Individual Lab Report - 5

Lunar ROADSTER

Team I

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

Teammate: **Ankit Aggarwal**
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: **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*

April 20, 2025

Carnegie Mellon University
Robotics Institute

Contents

1 Individual Progress

1.1 Navigation Setup and Integration with Localization Stack

For autonomous navigation, we employed the ROS2 Nav2 stack. Initially, the Nav2 stack was configured within a Docker container running on the NVIDIA Jetson platform. The objective was to enable the robot to receive a goal pose from RViz and autonomously navigate to that position by generating motor commands through the Nav2 stack.

The configuration involved initializing the 2D costmap in RViz and launching the navigation stack accordingly. Obstacle inflation was handled using the parameters inflation radius and cost scaling factor, ensuring that the robot maintained a safe distance from obstacles. This inflated map was visualized in RViz, and the robot was correctly localized at its initial position, as shown in Figure 1. Since our localization system is dependent on the onboard sensor suite, I ensured the necessary ROS2 topic data from the localization stack was correctly mapped to be compatible with the requirements of the Nav2 stack.

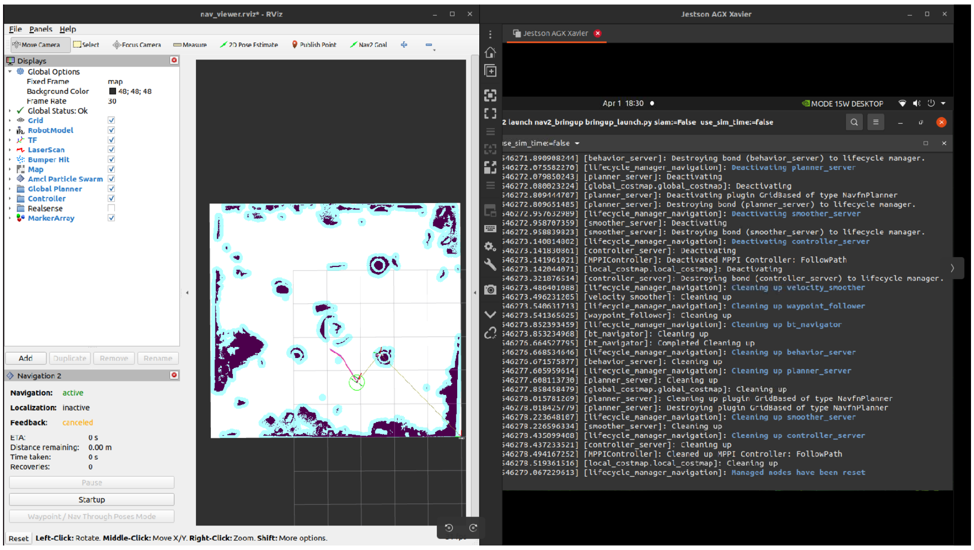

Figure 1: Navigation Stack Working

The navigation stack outputs velocity commands in terms of linear and angular velocities. These were converted to the robot's actuator command format, which uses wheel velocity and steer position values ranging from -100 to 100, with 0 representing the neutral or resting state. This conversion allowed the robot to accurately interpret and respond to navigation commands. Once this conversion pipeline was in place, the robot successfully received motion commands and navigated toward the designated goal. As shown in Figure 1, upon specifying a goal in RViz, the Nav2 planner generated a global path, and the robot responded by executing the corresponding actuator commands to move toward the target location.

1.2 E-box Assembly and Wiring

The original E-box on the robot, developed by the Crater Grader team, was large and had a complex, cluttered internal layout. To improve both usability and aesthetics, we decided to design and assemble a new, compact E-box with clean and organized wiring. I worked on the E-box manufacturing and wiring in collaboration with Bhaswanth and Deepam. The enclosure walls were constructed using laser-cut acrylic sheets to ensure precision and a professional finish. All necessary components, including a newly integrated Power Distribution Board (PDB), were securely mounted within the box.

To support the updated design, most of the wiring was redone. This was done not only to match the layout of the new components but also to minimize the chances of loose connections or dislodged wires during demonstrations. Ensuring that all connections were secure and reliable also aligned with our focus on Quality Assurance. The final assembled and wired E-box is shown in Figure 2.

