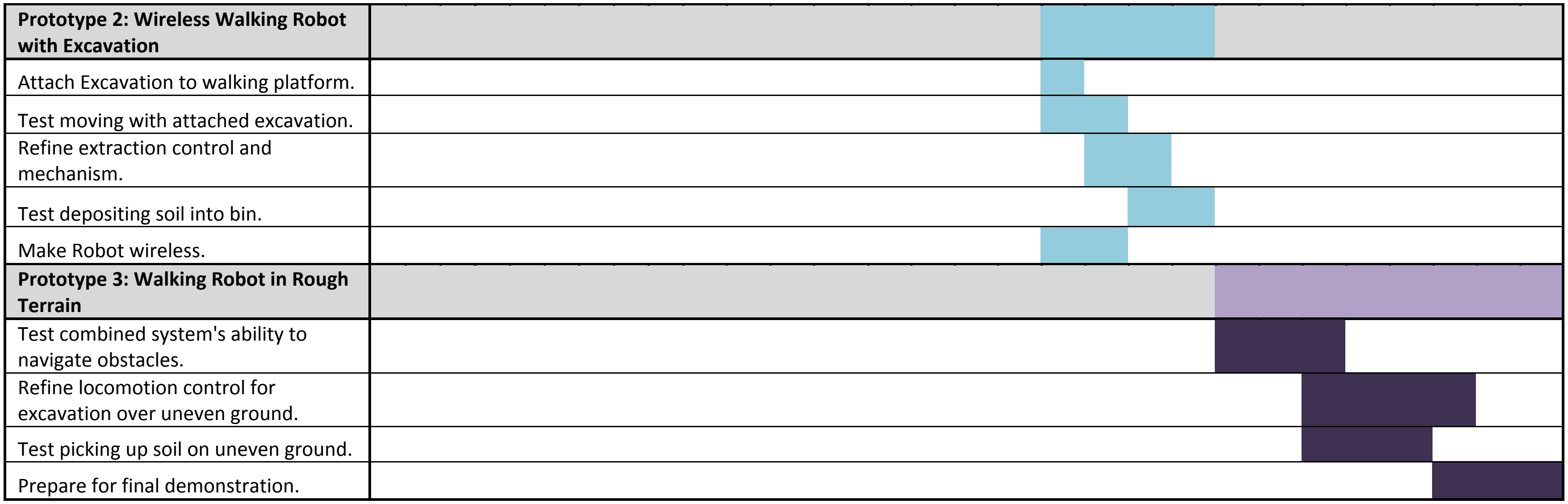

Figure 4: Ghant chart for developing the Hexcavator Platform.

Conclusion

Overall, our team is following the time line presented in the Gantt Chart and we expect to have a fully functional robot by the competition date. Our current design meets all the requirements set forth by NASA. As stated in the Final Design Deliverable, our ProEngineer simulations indicate that Hexcavator will have a mass of 67kg, have a starting height of 38.97cm, length of 123.01cm and a width of 75cm. A red safety button has been purchased, and our excavation drum analysis indicates that we should be able to excavate more than 10kg of regolith. To account for any problems that might arise, there is substantial time left for testing Hexcavator. A ProEngineer rendering of Hexcavator is shown in Figure 5.

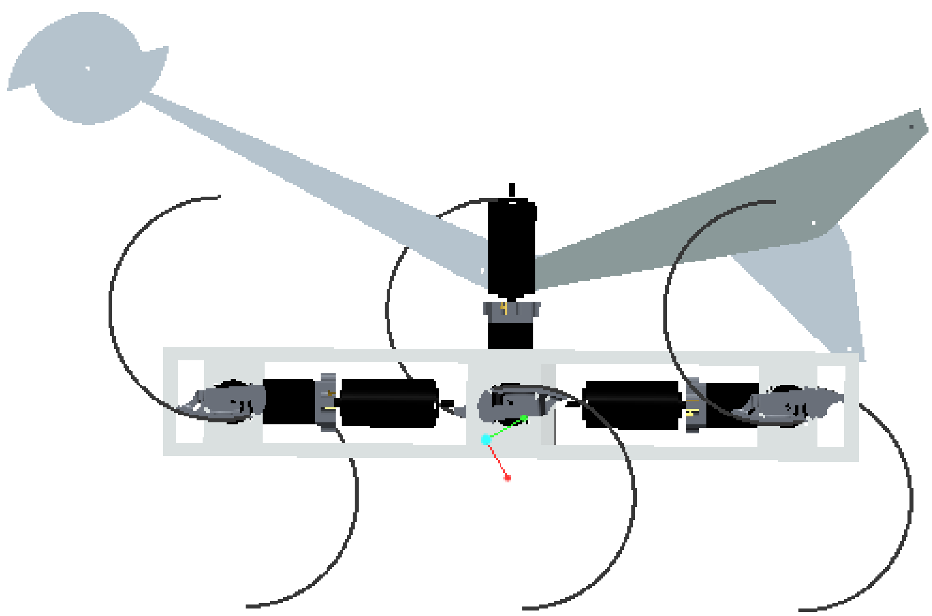

Figure 5: ProEngineer rendering of the Hexcavator Platform.

References

[1] National Aeronautics and Space Administration. Lunabotics Mining Competition. 2011. 29 September 2011 <http://www.nasa.gov/offices/education/centers/kennedy/technology/lunabotics.html>.