SYSTEMS ENGINEERING REPORT

3rd Annual NASA Lunabotics Mining Competition

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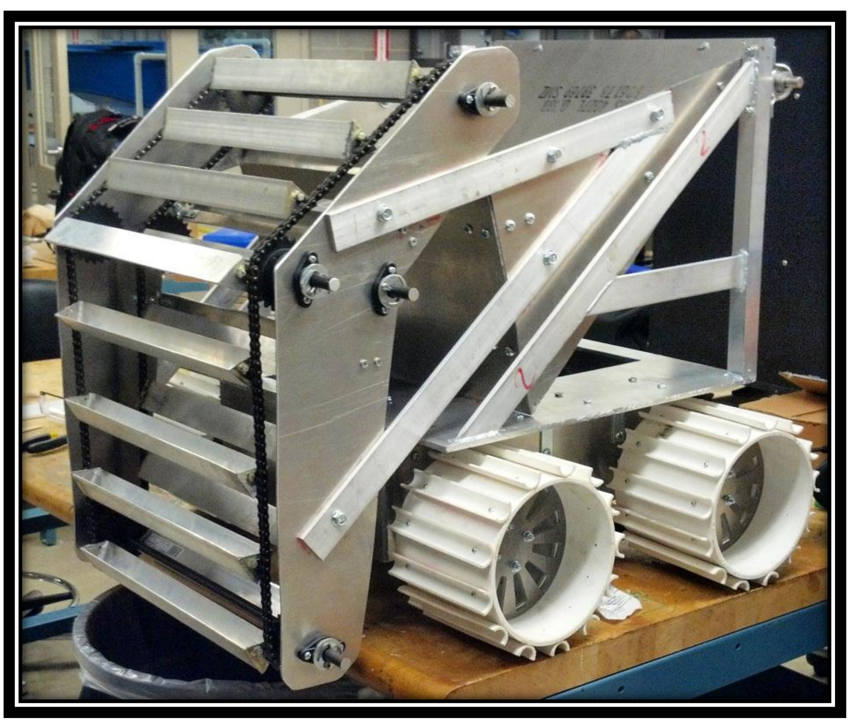
Abstract

We comprehended the necessity of NASA to excavate on the surface of the moon for research, lunar bases, and primarily for extracting regolith, a layer of loose material covering solid rock, to obtain useful resources such as water and oxygen for astronauts during a mission. For this reason, it is evident that NASA is concerned with innovative designs of excavating rovers. NASA's Lunabotic Mining Competition provides room for engineering students to develop, design and manufacture lunabots that may result in NASA's next mission. With this in mind, we obtained the responsibility of coming up with the design of a lunabot that will participate in the competition and will provide NASA the confidence of successfully completing a mission such as the one anticipated in this event. A visualization of every simple aspect of the problem had to be considered and analyzed before any further action. Since the physical conditions of the moon are very different from the earth, a special excavating lunabot had to be designed. One of the main aspects to be considered was the control system. The lunabot had to be controlled via Wi-Fi, an innovative long distance communication system, since no human contact with the lunabot is possible during the excavation process. Advantages and disadvantages for different approaches were analyzed to reach, step by step, a final design. As a complex NASA project, any requirements and constraints were accomplished to meet and over achieve NASA's standard within the given time period. The lunabot competition rules stipulate that the lunabot needs to be able to mine 10 kg of regolith and deposit into a bin 7.38 m away.



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Introduction

The National Aeronautics and Space Administration (NASA) has always been interested and occupied in aeronautics and aerospace innovations. NASA's mission statement has been to "pioneer the future in space exploration, scientific discovery and aeronautics research" ["What does NASA do?". NASA 2005. Retrieved August 29, 2007]. NASA's Lunabotics Mining Competition provides room for engineering students to develop innovative ideas and designs that may be used for NASA's research and space exploration. This competition provides students an actual real life experience, from generating ideas, research and concept selections to the actual design and manufacturing process of the project.

As a group of four mechanical engineering students for The University of Texas Pan American, we chose this competition as our final senior design project. In 2011, a previous group of students failed in completing this project but delivered in researching and providing part of the software and control systems for the present project. With minor start on the project, our team anxiously started working on the development, research and design of an innovative and competent lunar vehicle.

The objective and goal of the UTPA Lunabotics Team is to develop an innovative design and manufacture a lunar mining vehicle that will meet all the requirements in the competition. The competition rules stipulate that the lunabot needs to be able to mine 10 kg of regolith and deposit into a bin 7.38 m away and has to be controlled via Wi-Fi. The Systems Engineering paper will describe how the SE process was utilized in the development and final completion of the project.

Purpose

NASA has created a competition that challenges college level students to design a lunabotic mining vehicle which can excavate regolith. The designs of the lunabots will be studied for inspiration for possible lunar vehicles.

