2013 RASC-AL Robo-Ops Competition

Final Technical Report

Florida Agricultural & Mechanical University / Florida State University
College of Engineering

Team Members:

Electrical and Computer Engineering

Ricardo Asencio

Matthew Wilson

Mechanical Engineering

Myles Bean

Daniel Bucken

Parker Harwood

Jason Rhodan

Project Advisors:

Dr. Jonathan Clark, PhD

Department of Mechanical Engineering

Dr. Michael Frank, PhD

Department of Electrical and Computer Engineering

I. Introduction:

The FAMU-FSU team desired to prove the utility of the Rhex platform in planetary exploration by developing novel methods for sample acquisition and locomotion. The Rhex platform has been used successfully in a variety of terrains that wheeled rovers have had difficulty traversing, such as sand, rocky or rough terrain, and unknown terrain. Rovers based on the Rhex platform can easily walk through areas where wheeled rovers can become bogged down or even stuck.

The rover, Space-Hex, is the latest iteration of hexapedal robotic platforms sponsored by STRIDe laboratory on the FAMU-FSU College of Engineering campus. It is the largest Rhex platform in the world to walk with a manipulator. The previous Rhex platform sponsored by STRIDe, Hexcavator, though designed for the Lunabotics competition, provided knowledge that was invaluable to the successful completion of the rover. Hexcavator, demonstrated that a Rhex platform of the size desired for this competition was possible to construct and control. This platform, however, did not have the stability of other Rhex platforms, so an emphasis was placed on dynamically scaling the new platform correctly.

Due to the size and weight of the Hexcavator platform, it was unable to be used for the Robo-Ops competition. In addition, the wiring for the locomotion subsystem was quite cluttered with several microcontrollers, motor drivers, and decoder chips contributing to a complicated scheme of wires.

For these reasons, a completely new platform was designed. Taking the lessons learned from Hexcavator, the new platform was properly scaled for RoboOps. The team was determined to implement a cleaner solution to the electrical hardware; this led to the use of the field programmable gate array for the decoder logic and alternative, more efficient, control hardware.

II. Chassis and Drive System

A. Legs

This platform utilizes compliant C-shaped legs, instead of conventional wheels, for locomotion. In order for Space-Hex to maintain its stability, it has six of these legs. This ensures that at least one triplet of legs can be in contact with the ground at all times while it is in motion. The size of these legs was set based on the scale of the frame. They are 24 cm in diameter and 5 cm in width. This sizing allows for clearance between legs as well as clearance to the frame.

In order to have a smooth walking gait, the stiffness of the legs had to be tuned. After time delay in communication was considered, it was decided that a fast walk, as opposed to running, was going to provide a more than adequate speed for the rover. Therefore, the legs were tuned to be very stiff relative to Rhex platforms currently in use, as the flexing of the legs necessary for running would only provide a chassis with more vertical displacement resulting in a choppy camera feed. Since the legs were tuned for a specific rover speed, they would not be suited for significantly faster locomotion. While they would be capable of supporting the rover’s weight, they would provide a far less stable gait if the rover were to move fast enough for airborne phases.

Figure 1: Fiberglass leg with tire tread and two-piece aluminum clamp

The final set of tuned legs is comprised of 36 layers of fiberglass. These layers contain 8 layers where the weave of the fiberglass is offset from the normal by 45 degrees to provide out-of-plane stiffness, which is helpful while turning. The tire tread is taken from a bicycle and is attached to them using methacrylate. The legs are then attached to a custom two-sided aluminum mount, which attaches to the drive motor's output shaft.

In order to provide a walking motion the algorithm used is a Buehler clock. The Buehler clock has two phases. When a triplet of legs is in the sweep phase (Figure 2) the angular velocity ω_{upper} is approximately five times faster than the velocity in the step phase ω_{lower}. The triplets connected by the blue and red lines in the diagram below should ideally be in the same position relative to each other at any instance. In order to turn in place, the rover uses its normal walking gait but with one side of the rover's legs moving backwards while the other moves forward. Space-Hex does not use any conventional suspension system but rather the compliance of the legs allows each of them to independently react to the terrain.

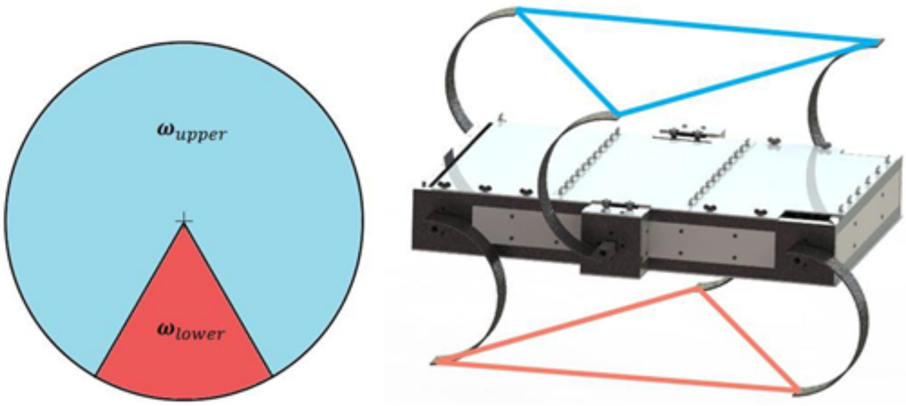

Figure 2: Depiction of the Buehler algorithm. On the left are two rotational speed zones corresponding to the color-matched leg sets on the right.

B. Chassis

The rover's chassis (Figure 2) is made primarily from 2cm hollow square aluminum tubing. This provides a strong and lightweight body for all of the rover's systems to be mounted to. The tubing was cut to exact size using a CNC machine and then welded together. The frame has numerous mounting points in the form of rivet nuts and clearance holes for bolts. These points serve as the attachment points for the sample extraction module as well as all of the electronic hardware. The frame is sealed from the environmental factors using ABS panels in all of the gaps between the tubing.

