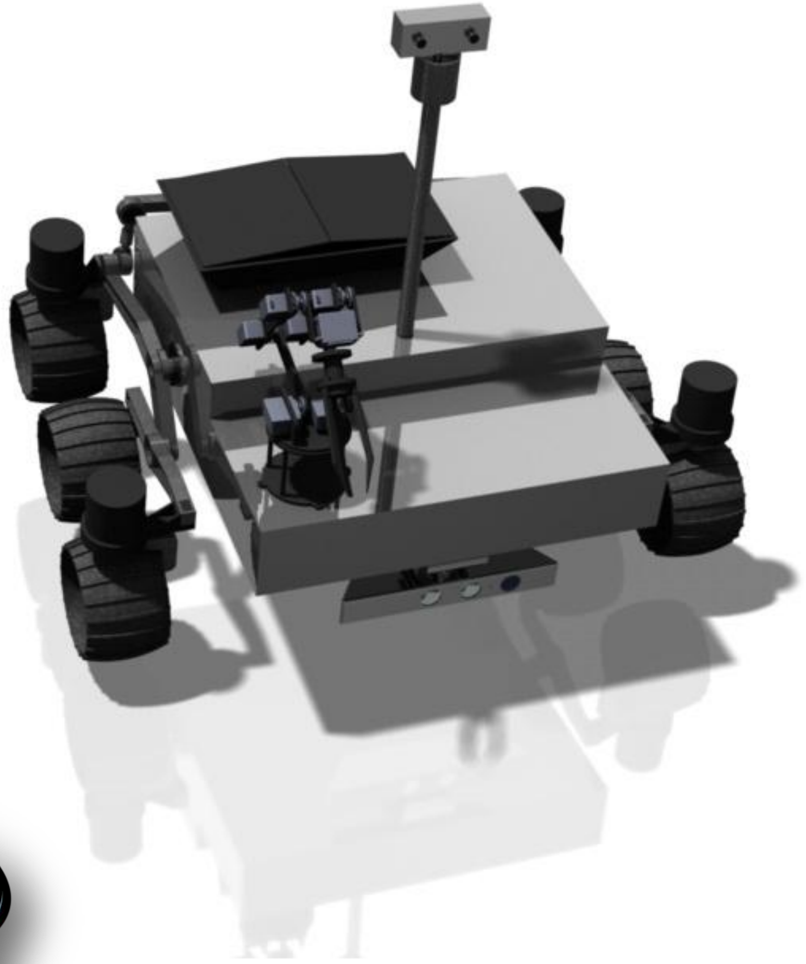
University at Buffalo 2012 Space Bulls Rover Design



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Advisor: Dr. Puneet Singla is an Assistant professor in the Department of Mechanical and Aerospace Engineering (MAE) in University at Buffalo (UB).

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Introduction

The University at Buffalo (UB) Space Bulls has constructed a fully integrated semi-autonomous rover design for the 2012 RASC-AL OPS Robo competition. The UB Space Bulls participated in the 2011 RASC-AL ROBO-OPS competition where they successfully designed and constructed a rover that completed many of the required tasks. The 2012 UB Space Bulls design features a number of very effective features including a rocker-bogie suspension system, a 4 degree-of-freedom manipulator, a 6 degree-of-freedom navigation solution, and on board image processing.

The 2012 Space Bulls team aimed to improve upon the previous design by lowering the overall weight, decreasing complexity and providing more reliability from each of the rover components. The team also encountered issues and other design challenges described further.

Specifications

Motor Assemblies

The main area of focus for the 2012 rover design was lower weight, high torque drive motors for each rover wheel. We have purchased motors from Maxon Precision Motor Inc. that meet our torque and weight goals, and also have an integrated motor encoder and control solution.

We have selected the following motor configuration from Maxon:

- RE35 #273754
- GP42C #203129
- HEDL Encoder #110514
- ADS 50/5 #1435391

The RE35 motor [1] we have selected is the 273754 configuration combined with the ++GP42C gearhead [2]. This provides us with 10-15Nm of torque depending on input voltage (24V and descending.)

This configuration reduces the weight from our original motor assembly of 2kg to 825g each. This reduction reduces the load exerted to our wheels and improves the drive motors' torque capabilities. This provides an overall improvement in the rover specifications.

We have also selected encoders and motor controllers for individual wheel control and feedback. This allows us to perform advanced control kinematics and turning of the rover. It also provides the operator with advanced control over each individual wheel depending on terrain conditions. The motor controllers selected have very straightforward control which assisted in programming and wiring of the motors.

