Individual Lab Report - 4

Lunar ROADSTER

Team I

Author: **Ankit Aggarwal**
Andrew ID: ankitagg
E-mail:
ankitagg@andrew.cmu.edu

Teammate: **Deepam Ameria**
ID: dameria
E-mail: *dameria@andrew.cmu.edu*

Teammate: **Bhaswanth Ayapilla**
ID: bayapill
E-mail: *bayapill@andrew.cmu.edu*

Teammate: **Simson D'Souza**
ID: sjdsouza
E-mail: *sjdsouza@andrew.cmu.edu*

Teammate: **Boxiang (William) Fu**
ID: boxiangf
E-mail: *boxiangf@andrew.cmu.edu*

Supervisor: **Dr. William "Red" Whittaker**
Department: Field Robotics Center
E-mail: *red@cmu.edu*

March 21, 2025

Carnegie Mellon University
Robotics Institute

1 Individual Progress

1.1 Tool Planner

1.1.1 Learning and Documentation

I learned and documented CraterGrader's manipulation methodology. Fig 1 shows the FSM decision process they followed. The main highlights are:

1. They used a mapping node called 'PlanExploration' to map the Moonyard and create transport volumes
2. The 'PlanTransport' node solves a linear optimization problem to get waypoints for moving sand into the crater
3. The Trajectory is planned based on a lattice A* search algorithm.