The chassis was scaled based on a successful Rhex platform's aspect ratio. The critical dimension for this design was the width based on the drive motor configuration. Using a width that provided just enough clearance for the drive motors not to contact each other, the other dimensions were calculated. The final chassis measures 72 cm long x 59.4cm wide x 10.2 cm tall. The chassis itself weighs slightly less than 5 kg, which still allows for plenty of weight for the locomotion hardware and sample extraction systems of the rover.

C. Sample Extraction Module (SEM)

The SEM was designed to accomplish the task of picking up rock samples both quickly and reliably. The design takes advantage of the fact that the hexapedal locomotion platform results in the body of the robot being non-planar. The vertical degree of freedom generally found in robotic arms was removed from the arm itself and compensated for through the use of the legs of the rover to vertically adjust the end effector. This resulted in the arm only having two actuated motions specific to it, thus operating in a planar motion.

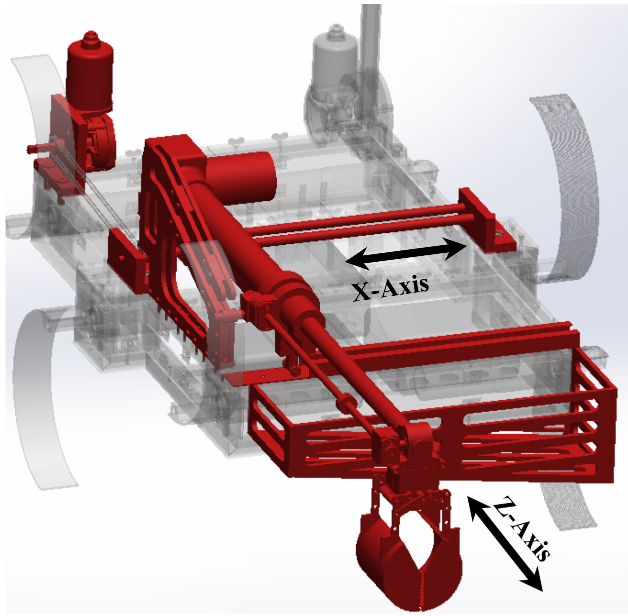

Figure 3- Sample Extraction Module on rover

The workspace of the end effector is 12 inches in the z-axis, 12 inches in the x-axis and the rover's legs are capable of lifting the end effector 5.5 inches from the ground. The SEM is capable of speeds of 2 inches per second in both axes, which allows any area within the workspace to be reachable within six seconds. In order for the sample to be deposited into the collection bin, the arm uses a passive degree of freedom in the form of a cam-follower slot (Figure 4). When the arm is at an x position of zero (the rover's right side), the linear actuator (z-axis) can be retracted and have the guide contact and rise up the follower slot.

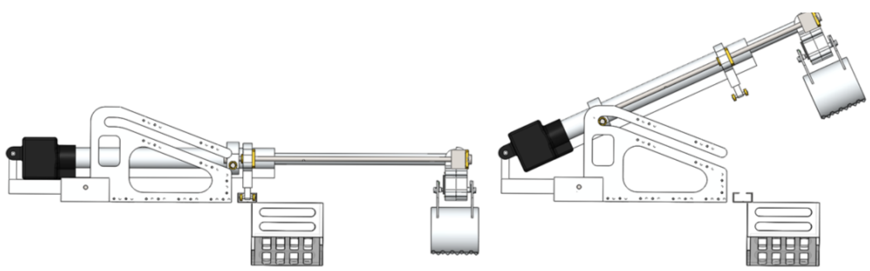

Figure 4 – (Left) Storage procedure starting position, (Right) End position

The end effector utilizes counter-rotating clamshell buckets that are controlled by a single actuator. A 7.2V geared motor is coupled with a 4:1 gear train to increase the output torque to 1.4 Nm. The output sprocket is directly attached to one of the bucket drive shafts. A 1:1 spur gear arrangement couples the two drive shafts together to achieve the desired counter-rotating motion. The arms, which connect the drive shafts to the buckets, are dimensioned so that the buckets sit at ground level in the clamped position. The surfaces of the buckets that face the rover are made from polycarbonate, which allows the operator to ensure the sample has been acquired.

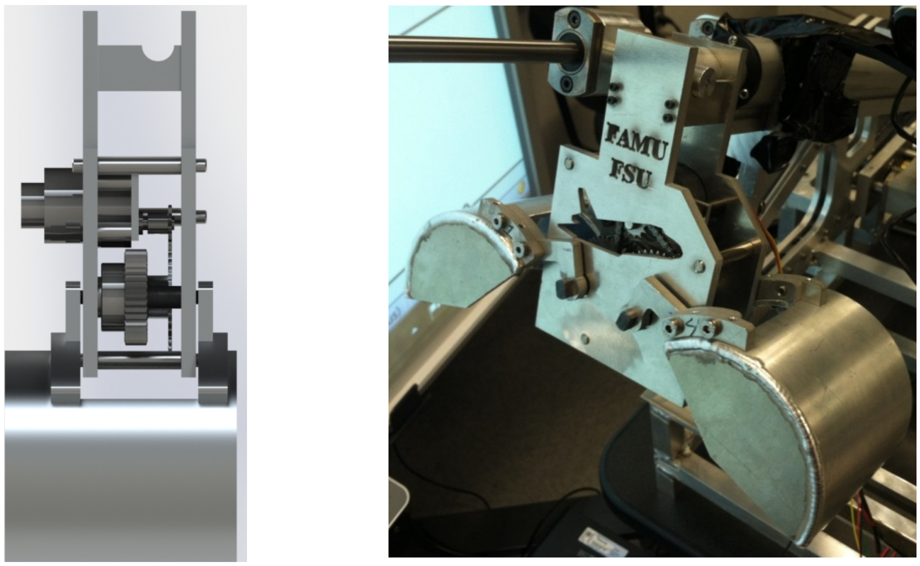

Figure 5: (Left) CAD model of finalized gripper depicting chain drive and gear train, (Right) Photo of the gripper in the open position