In addition to replacing the original drive motors for a tremendous savings in weight, we have also replaced the motors utilized for turning with four ultra-high-torque servos from Invenscience LC. These servos can deliver 115 kg-cm with a travel of 90 degrees within 1.5 seconds. These servo motors provide us the necessary torque for turning our wheel assemblies. Because the servo is also an integrated motor solution, it is self-correcting and contains an integrated motor controller. Programming the servos for the correct turning angle also becomes much more simplified than relying on an encoder for a traditional DC motor and estimating its position which proved to be a challenge in the previous year. Each servo weighs only 1kg, providing us with an additional weight savings. The servo is also much smaller than the motors utilized in the previous design which lowers stress on the suspension.

Power

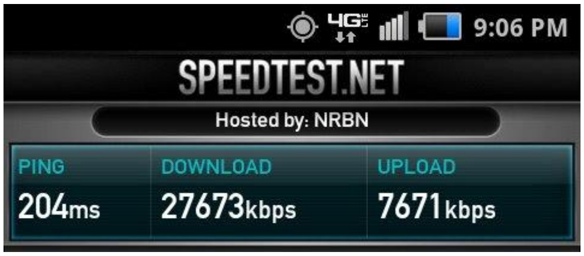
Figure 1

To power our rover during the course of the competition we have selected to use a 25.9V 21Ah battery. The native battery voltage can be used to power the motors directly with no regulation, and all other components on the rover can be powered using simple voltage regulators which convert the voltage to 12V and 5V with minimal wiring and complication. The 21Ah capacity of the battery provides us with adequate power throughout the duration of the competition.

We are also utilizing a Pyle 24V to 12V, 720W, 30A max load regulator for our computer, turning servos and other accessories. This unit provides us with adequate overhead in case of power usage spikes such as in the case of all 4 turning motors engaging at once.

Figure 2

Communication



SPEEDTEST.NET

Hosted by: NRBN

PING	DOWNLOAD	UPLOAD
204ms	27673kbps	7671 kbps

Figure 3

For remote communication with the rover, we have made it a priority to utilize 4G LTE as the data connection for the fastest possible uplink speeds instead of the 3G utilized last year. 4G LTE upload speeds are faster than 3G upload speeds by several factors and has achieved widespread industry adoption in the previous year. We have placed importance on this because we wanted to have the most flexibility and speed in transmitting video and images to our control center. We are using a Verizon Wireless 4G LTE smartphone as the 4G transmitter and sharing the internet connection with our onboard computer. In our testing we have achieved an average of 8 Megabits or 1 Megabyte upload speed outdoors without obstacles. We have found this to be enough to be able to transmit video in 1280x720 high definition resolution from our camera without a significant loss in video quality. Extensive testing was done to verify the stability of the internet connection and was found adequate for our needs. Data overhead for rover control was minimal and not significantly affected by in the increase in data throroughput.

Computer

Figure 4

The computer we have selected to serve as the rover's main control computer is a ZOTAC M880GITX-A-E Mini-ITX computer. The processor and motherboard are integrated into a very small and lightweight package having no excess parts and weight than our rover requires such as case, optical media drive and other accessories. It utilizes the latest dual core low power CPU and GPU solution from AMD. This processor allows us to perform complicated kinematic controls quickly and while using little power without complicating programming as it is based on the x86-64 architecture found in most common desktop computers. The computer is also equipped with 4GB of DDR3 desktop memory which is very quick and high capacity, benefiting us by increasing the amount of data we can process simultaneously. The computer provides an adequate amount of USB ports so that we are able to interface with all of our required hardware without needing external hubs or hardware. The heat output is also low, which is a factor when the aluminum chassis is exposed to direct sunlight and becomes hot.

Because of the low power requirements of our computer, we have chosen a PicoPSU as the main computer power supply. The PicoPSU is a very small DC computer power supply only slightly larger than the physical 24 pin power connector on the computer. It is also a DC supply which allows us to power the computer using only a voltage regulator from our battery. We are also able to power our main computer drive with this supply without excess circuitry and voltage regulation.

