OVER SAND VEHICLE PROJECT

MILESTONE 3 TECHNICAL REPORT

Goetzynski Terrain Mapper

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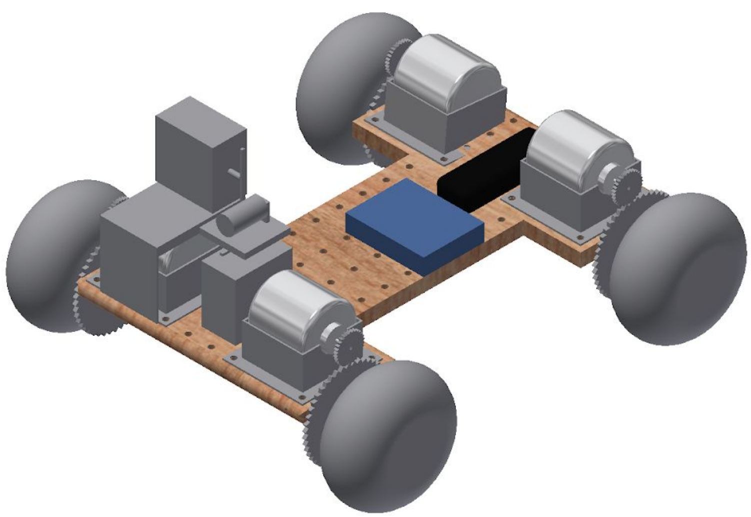
OCTOBER 16, 2015



THIS TECHNICAL REPORT CONTAINS THE PRELIMINARY CONCEPTS, IDEAS, AND DESIGNS THAT WILL BE UTILIZED IN THE CONSTRUCTION OF THE OVER SAND VEHICLE.

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APPROVALS

TAMER BADER

CAD drawings, Sensors and Actuators, and Propulsion

PATRICK DOUGHERTY

Title page, Table of contents, Approvals, Executive summary, Introduction, Decision matrix template, Gantt chart, Anticipated difficulties, Formatting, Editing, and Wiring schematic.

AUSTIN GONCZ

Structure, Power, decision matrices for Structure and Power, complete CAD model, Run Time Calculations, Construction and Testing Plans, Mass Estimation

GRANT HOOVER

Control Algorithm, Report compilation, editing, and formatting.

SHAINA PATEL 

Anticipated difficulties.

OUMOU SIDIBE

Reorganizing, proofreading

EUGENE WON

Propulsion, Power, Motor calculations, Bill of Materials, editing, formating.

CODY WRIGHT

OSV Mission details, Sensory design details.

EXECUTIVE SUMMARY

Background:

The Goetzynski Terrain Mapperz is a team of engineers designing a small and autonomous vehicle. This vehicle will be able to navigate an island in the Pacific Ocean and collect informations about plane wreckage that has washed ashore.

Goals:

The goals of the Over Sand Vehicle (OSV) are to successfully travel over the sandy beaches of the island, find the plane wreckage, and send back information about the terrain in under five minutes.

Objectives:

The team is dedicated to finding the boulder located at (2400mm, 800mm), accurately measuring its length along the y-axis, determining the its color, accurately calculating its surface area, and transmitting all of the data back to headquarters.

Constraints:

The OSV must be small enough to navigate the beach. In addition, it must be fully autonomous, using a combination of inputs from the navigation system and the Arduino. The battery used in the OSV must not be a Lithium-ion battery. Out of the motors, wheels, chassis, suspension, and transmission, only two pre-built components may be used. The OSV must not pose a safety hazard, limiting the possibility of any sharp edges.

Solution:

To begin, the OSV will be placed in the sandbox in a random orientation. The OSV has a black tracking marker that will allow the it to determine its location. Once the OSV travels to the boulder, it will measure the length and height of the boulder using a laser sensor. These measurements will be sent back to the headquarters using a radio module.

INTRODUCTION

Objectives:

Using the laser distance finder, the OSV can determine the y-length of the boulder. In Addition the OSV will determine the surface area of the boulder, using its measurement of the z-length, and send back the area calculation.

Constraints:

The OSV must not have a mass above 3kg or an overhead footprint of 35 cm by 35 cm. The mission must be completed in less than five minutes. Overall, the OSV cannot cost more than $350 at fair-market value, including the cost of all 3D printed parts. All of the expenses of the parts are explained in the Bill of Materials (p.15).

Design:

The Goetzynski Terrain Mapperz will utilize a Baltic Birch Plywood chassis that sits upon a four-wheel-drive system. To avoid the two obstacles, the OSV footprint will be smaller than 350 cm by 350 cm, allowing the OSV to move between the obstacles. When the OSV arrives at the boulder, it will measure the boulder with a laser distance finder that changes angles, detecting the distance between the edges of the boulder. With the known change in the angle and distance measurements, the OSV can calculate the length and surface area of the boulder. All of this information will be transmitted back to the headquarters using a APC220 Radio Communication Module.

Benchmarking:

The group feels confident that it can successfully complete the OSV project. The perceived success on Milestone 1 helped spur the group's sense of pride. Although the other groups did well, seeing the other presentations also made us feel good because the Mapperz appeared to have a more effective organization and better sense of direction. Carrying forward the auspicious feelings, the group plans to win the competition at the end of the year.