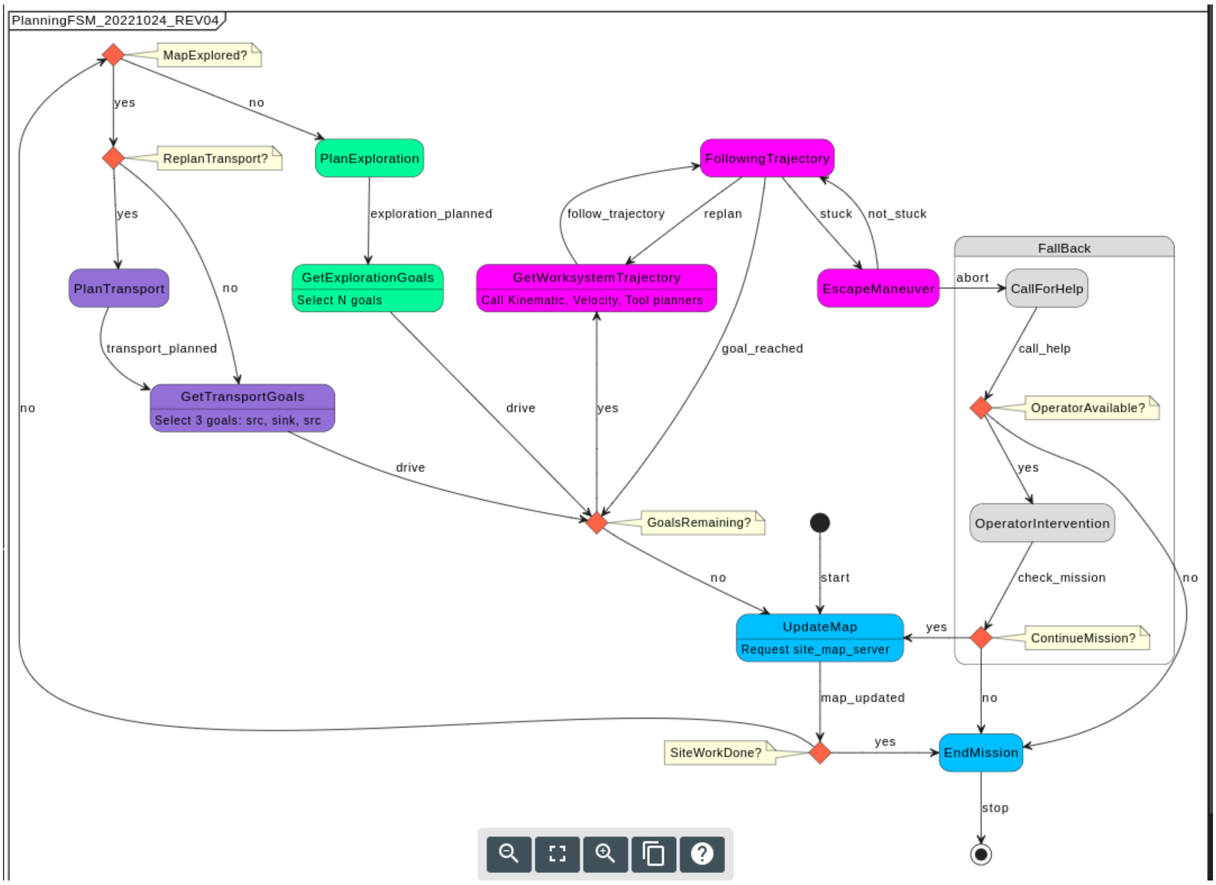

Figure 1: Crater Grader's Methodology

1.1.2 Implementation Methodology

Based on the point cloud generated by the FARO Laser Scanner, I used the Open3D library to create a CSV file containing x, y, and depth data for each point. This file will be the primary input to the optimization problem.

A datum will be decided based on a mean/median depth value (to be tuned). Any points above this datum will be added to an array of source nodes (positive volume), and the depth value will be added to the source volume, similarly for sink nodes (negative volume).

Intuition: We want to minimize the volume of sand moved and the distance it is moved. The constraints will be based on filling all sink nodes, clearing all source nodes, and keeping the distance positive. The problem should be robust enough to plan even when source and sink volumes do not match.

Problem Formulation: The cost function will be defined as transport volume times distance traveled. x are the sink nodes, and y are the source nodes, with each item in the array having position coordinates and a depth map.

$$cost = \min_{\pi} \sum_{i,j}^{n,m} \pi_{i,j} \cdot D_{i,j} \tag{1}$$

$$\textbf{s.t.} \quad -\pi_{i,j} \leq 0 \tag{2}$$

$$1_n^T \pi - x \leq 0 \tag{3}$$

$$\pi 1_m - y \leq 0 \tag{4}$$

$$-1_n^T \pi + x - M(1-b) \leq 0 \tag{5}$$

$$-\pi 1_m + y - Mb \leq 0 \tag{6}$$

$$where, \quad M = (\sum y, \sum x) \tag{7}$$

$$b = \begin{cases} 0 & if \quad \sum y < \sum x \\ 1 & if \quad \sum y \geq \sum x \end{cases} \tag{8}$$

I plan to solve this problem using either a stock linear optimization library or implementing Newton's method. Further, in the next semester, I plan to further optimize this method based on task time.

1.2 Power Distribution Board

I worked on finalizing the design of the PDB PCB. Figure 2 shows the final Gerber file view.