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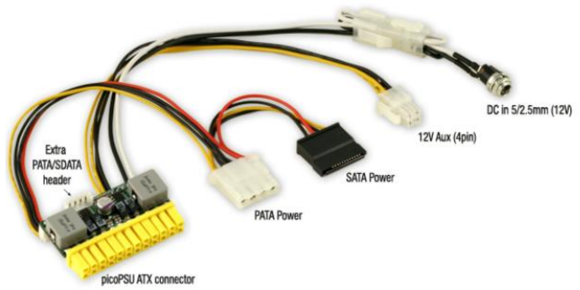

Figure 5

In addition, we have also chosen to utilize a Solid State Drive (SSD) for the main drive of the computer. Last year the team encountered issues using a traditional magnetic based hard drive due to vibrations of the rover during movement causing errors in reading and writing to the drive. The SSD is not affected by shocks from the rover, and has read/write speeds greatly exceeding that of the magnetic based drive. This also helps increase calculation speed for our kinematic controls during accessing data on the disk. The SSD also has a much lower power requirement which eases the load on the voltage regulator and increases the life of our battery.

Robotic Manipulator and Sample Acquisition

Our team went through a variety of testing phases selecting a robotic manipulator solution for the rover so that it can collect samples during the competition. The initial prototype was fabricated from wood using a CNC mill for quick manufacturing and looked promising during tests. We however encountered issues during manufacturing of the arm from aluminum and to save time the team has opted to utilize a prefabricated robotic arm solution from Lynxmotion.

The selected arm also includes a complete software package including position tracking and complete inverse kinematics. The robotic arm has 4 degrees of freedom in its travel and has predetermined points which were calibrated in the lab before the competition. These controls would allow for setting wave points which would calculate all the required turn angles of the servos on the manipulator. During the competition, the rocks will be positioned under one of the set-points and the manipulator will be tasked to maneuver to the set-point and pick up a sample rock.

Another set parameter is a sequence for the manipulator to maneuver and drop the rock into our sample collection unit. Manual control of the manipulator will be available in the case that the set-points fails or the required task is too complicated for the inverse kinematic or there are obstacles in the way.

Figure 6

Testing

The rover has gone through extensive testing in each of its component systems and as a whole system. Notable testing will be described further.

Robotic Manipulator and Sample Acquisition

The robotic manipulator was extensively testing throughout the rover design process. The rover operator went through many hours of becoming familiar with the arm control and practicing of moving objects and potential rover samples. In this testing it was revealed that the original arm selected had several issues:

- Large arm weight
- Issues with arm fabrication
- Issues with gripper manipulating samples

It was decided to choose an alternate robotic arm solution rather than spend time working out issues with the arm the team would purchase a completed robotic arm solution. The selected arm features a reduced weight, higher gripping force and inverse kinematic controls. The rover operator has also spent considerable time with the new robotic arm solution and has found it favorable to the previous selection.

Communication

Data communication using the 4G LTE connection was tested extensively. Utilizing the 4G LTE, latency delays averaged to be 1 second for sending control commands and 3 seconds for video. The rover operator has practiced controlling the rover and has successfully compensated for the delay and we feel it will not hinder our performance in the competition. The 4G connection was also tested for sustained data usage and encountered no issues

Additionally, the computer was able to successfully communicate to our operations center over the internet during our testing without issue. The team feels as though the 4G LTE connection will give us a necessary advantage in the competition.

Outreach

Our team has made a great effort to reach out to the public with our work. The Space Bulls team has participated in monthly trips to the Buffalo Museum of Science. This museum has provided us with great opportunities to inspire kids and adults with our engineering work and many people have been impressed with our displays.

Figure 7

Locomotion

The reduction in the motor mass will reduce over-all weight and will allow for smaller suspension members.

Wheel Size/Design

Each of the six wheels have individual motors, and the two front and rear wheels have another set of steering motors. The wheels are made of aluminum with a hollowed middle and extrudes that act as cleats for the rover. The dimensions of the wheel vary on the size of the overall rover. By having an increased diameter for the wheel, there is an increase in the available traction while decreasing the rotation by the motor. This presents a more robust wheel with good traction on rock surfaces. In a more realistic version for Mars rover, this wheel design fulfills an out gassing requirement.