PRELIMINARY DESIGN DETAILS

Structure:

The team initially wrestled with how to physically design the structure of the OSV. The sub-team went through many initial considerations including PVC pipe, 3D Printed PLA, and pre-built aluminum structures. After utilizing a decision matrix with various criteria (Figure 1.), the sub-team decided to build the OSV structure out of multiple layers of perforated (to attach motor housing, sensors, and Arduino) Baltic Birch plywood. This structure was preferable because of the combination of versatility, strength, cost effectiveness, and ease of construction. The nature of its construction allows us to manipulate many of the discussed features in order to account for design changes down the road.

Once ordered, the plywood will arrive as a single ⅛’ x 12” x 30” (3mm x 304.8mm x 762 mm) piece that the group will cut into the following dimensions. First, a 3 x 200 x 325 rectangle will be cut out of the original sheet. From there, 2 additional 3mm x 50mm x 162.5mm rectangles will be cut out of the 325mm side equidistant from both 200mm edges (Figure 2.). To increase strength and protect against torques produced by gravity, multiple layers of wood will be glued together. Each sheet will also be perforated with 112 holes, each 5mm in diameter to allow other structures to be attached to the OSV. The estimated total mass was calculated using a ratio of volumes and the initial mass of the plywood, as well as the number of sheets that will be used. It was determined to be approximately 0.343kg (Figure 3.). A counterweight will be added to balance the OSV and increase the friction between the wheels and the sand.

Decision Factors		PVC	Pre-Built Assembly	3D Print	Plywood Sheets	Decision Matrix - Structure	
Criteria	Wt.	1	2	3	4	Criteria	Definition
Lowest Cost	0.8	18	10	15	19	Lowest Cost	Allows for effective budgeting
Ease of Assembly	0.4	15	20	7	18	Ease of Assembly	The design should be such that it allows for freedom in the placement of parts during construction
Ideal Weight	0.5	11	15	8	14	Ideal Weight	The design should not be too light, nor too heavy. Rather, in an intermediate zone to provide friction to the wheels but allow for heavier parts to be placed elsewhere
Under Footprint Size	0.9	8	6	15	18	Under Footprint Size	The OSV Structure may not exceed 350x350mm
Necessary Strength	0.6	16	20	8	16	Necessary Strength	The design must be able to hold all necessary parts, as well as move across the pit and complete the mission without breaking, falling apart, bending, etc.
Easiest Integration	0.7	14	10	15	16	Easiest Integration	Ability to be integrated with other sensors and/or parts of the OSV
Weighted Scores		53	47.9	47.6	66.4		