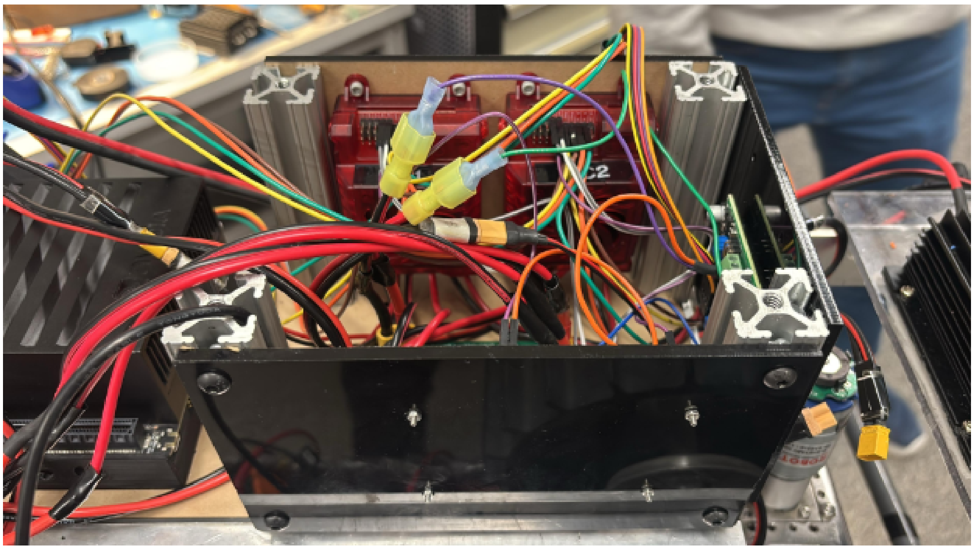

Figure 2: Assembled E-box

1.3 Moon Yard Scan

For the SVD (Surface Validation and Detection) module, the current plan involves having only one crater in the Moon Yard to simplify testing and evaluation. Previous maps contained multiple craters, which did not align with this objective. Therefore, a new scan of the Moon Yard was conducted using a FARO laser scanner, with the yard set up to include only a single crater. To properly test the tool planner, which is responsible for identifying craters from point cloud data and providing corresponding goal coordinates for the robot. All rocks were removed from the area, and the terrain was leveled. This setup is illustrated in Figure 3.

Figure 3: Flattened Moon Yard Terrain with one crater

Three scans were taken from different positions around the Moon Yard. These scans were stitched together to form a complete map, and the origin was defined at one corner of the yard. This origin also serves as the fixed point for the map frame. Following the scanning and mapping process, a costmap was created by adjusting the threshold values for obstacle detection. A global costmap was successfully generated, as shown in Figure 4, which can be used for autonomous navigation.

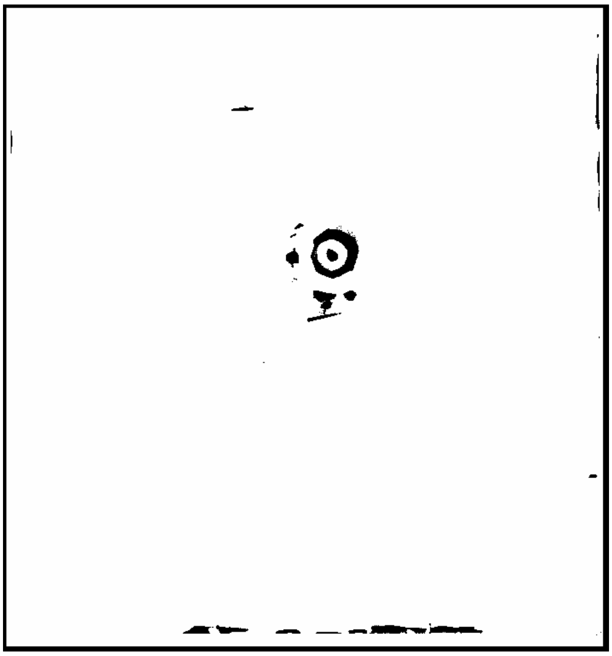

Figure 4: Global costmap

2 Challenges

A key challenge was integrating the navigation and localization stacks due to a mismatch between the velocity output format of the Nav2 stack and the input format expected by the robot's actuator system. This was resolved by developing a conversion script to map linear and angular velocities to wheel velocity and steer position.

The robot's performance on sand also posed issues. Limited mobility, especially during turns, often caused the robot to get stuck, leading to aborted navigation goals. Additionally, occasional loss of prism detection by the total station disrupted localization, further affecting navigation.

Assembling and wiring the new E-box was also challenging due to limited accessibility in the current robot design. Careful planning was required to ensure proper component placement and clean wiring, but the task was completed successfully.

3 Teamwork

Given my contributions outlined in the Individual Progress section, the following are the contributions of my team members.

1. **Ankit**: His primary responsibility was implementing the tool planner and testing it with the FARO laser scan data. He collaborated with William to integrate the Tool Planner into the FSM, and William assisted him in visualizing the planner outputs in RViz. He also worked with me, Deepam, and Bhaswanth on soldering the PCBs, finalizing the wiring connections for the new E-Box, and troubleshooting general hardware issues on the rover.

2. **Deepam**: He contributed by assisting and collaborating with everyone on various tasks. He worked alongside Ankit, me, and Bhaswanth to solder the PCBs and to manufacture, assemble, test, and debug the E-box and other rover hardware. He also focused on understanding and mapping out the software architecture. While working on visualizing the planning outputs, he encountered blockers, but ultimately, William was able to complete that task.

3. **Bhaswanth**: His initial work was in collaboration with William to debug the global localization stack and correct the yaw of the rover. He worked with me on the navigation stack and its integration with localization. We also set up a clean environment in the Moon Yard by removing rocks, flattening the area, and remapping it. He collaborated with Ankit, Deepam, and me in soldering the PCBs, assembling the E-box, testing it, troubleshooting issues, and performing quality assurance of the entire hardware setup.

4. **William**: His initial work primarily involved collaborating with Bhaswanth to debug the global localization stack of the rover. He then focused on finalizing the sensing stack and integrating it with the active mapping stack, which he worked on independently. However, he collaborated with Bhaswanth to integrate the localization with the mapping stack to output a global elevation map. He worked on writing the skeleton code for the FSM behavior tree, which was a collaborative effort with the entire team. He gathered input from each subsystem on their expected inputs and outputs and structured the flow of information in and out of each FSM state.

4 Plans

Until the next lab demo, my focus will be on ensuring reliable robot localization without lag or data loss from the total station. Navigation parameters will be fine-tuned to improve path-following accuracy and reduce deviations. We also plan to test the new Power Distribution Board (PDB) and verify all electrical connections to eliminate the risk of loose wiring or disconnections.

Additionally, the tool planner and navigation stack will be integrated so that the tool planner can send goal positions directly to the navigation stack, which will then generate actuator commands for the robot. Finally, all subsystems will be fully integrated, and the FSM (Finite-State Machine) will be set up to operate as intended for the SVD workflow.