III. Vision System

During early vision tests, it was concluded that the main camera used for navigation and finding the target samples needs to be elevated above the rover. A low point of view restricted the ability to depict the colored samples in various terrains. In order to achieve the elevated viewpoint, the rover's main camera will be located at the top of a camera mast, 74 cm above the base of the rover. The design uses a single motor coupled with a worm-spur gearbox to raise the mast from the stored position to the vertical position, as shown in Figure 6(left), where it will remain for the entirety of the competition. The camera mast motor is capable of producing 23 Nm of torque, which is more than sufficient than the required 6 Nm required to raise the camera mast and associated hardware. The motor was selected for its worm-spur gearbox and it's availability, as it could be reused from a previous project. The benefit of the gearbox is that the worm-spur mesh cannot be easily back driven; thus, induced moments about the output shaft due to the walking motion of the rover and the length of the mast will not be great enough to cause the mast to lower. When the mast is in its stored position it is laid across the top of the rover in the fore-aft direction. At the start of the competition, the camera mast motor will be actuated until the mast is sufficiently torqued against its backstop.

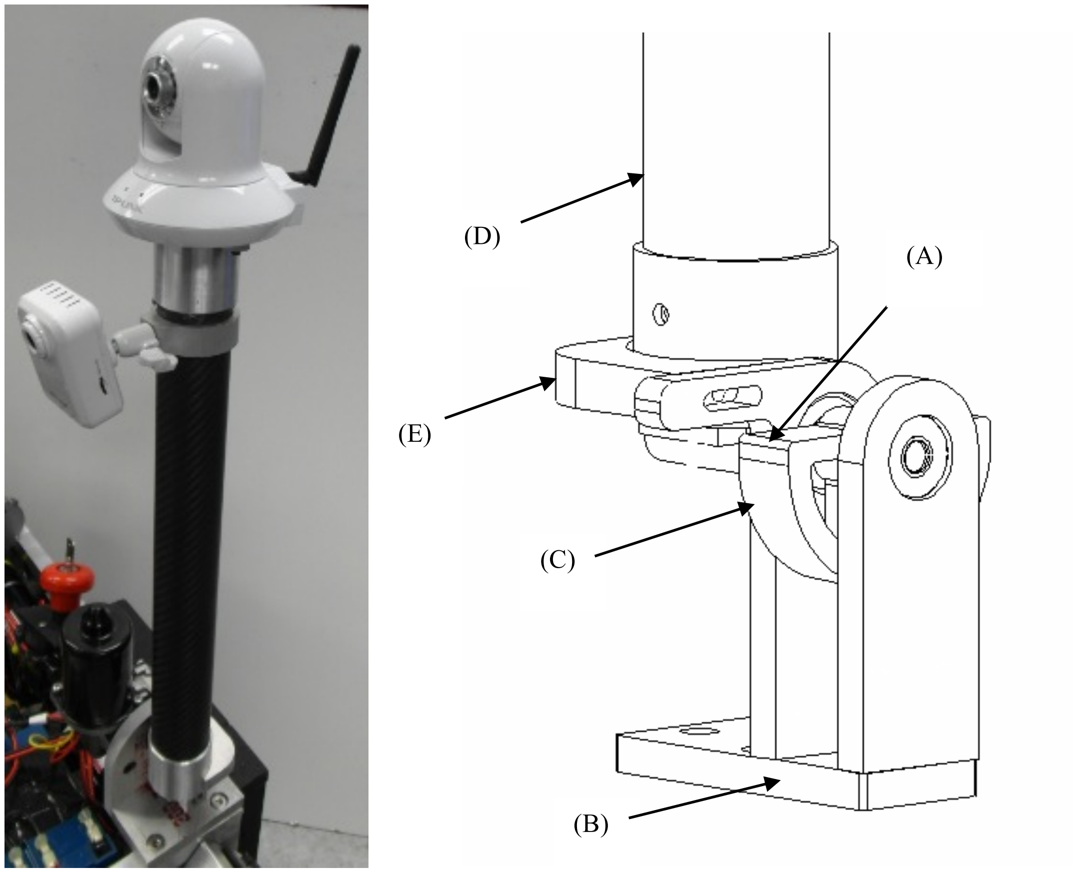

Figure 6-(Left) Camera mast mounted the rover, (Right) Spring loaded mast design

A spring loaded camera mast is currently in development to reduce the weight of the rover. It will utilize a spring mounted between points (A) and (B) on Figure 6 (right). When the camera mast is in the stored position, the spring will be curved around the spring rocker (C). A release mechanism will hold the camera mast (D) in the stored position. A spring loaded plunger pin will be mounted so when the mast reaches its vertical position against the backstop (E), the plunger will lock the mast in place. This design may replace the motor driven camera mast if it can be successfully implemented in time for competition.

A TP-Link pan and tilt (PT) Internet protocol (IP) camera will be mounted on top of the camera mast. It provides a 354° pan range and a 125° tilt range with a 50° viewing angle. This will give the operator a wide range of view to search for, and identify, the colored rocks during the competition. The camera also has a display resolution of 640x480 and an image frame rate of 25fps - 30fps. More importantly however, is the camera's ability to compress the video feed using MPEG-4 video compression. That allows for remote viewing without the need of computation from the onboard computer, freeing clock cycles to be used for leg motor control. The camera is also equipped with an Ethernet port so that it can be connected to the Internet via the onboard router. The camera has a maximum power consumption of 12 W.

A second, fixed, TP-Link camera will be mounted two inches below the PT camera on the camera mast for optimal viewing of the competition field. It compresses video with H.264 compression and will not require the onboard computer for video processing and transmission. Like the PT camera, it has an Ethernet port for connection to the router. Its maximum power consumption is 12 W and its frame rate is 30fps with a 1280x1024 image resolution. This higher resolution will be used for the blob detection algorithm so that the samples can be more easily identified.