Our goals are to create a lunabotic mining vehicle that can meet the needs of the client. That is, designing a lunabot that can successfully mine regolith and transport it across NASA's obstacle course with dimensions of 7.38 meters in length and 3.88 meters in width. The objective is to design and build a lunabot that is going to accomplish all the customer's needs and wants. The design will be manufactured taking into account all the requirements and constraints. We will need to design and construct and lunabot within the constraints provided by NASA, that is capable of successfully mining at least 10 kg of regolith and must be controlled using USA IEEE 802.11 b/g Wi-Fi.

Deliverables

In order to successfully complete this project, deliverables were assigned to each group member. The design process was divided into four systems. The systems included: power supply, mining, mobility, and controls. Each system was assigned to a group member who was in charge of researching, designing, and innovate that system. Once the design process was completed, deliverables such as the hardware purchases were done as a group in order to stay within the budget. Other deliverables such as the presentations required by the senior design class, the outreach project, and the manufacturing of the final design were completed by all group members.

Budget

The UTPA Broncs Lunabotic Mining Team has a budget comprised entirely by The University of Texas Pan American Engineering Department. Our Budget is set at $2,300 for building materials given by the Mechanical Engineering Department. Our travel budget is $2,800 given by the Engineering Department Dean's office. We will be continuing our search for donations to cover the remaining cost for travel expenses. A few components we will be using have been provided by the engineering department and are not included in the budget.

Our budget has been divided into two separate expense groups.

Building materials (includes shipping)

- Mining mechanism/Hopper $900.00
- Frame $170.00
- Mobility $743.80
- Control systems $369.52
- Power supply $98.23

Total: $2,281.80

Travel expenses (5 people)

- Airfare $2301.00
- Shipping $772.00
- Hotel $1281.00
- Per Diem $1260.00
- Car rental w/fuel $359.67
- Insurance $380.00

Total: $6,353.67

Schedule:

The following schedules consist of competition requirements, team goals, along with senior design tasks to be completed for Fall 2011 and Spring 2012. Competition requirements consist of the outreach project, system engineering report, and video of the lunabot showing full functionality. Team goals are made up of a list of goals that the team should follow in order to meet deadlines for both the competition and fabrication of the lunabot. An example of team goals consists of each sub functions completed date, along with testing dates and when full functionality should be achieved. Senior design tasks are presentations and reports that need to be turned in based on our progress with the project as a whole

