Sonoma State University

Electrical Engineering

NASA Robotic Mining Competition (RMC) LUNABOTICS

Senior Design Project Proposal
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Date: 12/3/2021

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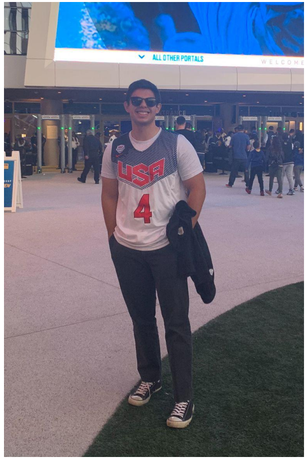
The Team



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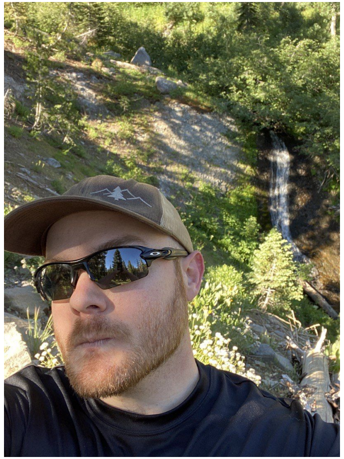

Bryce Jensen
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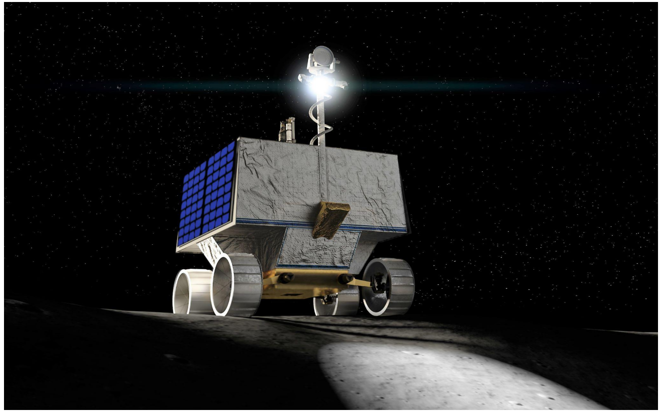
Overview



NASA VIPER rover

Problem Statement

NASA currently plans to return to the moon for the Artemis mission. Part of this mission includes a desire to have astronauts live and work on the lunar surface for longer periods of time. It is cost prohibitive to ship bulk materials like oxygen and water to the lunar surface. NASA intends to use a process known as ISRU, or In-Situ Resource Utilization to make these resources on the moon rather than ship them all there. NASA would like a robot to perform the task of collecting the regolith for ISRU, and thus is hosting a competition to design, build, and test robots that mine and collect regolith on a mockup of the lunar surface. This competition serves both to solve the technological problem itself of collecting regolith and to develop a potential workforce for NASA and other organizations.

Value Proposition

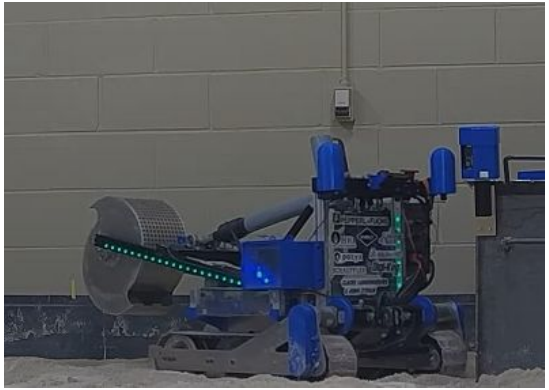
Our RMC robot helps NASA who wants to mine and collect regolith on the lunar surface by safely collecting, transporting, and depositing regolith and enabling access to the regolith for further uses.

Existing Solutions

- Previous methods for collecting regolith were hand tools
- These methods were very labor intense and slow
- Other universities have been competing in the same competition with the same goals for several years

Past winners of the Robotic On-Site Mining Award

- University of Alabama 2015 -2018
- University of Alabama in collaboration with Shelton State Community College 2014
- Iowa State University 2013