IV. Control and Communication System

D. Graphical User Interface

The Graphical User Interface, or GUI, is a custom computer application that aims to greatly simplify the operation of the rover by integrating video feeds, sensor data, and rover control. Actions performed by the interface can be separated into five categories: networking, locomotion control, SEM control, video processing, and safeguarding.

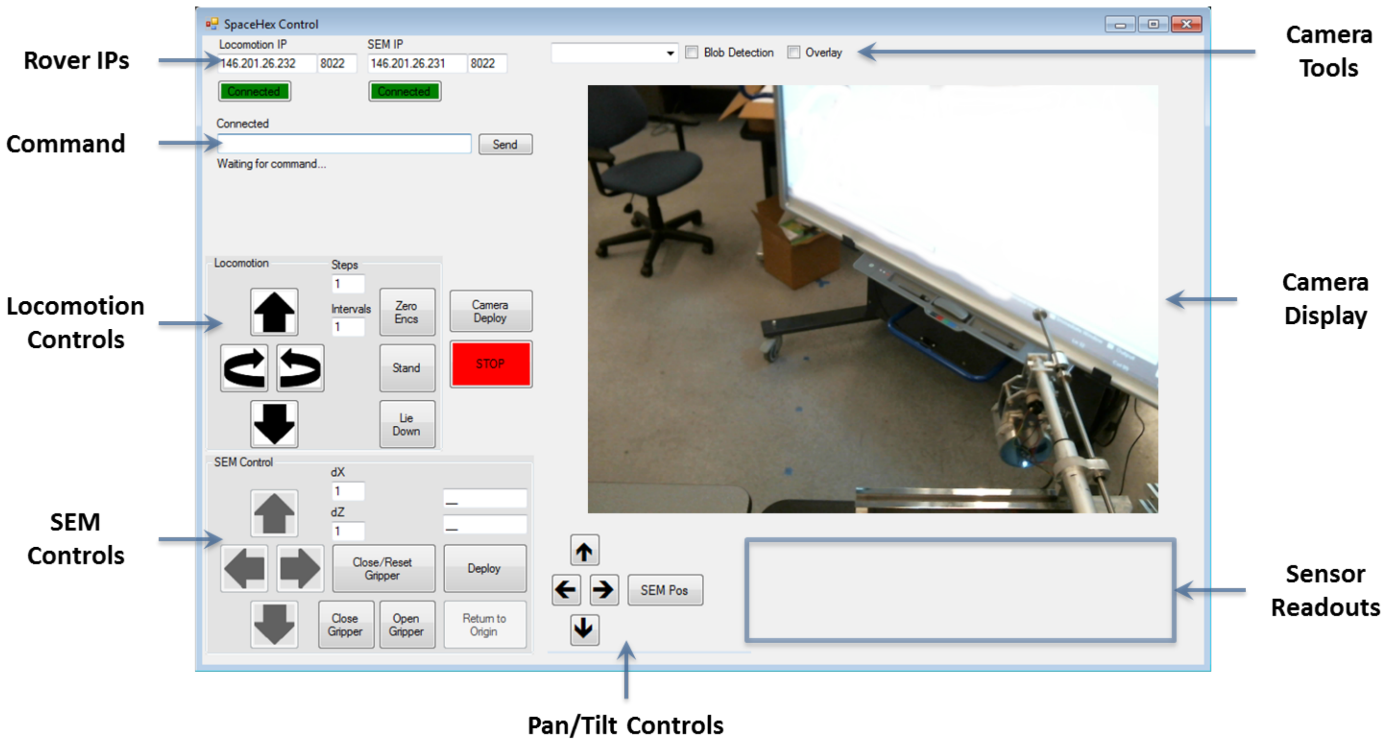

Figure 7: The GUI that the rover's operator will be using to control each of the subsystems and view the feedback

Networking

To establish communication between the computing systems on the rover and Mission Control, located at the college, some detailed networking procedures are required. The GUI and the software on the rover platform have been programmed to handle these tasks automatically after booting, thus streamlining the control process. Figure 8 displays the required communication links required for rover operation.

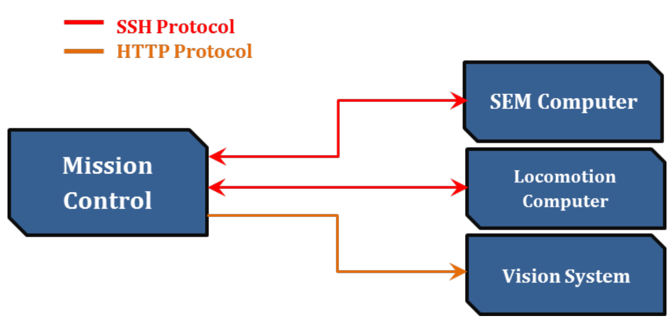

Figure 8: Communications diagram

Figure 8 shows communications via Secure Shell (SSH) must be established between the on-board computers and the mission control computer. Communication via HTTP is used to link the vision system (cameras) to the mission control server. Ordinarily all of these communications links would be fairly straightforward to establish. In this case, both the mission control computer and networked hardware on the rover are behind Network Address Translation (NAT) firewalls. This particular type of firewall effectively prevents all incoming connections to devices behind the firewall. In order to send commands and request video feeds through NAT firewalls, which typically only allow outbound communication, a workaround is established by employing a combination of local and remote port forwarding, and using reverse SSH tunnels.

SSH connections are established automatically at boot using a script. A reverse SSH tunnel creates a link between a port on the router of the server's local network and each on-board computer. Local port forwarding is then used to link the ports on the router to the server. Once this has been done, an SSH command sent to these router ports by the server will be redirected to the appropriate ports on the onboard computer and vice versa. The delay added by redirecting the communications through a router is negligible. The router is also used to redirect the video feeds broadcast by the IP cameras from ports on the on-board network to the local ports on the mission control computer allowing the GUI to navigate to these ports to extract the video feeds from the cameras.

Despite the rather convoluted process of linking the control and on-board computing hardware, the result is simple: the user clicks a button on the GUI and the rover, possibly hundreds of miles away, responds appropriately.

