San José State
UNIVERSITY

SJSU ROBOTICS CLUB

PROJECT FELDSPAR

Final Report

Author: Khalil ESTELL, Colin CHEN, Matthew BOYD, Rocely MATI

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1 Introduction

San Jose State University (SJSU) Project Feldspar is the culmination of 26 SJSU undergraduate students' hard work of varying disciplines in the 2014-2015 academic year. Built for the NASA Rasc-Al Robo Ops competition, the goal of the competition is to design and produce a rover that is capable of acquiring rock samples in a simulated environment that models after barren extraterrestrial planets while being controlled via long distance. The competition challenges student engineers to come up with new solutions to robotic rover control through telecommunication under the time constraints of a few months. Featuring some of the top engineering schools in the nation in a competition of efficiency and effectiveness.

One of the main goals for SJSU Robotics upon entering the competition was implementation of new technologies, specifically the universal gripper and the use of HTML5. The universal gripper uses a physics concept called jamming phase transition, relying on the compression of granular material (e.g. sand and coffee grounds) to transition from an object with a fluid structure to one that is rigid, allowing the gripper to wrap around objects of varying sizes, including objects larger than the gripper itself. After obtaining a secure grip on an object using the static friction of the membrane, the gripper is then free to manipulate the object granted that the motors controlling the manipulator can generate the force. The second advent of our rover is the integration of HTML5 in rover control. Using HTML5 as the baseline of client side control of the rover allows for easy and organized rover control on any computer with a modern browser.

We are thankful to NASA for giving us the opportunity to compete with the best and brightest universities and welcoming us as newcomers to this competition. The learning experience from a large scale project is invaluable and as we continue to develop to become engineers for the future.

2 System Description

2.1 Rover Capabilities

The major capabilities of Labrador 1 is based off of the general requirements and tasks needed for the competition:

- Be able to navigate and operate a rover at Houston, Texas from San Jose State University.
- Travel across different terrains while going over large rocks.
- Collect rock samples and store them within a bin on the rover.
- Stream a live feed and audio during the hour run of the competition.

2.2 Suspension & Steering

The rocker-bogie design is an active suspension system, allowing the rover to transverse over objects and through the various terrains. Compared to a passive system that uses springs, an active suspension system can climb obstacles based on the geometry of the legs of the rover. As the suspension climbs over objects, the front wheels come in contact with the object and the system is able to keep stability because the back wheels will be able to stay planted on the ground until it also comes into contact with the object. The legs are made out of various square aluminum tubing that fit together. The size of the tubing, where the largest is 1.75" and smallest is 1.25", was meant to allow the wires from the motor to be enclosed and unseen. In addition to hiding the wires, the tubing makes it easy to take apart the legs and allows for various access points for the wires. Bearings were used between the joints of the rocker and bogie.

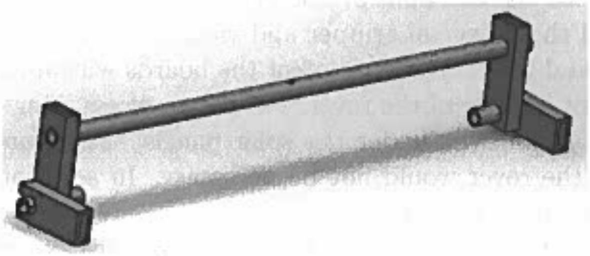

Figure 1: Physically assembled rover leg

A simple mechanical linkage was used to link the two sides of the rover, to prevent independent travel of the legs and to keep the chassis upright. This differential assembly uses a 17" long, ¼" thick solid steel rod as the differential bar, to provide the strength needed to resist bending and prevent deformation. The differential assembly is modeled after a human, where the differential bar represents the shoulders. The differential bar is connected to the legs through a "bicep" and "forearm", which are 2"x1" and 2"x½" rectangular aluminum tubes, respectively. The forearm-bicep linkage is designed to transfer the torsional movement into the differential bar, while absorbing the pivoting of the legs about their axles. This prevents the differential assembly, as a whole, from rocking vertically about its anchor and upsetting the balance of the rover.

The rover is capable of stationary turns and has a motor driving each of the six wheels. Specifying the rover to drive in inclines of at least 32 degrees and carry the maximum possible weight, 100 lbs, it was derived that six of the selected motor with a total peak torque of 1000 oz-in is sufficient to drive the entire rover. From the calculations, geared down brush DC motors that provide a total force of 1125 oz-in at 169 RPM were selected.