Figure 1: Structure Decision Matrix

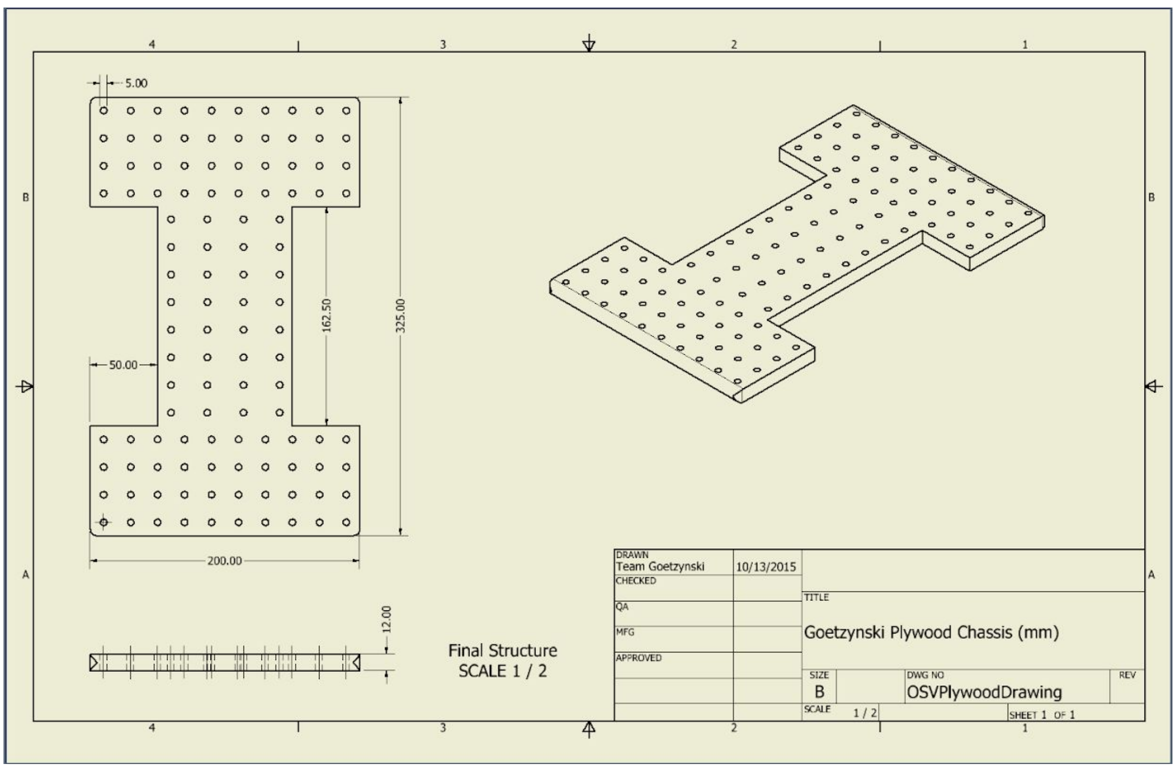


Figure 2: Plywood Chassis CAD Drawing

Goetzynski OSV Mass Estimate			
Plywood Mass (Amazon.com) (kg)	0.49895161	Volume of OSV = V of Rectangle - 2x V of Cutout - 112 x Vcylinders	119860.6217
Total Sheet Dimensions (mm)		Volume of Plywood Sheet	696772.8
Length	762	Volume Ratio = Vosv/Vsheet	0.172022533
Width	304.8		
Height	3		
Rectangle Dimensions (mm)		Mass of OSV = (# of Sheets used) x (Volume Ratio x Total Mass)	
Length	325	Using 4 Sheets...	
Width	200	Estimate (kg) =	0.343323678
Height	3		
Cutout Dimensions (mm)			
Length	162.5		
Width	50		
Height	3		
Cylinder Dimensions (mm)			
Radius	5		
Height	3		

Figure 3: Mass Estimation.

Propulsion:

Multiple ideas were generated for the propulsion system. Initially, the group decided on a steering and drivetrain/power system that were independent of each other, much like that of a car. However, the sub-team reconsidered using a system in which the steering and drivetrain were dependent on each other to reduce the number of components and the likelihood of complications with the system. As a result, the propulsion system will consist of four drive motors that drive each wheel independently. Each wheel will be geared to the same ratio so that it can act as one and be independently steered.

This steering system is called a track steering system, similar to that of tanks, minus the tracks. The left and right sides are propelled in a manner in which the variable speeds of the wheels determines how the vehicle steers. All four wheels will spin forward at the same rate, propelling the OSV forward in a straight line. The same applies for reverse, with the wheels spinning backward. If the left and right wheels spin in opposite directions, however, the vehicle can rotate with a virtually zero turning radius.

Each wheel will be powered independently by a 6-24V motor, a pinion gear, and a drive gear. The pinion gear spins the drive gear, which is attached to the axle, thus propelling the wheel. The motor provides a relatively slow rotational speed at a low voltage, which means that the gear ratio does not need to be as high as what was originally anticipated. The mass limit of the vehicle is 3 kg, and if we use wheels with a radii of 100mm, the torque necessary to move the vehicle is approximately 0.4 Nm. We have yet to calculate the stall torque of the motor, but given the voltage, current draw, and a motor speed (6V, 180mA, 2500rpm), we can calculate the stall torque as we are testing the motor.

The wheels come from a radio controlled truck. They will have treads and be made of a soft compound for increased traction. The sub-team is also looking for a tire diameter of no larger than 100mm each to stay within the footprint requirement and large enough to reduce the likelihood of getting bogged down and stuck in the sand.

OSV Mission:

The OSV Mission Objectives for Terrain Mapping:

- Navigate to within 250mm of the boulder
- Measure and transmit the length of the boulder oriented along the y-axis
- Transmit the boulder length to within 25mm

Bonus Objectives:

- Determine and transmit to command the color of the boulder
- Determine and transmit the surface area of the y-axis profile of the boulder to within 75cm^2

Plan of Action:

Our team plans on using the overhead visionary system almost entirely as our navigation guide. The overhead visionary system will provide our OSV with the coordinates of its location in the arena based on the location of the corners of the arena. While the obstacles we are required to navigate around do not appear through the overhead visionary system, according to the background mission requirements the obstacles will be at the x-coordinates of 1200mm, and the y-coordinates of obstacle 1 will be between 200-800 mm whereas the y-coordinates of obstacle 2 will be between 1200-1800 mm. After reviewing the potential location of the obstacles, our team realized with certainty that we will be guaranteed a space of at least 400mm between the two obstacles, if the obstacles are their closest together. We also know that the overhead footprint of our OSV must be less than 350 x 350 mm, giving us a margin of at least 25mm on each side of the OSV. If we use the overhead visionary system to navigate our OSV to the middle of the arena, we should ideally be able to fit right between the obstacles without actually knowing specifically where they are. After navigating past the obstacles our focus will then be on navigating to within 250mm of the boulder, for which we are given the coordinates of (2400, 800). After having completed all of our navigation for the mission, our focus is then entirely on measuring the boulder and determining its color.

In order to measure the boulder we plan on using a combination of servo motors and a laser distance measurer. Based on the way we will park our OSV in front of the boulder when the laser is turned on, the laser should initially shine perpendicular to the plane of the face of the boulder that we are measuring. Treating the face of the boulder like a plane, the servo motors will slowly turn the laser in one direction, either positive x, negative x, positive y, or negative y, and record how much it is turning. Meanwhile, the laser distance measurer will be measuring the distances between the measurer and the boulder as it turns. Because the measurer will be pivoting, the distance between the measurer and the plane will vary as the angle increases. Therefore using trigonometric relationships, we will program into the OSV's Arduino guideline measurements with which the laser distance measurer should come close to, within some amount of small error, as it rotates along the boulder. Using these guideline measurements, the Arduino will know when the laser has reached the end of the block because it will either point off the edge of the block or into the sand. Using the servo motors' output, the Arduino will know how far the laser has turned when the laser reaches the edge of the block, and it will use this angle to calculate the distance along the block that it measured. The OSV will do this left from center, right from center, up from center, and down from center which will yield the height and width of the boulder, completing those mission requirements. Determining the color will be done separately with an individual color sensor.

