

Team 11 – Robo-Ops

Operation Manual



*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

1.0 Introduction

Space-Hex is a six-legged planetary rover designed to efficiently extract material samples from the Johnson Space Center Rock Yard during the 2013 RASC-AL Robo-Ops competition. Operation of the rover is centered about the Graphical User Interface which allows the operator to control all sub-systems of the rover from hundreds of miles away through the use of the Verizon cellular network. This document provides a general functional overview and control strategy for the rover.

2.0 System Diagram

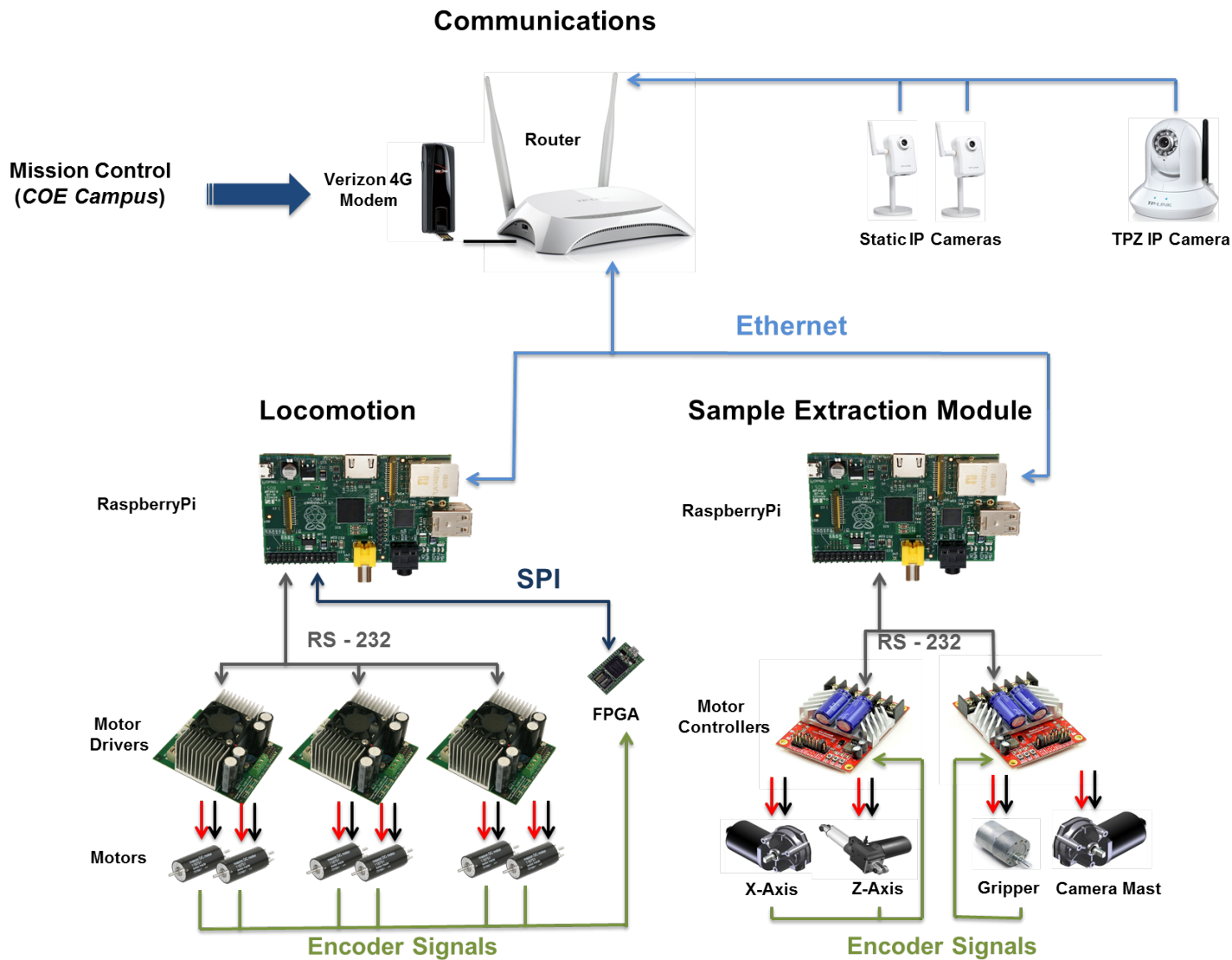


Figure 1 - High-level system diagram.