2.3 Wheels

The Labrador 1 uses six wheels, where each pair of wheels has a different design and purpose. Although the wheels were made out of ABS-Plus, allowing a high level of customization, the designs had to optimize the amount of material used and keep in mind the strength the ABS-Plus can carry at the wheel's most vulnerable point, the spokes. Keeping in mind, each wheel was created dependent on its position. The front most wheels has fortified spokes, using ribbing inside the wheel. Because the wheel needs to withstand the impact it faces when it first comes into contact with rocks, it needs extra fortification at the spokes. Unlike the front wheels, the middle and back wheels were designed with no ribs and have a higher density than the frontal wheels. The middle and back wheels have only a slight difference from one another. The middle wheels have .25" thick spokes and the back wheels have .375" thick spokes. The difference in thickness accounts for the position. By observation, the middle wheel does not face any large impacts on the ground. When driving over large objects, the middle wheels impact is softened by the front and back wheels adding stability. The back wheel uses a slightly thicker spoke because in the same situation, depending on how the rover goes over an object, the back wheel can drop directly to the ground.

Due to the various terrains the wheels have to withstand, prefabricated 4" wide all terrain treads were used. The thickness of the tread is .33" with the ridges and .15" without it. The wide tread size ensures that the rover stays atop of the sand and does not sink in. In addition, the "U" shaped ridges are oriented to scoop into the ground providing extra traction.

2.4 Chassis

The skeleton of the chassis has a rectangular shape and is constructed with 1" x 1" T-Slot Extruded Aluminum. The shape is an ideal choice because it is easy to construct with extruded aluminum and gave ample amount of working space inside. The extruded aluminum is a lightweight material, making the overall structure of the chassis skeleton weigh 11.43 lbs. At the front of the chassis, a shelf extrudes from the main body. The purpose of the shelf is to hold the universal gripper and vacuum pumps.

Acrylic panels were used to enclose the open spaces and to mount and protect the boards within the chassis. The electrical components are housed in the front interior of the rover. For easier access, hinges are attached to the ramp that goes above the battery and acrylic under the solar panels. Therefore, to reach the internal components, fully deconstructing the rover would not be necessary. In addition, access points for wires to run through the rover were cut into the acrylic.

The storage area for the rocks is in the rear section of the rover. Since the arm is unable to extend all the way to the back, a ramp was created in the rover's mid-section. This enables the gripper to drop the rocks onto the ramp, leaving gravity to place any rocks in the bin.

A ventilation system was modeled and implemented to provide a constant temperature within the rover. A steady temperature is essential as there are roughly 15 different boards that may overheat without air flow. The system consists of six fans, two large fans produce an airflow of 27.9 cubic feet per minute and four small fans producing 10.48 cubic feet per minute. Basic qualitative flow analysis software was used to gauge how the position of the fans and speed of airflow effects what happens in the frontal interior without any exterior heat from the boards. Using the four smaller fans to intake and the two large fans as an outtake, the outside air at atmospheric pressure by 604 cubic inches per second, and assuming the air coming in is 80°F, the maximum velocity air will flow through the front part of the rover is 108.48 inches per second. Considering that the maximum velocity was based on only one inlet and outlet because of software limitations, whereas the actual rover has two inlets and one outlet, air flowing 108.48 inches per second gives a consistent amount of air circulating over the boards.

2.5 Camera Specifications

Four cameras are used in the visual system of the rover. Three of the them are Logitech web cameras, fully capable of 1080p HD video. They located on the rover arm for up-close visuals, on the tracker mast for a permanent navigation feed, and on the rear of the hull for looking behind. The fourth camera is a 30X FPV analog zoom camera with 700 TVL or approximately a resolution of 976 x 582 pixels located on the camera mast. The natural video is quite whitewashed so the gamma is set to 0.75 of the normal 1.0 and a filter called vibrance (takes saturated colors and saturates them further) is used to make bright colors pop out more.

3 Tracker System

The system that enables active searching for rocks on the field is dubbed the tracker. The overall goal of the tracker is to allow mission control to find rocks that are far away from the rover's current position, compute the location for each rock with GPS information and calculate the shortest path between them. Hardware and software components work together on the rover to allow the control center to utilize the tracker. The hardware components consist of an Arduino, gimbal, linear actuator, video camera, and lidar sensor. The video camera and lidar sensor are encased in a 3D-printed housing that is mounted onto the gimbal. The gimbal uses the Phobotics Centerpiece gimbal controller, which can be controlled through

RC signals sent via an Arduino. A Beaglebone Black embedded Linux device acts as the brain of the rover, delegating commands sent from the tracker controller web portal and all other portals.