Power:

Power for the Arduino, Arduino-compatible laser sensor, and motors will be provided by a Venom 6V 1200mAh NiMH 5-Cell Flat Receiver Battery purchased from Amazon for $12.15. The wheels will be powered by four 6-24V DC High Speed Hobby Motors from skycraftsurplus.com, while the laser sensor will be operated by two servo motors from the Arduino Course Pack. At 6V, the current draw of each individual drive motor is 180mA, bringing the current draw for all four motors to 720mA. According to the specifications online, the Arduino will pull 20mA on each digital I/O pin (20 total) in use, bringing the maximum possible Arduino current draw to 400mA. Additionally, the sub-team estimated that the servo motors will likely draw around 200mA each. Overall, the maximum possible current draw will be approximately 1520mA. Using the data sheet of the battery, the estimated run time of the Arduino will be approximately 47 minutes (Figure 4.). It should be noted that in this case, the Arduino is drawing current in all 20 I/O pins, which is unlikely. In addition, this does not take into account the servo motor draw, however this should be relatively small. Each drive motor will be geared up such that the overall torque output to each motor is increased. Exact calculations will be done when the motor arrives and stall torque can be tested in the lab. Decisions made during power considerations were made in conjunction with propulsion considerations due to the strong relationship between the two systems. Because of this, only one decision matrix was used for both systems.

Power Consumption	mA	Battery Output (mAH)
Motors (4) =	720	1200
Arduino I/O Pins (20 MAX) =	400	
Servo's (2) =	400	
	1520	
Estimated Run Time (min) =	60*(Battery Output)/(SUM(Motors + I/O Pins + Servo's))	
Estimated Run Time (min) =	47.36842105	

Figure 4: OSV Run Time Calculations.

Sensors and Actuators:

In total the OSV will consist of only two actual sensors, the laser distance measurer and the color sensor. The laser distance measurer will be as centered on the OSV so that after the OSV navigates to the most ideal position in front of the boulder, the laser would be centered to shine perpendicular to the center of the boulder. The color sensor will be placed on the OSV separate from the laser distance measurer, but will be close to the base of the laser so that it can simply point itself straight and find the boulder to decipher its color.

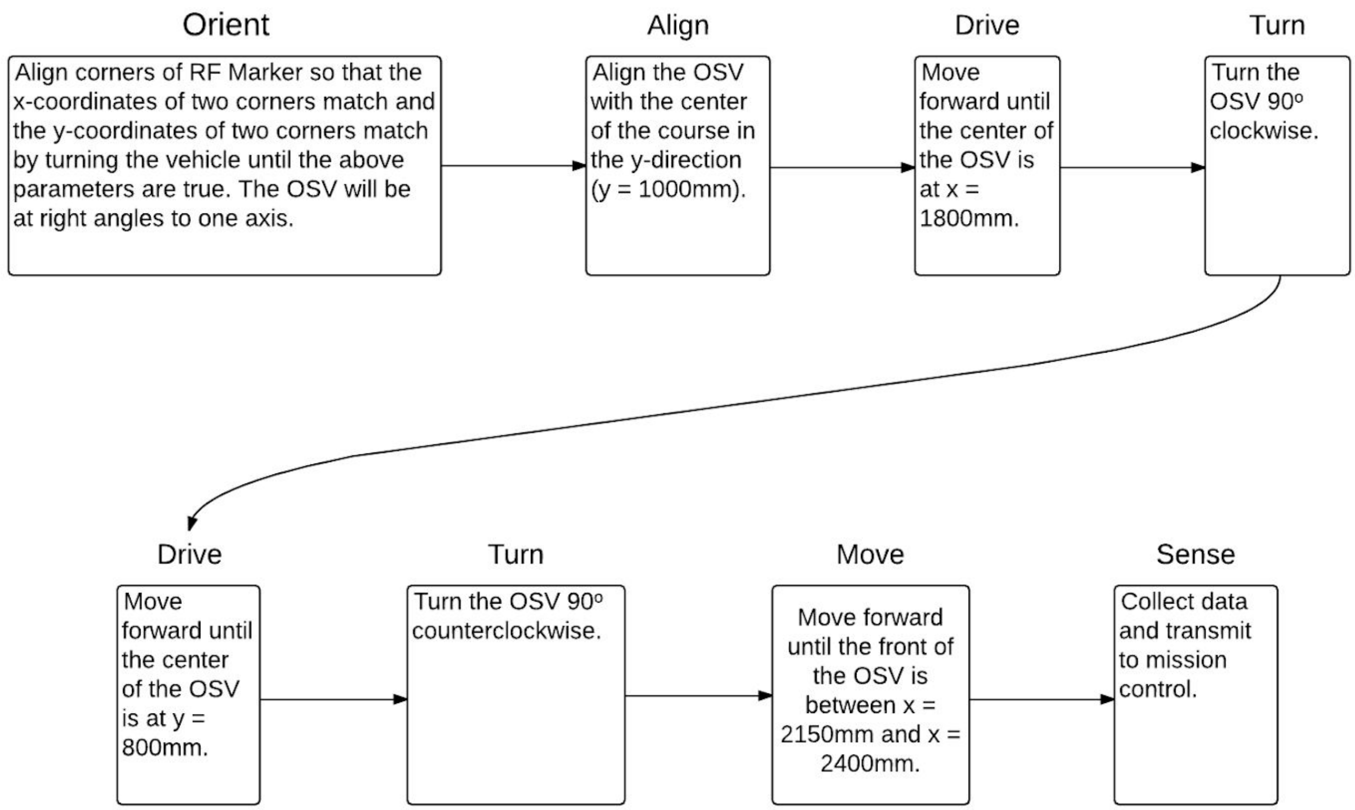
The color sensor will be integrated into the Arduino as a tertiary instrument and will simply output into the Arduino the color of the boulder in terms of code. The laser however is able to fully integrate with the Arduino, so there will be a separate Arduino attached directly to the laser in order to process solely the sensory code, which will ultimately be linked to the main Arduino that will communicate with command.