3.0 Rover Control

Control of all rover sub-systems has been integrated into a single Graphical User Interface (GUI), which can be installed on any Windows-based PC. In this section, a detailed description of each control and feature of the user interface will be provided.

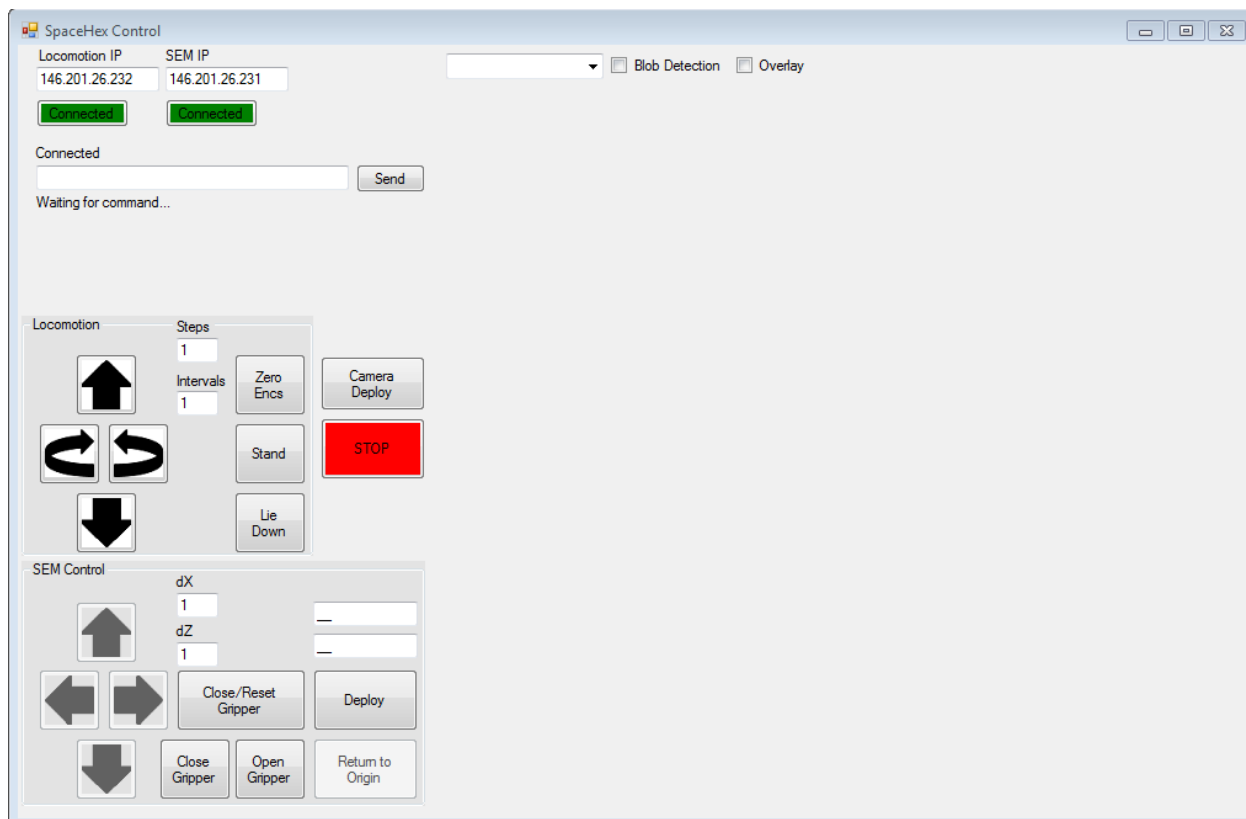


Figure 2 - User interface used to control the rover's sub-systems.

3.1 Networking

For full control of the rover, network connections to the locomotion computer, Sample Extraction Module (SEM) computer and cameras must be established.

Locomotion and SEM Computer Networking

To connect to the two computers on the rover, simply enter their IP addresses into the 'Locomotion IP' and 'SEM IP' fields at the top left and click "Connect". The colors of the "Connect" buttons indicate whether the connection has been successfully established.

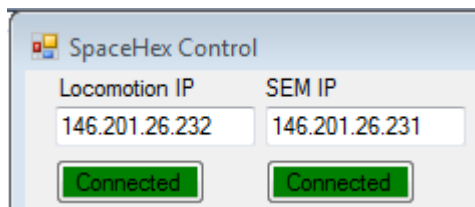


Figure 3 - IP address fields and connect buttons which serve as status indicators.

Connection to both of the Rover's computers is required before the locomotion and SEM controls are enabled.