Robot credit
University of Akron

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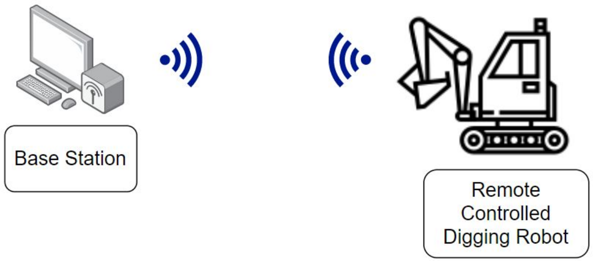
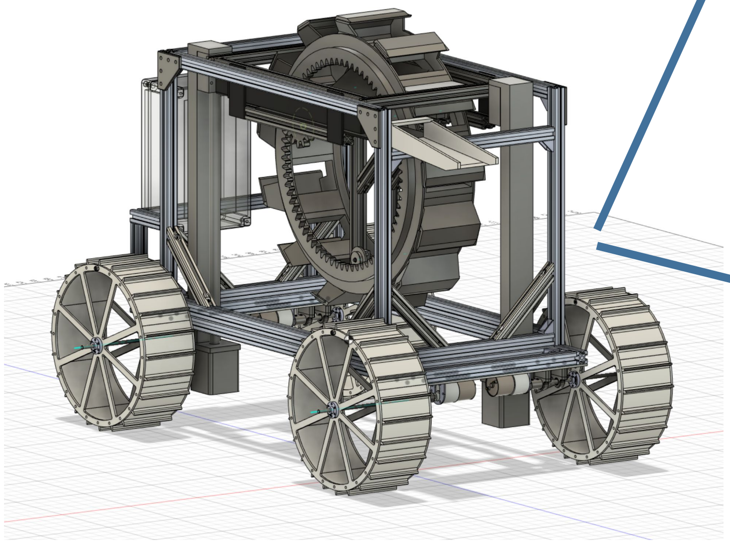
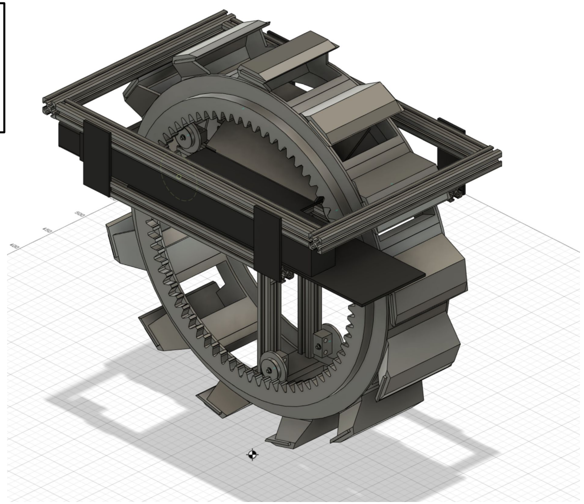
Proposed Solution

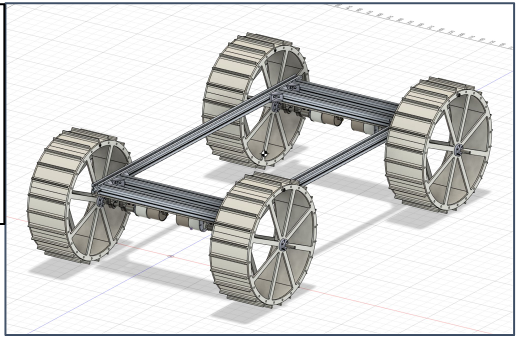




Mining and Dumping Tools



Wheels and main drive motors



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Marketing Requirements

- M.R. 1: Provide a robot with a means to collect regolith for the competition
- M.R. 2: The robot shall be able to drive to the mining site in a reasonable amount of time
- M.R. 3: The robot shall be able to have its power cut in case of emergency
- M.R. 4: The team shall be trained for safely operating the robot
- M.R. 5: The robot shall be able to operate tele robotically via a wireless communication link
- M.R. 6: The communication link shall stay below the competition bandwidth limits
- M.R. 7: The battery shall provide enough power to operate for a competition run
- M.R. 8: The robot shall be compact enough and lightweight enough to be easily transported

Highlighted Requirements represent most critical requirements

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Engineering Requirements

- E.R.1: The robot shall have a digging system capable of mining 1 kilogram in 15 minutes (M.R.1)
- E.R.2: The robot shall be able to drive 7 meters in 90 seconds. (M.R.2)
- E.R.3: The robot shall have an emergency stop capable of cutting the robot power in 5 seconds (M.R.3)
- E.R.4: The robot operators shall pass a RMC robot operation safety exam with a score of 75% or higher (M.R.4)
- E.R.5: The robot shall use wireless communication standard IEEE 802.11b, 802.11g, or 802.11n for main communication. (M.R.5)
- E.R.6: The robot shall use an average bandwidth to not exceed 5Mb/s. (M.R. 6)
- E.R.7: Battery shall be able to provide power for a minimum of 15 minutes to the robot during expected load. (M.R.7)
- E.R.8: The robot shall fit inside a volume envelope no larger than 1.1m length by 0.6m wide and 0.6m tall, and weigh no more than 80kg (M.R.8)