Control Algorithm:

The OSV will follow a logical series of movements to reach the boulder. First, the OSV will orient itself to face in the positive y direction. This will be made possible by utilizing feedback loops in which the OSV turns clockwise until the corners of the RF Marker share coordinate values. The coordinate values will be provided to the OSV by the mission control computer and the APC 220 radio module. Two corner data points will have the same x-coordinate and two corner points will have the same y-coordinate when this is completed. After this step, the OSV will move forward or backward, depending on its original placement compared to the y-axis center of the course. This will place the center of the OSV at a y-coordinate of y = 1000mm. Then, a 90º clockwise turn will be performed, changing the orientation to one in the positive x direction. The OSV will move forward until the center is at x = 1800mm. This is possible because a space of at least 400mm will be between the obstacles and the width of the vehicle will be no larger than 350mm. The OSV will navigate between the obstacles under this design. Another 90º clockwise turn will be performed resulting in an orientation in the negative y direction. At this point, the vehicle will move forward until the center is at y = 800mm. The OSV will turn 90º counterclockwise to its final orientation, in the positive x direction. The last movement will entail a forward movement until the center is between x = 2150mm and x = 2400mm. The exact ending coordinate will be experimentally discovered, and will be based on the optimal distance for the laser sensor. This portion of the control algorithm is displayed in Figure 5.

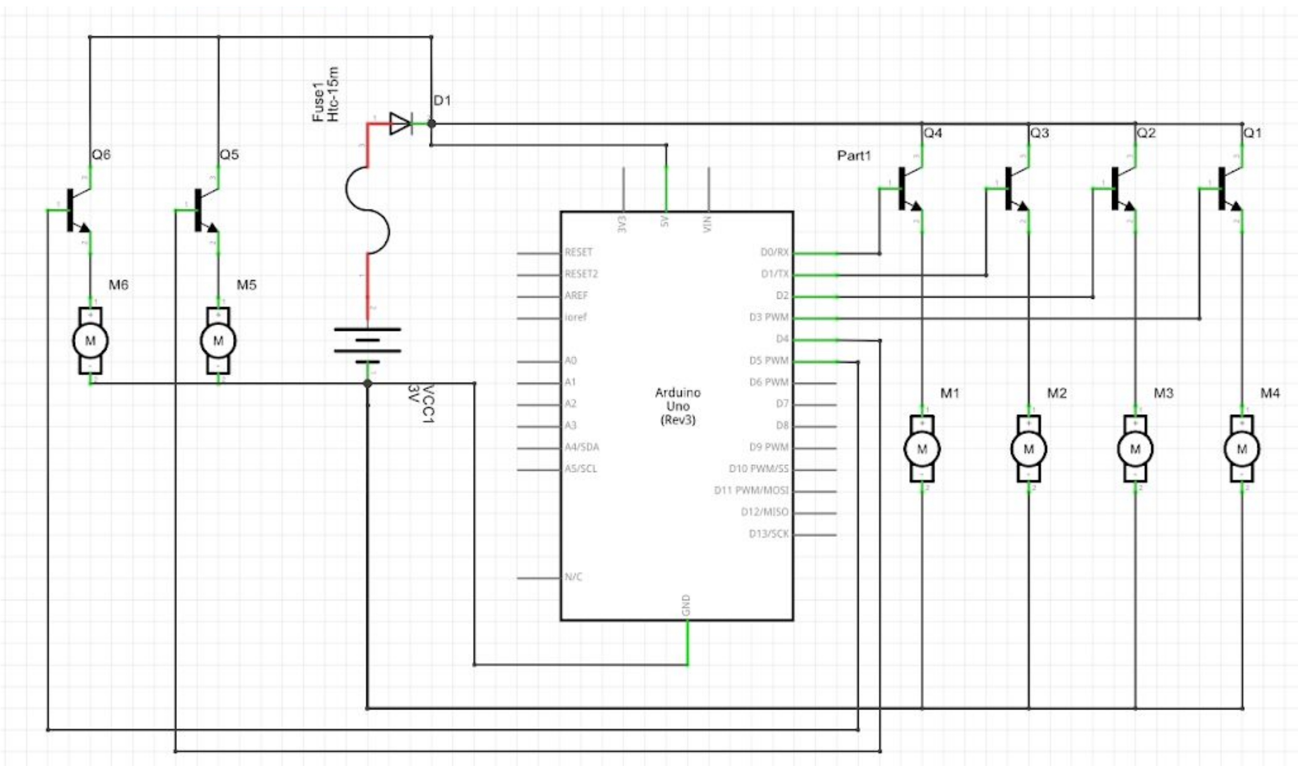
Once at its final destination, the sensing and data collection phase will begin. Utilizing the laser distance measurer that is controlled by servo motors, the OSV will be able to measure in the y and z directions. To do this, the edges of the boulder will be determined. As the laser shines on the surface of the boulder, the sensor will calculate the distance between the OSV and the boulder. The servo motors will allow the laser and sensor to "sweep" back and forth in a horizontal direction. When the laser is first shone off of the boulder's surface, the distance sensor will output a suddenly much larger value. This signifies an edge of the boulder. After finding both edges multiple times and averaging the values to decrease error, the program will determine the y-axis length of the boulder using a trigonometric relationship. This will also be done in the vertical direction, resulting in the height and width of the boulder. Multiplying these values will yield the surface area. After the measurements and calculations have been completed and sent to mission control, the light sensor will detect the color of the boulder based on calibrations that the team will perform prior to the final run.