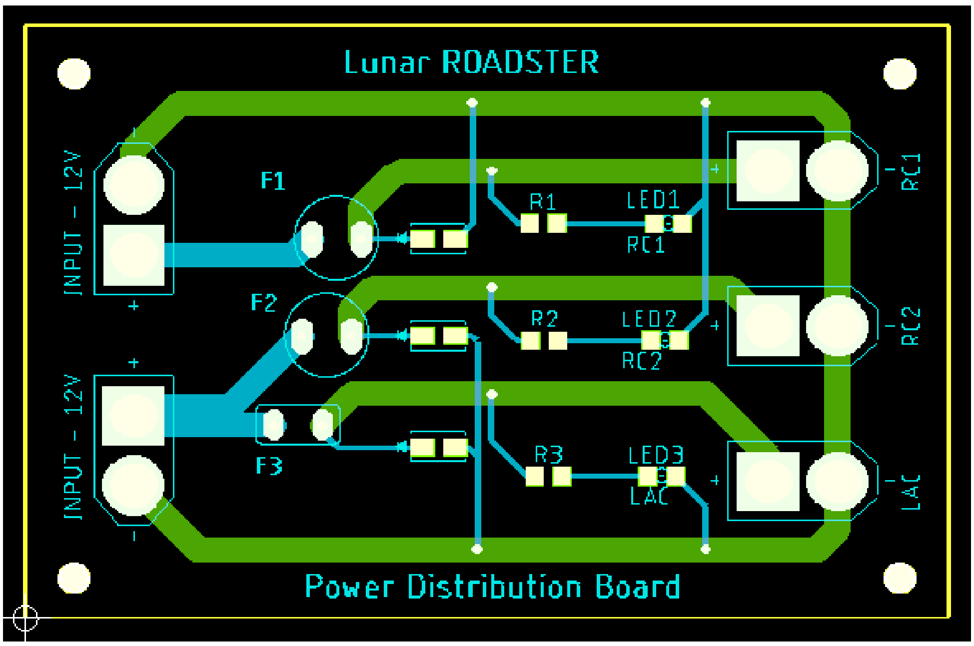

Figure 2: Final Gerber View

The schematic design is shown in Figure 3. Based on feedback from Luis and Adrian, I used an alternate method of reverse current protection that will not cause voltage drops. I also added the required resistors to limit current into the indicator LEDs.

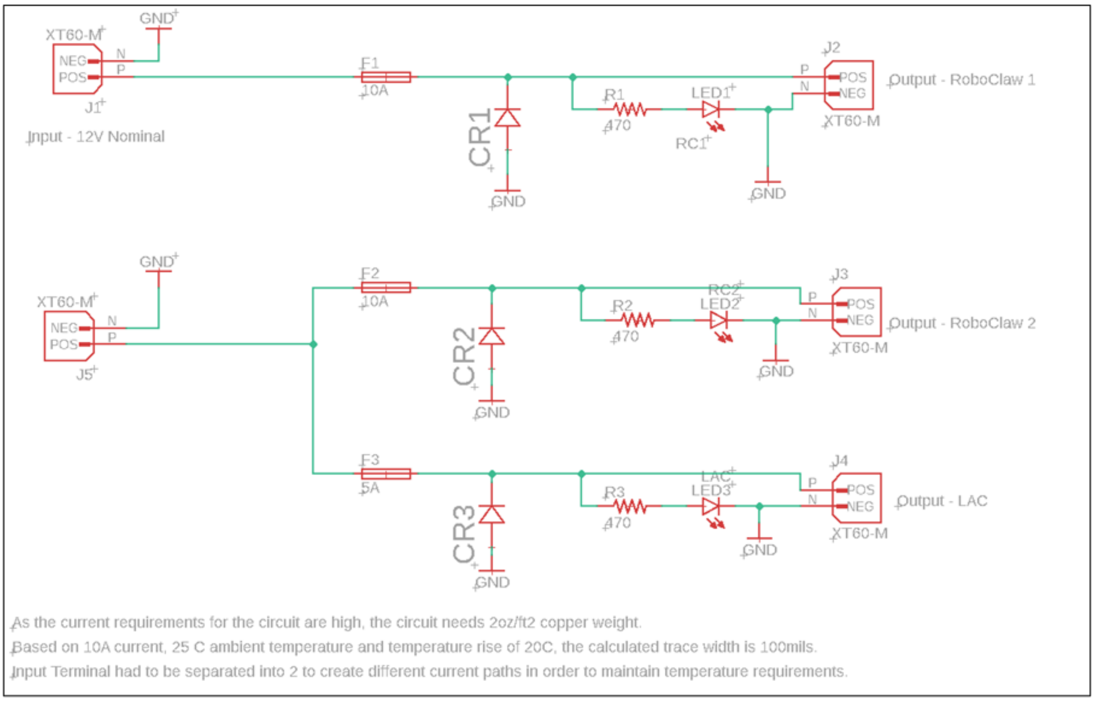

Figure 3: Schematic Design

My biggest challenge while designing the board was handling the high current values (up to 10A). I had to switch to 2oz copper and used trace widths of 100mils to disperse the heat generated adequately. Additionally, I added XT60 onboard connectors instead of standard screw connectors to allow easy integration into our circuit. The final board design is shown in Fig 4.