Camera Networking

Connections the various cameras on the rover are made automatically by the interface upon selection of the desired camera from the drop down menu as shown below. If credentials are required to access the camera, a prompt will appear upon selection of the camera. Default credentials are admin/admin (username/password) for all cameras.

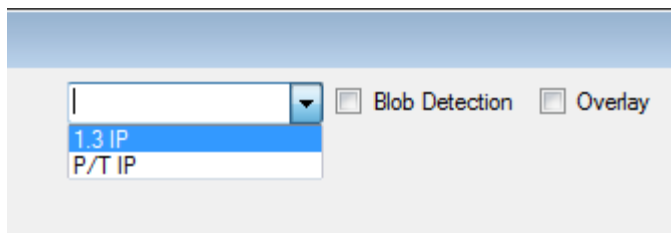


Figure 4 - Camera selection drop-down menu.

The video feed for the selected camera will appear automatically once a connection has been established (5-10 seconds).

3.2 Rover Movement

Before attempting to control the movement of the rover, the user should carefully consider the implications of the legged nature of the locomotion system. The rover makes discreet movements with respect to linear motion and rotation. The path of the rover must therefore be planned carefully to ensure the rover does not overshoot the intended final position or orientation. The step size and rotation turn interval vary depending on the surface being traversed (less traction will result in smaller steps and turn intervals). On high-traction surfaces the rover takes steps of approximately 9” and rotates at 30° intervals.

In addition to the discreet nature of the rover movement the user must also consider that all sent commands and returned rover feedback (messages, camera feeds and sensor data) are subject to a network delay of 3-7 seconds. This means that if a movement command puts the rover in a dangerous position the user will not know for a significant interval of time. Careful route planning is essential for successful rover operation and is discussed in the section on rover navigation.

GUI Controls

Shown below is the control set used to move the rover.

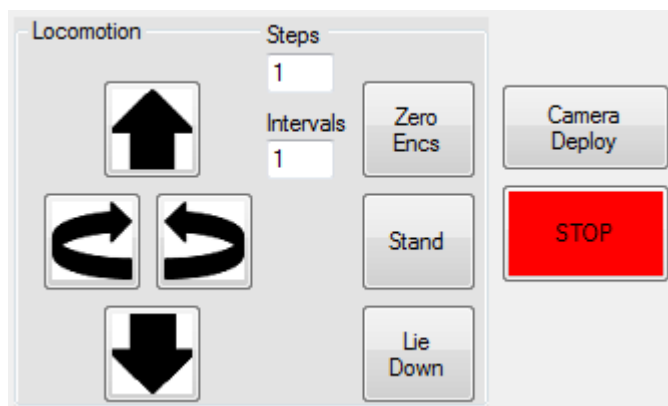


Figure 5 - Rover locomotion controls.

Leg Calibration

Prior to attempting to stand or move the rover, the positions of the legs must be synchronized and calibrated. The procedure for calibrating the legs is as follows:

1. With the rover on **FLAT** and **LEVEL** ground, click the “Zero Encs” button.
2. Wait for the legs to finishing rotating into the synchronized position.

Shown below is a photo of the Hexcavator robot at the end of the calibration routine.

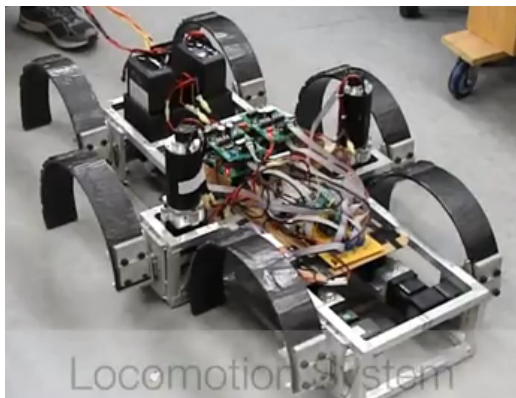


Figure 6 - Synchronized legs following calibration routine.

Laying Down/Standing the Rover

The rover can be raised to the standing position or lowered to the laying position using the corresponding buttons on the GUI. Although safeguards are integrated into the interface to prevent invalid commands, such as issuing a stand command when the rover is already standing, the operator should always check to make sure the desired command is valid prior to moving the rover through the use of the cameras.

Linear Movement and Rotation

Linear movement of the rover can be executed using the forward/backward buttons on the GUI and setting the desired number of steps in the “Steps” field. The rover will execute the number of steps entered in the direction of the button pressed for each press of the button. **Caution: the rover must be in the standing position to execute linear motion or rotation.** Rotation of the rover is achieved in the same manner as linear motion. The number of rotation intervals is specified in the “Intervals” field and the direction of rotation is chosen by clicking the corresponding button. Refer to the section on rover navigation for tips on route planning and obstacle navigation.