Locomotion Control

Rover movement can generally be described by the following terms: standing, walking, turning, and lying down. Depending on the function, several parameters must be sent to the on-board computer along with the command itself, such as speed or number of steps. Due to the legged nature of the locomotion system, these parameters are integers, and are entered via general text fields. Once the proper supporting parameters have been entered, the user issues the command by pressing a button. The command is sent as a string to the locomotion computer on the rover. For example, a command could read as follows: "./rvr –w 30 F 15". This would result in the rover walking forward for 15 steps at a leg speed of 30 RPM and would be initiated by entering these values into the corresponding fields and clicking the forward button. Turn commands are issued in the same manner. Some additional functions exist such as calibration of the legs (setting all decoders equal to zero at a common reference point), standing/laying down, and holding the legs at a specified orientation to control the height of the robot.

SEM Control

Two options exist for controlling the movement of the sample extraction module: manual control and click-to-move (CTM). Manual operation is performed by entering numerical values into the text fields which represent the desired movement in inches and then clicking the corresponding button to initiate movement. Moves can be performed to displace the arm relative to its current position or to deploy the arm to an absolute position relative to the origin.

Manual operation is initiated by entering numerical values into the fields above the deploy button, corresponding to absolute X and Z positions, and clicking deploy. Once the arm is deployed, relative moves are enabled (they are disabled in Figure 7 to prevent damage to the arm), and can be performed by entering a dx or dz (left/right or forward/backward) value in inches and clicking the corresponding button. When the sample is below the gripper, the "Close Gripper" button is clicked to capture the sample, and then the 'Return to Origin" button is clicked to return the gripper to its original location above the storage bin. The sample is then dropped into the bin for storage.

If the arm has already been deployed from the origin, the CTM feature can be used by holding down the right mouse button and left-clicking anywhere within the extraction zone will result in the gripper automatically moving to the point of the click. If the arm has not yet been deployed it will deploy to the site of the click. Algorithmically, the interface is simply converting the horizontal and vertical locations of the pixel that is clicked on into the Cartesian space of the SEM. The algorithm takes the perspective of the camera into account. This method of control is only feasible because of the planar design of the arm and this control implementation should allow the user to take full advantage of this design and to achieve low sample extraction times.

Video Processing

The GUI's blob detection utilizes a video processing technique in which clusters of pixels within a specified RGB and physical size range are highlighted on the video stream. The algorithm can be activated by clicking the "Blob Detection" checkbox above the video feed. Figure 9 below shows an example of samples being highlighted by the algorithm.

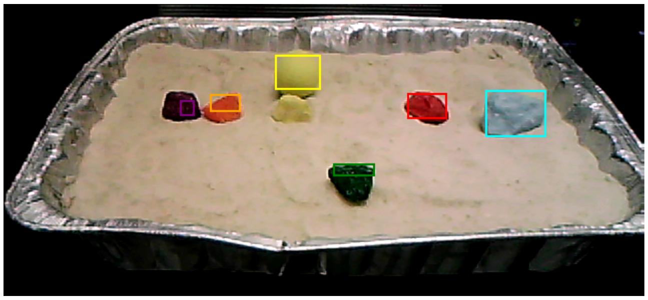

Figure 9- An assortment of rock samples being highlighted by the blob detection algorithm.

The effectiveness of the blob detection algorithm depends on two main factors: the calibration (RGB ranges) and the quality of the video feed. The max/min RGB values can be manually adjusted to calibrate the algorithm. The calibration is performed in the approximate lighting conditions in which the rover will be operated. Colored rock samples are placed in the view of the rover's onboard cameras; in calibration mode, the user clicks 5 times at different locations on each rock sample to gather a range of RGB values for each of the 6 colors for the lighting condition.

Due to limited bandwidth, the rover's main camera resolution is not high enough to perform the blob detection algorithms. The solution to this problem is to pass a high-quality video feed to the blob detection algorithm at a low frame rate and to then superimpose the results produced by the algorithm onto the low-quality, higher frame rate pan/tilt camera. This process is depicted graphically in Figure 10 below.

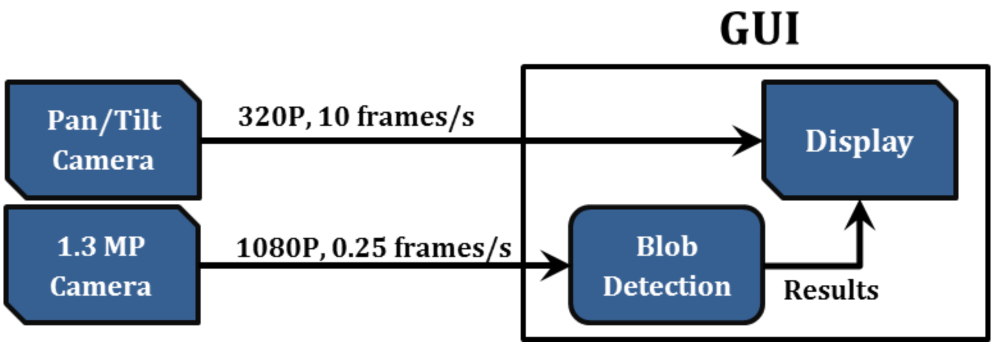

Figure 10- Blob detection flowchart

Safeguards

The GUI offers an opportunity to include redundant safeguards for both the SEM and Locomotion systems. Although there are safeguards in place on the rover's on-board software to prevent invalid SEM moves and to make sure the rover does not tip or flip, implementing these safeguards again in the GUI increases system reliability and the team's confidence in the rover.