Highlighted Requirements represent most critical requirements

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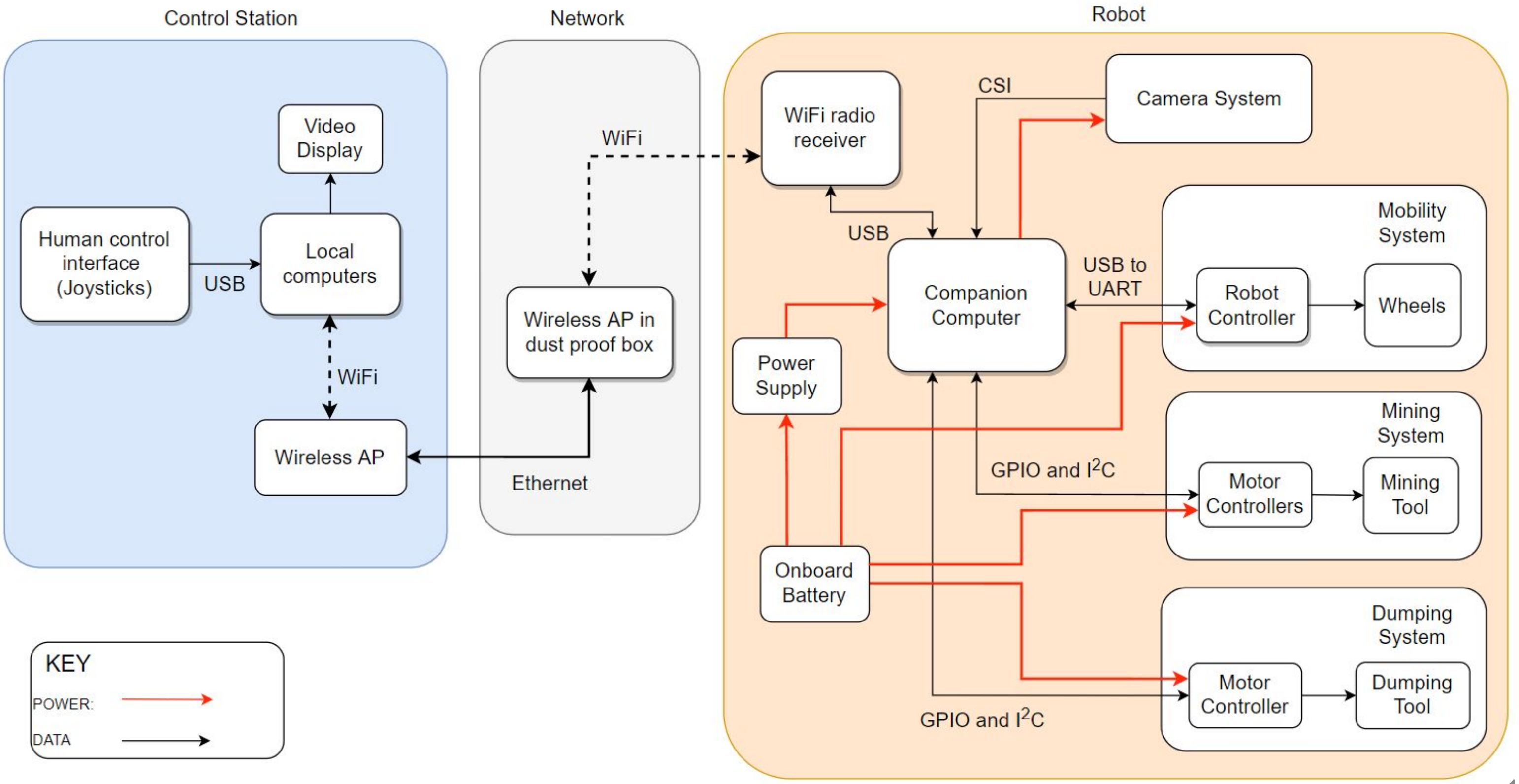
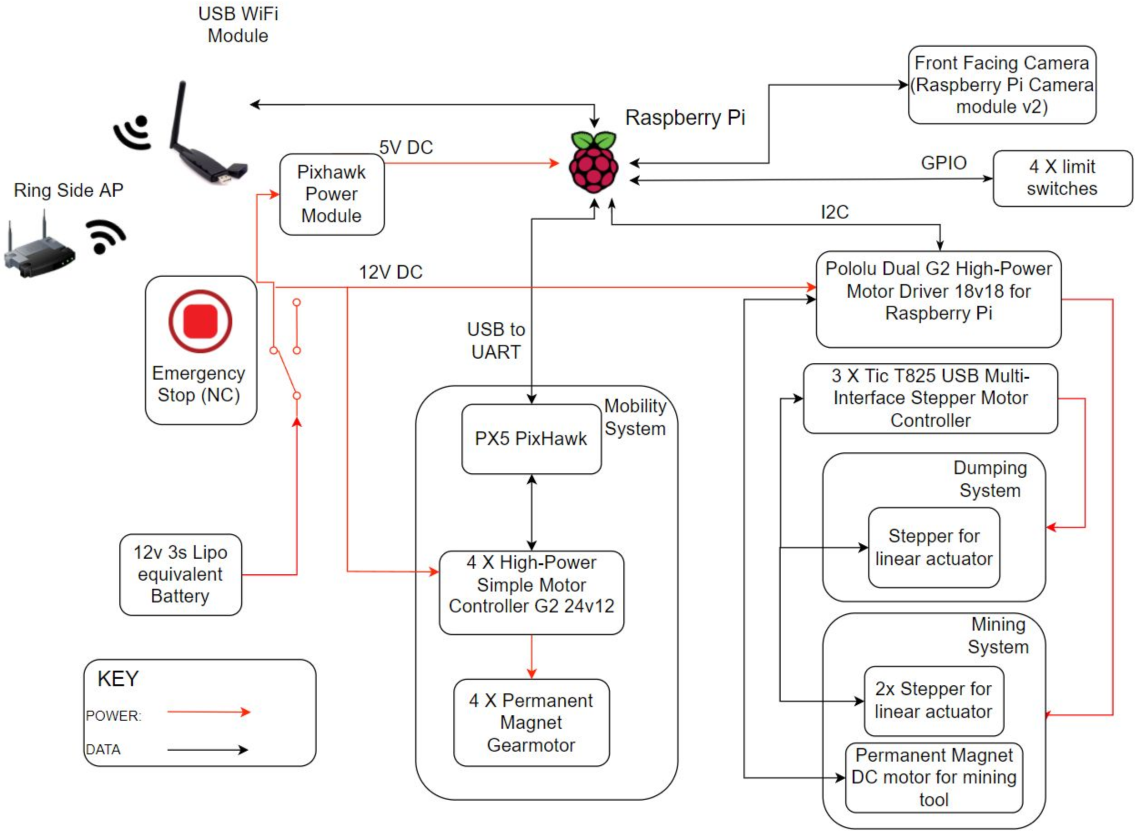
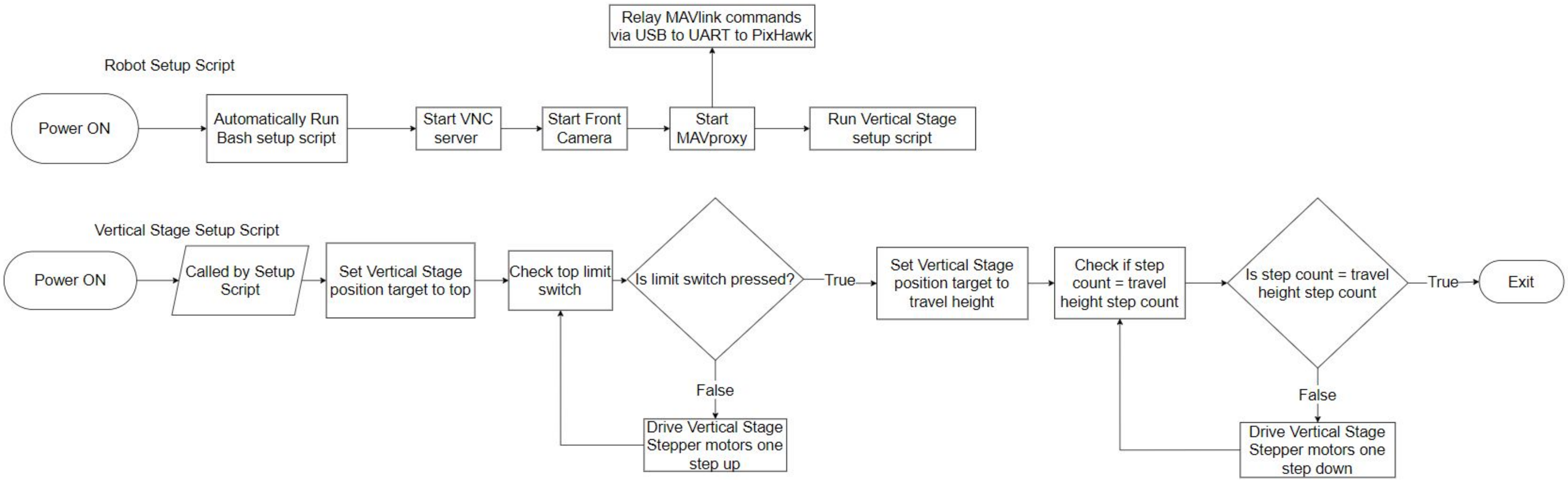
System Overview