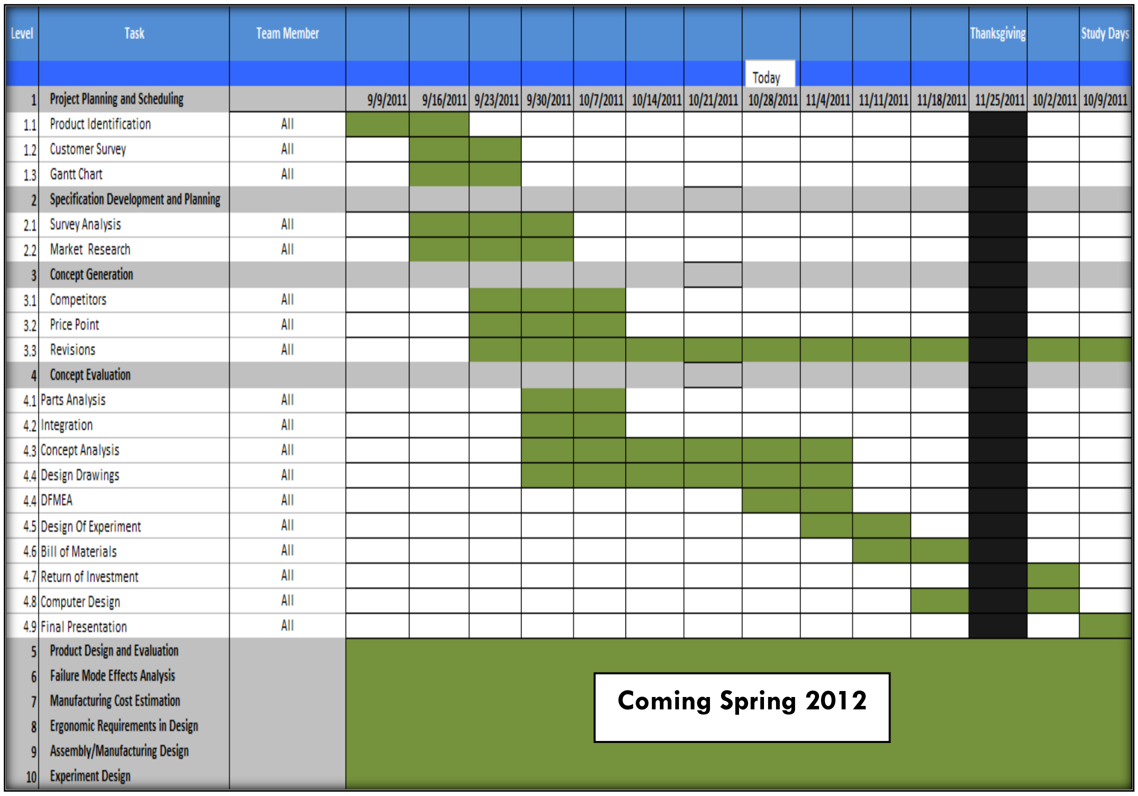


Figure A.1 - Fall 2011 MECE 4361 Project Schedule

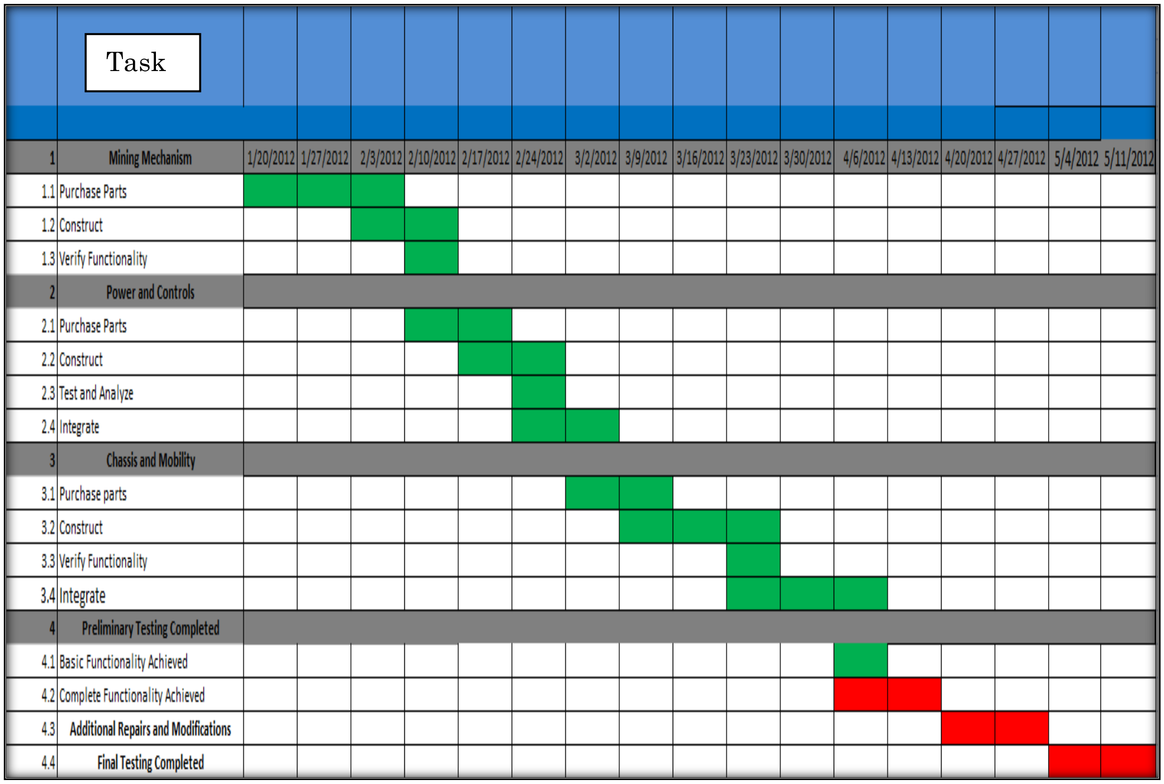


Figure A.3 - Spring 2012 MECE 4362 Project schedule

System Requirements:

NASA needs a lunabot vehicle to mine regolith, a lightweight chalk like soil which is found on the moon, for study and analysis. In order to compete in the competition, teams must abide by the rules set by NASA. The lunabot must also be designed with the parameters of the moon in a count for the mechanism design.

The system requirements were provided by NASA with the challenge of successfully building a Lunabotic Mining Vehicle while staying within the constraints provided for the competition.

A few of these constraints consist of:

The Lunabot must mine a minimum of 10kg within a time limit of 10 minutes.
The Lunabot must not exceed a maximum weight of 80kg.
The Lunabot will be operated via telecommunications.
The Lunabot must fit within a space of 0.75m tall x .75m wide x 1.5 long.

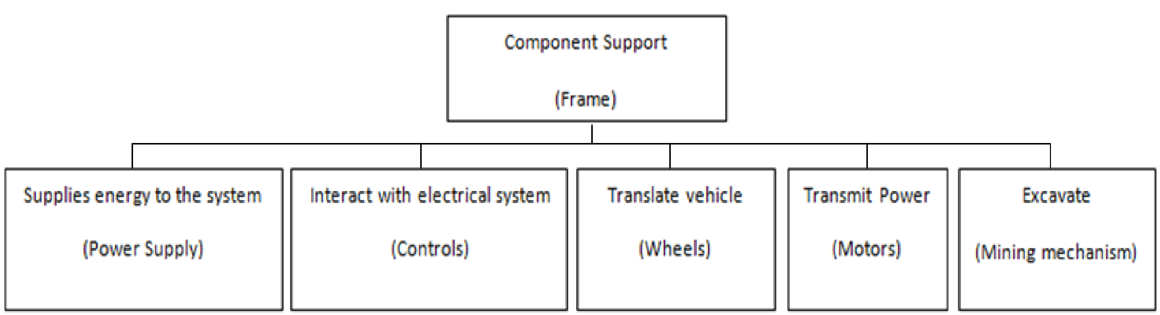
For a full set of rules and regulations for NASA's Third Annual Lunabotics Mining Competition refer to http://www.nasa.gov/pdf/390619main_lunaboticsrules.pdf