Figure 5: Control Algorithm Flow Chart.



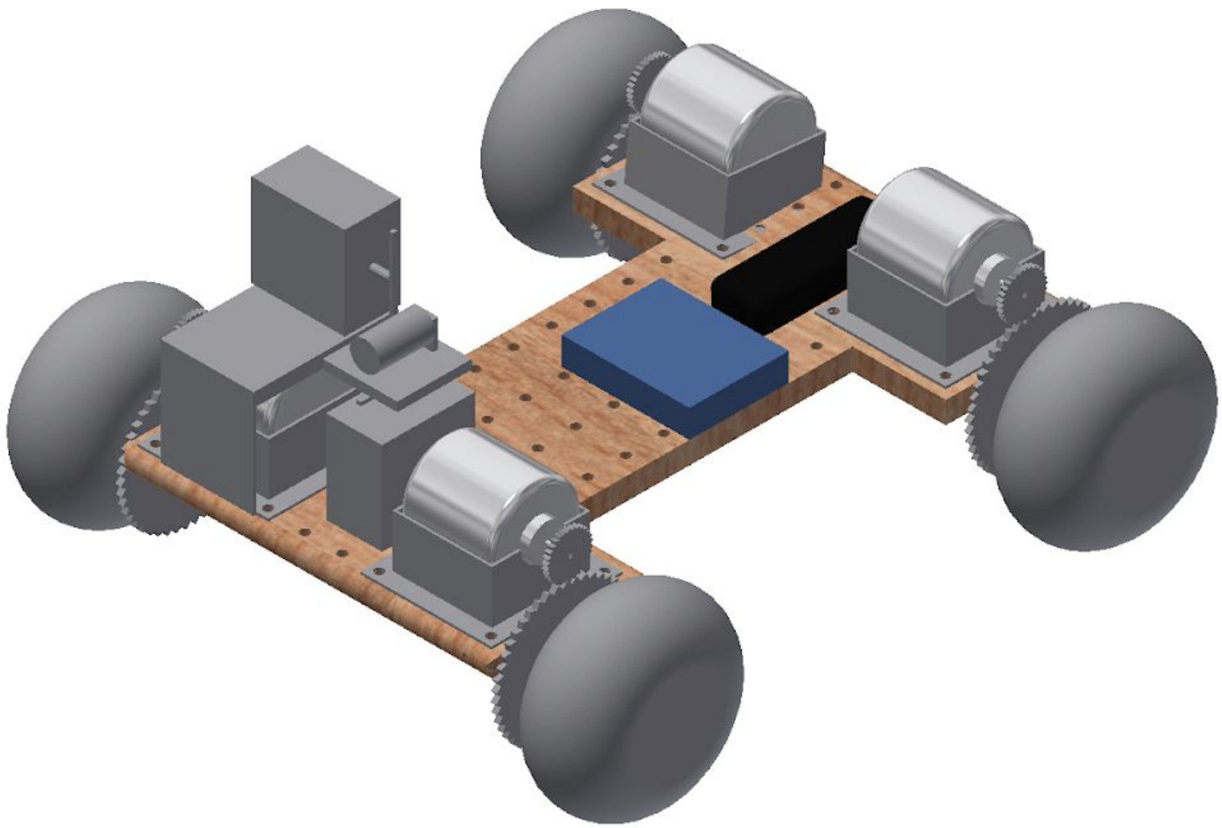
PRELIMINARY DESIGN DRAWINGS

Wiring Schematic:



Here is the preliminary design for the wiring schematic of the OSV. Motors 1, 2, 3, and 4 are the motors that drive the wheels. The motors are controlled by the Arduino using a transistor. When the Arduino sends out a voltage from the corresponding output pin, the transistor allows the current to flow through the motor, causing it to spin the wheel. Motors 5 and 6 are servo motors that will be turning the angle of the laser sensor to determine the length of the boulder. The circuit also incorporates a fuse, to break the circuit if it begins to draw too much amperage, and a diode, to prevent reversed voltage polarity. Depending on the amount of heat generated by this system, a heat sink may also be incorporated to prevent circuit damage.