Figure 2: Mission Control: Tracker Control Interface

The tracker web portal has several important components that were implemented using HTML5. The lower right text field labeled 'Sensors' outputs all sensor data on the rover, including the pitch, yaw, roll, zoom, and lidar values from the tracker. Straddling the center map on either sides are several canvas elements that provide graphical display of the yaw, pitch, and roll values of the gimbal as well as camera zoom. The zoom area allows for the user go from different levels of optical zoom with a slider. The center of the tracker web portal hosts a Google map display of the Johnson Space Center. There are several colored buttons above the map that allow for specifying what color of rock the tracker is looking at. When the 'Coordinates' button is clicked (or the space bar is pressed), information from the tracker is compiled together to create a latitude-longitude point for the rock. Once the rock is placed onto the map of the area, the shortest path between all rocks is calculated and drawn onto the map. Some error will propagate in the calculations, therefore the rock icons can be dragged to fine tune their locations.

Controlling the gimbal from the web portal can be done in two fashions: using a USB connected game controller or using 'W', 'A', 'S', 'D' and numerical keys on a keyboard. When a game controller is connected, controlling the gimbal is much like playing a first-person game. The two joysticks are used for controlling pitch and yaw; the buttons and bumpers on the controller all have a dedicated function such as adjusting the roll of the gimbal, zooming the tracker camera in and out, cycling between the different colors of rocks, and adding/deleting nodes on the Google map shortest path. The keyboard accomplishes the same control as the gamepad with certain functionality delegated to keys. Control of pitch, yaw, and roll is accomplished when a value, either positive or negative, is sent to the gimbal indicating whether to increase or decrease its PWM duty cycle for any of the gimbal axes. Creating points of interest on the mini-map is essential. When a 'Create POI' request is issued from either the gamepad or the controller, the portal sends a request to the lidar sensor for a reading from the tracker. The web portal will delay briefly while waiting for a response from the lidar before calculating the GPS position of a rock. Rock GPS information is stored on a stack to allow quick removal of any points from the map.

3.1 Calculating GPS Coordinates

Calculating the GPS coordinates of rocks are a simple matter of compiling all relevant information and plugging it into a function. The rover's GPS coordinates, heading, the yaw on the gimbal, and the reading from the lidar are used to perform this task. The formula for calculating latitude and longitude of a rock is derived from simple trigonometry.

yaw = The yaw of the gimbal with due East equal to 0 radians and due North equal to $/2$ radians
$Feet_{Longitude}$ and $Feet_{Latitude}$ are Conversion factors

$$Rock_{Lat} = Rover_{Lat} + (\frac{Lidar_{Reading}}{Feet_{Latitude}})sin(yaw)$$

$$Rock_{Long} = Rover_{Long} + (\frac{Lidar_{Reading}}{Feet_{Longitude}})cos(yaw)$$

The shortest path from the rover to all of the rocks uses a brute force recursive function to find the optimal path. Assuming that the map won't have more than 10 rocks on the map at any time, brute forcing the shortest path is a viable option. The tricky part of calculating shortest path is coming up with a heuristic for edge weights between rocks. The edge (u, v) - where u is the rover at some GPS coordinate, and v is a rock at a different GPS coordinate - is a function of rock point value, distance, and whether or not the rock is in a "hard" place." The function for the weight of edge (u, v) is

$$w(u, v) = (1 + isHard)distance - \frac{point_{value}^{1.5}}{distance}$$

isHard is either 1 or 0 depending on if the rock appears to be in a hard place, such as the center of the densest part of the rock field or in a crater. These "hard" geographical spots are predetermined and coded into the heuristic.

3.2 Camera Mast

The camera mast is capable of holding the camera attached to the gimbal, lidar and their housing. In the stowed configuration, it lays flat against the chassis then is propped up by a linear actuator. When the mast is propped up it reaches 13" above the rover and pivots about the base where a connection rod is pressed into two ball bearings. The bearings are fixed within a support wall that is mounted onto the acrylic. The support wall is 3.5" high and .75" thick, capable of supporting the entire tracking system as it is being propped up and holds the mast snugly as the rover moves. The support wall is made of out of ABS-plus and was designed as two separate pieces that interlock together for simple assembly and access.

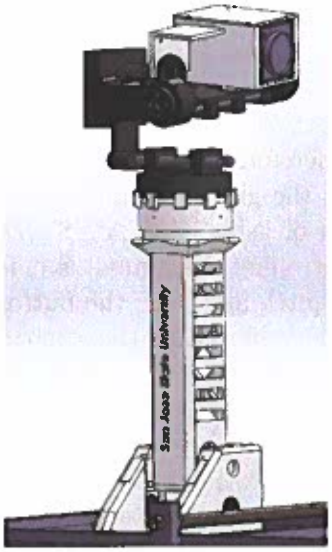

Figure 3: CAD of Camera Gimbal with Camera and Lidar Mounted

3.3 Manipulator System

To collect and store rocks, the Labrador 1 uses a universal gripper with four degrees of freedom mounted onto the shelf of the chassis. The four degrees of freedom includes the shoulder controlling both pitch and yaw motion and an elbow and wrist with pitch motion. The servo at the shoulder of gripper can rotate 180 degrees and pitch 175from the base platform. The elbow and wrist uses the same servos and are able to move 150 degrees and 120 degrees respectively. From servo to servo, both the arm segments are about 10 inches long. The lengths were based on giving the arm a considerable reach and to ensure that the stowed position would not infringe on size limitations.