Hardware Diagram



Software Flow (Setup)



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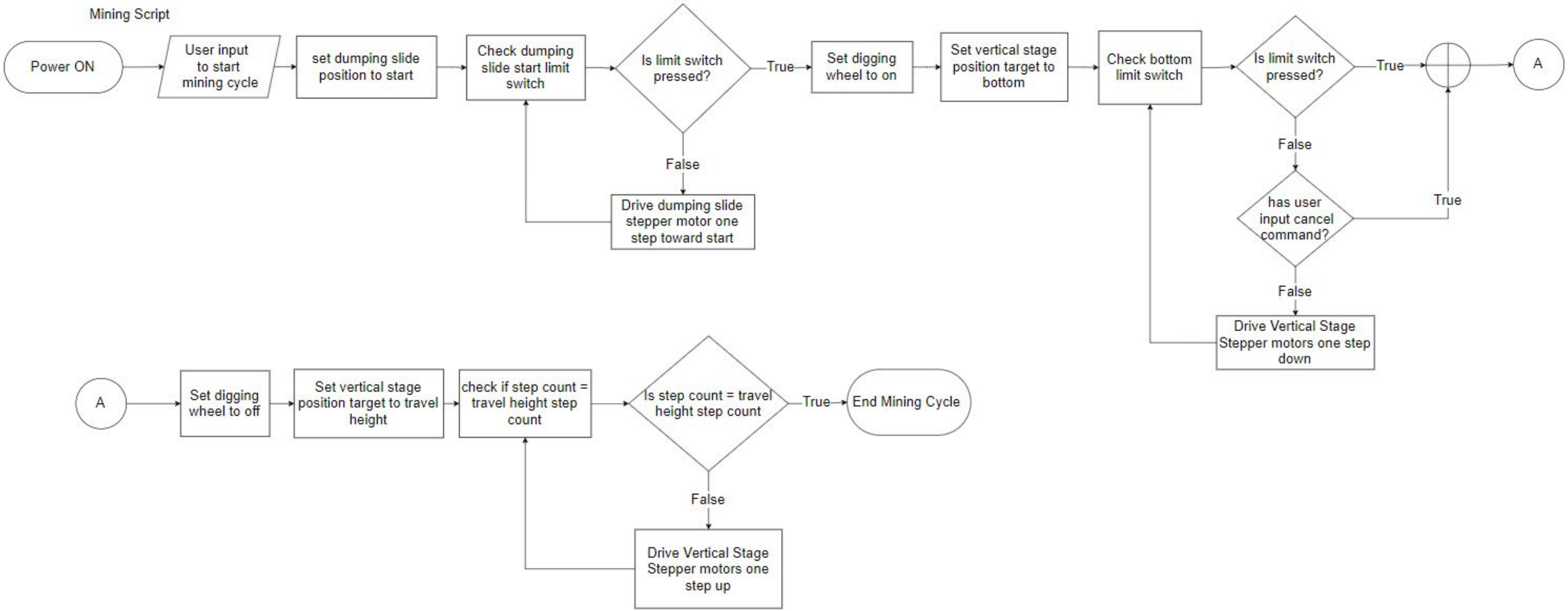
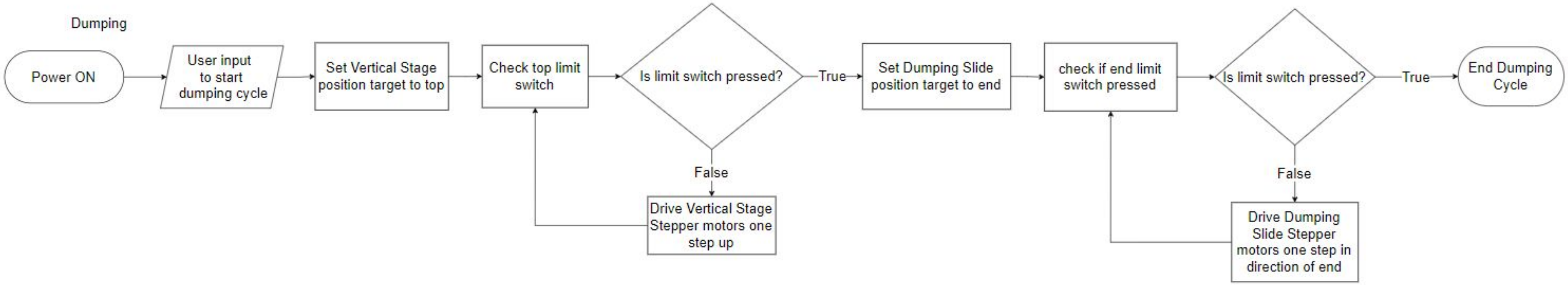
Software Flow 2 (Mining)