V. Technical Specifications

Mechanical		Electrical/Computing	
Stowed Dimensions:	89 cm x 72 cm x 50 cm	**On-Board Computing:**	Raspberry Pi
Weight:	44.5 kg	**Processor Frequency:**	700 MHz
Ground Clearance:	14 cm	**Logic Device:**	Xilinx Spartan-6 FPGA
Tipping Angle:	43.2˚	**Operating System:**	Arch Linux
Claw Movement Speed:	5 cm/s	**Control Method:**	SSH
Top Speed:	0.8 m/s	**Networking:**	Verizon 4G LTE USB modem
Rated Payload	10 kg	**Operating Time**	1h 15m
Vision System Elevation	88 cm	**Drive Power**	1.2 kW
		Battery Power	25.9V 50Ah Li-Po

A. Control System Overview

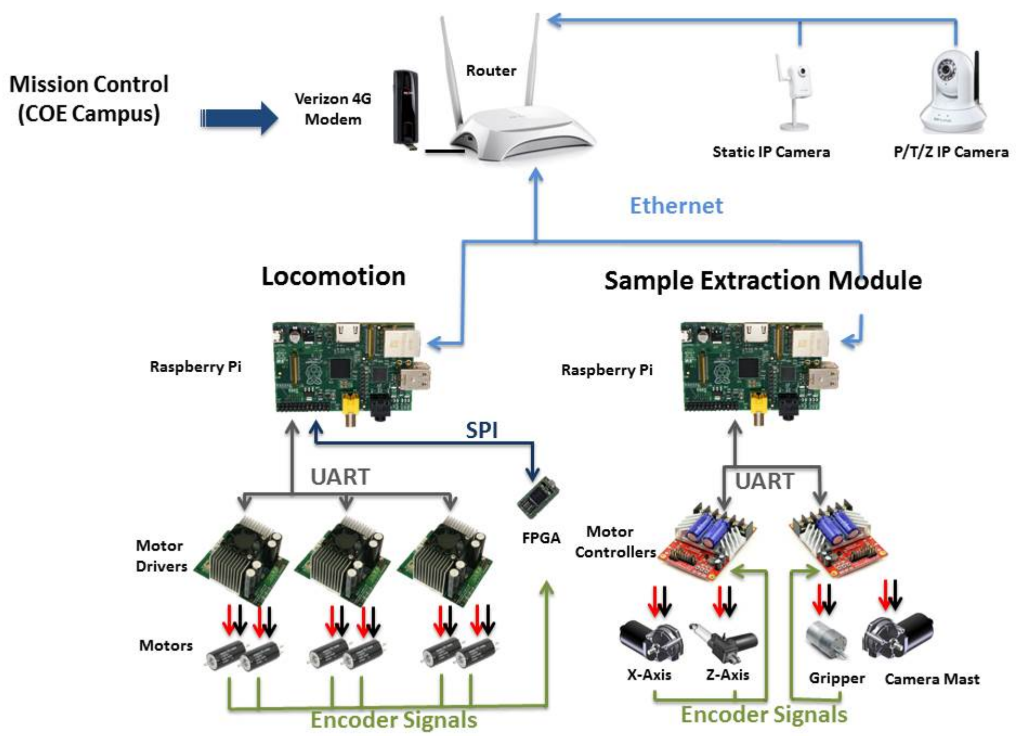

Figure 11: High level diagram of the control system

The heart of the control system for both the SEM and locomotion subsystems are two independent Raspberry Pis (RasPi) each running the Arch Linux operating system. The rover operator sends high level commands such as 'walk' or 'deploy' to the respective computer and it relays the commands to the appropriate motor drivers; the Sabertooth for locomotion and Roboclaw for the SEM. The Roboclaw motor controllers have onboard decoders to track the SEM motor positions, so that the motors' actions are properly regulated. The Sabertooth motor drivers do not have onboard decoders; this is where the field programmable gate array (FPGA) is used. The decoder logic is implemented on the FPGA to keep track and relay the motor positions to the locomotion RasPi via serial peripheral interface (SPI).

B. Onboard Computing System

There were many factors behind the choice of the RasPi: it has a plethora of open-source libraries (wiringPi), it is low cost ($35), and it has the necessary capabilities to run control and the communication hardware required. The main reason behind the choice was its low power consumption being 3.5 W. With six motors each consuming 200 W, minimizing the power consumption of the computing system was extremely important.

The RasPi does not come without limitations, however, as it did not have the number of GPIO pins required to read six quadrature decoder chips. The solution was to implement all of the decoder logic on a FPGA and utilize the dedicated SPI pins on the RasPi. With this solution, only four pins on the RasPi are used to communicate the decoder output, leaving a sufficient number of pins to communicate with the motor drivers.

Leg control is achieved through Proportional Derivative (PD) control implemented on the RasPi in the C programming language. The fundamental idea behind leg control is calculation of the position where the motor *should* be, called the ideal position. Using PD control, the ideal position and the decoder output (the measured position) produce a calculated duty cycle to stay synced with the Buehler motion. This allows every leg to respond dynamically to the terrain it is currently traversing. With this modular approach, the leg movement can be divided into two similar but ultimately different sets, walk and the generic move (move). Walk will simply use the Buehler algorithm to walk a given number of steps before stopping. The generic move is for situations where the legs need to be moved but not in the Buehler motion, such as lying down to pick up a rock sample. While both algorithms rely on the synergy of the PD control and the ideal position, the major differences between them force their separation. First, they have different exit conditions, the walking algorithm will end once the desired number of steps has been taken. The move algorithm will end only when the motor reaches the desired position. The ideal position generators are also different in that the move algorithm's ideal position generator will produce a constant rotational speed in the leg whereas the walk algorithm changes the leg's rotational speed as it changes between the sweep and step phases.

The previous algorithms are not functional without proper leg calibration, which allows the legs to share a common reference point. This is done by slowly moving the legs backwards until they contact the ground. At slow speeds, the legs cannot lift the rover, completely stymied by the ground. When all legs are in the same position, the decoders are reset through a pin on the RasPi and the legs now have a common reference.

C. Field Programmable Gate Array

The Xess Xula2 board houses the Xilinx Spartan-6 FPGA along with 8 Mbits of Flash memory, an onboard 12 MHz oscillator, and a 40-pin interface, 33 of which are general input/output pins. The Spartan-6 has 24,051 logic cells, four digital clock managers (DCM), and two phase lock loops (PLL). The DCM multiplies the onboard oscillator to 150 MHz to oversample the SPI line and ensure correct communication between the RasPi and the FPGA.