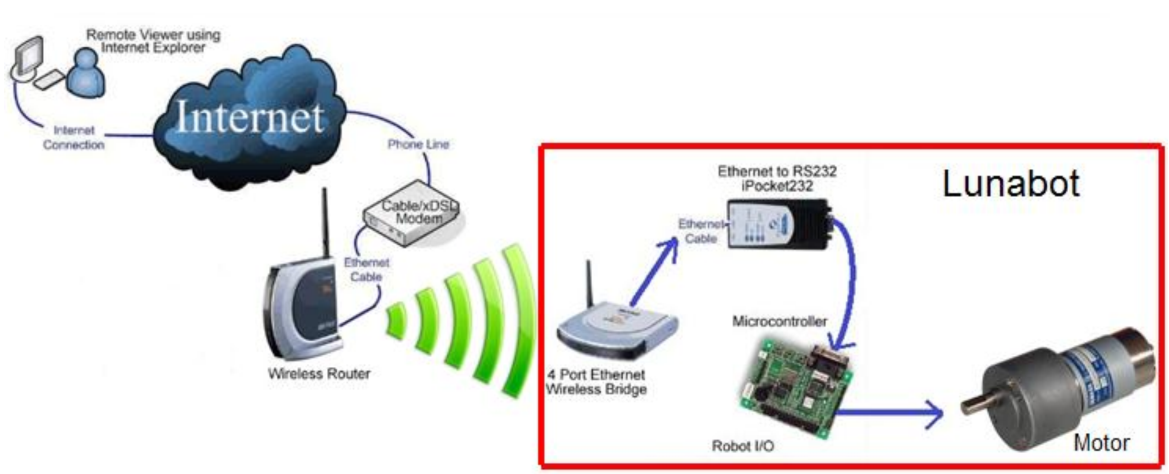
Design Concepts

In order to develop our concepts and generate ideas for the design, we researched the previous competition winner's designs. Unfortunately there is very little information on the competitor's design in order to keep their advantage over other competitors. Our group brainstormed ideas and created sketches for the several concepts we considered for design. Along with the brainstorming, we also researched images and design papers for existing components used in the same manner as our project's design purpose. Many of the winning concepts use preexisting mining techniques that have been slightly modified for their own needs.

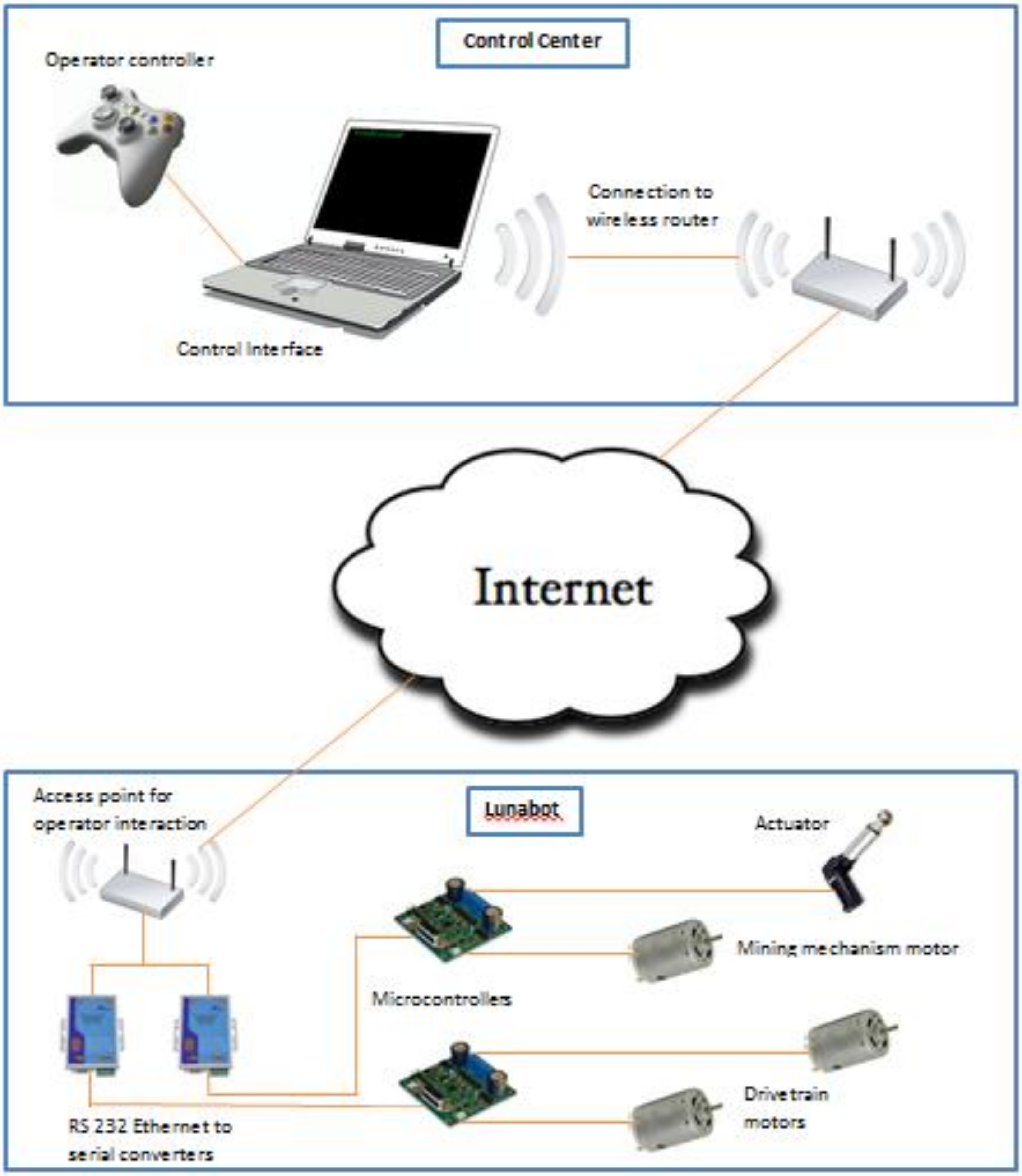
Our team has broken up the entire design process into four sub design components which are: power supply, mining mechanism, mobility, and controls and electronic systems. The power supply will take into account the motors, actuators, electronics, and weight used in the other three categories. We will also create a chart or diagram to find the maximum current load and power required to run the system. The mining mechanism will take into account the several possible mining techniques currently available and we will find the optimal technique for the design. Mobility will compare the wheels versus tracks for design and take into account the various materials and sizes available. For the controls, we will find several motor controllers and ways to control the vehicle and optimize the controller interface for ease of use.