Software Flow 3 (Dumping)



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Alternative Design Matrix

Embedded System	Power use	IOs	Mass	Libraries	Total Score
Raspberry Pi 3B+	5	4	5	5	19/20
NVIDIA Jetson Nano	2	4	4	2	12/20
Beagle Bone Blue	5	5	5	3	18/20
Intel NUC	1	1	2	3	7/20

Scale : 1-5 with 5 matching requirement the most

Alternative Design Matrix

Controller	PWM Connectors	Host GPIO accessibility	Commercial Availability	Link Complexity (Less complex scores higher)	Total Score
V5 Pixhawk	5	5	5	3	18/20
Navio2	5	1	2	5	13/20
Beagle Bone Blue	3	4	4	4	15/20

Scale : 1-5 with 5 matching requirement the most

Fall Semester Test Summary

Test	Test Name	ER	Status	Notes
FT-1	Average Bandwidth Test	ER.5	50%	IN PROGRESS
FT-2	Wireless Standard Compliance Test	ER.4	Completed	PASS
FT-3	Arena Bandwidth Test	ER.1	Completed	PASS
FT-4	Power Draw Test	ER.6	Pending Receiving of Parts	PENDING
ST-1	Network Control Test	ER. 2	Pending Receiving of Parts	IN PROGRESS

Tests Conducted: Average Bandwidth Test (FT.1)

Purpose: Measure system bandwidth while using camera and control system (E.R.5).

Procedure/Setup:

- Turn on Camera and stream video
- Issue random commands over Mavlink to pixhawk for 15 minutes
- Measure Average Bandwidth over 15 minutes using wireshark

Expected Results:

- Pass if less than 5Mbps. Fail if exceed 5Mbps.

Tests Conducted: Average Bandwidth Test (Expected Results)

Expected Results:

Rpi Camera Raw Bitrate	
Number of Pixels (Height * Width)	8 Megapixels
Color Depth	8 bits
Color Channels	3
Frames per second	30
Uncompressed bitrate	**5.67 Gb/s!!!**

Video raw bitrate = Width of video * Height of video * Color depth * Number of color channels * Video frames per second

Conclusion: Video compression or downsampling will likely be needed. Waiting on parts for actual test with real bit rate

Tests Conducted: Wireless Standard Compliance Test (FT.2)

Purpose: Measure Network setup to verify the network is only on 802.11b, g, or n standards (E.R.4).

Procedure/Setup:

- Measure wireless network using netspot to verify correct SSID and channel as per competition guidelines.
- Change channel to alternate channel as per competition guidelines.
- Measure time it takes to change channels.

Expected Results:

- Pass if the network is on the correct channel and with the correct SSID and is able to change to the correct alternate channel within 15 minutes. Fail if the network is on other bands or takes longer than 15 minutes to update.