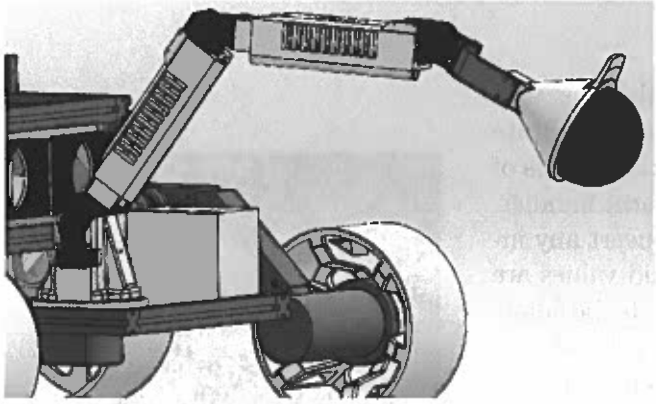

Figure 4: CAD of Gripper Robotic Arm

The universal gripper uses a flexible membrane, such as rubber, and is filled with a jamming material, usually granular types of material. By placing the filled membrane on an object, or in our case a rock, and using a system of three vacuum pumps and two valves to suck the air out of the membrane, the jamming effect is created within the membrane where the granular material inside starts locking into one another due to friction and the balloon encases the object and creates a solid grip, giving the rover the ability to lift and move the object.

One of the factors that effect gripper's ability to pick up an object is based on the size of the object and radius of the gripper. Based on studies done under the National Academy of Sciences of the United States of America and in-house experimentation, the functionality of the gripper increases when the radius of the object is less than or equal to 65% of the gripper radius. The universal gripper on the rover uses a 24-inch balloon as its membrane. The 24-inch balloon is specific for the purpose of picking up the largest possible rock that needs to be collected, which is 3.148" or approximately 8 centimeters.

Unlike most reported universal grippers that utilize coffee grounds and sand, the membrane on the Labrador 1 is filled with extruded polystyrene granules (EPS Beads). EPS Beads performed better than the common coffee grounds because as the membrane shrinks, the EPS Beads also shrinks in size causing the jamming factor.When comparing the weight of the coffee grounds to the weight of EPS Beads, the difference is considerable with the beads being obviously much lighter.

3.4 Arm Interface

The control center has a GUI specifically for arm control which includes basic user instructions, connect/disconnect buttons to connect to a server from the drop down list, and sliding controls on the right controlling the speed of the arm. The interface displays a feedback log to see data feedback which is useful in confirming server connection and ensuring signals are going to the rover. To prevent the arm from destroying itself there is an angular limiter function that prohibits any invalid degree values from being sent to the arm.

With the button labeled 'Control Type', the user can control the arm in three different modes: Scrollbar, Text Entry, and Mimic mode. Scrollbar mode utilizes a Bootstrap slider library. When activated by the corresponding motor, each slide controls one joint, either the base, shoulder, elbow, or wrist. As the slide moves, a JSON packet containing the position values of each scroll bar is sent to the Beaglebone through the web server. The Text Entry mode consists of text input boxes and submission buttons that control their respective motors. The main method of control is Mimic mode. It entails the use of the mimic arm, or a controller module that resembles the arm. As it is moved, the interface receives values from the mimic which are sent to the rover to have the arm's position resemble that of the mimic. The interface also houses gripper control buttons, such as 'Grip', 'Stop', and 'Drop', controlling the universal gripper and arm protocol buttons, such as 'Rest' and 'Examine', to move the arm into preset positions. The 'De-torque' button gives the user the ability to manually disable the arm in an emergency.

3.4.1 Arm Hanlder

An arm handler program receives commands from the user arm interface and sends appropriate signals to the servos to facilitate movement using a control signal format provided by the makers of the Dynamixel servos. As an extra precaution, the arm handler, like the interface, also includes angular limiters to convert any invalid position values into valid ones. Once any invalid values are dealt with, they are translated into packets of data to be interpreted by the motors and move them. Within this process, the shoulder value is converted into two values, each dealing with one of the two shoulder motors which are oriented differently. Once this calculation is done, the commands are sent to their respective servos and move the two shoulder servos in sync. The handler also handles control of the gripper module on the arm. Once the gripper's control packet is received, the data is interpreted and the handler changes the Beaglebone's digital outputs connected to several MOSFETS that power the pumps and valves.