Technical Content Illustrations

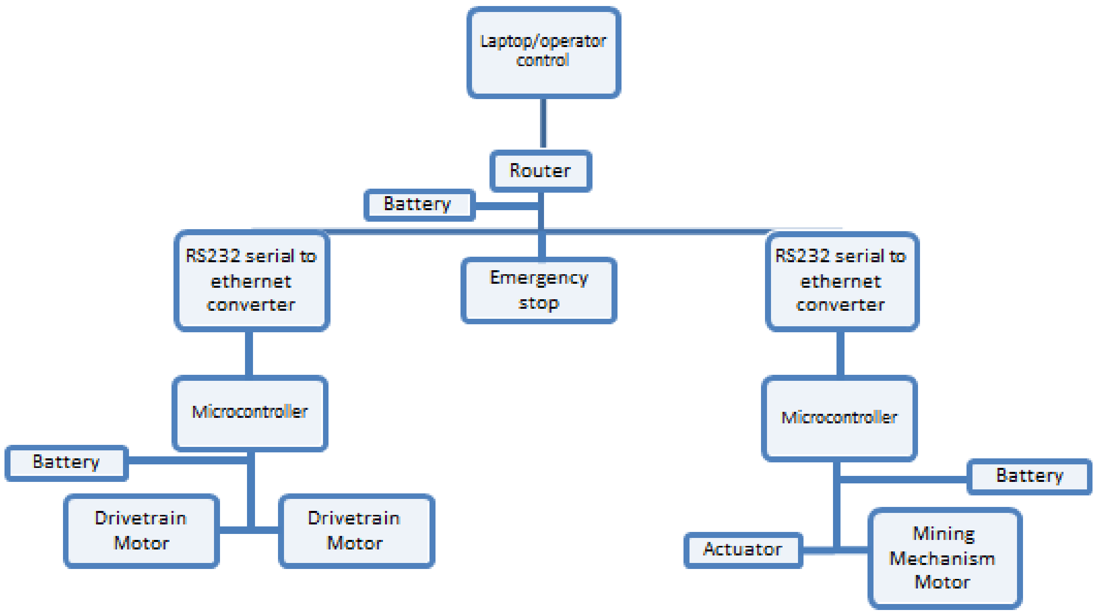




Concept of Operations



System Hierarchy



Basis of design

Our design was composed using several decision matrices which affected the components we would use. The decision matrices were created for every component we have available for possible use in each sub function for the entire system. The main sub functions were mobility, power supply, control systems, mining mechanism, and chassis. The matrices used the most important features for each individual component and were weighted properly. Once the final winning variant was selected, we took into account previous competitors which used similar components. The overall design had upgraded features of previous designs and implemented our own unique applications.