Tests Conducted: Wireless Standard Compliance Test (Results)

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■	SSID	BSSID	Alias	Graph	Signal	%	Min.	Max.	Average	Level	Band	Channel	Width	Vendor	Security	Mode	Last seen
	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		2.4	[illegible]	20	[illegible]	WPA2 Personal	[illegible]	2 s ago
✓	SonomaRMCrouter	60:A4:B7:91:6A:14			-44	60	-52	-40	-44		2.4	11	20	TP-Link	WPA2 Personal	n	2 s ago

■	SSID	BSSID	Alias	Graph	Signal	%	Min.	Max.	Average	Level	Band	Channel	Width	Vendor	Security	Mode	Last seen
✓	SonomaRMCrouter	60:A4:B7:91:6A:14			-40	65	-52	-40	-44		2.4	1	20	TP-Link	WPA2 Personal	n	2 s ago

SonomaRMCrouter - 60:A4:B7:91:6A:14

Signal | Tabular Data | Channels 2.4 GHz | Channels 5 GHz

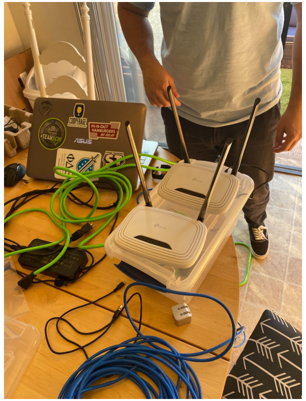
60:A4:B7:91:6A:14 - SonomaRMCrouter

Time	Signal	Channel	Security mode
now	-44	11	WPA2 Personal
4 s ago	-44	11	WPA2 Personal
3:21:15 PM	-44	11	WPA2 Personal
3:21:09 PM	-44	11	WPA2 Personal
3:21:04 PM	-42	11	WPA2 Personal
3:21:00 PM	-48	11	WPA2 Personal
3:20:55 PM	-44	1	WPA2 Personal
3:20:50 PM	-44	1	WPA2 Personal
3:20:46 PM	-41	1	WPA2 Personal
3:20:40 PM	-40	1	WPA2 Personal
3:20:35 PM	-44	1	WPA2 Personal
3:20:30 PM	-44	1	WPA2 Personal

Results:

- Verified Network could switch channels between 1 and 11 within 15 minutes.
- Verified AP was on 802.11b,g,n standard.
- Verified Max spectral bandwidth as 20MHz for all 2.4 GHz transmission equipment.

Conclusion: The AP is able to provide network requirements.



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Tests Conducted: Arena Bandwidth Test (FT.3)

Purpose: To measure wireless data rate in an area like the expected arena to verify we can make connection at any point in the arena (E.R.1).

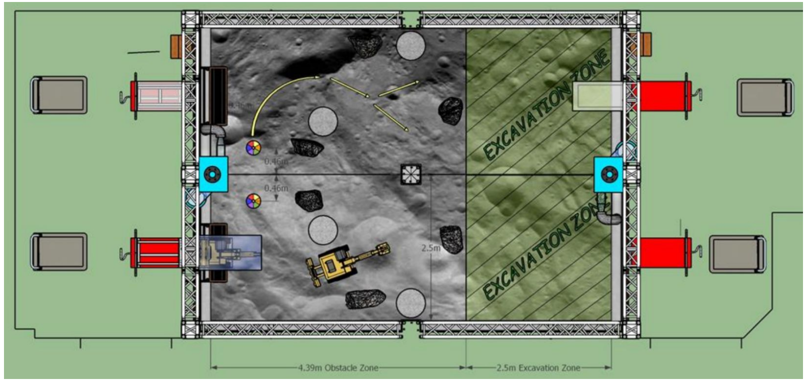
Procedure/Setup:

- Mark area of open space to the size of the competition arena
- Place AP where it would be at competition, inside dust proof box to simulate competition arena conditions
- Measure data rate at closest and farthest corners of arena to verify line of sight data rates at extreme positions
- Average data over several runs

$$\bar{r}_A \equiv \frac{\sum_{t=1}^{T} r_t}{T}$$

Expected Results:

- Network can sustain at least 5Mb/s at closest and farthest corners of the arena



Tests Conducted: Arena Bandwidth Test (Results)

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Results:

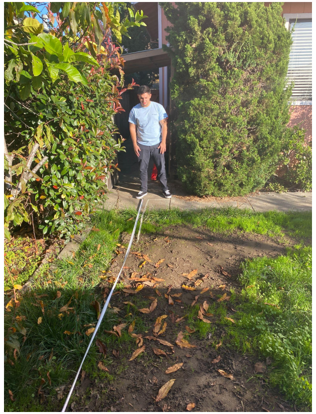
- Verified size of arena in backyard
- Verified sufficient bandwidth 5x for best-case location and worst-case location

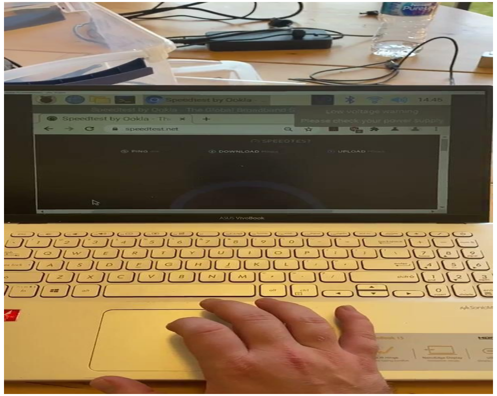
- **Close-** Avg Down: 39.8 Mb/s

  Avg Up: 39.9 Mb/s

- **Worst-** Avg Down: 26.3 Mb/s

  Avg Up: 41.3 Mb/s




Conclusion: AP can support at least 5Mb/s to the Pi in the arena**.**

Tests Conducted: Power Draw Test (FT.4)

Purpose: Measure the power draw of motors during load to accurately determine how much battery storage to put on the robot.

Procedure/Setup:

- Energize steppers and spin brushed DC motors.
- Measure current flow via Hall effect current sensor.

Expected Results:

- This is a measurement test intended to provide a consumption baseline.