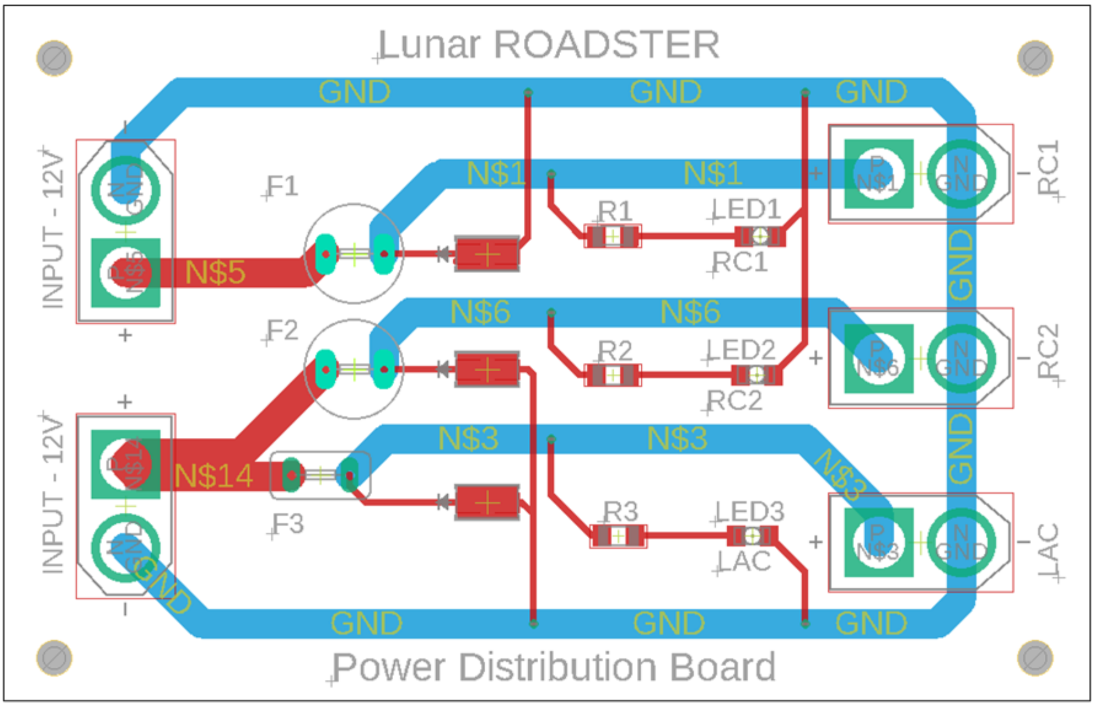

Figure 4: Board Design

1.3 Wheel

The current iteration of the wheel has been tested. It slips less and provides more traction than the stock rubber wheels. Fig 5 shows the sinkage of the wheel in the

MoonYard. The entire length of the grouser sinks into the ground, enabling increased traction. A point of concern is that since the contact area of the wheel is now flat, as opposed to arched, steering friction may increase. However, no significant performance reductions have been observed.

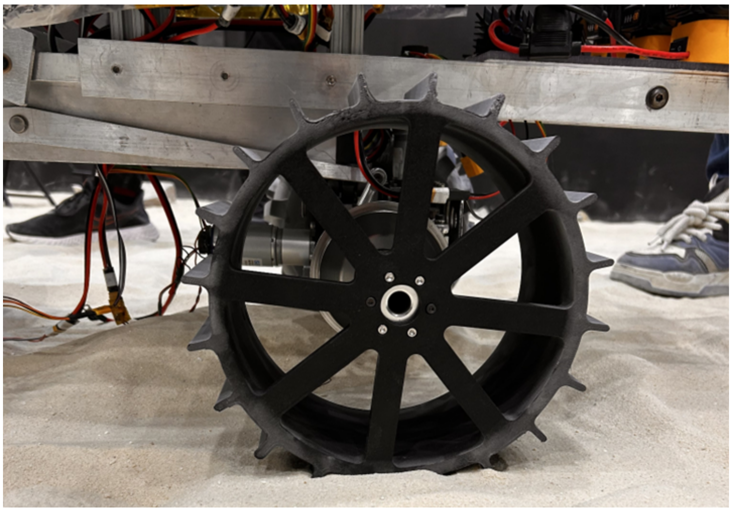

Figure 5: Wheel Sinkage in Moon Yard

1.4 Rover Hardware Maintenance/Debugging

Hardware maintenance continues to be a time-consuming task. We faced several issues with the rover, outlined below:

1. **Drive Axle Breakage:** The rear drive axle of the rover wore out to complete disengagement. As the rover components are old, they are no longer being sold by the manufacturing company. This is a significant risk for us; we are working on a mitigation plan. We found a twin rover, and I replaced the broken axle.

2. **Wheel Encoder Wires:** Wheel odometry was not publishing position data despite all systems in place. After several hours of debugging, I found that the issue was due to one of the jumper wires being pulled out of its header. We plan to solve this issue by making jumper connections permanent using tape before the SVD.

3. **Rover Startup In-rush Current:** The electrical system has a high in-rush current when all actuators are connected. This causes the main DC-DC converter to reach its current limit and shut down. The reason is currently unknown, and we are circumventing it by powering the rover before connecting all actuators.

2 Challenges

The biggest challenge with the Tool Planner is the steep learning curve. I was able to leverage my coursework in OCRL to understand and formulate the problem statement. However, finding the right implementation method and libraries in C++ is a significant challenge.

Dealing with high current flow through the PDB was a significant challenge that was causing unrealistic trace widths. Adrian's advice for using thicker copper traces was greatly helpful. I also looked at using vias stitching as a solution, but it seemed overkill for this problem.

Printing of the wheels and the availability of Tim continue to be a blocker. I hope to speed up wheel iteration times by reducing the number of tests and getting more inferences out of each test.

3 Teamwork

My work mainly focused on the tool planner methodology. I took inputs from the team for insights on the best way to set up the planner to minimize integration issues. I worked with Simson and Deepam to set up a manufacturing plant for the E-Box. I also worked on debugging wheel odometry with William. Additionally, I worked with Deepam to mitigate the issue of rover breakdown due to a worn-out rear drive axle.

Deepam Ameria: Deepam's primary work was to finalize the best linear actuator for our use case. He worked with Bhaswanth on making the tool tele-operable. He collaborated with Simson to create the testing terrain in the MoonYard. He and I worked together to mitigate the issue of the rover breaking down due to a worn-out rear axle. We scavenged the spares off a twin rover and successfully replaced it on ROADSTER. He used my design to laser-cut the walls of the E-Box at TechSpark.

Bhaswanth Ayapilla: Bhaswanth's work with William involved testing and debugging the localization stack in the Moon Yard. He worked with Deepam in helping him implement dozer teleoperation. He also worked with Simson on the initial navigation stack setup on our Jetson board.

Simson D'Souza: Simson worked on refining the global cost map and tuned parameters to obtain an accurate ground plane. He collaborated with Deepam to create the testing environment in the Moon Yard. Additionally, he developed an algorithm to identify gradable craters and extract their coordinates. He collaborated with Bhaswanth on the navigation stack setup, to configure and integrate it on the NVIDIA Jetson. He also used my design for E-box manufacturing.

Boxiang Fu: William's work was in collaboration with Bhaswanth in debugging the localization stack for the rover. He also worked on the sensor stack and interfaced the RealSense camera with the docker container. Both the localization and sensor stack are related to Simson's work, as the local elevation map will be fused with his global map for navigation and mapping. It will also relate to Deepam and I 'swork as the local map will feed into the tool planner to identify the source and sink locations.

4 Plans

The team plans to have the MVP for SVD ready by the next Progress Review. My plans until the next PR are:

1. Manufacture the PDB and integrate into the system
2. Test all 4 3D printed wheels on the rover
3. Implementing the tool planner for SVD i.e., for a single crater
4. Integrating the tool planner into the software stack
5. Hardware maintenance and minimizing mechanical failure possibilities