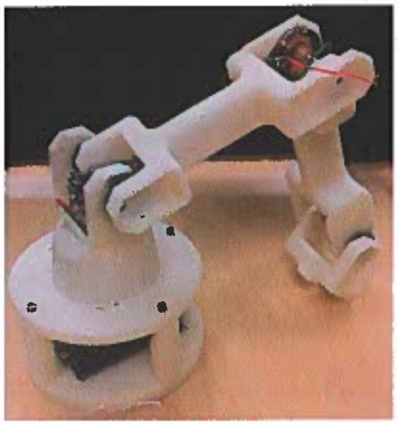

Figure 5: Mimic Arm

3.4.2 Mimic Arm System

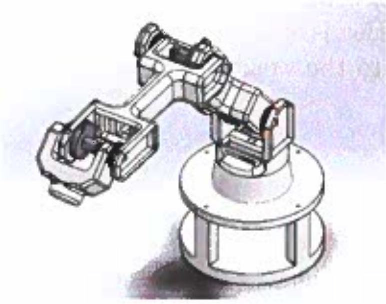

Figure 6: CAD of Mimic Arm

The mimic arm is a device that is used to control the full functionality of the mechanical arm. The same movement on the rover's arm immediately represents any actions that are performed to the mimic arm. The mimic arm is constructed from ABS plastic and is roughly a half scale representation of the mechanical arm. To simulate the same four degrees of freedom that the rover's arm utilizes, the mimic arm uses potentiometers instead of servos. The potentiometers are placed at joints that represent the servos on the full-scale arm. One is placed on the base plate to rotate the arm; the remaining three are placed on the shoulder housing and remaining arm links respectively.

For ease of use, the components and arm links are made to comfortably fit in the users hand when they are manipulating it. The arm links are roughly 3.5 inches in length and feature a 2-inch grip section that is filleted to be ergonomic and allow for easy manipulation of each joint. The ends of each link were designed to represent the bracket as the main connection point for the potentiometer to connect to the mimic arm. At the ends of each bracket section, the corners are cut at 45-degree angles to increase the rotational freedom for each of the link. The middle of each arm link was also hollowed out to represent a wire channel. This would ensure that the wiring from each of the potentiometers to the Arduino board is incon-

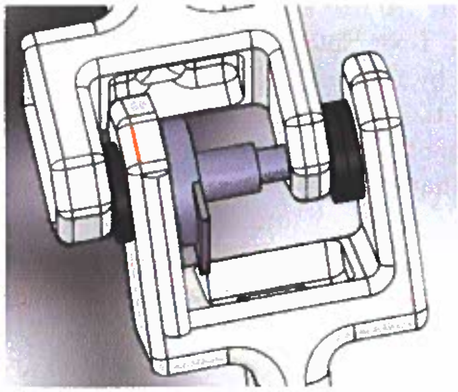

Figure 7: Mimic Arm Joint

spicuous. While this feature allows for the wiring
to pass through the arm, it's also implemented to reduce weight. At the base plate, a shoulder mount or rotating base was designed to represent the servo holder on the actual gripper. Like the arm links, the connection brackets are also cut at a 45-degree angle to allow for increased rotation. Down the middle of the rotating base, a hole was extruded out to house the shaft of the potentiometer on the base plate. Around the shaft housing, extrusions were made to reduce material and act as a channel to feed the wiring through. The rotating base also features a skirt that extends downward to act as a support mechanism for the base plate potentiometer and to conceal the wiring. As the base plate is connected to the rest of the arm, the base plate is then connected to the Arduino holder. The Arduino holder is connected to the plate by four "pillars" which connect it to the base plate. The space in between the pillars was extruded out and the holder has a 1.5 inch tall clearance space to accommodate substantial amounts of room for the pin connections and wiring to the Arduino board.

An important factor considered throughout the design of the mimic arm is ways to make it easier for the operator to use the mimic arm was to limit the effects of gravity that can cause the mimic arm to lose position. Rubber grommets were installed in line with the potentiometers to create the necessary amount of friction to prevent this from occurring. The grommets were also placed in positions where rotation would occur so the outward force from the compressed grommets in addition to friction would hold the arm links in place. The length of the arm is also shortened to roughly 11 inches to reduce the length of the moment arm if the mimic were to be extended out horizontally. This would ensure that the rotational torque limit of the potentiometer with the grommets would be able to resist the arm's moment.

3.5 Sensory system

The rover supports a wide variety of sensors that are all used to enable or aid the rover's different functionalities.