Tests Conducted: Power Draw Test (Results)

Results: Pending Parts

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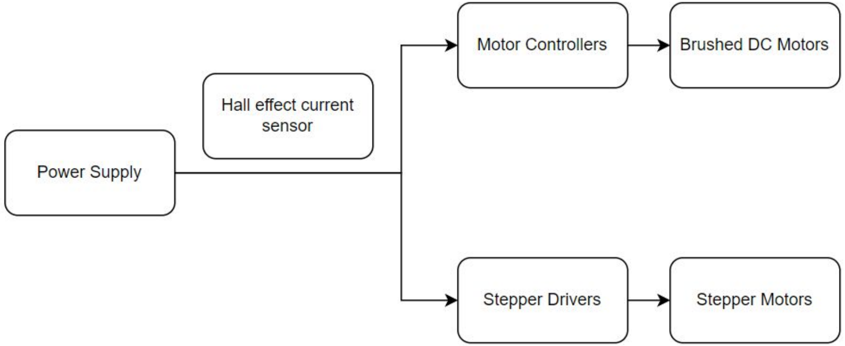
Test setup diagram



Conclusion: PENDING

Tests Conducted: Network Control Test (ST.1)

Purpose: Show that the drive motors will spin when issued network commands (E.R.2).

Procedure/Setup:

- User inputs forwards, backwards, left or right command
- Observe results

Expected Results:

- All four motors spin in correct directions when control commands are input. All forward for forward, all backward for reverse, and half forward and half backwards for left and right.

Tests Conducted: Network Control Test (Results)

Results: In-Progress

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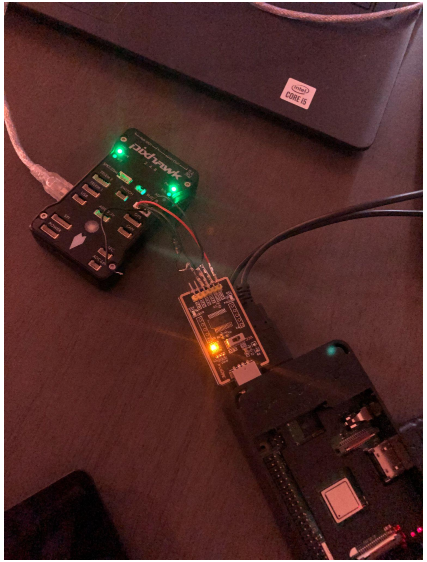

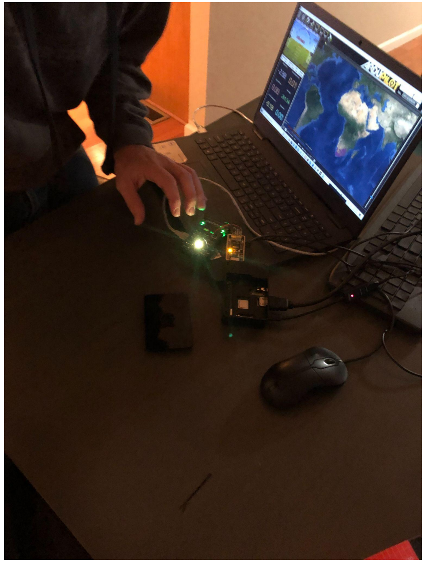

Conclusion: PENDING

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Qualitative Risk Analysis Model

	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)
Negligible (1)	Low 1	Low 2	Low 3	Moderate 4	Moderate 5
Minor (2)	Low 2	Moderate 4	Moderate 6	High 8	High 10
Moderate (3)	Low 3	Moderate 6	High 9	High 12	Extreme 15
Major (4)	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
Catastrophic (5)	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25