Interface Requirements

ID	DESCRIPTION	REQUIREMENT	TRACED FROM	PERFORMANCE	MARGIN	COMMENTS	REF
PC	Allows user to control motors wirelessly	Windows XP OS	WRT 54G, ATC 2000, VCOM, ROBORUN+	Complies	N/A		F-2
WRT 54G	Allows wireless interactivity between PC and Motor Controllers	Windows XP OS, 12V Power Supply	PC, ATC 2000	Complies	N/A		F-2
ATC 2000	Serial to Ethernet converter	12V Power Supply	PC, WRT 54G, VCOM	Complies	N/A		F-2
ATC 2000	Serial to Ethernet converter	12V Power Supply	PC, WRT 54G, VCOM	Complies	N/A		F-2
VCOM	ATC 2000 interface setup	Windows XP OS	PC, ATC 2000	Complies	N/A	Program setup for stability has room for improvement	F-2 F-2
ROBORUN+	Motor Controller interface	Windows based OS	PC, LDC 2250, SDC 2130	Complies	N/A	Program setup for stability has room for improvement	F-2 F-2
LDC 2250	Supplies power to Motors 1 & 2	10-50V Power Supply	PC, ROBORUN+	Complies	N/A		F-2
SDC 2130	Supplies power to Motors 3 & 4	7-30V Power Supply	PC, ROBORUN+	Complies	N/A		F-2

Figure F-1 Requirements allocation sheet

Requirements definition

Needs
Wi-Fi control, mine 10 kg of regolith in 10 minutes, use mining techniques suitable for lunar atmosphere, limit mass to 80 kg.

Wants
Mine 250 kg of regolith in 10 minutes, keep mass well under 80 kg, operate with a high energy efficiency, exceed the needs of the client.

Constraints
Have a mass no more than 80 kg, remain within size constraints W 0.75 m x H 0.75 m x L 1.5 m, Wi-Fi control is a must.

Overall System Design
Design each system to be very simple in operation to reduce the possibility of errors when in operation and increase reliability.

System interfaces
Mining mechanism, motor and actuator activation, mobility, operator software interface, electrical control systems.

Mining mechanism will be controlled by activating the motor attached to it for obtaining regolith. The height and depth of mining will be controlled using the actuator.

Mobility will be controlled using the motors it has attached to it. Directional control will operate by activating the separate left and right motors.

Software interface will provide the connection of the operator to the electronics. The controller will interact with the software and send signals for electronic systems control.

Electronics will be controlled using the software for the microcontrollers. Once the operator has implemented a function in the control system a signal will transmit to the router and be sent to the microcontroller.

Design margins

In order to design the lunabot, it needed to be designed to operate effectively and remain within certain parameters. The team was asked to be creative in the original designing of the lunabot but refrain from designing something to elaborate. In the end, it was the chassis engineer who had the final call on the structure and lead engineer in each of their system sub functions. Our team considered many components to be used in the design and used matrices to select the final components to reduce the margin of error in the system.

Trade off assessment

Based on our component choices, our lunabot will have tradeoffs in the design and functionality in operation. This trade off assessment will state the negative and positive features of the components we have chosen.

Mobility: Our mobility system uses wheels rather than tracks which give us less surface area for traction. It does not have a suspension which means we cannot drive over obstacles and must maneuver around them. The wheels are lighter than tracks, have fewer components, and are less expensive. The positive outcome for not including a suspension is we save money and time used for designing the suspension.

Control systems: The microcontrollers we are using are nearly 6 times more costly than alternative solutions. The positive features from the microcontrollers we are using are very significant and easily outweigh the cost. The operating software is much more user friendly, fewer parts are required to operate, it can handle higher currents, and has a built in heat sink.

Motors: The motors we have on our lunabots run at high currents which are very dangerous and require expensive microcontrollers. The positive features about the motors are high amounts of torque and excellent build quality.

Power supply: Our batteries are sealed lead acid and have a low energy to weight ratio and need to have a capacity twice the amount necessary to operate safely. The positive features are the high current rate of discharge and inexpensive purchase cost.

Mining mechanism and hopper: The mining mechanism we chose uses cups revolving around a chain similar to a conveyor belt system rather than using a scoop or auger. The negative features are higher weight, more components and risk of problems, and the power required is higher. The positive features are fast mining abilities and higher load capacity in one trip.

Risk assessment

Risk assessment is imperative in the design of any subsystem in order for the system to function as a whole. A system can fail in various points of any subsystem and that is why it is important to analyze each component in a subsystem to reduce or prevent failure. Also it is significant to identify what modifications can be made to the system to continue operating. Risk assessment takes into account all these things and this analysis helps locate failure points by implementing the table in Appendix A which identifies the subsystems and examines which components might fail. Also this analysis detects methods to recover in case of failure.

RISK MANAGEMENT

1 - Failure: Operation cannot be accomplished.

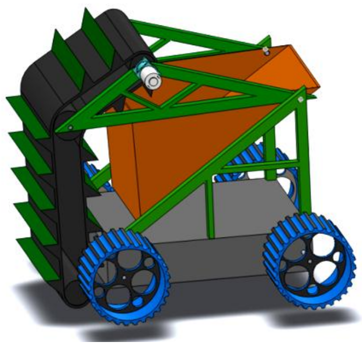
2 - Limited time: Operation can be completed in less time than anticipated.

3 - Limited performance: Operation can be completed with compact capabilities.