Table 1: List of Rover Sensors and Their Purpose/Use

Gyroscope/Accelerometer	Rover Orientation.
Magnetometer	Compass direction.
GPS	Locates the rover's longitude and latitude coordinates.
Voltage Monitor	Monitors the battery voltage.
Current Monitor	Monitors the amount of current flowing out of the battery
Lidar	Calculates the distance from the tracker camera to the object of interest.

3.6 Motor Controlling System

Supported by six motors the Labrador 1 is controlled through simple DC motor controllers that receive PWM signals from the Beaglebone Black. Incorporating accelerometer and gyroscope data ensures that rover can self correct itself when stopped at an incline thus compensating for gravity by powering motors just enough to remain immobile. Receiving angle and speed signals from mission control navigator via a GUI, we are able to control rover movement as well as individual motors upon request.

Figure 8: Mission control: Navigation Interface

The mission control navigation interface built using HTML5 enables ease of controlling the rover. The server relays a predefined structure of control information between mission control and the rover. Sensor information is also broad casted by the server to all relevant parties, which is displayed on the left. To the right of this interface are buttons to enable individual control of motors to be used in specific circumstances where rover is made immobile. Optionally video feeds can be shown on this interface or alternatively in conjunction with a separate video display interface.

Controlling the rover from this portal can be done in several fashions: using a USB game controller, keyboard WASD or worst case manual control of individual motors. When a game controller is used, maneuvering the rover is much like driving a car. The joystick acts like a vector controlling angle and speed, with max speed being set by a dedicated lever on the device. Additional buttons are also mapped for individual motor control and rotation in place. Similarly a keyboard accomplishes the same tasks as the gamepad with certain functionality dedicated to individual keys.

3.7 Telecommunication System

The above diagram represents the data path from the user to the interface to the server and down to the rover. The high level nodes are separated by user space, interface, server, and the Rover Core Suite.

3.7.1 User Space

User space is comprised of four users that control the rover at mission control. The four users are the navigator, archaeologist, tracker, and the captain.

The Navigator
controls the rover's motor control system and drives it to its next destination.

The Archaeologist
controls the gripper robotic arm system which retrieves rock specimens for the rover.

The tracker
scout beyond what can be normally seen and see if there are any rock specimens further way. The tracker, when it sees a rock, calculates where the rock is on Earth, adds that rock to the map of other rocks, and then calculates the most optimum path from one rock to another.

The Captain
leads the other three users, make decisions based on the feedback from the rover, such as core CPU temperatures, battery voltage, GPS location, chassis orientation, control video and audio feeds,

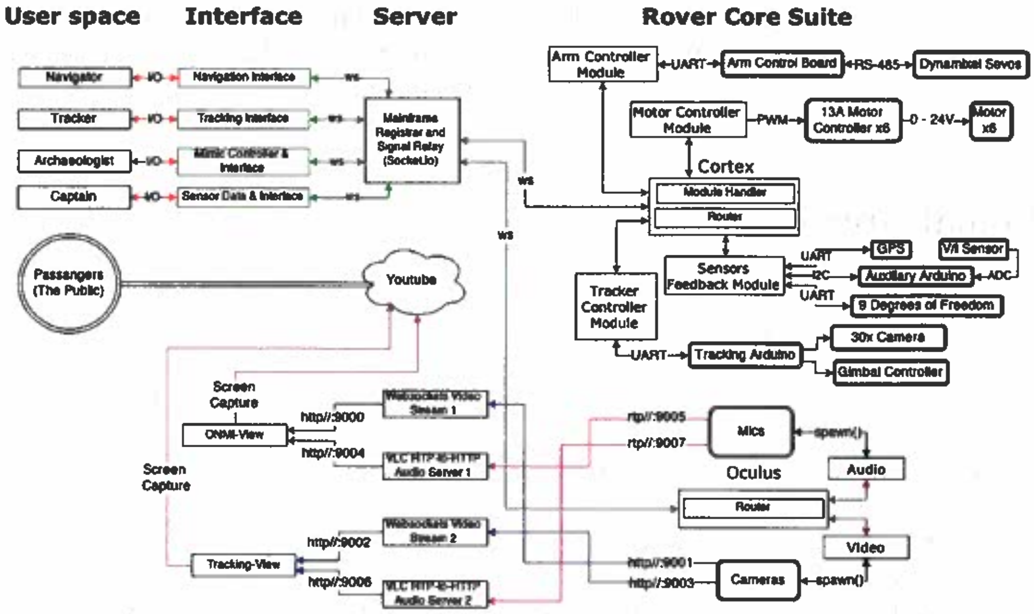

Figure 9: Mission control: Telecommunication Data Path

as well as control the system protocols of the rover such as when systems need restarting, module overriding, and peripheral system control.