Isometric CAD Pictorial:



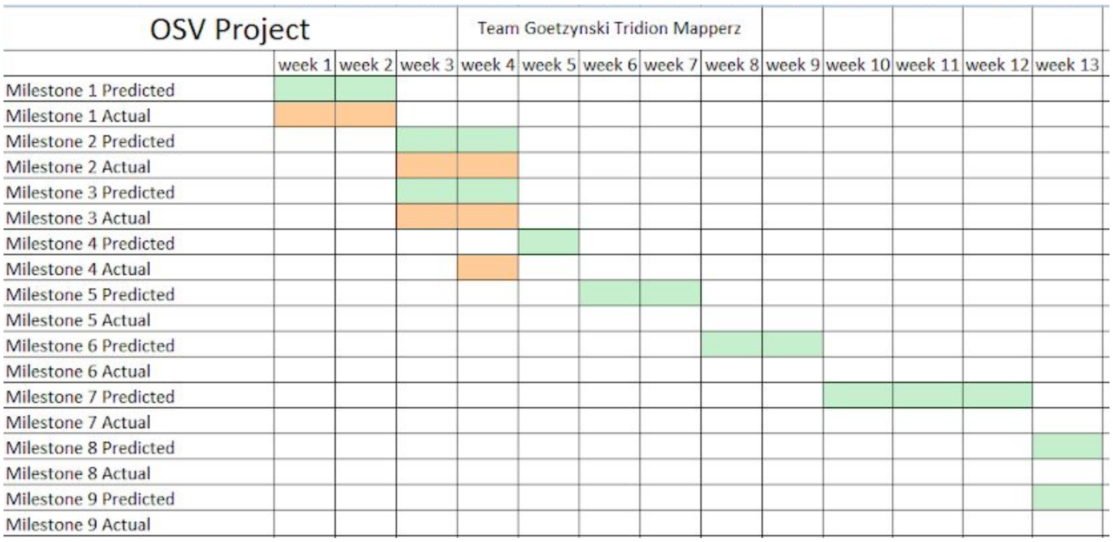
This image shows an isometric view of the proposed Over Sand Vehicle. The pictorial shows the plywood chassis, motors, Arduino, sensor assembly, battery, and wheels.

PRELIMINARY BILL OF MATERIALS

Bill of Materials

Part	Quantity	Price	Supplier
Venom 6V 1200mAh 5-Cell Flat Receiver NiMH Battery	1	$12.15	Amazon
6-24V Hobby Motor	4	$23.50	Skycraft Surplus
Woodcraft Birch Plywood (1/8”x12”x30”)	1	$5.99	Sears
Gorilla Glue	1	$5.79	Amazon
Tires (2)	2	$39.98	amain Hobbies
Laser Distance	1	$7.99	Amazon
Wires	N/A	~$10.00	Amazon
Fuses	10	~$10.00	Amazon
APC 220 Module	1	$32.95	RobotMesh
Parallax Servo Motors	2	$29.99	Amazon
Total		**$178.34**	

GANTT CHART



OSV Project
Team Goetzynski Tridion Mapperz
week 1
week 2
week 3
week 4
week 5
week 6
week 7
week 8
week 9
week 10
week 11
week 12
week 13
Milestone 1 Predicted
Milestone 1 Actual
Milestone 2 Predicted
Milestone 2 Actual
Milestone 3 Predicted
Milestone 3 Actual
Milestone 4 Predicted
Milestone 4 Actual
Milestone 5 Predicted
Milestone 5 Actual
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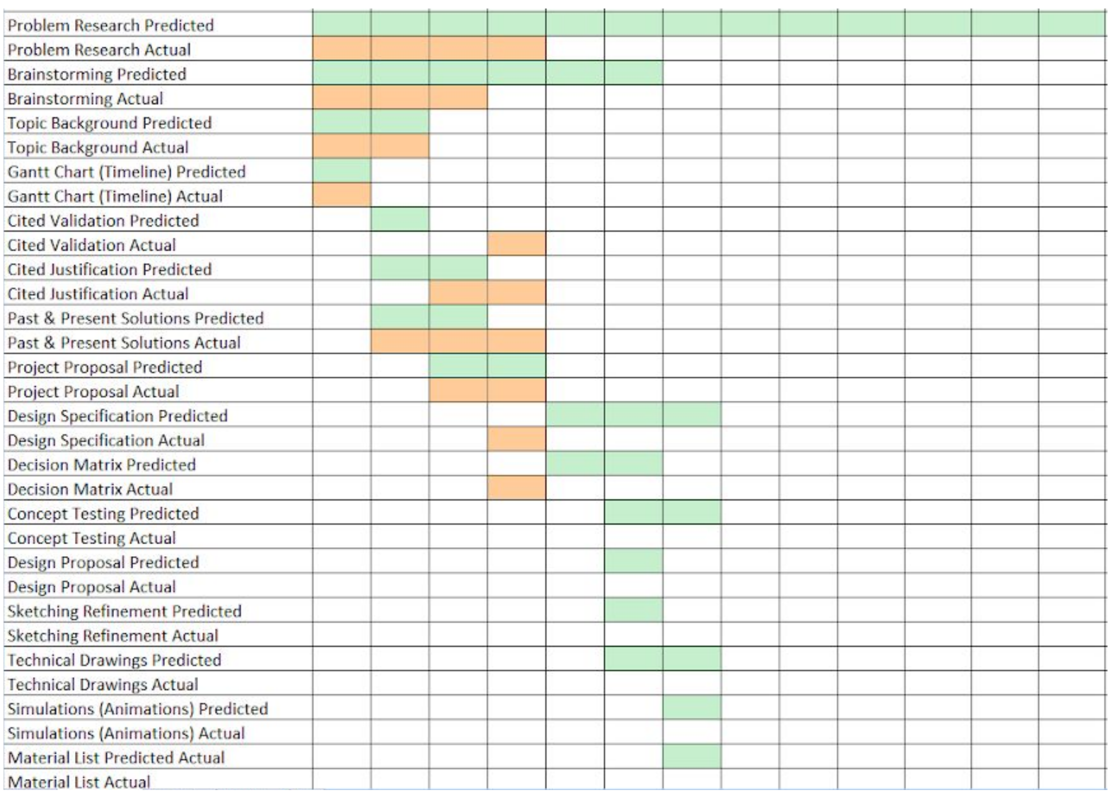
Milestone 8 Predicted
Milestone 8 Actual
Milestone 9 Predicted
Milestone 9 Actual