4 – Non-dangerous: Operation can be completed with minor difficulties.

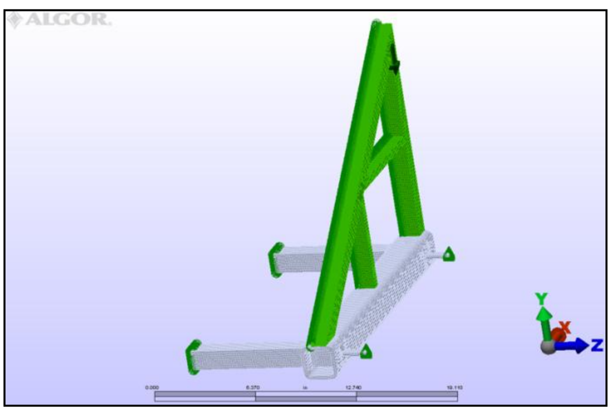
Subsystem	Component	Risk	Effect	Level	Solution
Power Supply	Batteries	High current draw	Melting of wires/Fire	2	Proper wiring was chosen
Mining	Cups	Excessive force	Breaking of cups	3	Replaceable cups
	Chain	Excessive force	Breaking of chain	3	Adjustable actuator
Mobility	Wheels	Excessive Weight	Breaking of wheel	1	Aluminum rims attached
Controls	Ethernet transmitter	Loosing communication	No control of vehicle	1	Previous testing

Reliability Requirements



Total mass = 109.35 lb

- The lunabot has to excavate and transport back to the collector 114.64lbs as many times as possible without any failure, in this case without frame failure.
- The load will be applied vertically in the negative direction where the hopper will be pinned to structural frame.

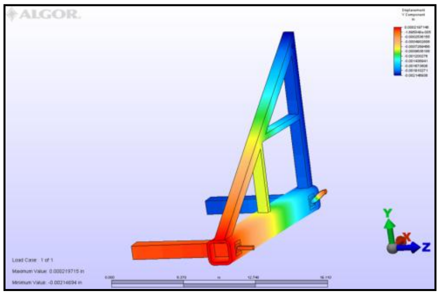


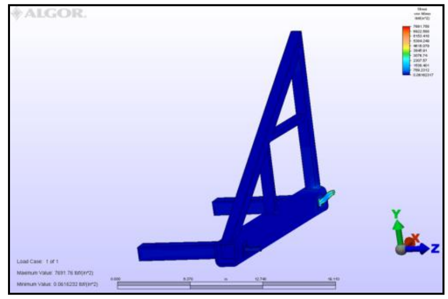
Finite element model using symmetry

- Solid mesh's surface:
  - 6 parts
  - 60,431 elements
- Mesh Type:
  - Solid
- Solid Mesh Type:
  - Mix of bricks, wedges, pyramids and tetrahedral

- Boundary Conditions:
  - Fixed at the tip of the shafts
  - Model symmetric with respect to the Z-axis
- Forces applied:
  - 57.34 lbf on the upper frame section

Results for Aluminum 7075-O



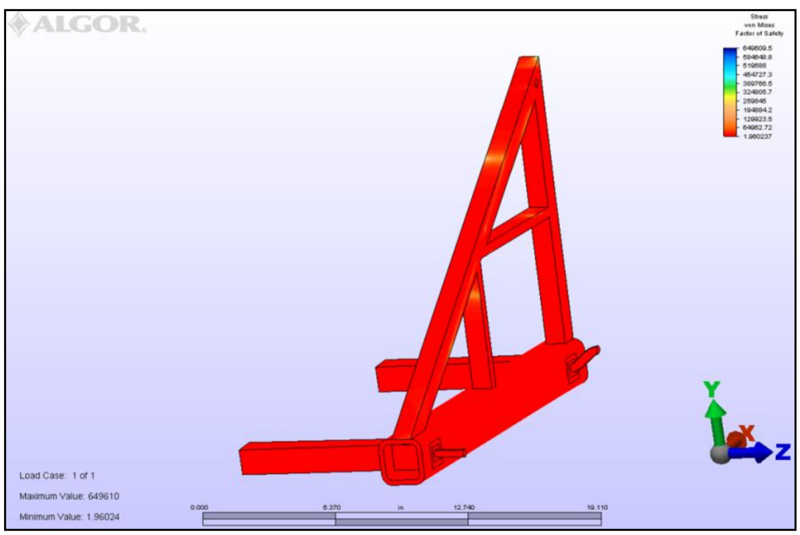


- Displacement Analysis:

- Max value = 0.0002197 in
- Min value = -.0021469 in

- Stress Analysis; Von-Mises(psi):

- Max value = 7691.76
- Min value = 0.061623



- Factor of Safety with respect to Von-Mises:
  - Max. value = 649610
  - Min. value = 1.96024

Product Verification

As of today all the testing regarding the correct functionality of our lunabot as a system is complete and further testing regarding data gathering will be completed in the next following days. The system model conforms to the build-to requirements as well as complies with the interface for participation in the 3rd annual NASA Lunabotics mining competition.