3.7.2 Interface

Every interface designed for mission control is written in HTML5 and is made for the web. The protocol for communication to and from the server is client Websockets. The Websockets protocol allows for a persistent full duplex communication to and from the server. Each interface inherits a mission control prototype, which not only properly establishes and registers each user, but also allows each user to see the connection status of the other users and devices connected to the server. Each interface is specialized to the user who will be using it. Everything from control with a gamepad to video and audio feedback is possible with the current HTML5 standard.

3.7.3 Server

The server has two functions which are acting as a signal relay for video and for audio transmission between mission control and the rover. The server is written in NodeJS and uses web sockets for relaying signals and video. The server relays audio using VLC servers.

3.7.4 Rover Core Suite

The whole Rover Core Suite (which does not include the Arduinos) is developed entirely in NodeJS. The Rover Core Suite comes with two main applications; Cortex and Oculus. The Cortex framework is built to be modular, which allows for adding and removing of modules in order to add or subtract functionality from the software. The Cortex application handles controlling every aspect of the rover, from motor control, sensor input, communication to Rover Neurons, the Arduinos, and communicating with the server. The Oculus application handles video and audio feeds from the rover to the server. Currently, there can be N many Oculus devices streaming to N many channels to the server, but only one cortex. The current version of Labrador 1 uses two Oculus applications run on separate Raspberry Pi 2s. Cortex is run on the Beagle Bone black.

4 Technical Specifications

Table 2: Rover Technical Specifications

Dimensions	99.44 cm long x 89.93 cm wide x 47.625 cm tall
Mass	85 lbs
Maximum Speed	3.97 MPH
Maximum Obstacle Size	15 cm
Battery Ratings 12Ah	24V
Operational Power	95W
On Board Computer System	Single Core 1-GHz ARM® Cortex™-A8 Beagle Bone Black Quad Core 900-MHz BCM2836, ARMv7 Cortex - Raspberry Pie 2 Model B 3x Arduino Mini
Communications	Verison 4G Network
Cameras & Video	3x Logitech HD Pro Webcam C920 1x Aomway 30x Optical Zoom Camera
Software	Linux, Arduino, NodeJS, HTM5

5 Testing Strategy

Due to the modularity of our rover, a large amount of the system preliminary testing and verification were done in isolation of the entire rover system. This form of testing allowed for certain systems to be tested extensively while other systems were being worked on. The main systems that were tested include the drive train and universal gripper system.

Drive train testing was done primarily outdoors in several different terrains that were easily accessible at SJSU. The rigorousness and difficulty of the terrain that the rover traversed over was gradually increased with the hardest of the terrain being a local mountain off road trails.

The universal gripper technology that was used in our rover was one of our most extensively tested systems. Due to the various tasks and needs that our gripper needed to fulfil, our gripper exhibited many iterations to meet the standards that we had set at the beginning of the competition. Testing for the universal gripper can be segmented to three different subsections. Jamming material, membrane specifications, and arm design. The material used in our current universal gripper, extruded polystyrene, was tested against many of the conventional materials, such as sand, coffee grounds, sugar, salt, and compared in terms of both gripping strength and weight. Membrane size was also a key factor to consider as larger membranes were better at gripping while smaller membrane was significantly lighter weight. The membrane thickness and type were also contributed to weight and gripping strength. All of these factors were interchanged in our tests to maximize performance and efficiency in rock collection.

6 Mission Control Center Operational Plan

Our tactic for getting the best performance and score, given our rover is to do the following:

0 min → 15 min

Initially play it safe and go down the shallow side of the Mars Hill and pick up any rocks we come across. As we do this, the tracker will be scanning the area adding any rocks it finds to our map of the area, generating an optimum path for greatest score with the rocks. Once a rock of optimum distance and score is found near the rover, we will change our path to retrieve that rock.

15 min → 30 min

After 15 minutes of wandering and tracking rocks, we will begin to close in on the more difficult zones, craters or rocky area, to find rocks. We will attempt to get as far from the Mars Hill from this point. If we are successful in the area we have chosen to retrieve rocks in, we will stay there until the 30 minute mark. If we put our rover in danger of damage or getting incapacitated, we will attempt to enter another area else where or different zones.

30 min → 45 min

At the 30 minute mark, we will attempt to enter the other zone approaching Mars Hill of and acquire rocks. Any advantageous rocks above the point value of the zone we are heading to will be picked up along the way. The procedure for this zone is the same as step before.

45 min → 55 min

At this point, we will decide which area has the highest concentration of rocks that our rover can acquire and then stay there. We will try to decrease our distance from Mars Hill as much as possible as we proceed in this area.