Problem Research Predicted
Problem Research Actual
Brainstorming Predicted
Brainstorming Actual
Topic Background Predicted
Topic Background Actual
Gantt Chart (Timeline) Predicted
Gantt Chart (Timeline) Actual
Cited Validation Predicted
Cited Validation Actual
Cited Justification Predicted
Cited Justification Actual
Past & Present Solutions Predicted
Past & Present Solutions Actual
Project Proposal Predicted
Project Proposal Actual
Design Specification Predicted
Design Specification Actual
Decision Matrix Predicted
Decision Matrix Actual
Concept Testing Predicted
Concept Testing Actual
Design Proposal Predicted
Design Proposal Actual
Sketching Refinement Predicted
Sketching Refinement Actual
Technical Drawings Predicted
Technical Drawings Actual
Simulations (Animations) Predicted
Simulations (Animations) Actual
Material List Predicted Actual
Material List Actual

Project Proposal Actual													
Design Specification Predicted													
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Cost Predicted													
Cost Actual													
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Physical Testing Actual													
Record Data Predicted													
Record Data Actual													

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Prototype Construction Predicted													
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Redesign and Refine Actual													
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Re-test Actual													
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Determine Conclusion Actual													
Recommendations Predicted													
Recommendations Actual													
Multimedia Display Predicted													
Multimedia Display Actual													
Presentation Practice Predicted													
Presentation Practice Actual													
Final Portfolio Predicted													
Final Portfolio Actual													
Thank you letters Predicted													
Thank you letters Actual													
Key		Predicted Time of Work						Start day is September 15					
		Actual Time of Work						End day is December 18					

CONSTRUCTION AND TESTING PLANS

Construction on the OSV will begin the week of October 19th, 2015, when preliminary materials are purchased. Before any assembly can begin, the team must test the purchased motors to determine stall-torque and calculate specific gear ratios and OSV Speeds. Once this step is done, adjustments will need to be made to account for the findings. Regardless, many initial materials may still be purchased because they are not directly affected by the motor change, or can be easily revised to account for such changes. It is estimated that motor testing and adjustment will only require a few days. After proper motor calculations have been completed, construction will begin on the OSV and testing will begin as soon as possible thereafter. The $350.00 budget will be contributed to evenly by each group member and ultimately allocated to one Finances manager. When parts need to be purchased, they will be paid for by the Finances manager using the allocated funds. The Structure Subteam will be responsible for the motor calculations as well as the woodworking, motor housing, and gearing construction. The Electronics subteam will use CodeBender Software to simultaneously edit, compile, and revise the code, as well as be responsible for wiring the OSV Battery to both Arduino and each motor. Both sub-teams will work closely to ensure that integration of all systems is possible during all phases of construction.

ANTICIPATED DIFFICULTIES

The Mapperz are aware of several possible setbacks. One problem that may be encountered is that the OSV may be too light or too heavy, preventing the vehicle from navigating the course. If the vehicle is too light, then wheels of the OSV may spin and not gain traction. To solve this problem, the team may need to add weight to the OSV, testing to see what amount of weight solves this problem. If the vehicle is too heavy, the OSV may overload the motors. To solve this problem, the group must carefully reconsider which type materials are on the vehicle and create a way to minimize the weight. Other problems may arise with the prototype fabrication. The OSV parts may not fit together as anticipated, even with the Inventor assembly completed. As a result, we may need to find a new way to arrange parts, accommodate an odd fit, or, as a last resort, order a new part. Another issue is preventing blown-out motors, Arduinos, and batteries. To prevent this possible setback, the electronic sub-team will need to incorporate circuit protections into the design. Heat sinks dissipate heat that could cause melting or overheating of sensitive circuit parts. Diodes prevent reversed voltage polarity that could damage the Arduino. Lastly, a fuse would prevent drawing too much current into the circuit, protecting the motors and arduino from an overload.