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Risks

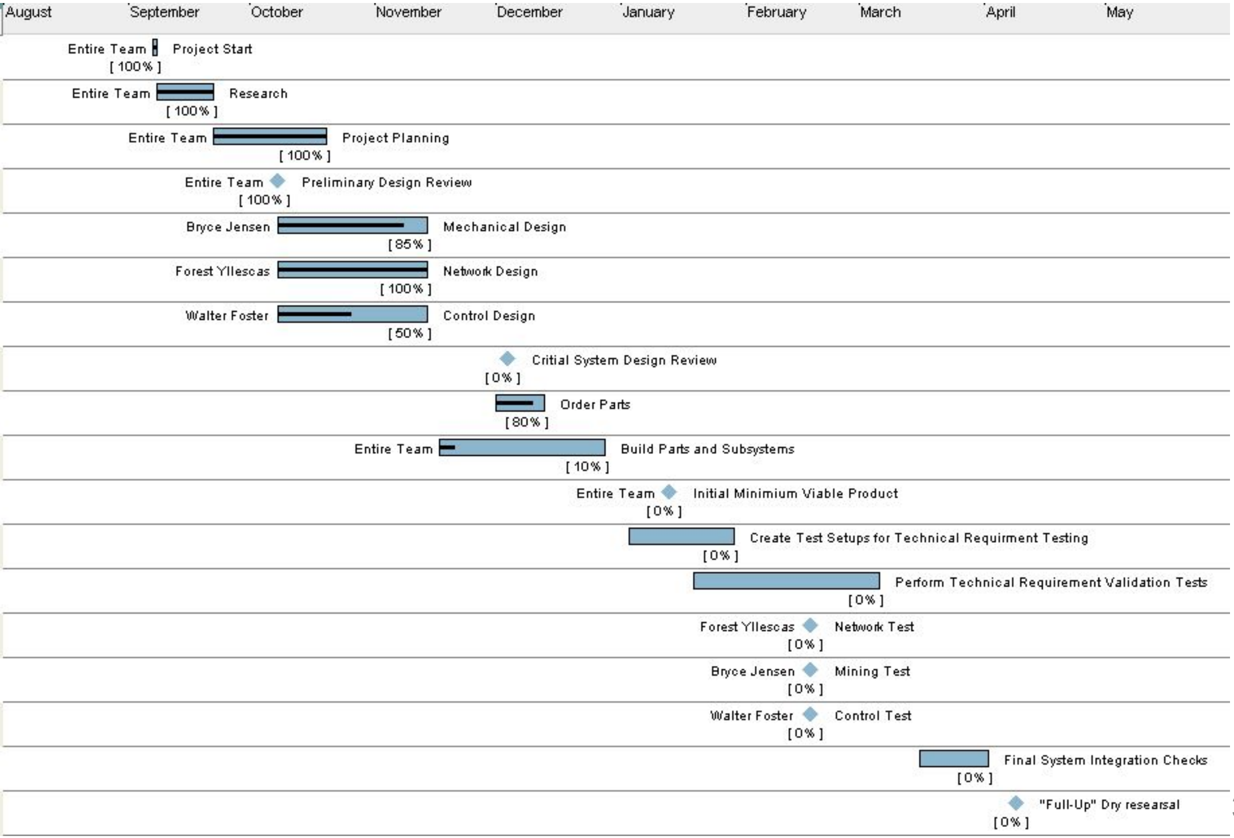
Risk	Risk Statement	Risk Level	Mitigation Plan	Contingency Plan
Robot stuck in regolith	The Regolith simulant chamber is a very challenging environment and there is a potential for serious mobility issues (possibly getting stuck).	Likelihood: 4 Consequences: 4 Overall Risk: 16 Extreme	Test wheels in a similar environment to regolith.	Software defined motor control can be changed on the spot to create low speed mode.
Lose network connection	The robot is controlled over a single point of failure radio WiFi link. The potential exists for that link to be severed mid-round.	Likelihood: 3 Consequences: 4 Overall Risk: 12 High	Use secondary WiFi module for Pi instead of onboard WiFi module to boost reception.	Have a script to check the WiFi module. If module is not working, turn on Pi internal WiFi as a backup mode.
Scope exceeds time and resources	If scope is not properly defined, team bandwidth may potentially not be enough to complete all scoped tasks in time	Likelihood:3 Consequences:4 Overall Risk:12 High	Careful consideration of scope before commitment.	If risk materializes, scope needs to change to reflect amount of available personnel

Challenges

Challenge	Statement	Strategy Plan
Lack of institutional knowledge	Since we are the first SSU team to attempt the robotic mining challenge, we will had to start from scratch, with potential for pitfalls.	Performed trade studies on previous teams.
System integration	The integration of all robot subsystems will be difficult.	Budgeted extra time for system integration during planning
Lack of personnel	Since we are a small team compared to other LUNABOTICS teams, we are potentially faced with more work per team member compared to other teams.	Added junior students to help the larger project.
Environmental Hazards during competition	The amount of fine dust in the arena can affect the overall performance of the robot.	Multiple dust mitigation strategies pursued

Schedule: Gantt Chart

Name	Begin date	End date
Project Start	9/7/21	9/7/21
Research	9/8/21	9/21/21
Project Planning	9/22/21	10/19/21
Preliminary Design Review	10/7/21	10/7/21
Mechanical Design	10/8/21	11/13/21
Network Design	10/8/21	11/13/21
Control Design	10/8/21	11/13/21
Critial System Design Review	12/3/21	12/3/21
Order Parts	12/1/21	12/12/21
Build Parts and Subsystems	11/17/21	12/27/21
Initial Minimium Viable Product	1/12/22	1/12/22
Create Test Setups for Technic...	1/3/22	1/28/22
Perform Technical Requireme...	1/19/22	3/5/22
Network Test	2/16/22	2/16/22
Mining Test	2/16/22	2/16/22
Control Test	2/16/22	2/16/22
Final System Integration Checks	3/16/22	4/1/22
"Full-Up" Dry researsal	4/8/22	4/8/22



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Budget

Costs by system	Cost Estimate
Materials and Systems	
Mobility System	$ 1,750.00
Mining System	$ 1,250.00
Communications System	$ 400.00
Companion Computers and Robot Controllers	$ 500.00
Power System	$ 500.00
Ringside communications system	$ 250.00
Control Station communications system	$ 100.00
Tools	$ 250.00
Labor	
CNC shop time for large robot parts	$ 750.00
Materials and systems subtotal	$ 5,750.00
Total Costs	$ 5,750.00

Travel and shipping	Cost Estimate
Airfare+Lodging	$2,250.00
Crate and shipping costs	$2,000.00
Total Costs	$4,250.00

Supporting Courses

- EE 310: Microprocessors and System Design
- EE 442: Analog and Digital Communications
- EE 465: Introduction to Networking and Network Management
- CS 115: Programming I
- CS 210: Introduction to Unix
- SCI 220: Dream, Make, and Innovate

Acknowledgements

- Sonoma State Department of Engineering Science
- Jason Knight-Han, Jesus Perez Quintero
- Olga Stotzky, Tom Luzod, Duane Dier, Stephan Ord
- Dr. Nansong Wu

Questions

Questions or comments?

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References

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