55 min → 60 min

At this point, we need to make our way back up Mars Hill. To take advantage of the bonus points for each rock we bring up. At this point, our objective is slowly get up the hill in order to receive the bonus points. The only override for this is if there are high value rocks along the way. The high value rocks would have to give us a score that would make a crucial difference in our final competition scoring. Otherwise, all other rocks will be ignored.

Due to the mission controls lack of practice in the rock field, our strategy is subject to change after getting the six hour practice on the rock field since we have never been there.

6.1 Staffing

The mission control team will be staffed by four members of the control systems. Those select members created the interfaces that control the four aspects of the rover, such as navigation, arm control, tracking and sensors/system feedback. SEE USER SPACE.

6.2 Practicing

Practicing for mission control before the competition, was done by going on missions with the rover to various places in the area. One such mission was at Mission Peak in Fremont, California, where the rover was taken on hills where the reception was spotty and the terrain bumpy.

6.3 Decision Making

The decisions are made by the captain, navigation, and the optimum path map with respective priority. The optimum map created by tracker will be the key to finding the best route to get the most points. The navigator also makes the decision on whether or not a given location is reachable given the current status of the rover. The navigator can override the optimum map path if it is decided that the path is not advantageous. The captain directs the three other mission control users and overrides all other users and controls if needed.

6.4 Plan for Contingencies and Redundancies

Every aspect of the rover's control system can be gracefully shutdown from mission control at anytime. If any application cuts off or hits a fatal error, a watch dog will detect the failure and will reboot. If the rover is struggling to get back online or the 4G router issued a DHCP IP release, then the rover devices will request a new IP from the rover.

7 Budget

The projected budget for the project was $13,570.96. The estimation included major purchases (motors, data plan, battery, etc.), travel and registration, and overcompensated for manufacturing costs. Although the funds were not allocated as our preliminary reports projected, the final expense report exhibits that the estimated budget was an accurate approximation of what was spent as seen in Appendix A. A special thanks also goes to those who generously helped through their contributions to our club:

8 Public/Stakeholder Engagement

8.1 National Association of the Academies of Science - Breakfast with Scientists

Figure 10: National Association of the Academies of Science - Breakfast with Scientists

The National Association of the Academies of Science held their annual meeting at San Jose State University. The conference invites middle and high school students from each state selected by the American Junior Academy of Science to be inducted. As the host school, they invited San Jose State clubs and organizations, Robotics Club included. Over 100 students came by the table and asked what our project is.

8.2 Science Extravaganza - Science Fair

Figure 11: Science Extravaganza - Science Fair

Science Extravaganza is an annual event inviting over 300 middle school students to San Jose State University to promote STEM careers through interesting workshops and presentations. The Robotics Club was invited to present and talk with middle school students about our project, what are the rover's objectives, how the universal gripper works, the motor controller used to move the rover, and any curiosities they may have about our project or engineering.

8.3 Admitted Spartan Day

Figure 12: Admitted Spartan Day

Every semester San Jose State holds a welcoming event for all incoming freshmen. Thousands of future SJSU students attend this event in hopes to get an ideas of what SJSU is all about. The Robotics Club held a booth for the club and created a public viewing screening to watch the rover as it was driven about the school and through the large crowds.

8.4 The Viewer Portal

Figure 13: Mission control: Viewer Portal

The viewer's portal is a passive user interface which enables spectators to view a live stream of the rover during runtime. The portal will not only show a rover-point-of-view video stream, but it will also toggle into a live feed of the control room to give an insight of how commands are being issued and taken by the rover in real-time.

This control systems branch was created for spectators of all types, some of those being: judges, members of the SJSU Robotics Team, supporters outside the team, and so on. The portal also serves as a hub of information, providing viewers with details of the RASC-AL competition constraints, themes, and deadlines.

9 References Cited

T-slotted aluminum weight http://www.8020.net/T-Slot-4.asp

Universal gripper http://www.eng.yale.edu/brown/ABRJL12.pdf, http://creativemachines.cornell.edu/sit

Treads http://www.superdroidrobots.com/shop/item.aspx/all-terrain-reinforced-4-inch-wide-tread-by-the-foot/1625/

10 Appendix

10.1 Appendix A.

Table 3: Distrubution of Funds

Electrical	$6,804.03
Mechanical	$2,280.32
Telecommunications	$1,596.27
Travel & Registration	$2,280.32
TOTAL	$13,672.71

Table 4: Contributers

Excess Solution	Discount & Donation
Luat Nguyen	Monetary
NASA	Monetary
Phobotics	Donation
Sai Karra	Donation
Sims Materials	Donation
SJSU General Engineering	Monetary
TechShop	Complimentary Membership
Wendell Boyd	Monetary