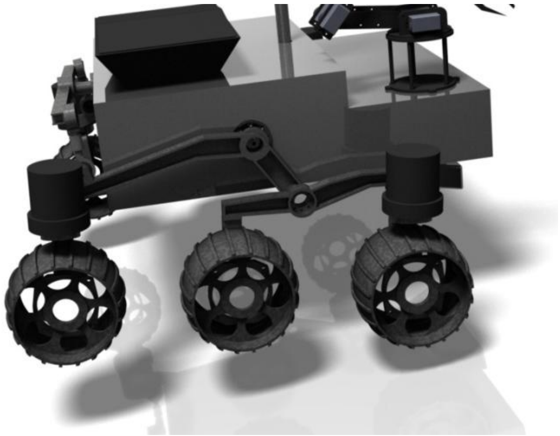

Figure 8: This figure displays a clear view of the wheels and its allocated positions within the rocker bogie suspension. The wheels are driven with independent motors. The wheels clearly show extrusions that would function as increased grip when climbing over obstacles

Video and Camera

A live video feed from the rover is the most critical component to the rover operator. The operator will rely on video for navigation, detection of obstacles, and control of the manipulator. To improve upon the existing system of two low-resolution cameras, a high resolution camera will be place on top of the rover, and a Microsoft Kinect sensor will be situated at the front.

In some situations the video feed may not provide enough detail for the operator to make the best navigation choice. The operator can command the rover to provide a single, high-resolution still image. An image may take several seconds to be transmitted so the rover will remain stationary while the image is received. A focused and detailed high resolution photo provides valuable information about the rover's environment.

3 View Drawing or Solid Model Representation and Dimensions

The Figure 11 above displays the major components of the system. The camera is mounted on a stowable mast which will allow for compact storage and increase visibility when extended. On the bottom of the rover is the location of a mounted Microsoft Kinect, which will act as a depth sensor. On the rover's front right side, a manipulator is attached which will be used to grab the required rocks and place it in a payload container at the rear of its chassis during the competition. The wheels can be seen with four steering motors, attached to a rocker bogie suspension system.

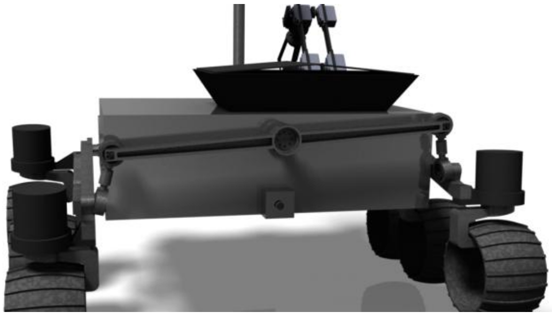

Figure 9: This figure showcases a CAD model of the averaging link at the rear of the rover. This allows for the chassis to maintain its initial or leveled position while overcoming obstacles. Impulses and drifting caused by rocks would be eliminated through this link by maintaining the pitching moment of the wheels

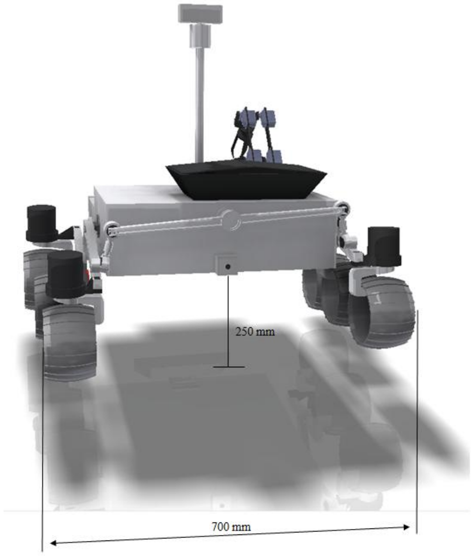

Figure 10: This figure displays the dimensions of the maximum width of the rover. The averaging link's location is also displayed

Material Selection

Materials that would be chosen for the rover are compared for meeting our specification requirements listed below:

1. Weight: One of the most important requirement, as the limit for the mass is 45kg. A light weight material for these parts is a must.
2. Strength: The material selected should be strong enough to withstand impact loadings and fatigue from the terrain.
3. Cost: Due to a limited budget, desired properties of the different material of are compared for inexpensiveness.

Taking these requirements into consideration, a decision for 6061T6 Aluminum Alloy was chosen. Below is a table of the chemical compositions of the alloy.

Aluminum Alloy are used widely in many applications including aerospace applications. It is easily fabricated and resistive to corrosive atmosphere. The composition of 6061 allows the metal to possess high strength, high resistance to corrosion, good workability and joining characteristics. Out of the heat treatable alloys, 6061T6 incorporates an annealed condition which allows excellent weld-ability and formability while improving its strength and hardness. Below are tables of the physical properties and the mechanical properties of the alloy.