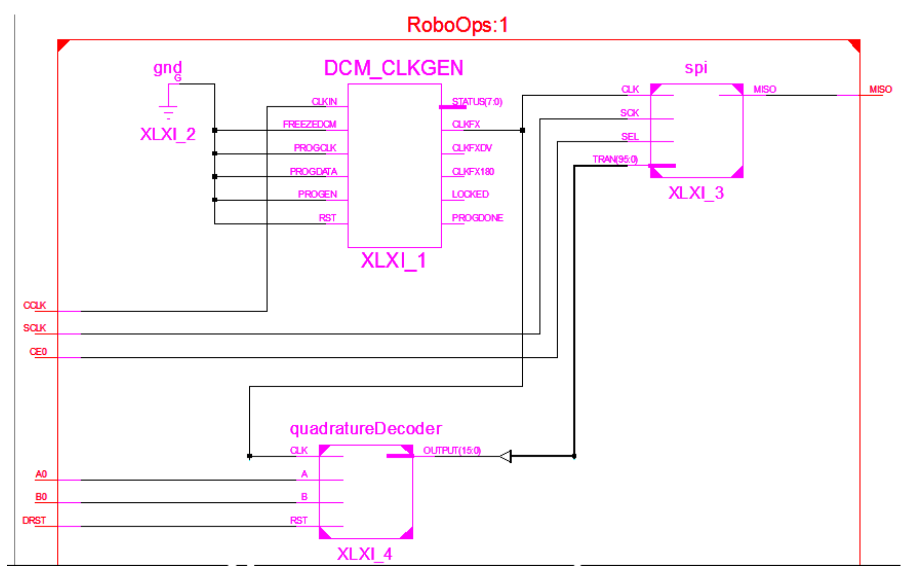

Figure 12 - Top level of the FPGA cicuit instantiated by the Xilinx ISE Register Transfer Level (RTL) Viewer

Figure 12 gives a top-level diagram of the decoder logic described in Very high-speed integrated circuit Hardware Description Language (VHDL). For simplicity and space, this portion of the circuit only depicts a single decoder module. When communicating with the FPGA circuit, the RasPi acts only as a receiver of the decoder modules' outputs. Both the decoder and SPI modules were custom made for the purpose of the competition. The decoder modules receive the encoded signal from the motor encoders and produce a number representing the position of the leg. This is then stored in a register and transmitted to the RasPi as dictated by the SPI protocol. The SPI module does not receive any meaningful information from the RasPi.

D. Sabertooth Motor Driver

The Sabertooth motor drivers, a 2 channel motor driver that can provide up to 60 A continuous current in each channel, are used to drive the locomotion motors. Since the maximum current draw of each of the motors is 11 A, each of these motor drivers can easily drive two motors simultaneously. The motor drivers are communicated with via UART through packet serial. The four-byte packets consist of an address byte, a command byte, a data byte and a 7-bit checksum. The address byte only chooses which motor driver to communicate with. The command byte is used to determine which of the two motors will run and its direction. The data packet is the desired duty cycle at which to run the motors. The final seven bits serve as a checksum that is used for error detection. If the checksum is not the correct value, the command will not be acted upon. The checksum is calculated as follows:

$$checksum = address + command + data$$

In the packetized serial mode, the driver configures a second serial input line as an emergency stop input. This active low signal is also used by the team in the unlikely case of the rover having to stop suddenly. In addition to driving the motors, the Sabertooth drivers also provide a regulated 5V to power the RasPi and FPGA.

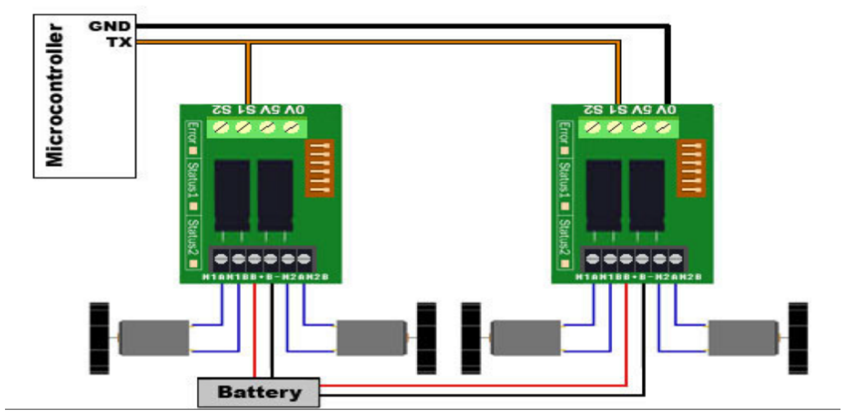

Figure 13: Diagram of Motor Driver Connections

E. Modem

The modem that was chosen for 3G/4G wireless connection is the Novatel USB551L. The wireless technology that it supports is 4G LTE and CDMA. It is backwards compatible with 3G networks which will be useful in case of loss of 4G connection. The system requirements specify that a 166 MHz processor and 128 MB of RAM are required. The RasPi easily exceeds these requirements. The modem also supports the Linux operating system. Its dimensions in centimeters are 8.79 x 3.51 x 1.19 and it weighs 34.9 grams.

F. Router

The router used to facilitate both communication between the operator and various components on the rover was the TP-Link TL-MR3430.This is a router that is compatible with various 3/4G modems to access the Internet. The router then acts as a hub to connect various devices. The router has 4 Ethernet ports available. Two of the Ethernet ports are used for the IP cameras and the other two are used to provide Internet connection for both of the RasPis. This allows the user to remotely control the RasPi with the Internet connection provided by the modem-router configuration. The router has a maximum power consumption of 8W when a 9 volt supply is used.