Emergency Stop

If at any time the user wishes to halt the command currently being executed, the red **STOP** button can be pressed and the rover will immediately cease movement.

4.0 Sample Extraction Module Operation

The goal of the SEM is to quickly locate, extract, and store the colored rock samples strewn throughout the JSC Rock Yard during the competition.

4.1 Sample Detection

Detection of the colored rock samples is done manually by the user through the use of the multiple camera feeds available on the rover. Detection is aided by the blob detection algorithm that built into the GUI. When properly calibrated,

the blob detection algorithm highlights samples that are not visible to the operator by placing a colored rectangle at the sample's location on the operator's video feed.

Calibration of Blob Detection

Calibration should be performed each time the lighting conditions change significantly. Six samples representing the colors that are to be detected are required to calibrate.

1. Place the samples in view of the rover's cameras.
2. In the GUI, select the 1.3 Megapixel camera from the camera selection drop-down.
3. Click the blob detection check box.
4. Click "Calibrate Filters" to take a screenshot of the current camera feed.
5. Sample the color indicated by clicking on it in various places 10 times.
6. Store the RGB thresholds for each color by clicking the "Store Vals" button when it turns green.
7. Repeat for all colors.



8. Click the "Apply Calibration" button to see the results of the calibration. Repeat as necessary until are samples are well detected by the algorithm.

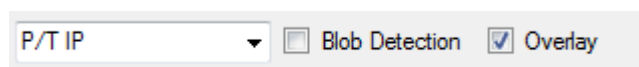
Detection During Navigation

When the "Blob Detection" button is checked and the low-resolution Pan/Tilt camera is being used during navigation, the GUI will apply the blob detection algorithm to the higher-quality 1.3 Megapixel camera and superimpose the results on the lower-quality feed. Expect the blob detection results to update every 3-5 seconds in this configuration.

4.2 Sample Extraction and Storage

Once a sample has been located the following procedure can be used to capture it within the gripper:

1. Orient the rover so that the sample is within the extraction zone. Select the "Overlay" checkbox to display the extraction zone on the screen.



2. Lay down the rover.

3. Deploy the gripper by **HOLDING DOWN** the right mouse button and **CLICKING** on the sample with the left mouse button once. The gripper will exit the cam-follower slot and move to the position clicked on.
4. If the gripper is not close enough to the sample to capture it when the buckets are closed, perform additional relative moves by clicking on the screen the same as was done before.
5. Once the gripper is positioned over the sample click “Close Gripper” to capture the sample.
6. To store the sample simply click “Return Home” and arm will return the gripper to the top of the cam-follower slot. The legs will also return to the standing position when “Return Home” is pressed. Once the gripper has returned to the top of the slot the gripper will automatically open so that the sample falls into the storage box on the front of the rover.

5.0 Troubleshooting

This section will provide a general strategy for diagnosing rover issues. Please keep in mind that the complexity of the rover and the number of components present makes the creation of an exhaustive troubleshooting guide impractical. Because this rover is not a commercial product, it is expected that the operator be thoroughly familiar with the hardware, software, and operating procedure of the rover.

5.1 Network Issues

The most probable issues that a user may encounter when operating the rover involve the rover’s networking and communications subsystem. A diagram for this sub-system is shown below to clarify to the troubleshooting discussion. A computer able to access the rover’s local network is required to effectively troubleshoot networking problems.