Density	2.7 $\frac{g}{cm^3}$
Elastic Modulus	69500 MPa
Linear thermal expansion coefficient (20^0~100^oC)	24.3 µm/m-°C
Thermal conductivity	167 W/m-K
Electrical conductivity	43 MS/m

Table 1: Physical Properties of 6061T6 Aluminum Alloy **Team:** Calvin Lau, Alexy Mikhailichenko, Richard Linares, Jimmy Lam, Varunkumar Vruddhula, Muazzam Azam, Pramod Chembrammel, Christina Pinzone, Jeevan Suparmaniam, Deepak Kumar

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Thickness (mm)	Ultimate tensile strength (MPa)	Yield strength (MPa)	Elongation (%)	HB
1.6mm 12.7mm	310 Mpa	276 Mpa	12% 17%	95-100

Table 2: Mechanical Properties of 6061T6 Aluminum Alloy

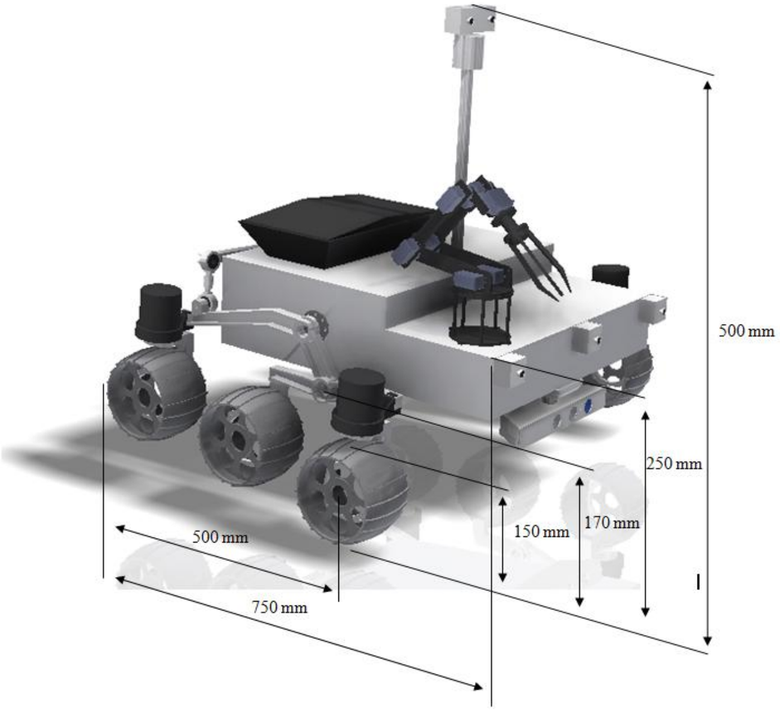

Figure 11: This figure displays the overall dimensions of the rover. It is evident that the model is within the competition's requirements. It is also evident of a good clearance from the bottom of the chassis towards the ground, and that the major components such as the wheels are spaced to prevent component interference

Team Subsystem Leads Background

Advisor: Dr. Puneet Singla is an Assistant professor in the Department of Mechanical and Aerospace Engineering (MAE) in University at Buffalo (UB). His area of research is Uncertainty propagation in dynamic systems and stochastic control.

Team Lead: Calvin Lau (BS in Electrical, Mechanical, and Aerospace Eng.) has experience in CAD, integrated circuits, mechanical designs and fabrications, and power systems.

Mechanical: Sean Bicknell (BS in Mechanical Eng.) has experience with CNC machining and robotic suspension design and fabrication.

Controls: Richard Linares (Ph.d Student Aerospace Engineering, MS and BS Aerospace Engineering). Has experiment with controls algorithm design for dynamics systems and developing inverse kinematic models.

Navigation: Philip Odonkor (BS in Mechanical and Aerospace Eng.) has done research in dynamics lab and has experience with Kalman filtering and navigation algorithms.

Telecommunication: Alexy Mikhailichenko (BS in Computer Eng.) has background in networking and programming in Linux based systems and C related languages.

References

[1]http://www.maxonmotor.com/medias/sys_master/8796761227294/RE-35-273752_11_EN_081.pdf
[2]http://www.maxonmotor.com/medias/sys_master/8796903866398/GP-42-C-203113_11_EN_237-238.pdf
[3] http://www.ros.org/wiki/
[4]http://www.ros.org/wiki/rgbdslam