VI. Testing Strategy

The SEM has been tested on multiple terrains including soft sand, compacted dirt, gravel and even asphalt. During the preliminary testing, it was observed that the drivetrain had trouble digging into any of the terrains with expectation of the soft sand. To help the gripper acquire its samples, the arms of the buckets were then shortened to allow the bottom of the buckets to close at ground level. Once this change was made, the SEM was successful on all terrains and provided a very repeatable process. If the digging in of the gripper is desired at any point in the competition, the rover's legs can be used to adjust the angle of pitch of the rover, allowing the buckets to close beneath the surface.

The Rhex family of robots have been extensively tested and proven on the terrains that the rover will encounter during the competition. Since the Space-Hex rover is dynamically scaled up from a Rhex robot, the dynamic behaviors on these terrains will be similar. Locomotion testing for the rover primarily focused on the functionality and robustness of the various gaits and functions. Each function and gait was first run with the rover on a stand so that the legs were not in contact with the ground. This allowed for a safe testing environment since malfunctions with this type of locomotion have the potential cause catastrophic damage to the rover. After the functions and gaits were established, each was tested on grass, sand, and hard surfaces. On these surfaces, the platform was able to walk and turn without becoming stuck or having difficulties. The team also tested the rover's ability to climb as shown in Figure 14.

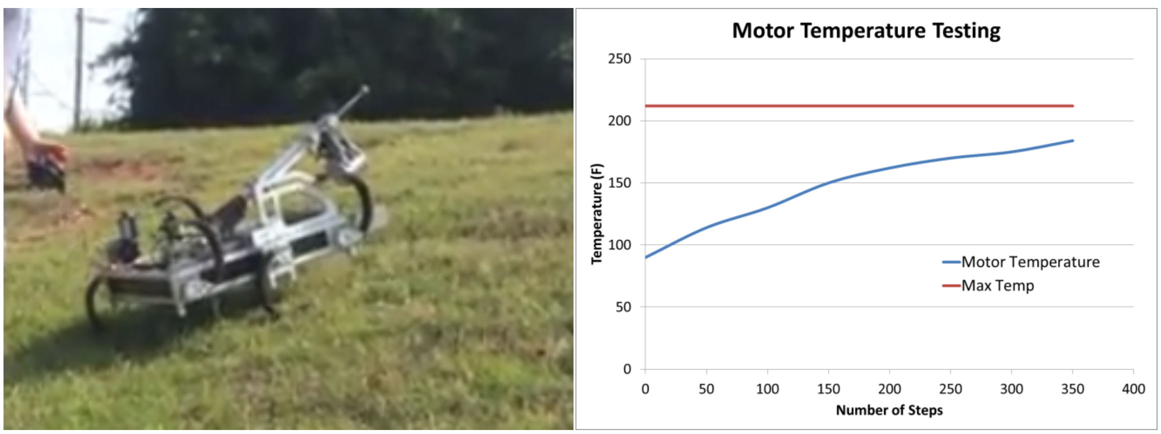

Figure 14 (Left) Rover climbing 25% grade, (Right) Plot of motor temperature motor temperature vs number of steps

Due to the nature of the Buehler clock, when the drive motors change from the step phase to the sweep phase there is a current spike which causes more heat generation than if the motors were run at a constant speed. A hexapedal platform also creates extra heat due to the fact that with each step the motors have to lift and lower the rover. Temperature testing was performed to determine if the motors would exceed the max operating temperature of the motors, 212˚ F. The results of this can be seen in Figure 14. It was concluded that active temperature dissipation was needed since the motor temperature did not reach a maximum before approaching the maximum allowable temperature. To solve this problem, forced convection over the motors was implemented. Ambient air will be pulled in through six 13 cfm fans and pulled out through six 13 cfm fans in the vicinity of the drive motors.

VII. Educational/Public Outreach

A large part of this project is to engage the public in space exploration and STEM (science, technology, engineering and mathematics). To do so, the team held and participated in several events to engage audiences of all ages. The aim of engaging elementary and middle school children was to show how exciting and fun space exploration and STEM can be. Multiple events were held at a local science museum, Challenger Learning Center, to engage this age group. The team showed off their prototype rover as well as had activities for the audience to participate in. The children were able to adjust parameters such as sensor thresholds and speed on pre-programmed robots and race each other on paralleled curved lines. This allowed the children see how changes in parameters changed a robots behavior. There was also a gripper building competition where the participants built Popsicle stick grippers to grasp rocks similar to the samples in the ROBO-OPS competition.

Figure 15: (left) Line following races at Challenger Learning Center, (right) 1st place gripper design contest winner, (bottom) FAMU/FSU ROBO-OPS team at Digitech

A high school and college level crowd was engaged through the FSU Digitech event, an exhibition for students to showcase their innovation through technology. The team was able to demonstrate the rover's capabilities and talk with event goers about the project and what inspires them to pursue a path in their fields. They were also able to bring awareness to the RASC-AL RoboOps competition and space exploration, in general.

The team attended the Florida Conference on Recent Advances in Robotics (FCRAR) where they again demonstrated the rover's capabilities and discussed the more technical aspects of how the rover was designed, constructed, and programmed. Here they were able to showcase the fact that they have developed the world's largest Rhex platform that utilizes a manipulator and is controlled by the smallest electrical hardware configuration ever utilized by a Rhex. Discussing these topics with a professional audience of robotics researchers yielded interest in their control hardware, which despite its size and cost is capable of running the control algorithm at a quicker rate than many systems currently in use.

VIII. Sponsorship and Budget

STRIDe Lab – Motor Drivers, Fiber Glass, Lab Access

CISCOR – Monetary Donation

AME – Monetary Donation

National Institute of Aerospace – Stipend

Misumi – Store Credit

Progressive Automation – Product Donation

Maxon Motors – Educational Discount
DS Solid Works – Software Donation
TP-Link – Product Donation

Purchases	**Cost**
Drive Motors	$6,099
Raw Materials	$352
Misc. Hardware	$265
Configured Hardware	$1,032
Electrical Hardware	$2,463
Verizon Service	$285
Batteries	$3,500
Travel	$1,442
Donated Items (Retail)	$835
Grand Total	$16,273