The Flow down of Requirements

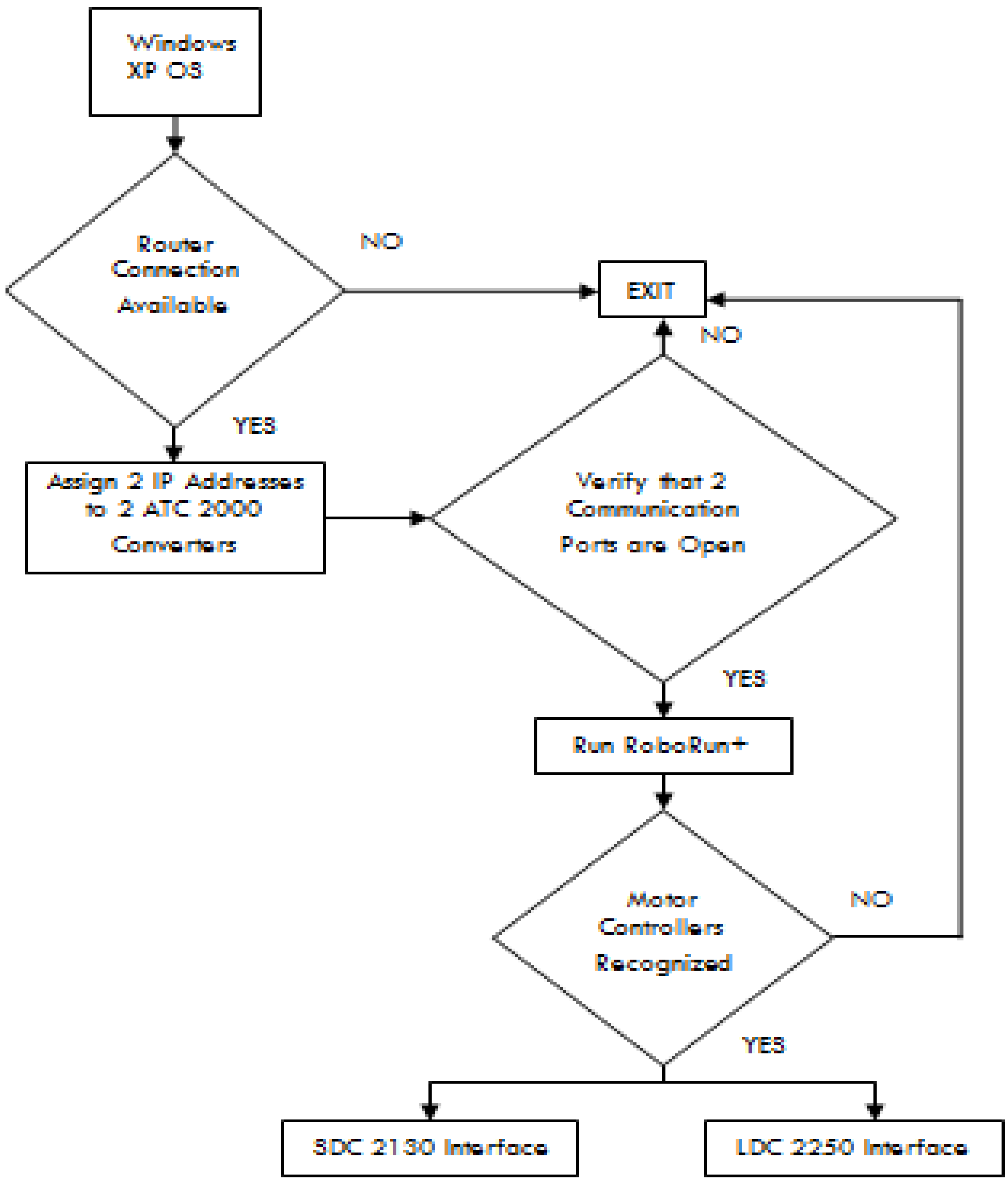


Figure F-2 The Flow down of Requirements

Project Life Cycle

Phase A (Conceptual Design):

In order to develop our concepts and generate ideas for the design, we researched the previous competition winner's designs. Unfortunately there is very little information on the competitor's design in order to keep their advantage over other competitors. Our group brainstormed ideas and created sketches for the several concepts we considered for design. Along with the brainstorming, we also researched images and design papers for existing components used in the same manner as our project's design purpose. Many of the winning concepts use preexisting mining techniques that have been slightly modified for their own needs.

Phase B (System Concept):

- Power Supply: Supplies the power to the controls, motors, and electrical systems.
- Controls: Provides the connection from the user control system to the vehicle's electronic function systems.
- Mobility: Provides the vehicle with traction and directional control with contact between terrains.
- Motors: Converts electrical energy to rotational energy used for rotating wheels or powering the mining mechanism.
- Frame: Supports and combines the components which create the entire vehicle.
  Mining mechanism: Mines the material used in the competition.

Phase C (Final Design):

The final design was based on the wining concept variants with the revolving cups as the mining mechanism and wheels as the mobility component.

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