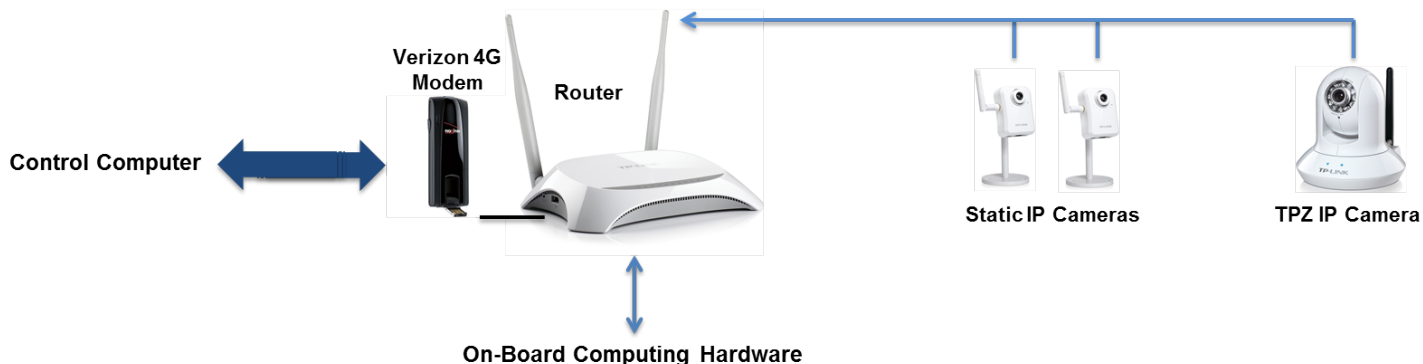


Figure 7 - Communication sub-system diagram.

Router and Modem Troubleshooting

If an SSH connection cannot be established through the user interface, the following message will be displayed in the GUI “Response” text field:

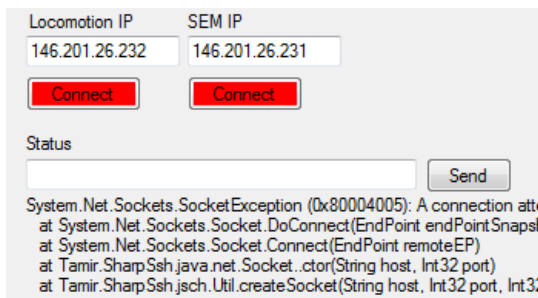


Figure 8 - SSH connection failure message.

The following steps should be followed to troubleshoot connection problems:

1. Ensure that the IP addresses entered are correct by executing the “ifconfig” command on the rover’s local computers.
2. Using the diagnostic computer on the rover’s local network, access the router’s configuration and information program by entering “192.168.0.1” into the web browser.
 - a. On the “Home” page of the router, check that a 3G/4G connection has been established. If not, disconnect the modem from the router, wait 10-15 seconds, and reconnect. If the connection is still not working, call the service provider for further troubleshooting.
 - b. Check that the connection mode of the router is set to “3G/4G Only” on the connections page.
3. Reboot the router.
4. Check the router user guide for further troubleshooting advice,

5.2 General Rover Non-Responsiveness

If connection to the rover has been established but is partially/fully non-responsive, the following sections suggest the first steps that can be taken to begin the troubleshooting process.

A low charge on the battery can cause any of the issues discussed below and should be eliminated as a possibility before further troubleshooting.

Locomotion AND SEM Systems Non-Responsive

If connections have been established to both of the rover’s computers but the rover does not respond to commands to either of the main subsystems, the IP addresses of the two computers are likely switched, meaning the SEM connection has been established to the Locomotion computer and vice versa. Restart the user interface program and switch the IP addresses. If the problem persists, more thorough component-by-component troubleshooting is required locally. Refer to the next sections for individual troubleshooting strategies for the SEM and Locomotion systems.

Locomotion Non-Responsive, SEM Responsive

If a connection has been established to the computer used to control locomotion but no response is observed to sent commands, the most likely issue is related to the wiring of the power system. Check the battery connections to the motor drivers. If some legs are responsive but others are not, check the +/- motor connections between the motor drivers and motors.

SEM Non-Responsive, Locomotion Responsive

Similar to the section above, first check the battery connections to the motor drivers, then check the connections between the drivers and motors.

5.3 Erratic Motor Response (SEM and Locomotion)

Improperly connected or disconnected encoders can cause motors to respond in an erratic manner. The correct motors have a response when a command is sent, but the response is not what was expected, check to make sure the encoder connectors have not become dislodged and that the wires are intact. In the case of erratic locomotion motors, a dislodged or damaged FPGA could also be the cause of erratic motor response.

6.0 Maintenance

This rover is not intended for commercial use and therefore no maintenance schedule shall be provided. The following spare parts will be brought to the competition in the case of malfunction or breakage during the competition:

(1) Carbon fiber or fiberglass leg

(1) Router

(Multiple) Fasteners, miscellaneous physical hardware

(Multiple) Wires, leads, connectors, miscellaneous electrical hardware

(2) Raspberry Pi computers

(1) Sabertooth motor driver (Locomotion motors)

(1) RoboClaw motor driver (SEM motors)

(2) SD cards, one pre-programmed for the locomotion computer, one for the SEM computer

(1) Fully charged battery set

The team is allotted up to 10 minutes (subtracted from roving time) during the competition for troubleshooting or repair of the rover.