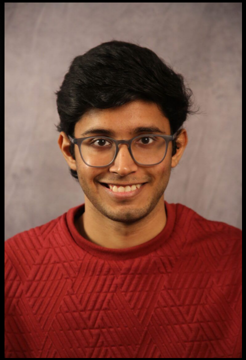
Lunar ROADSTER

(Robotic Operator for Autonomous Development of Surface Trails and Exploration Routes)

“Starting with a foothold on the Moon, we pave the way to the cosmos”

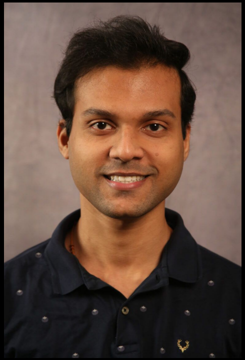
The Team

Ankit Aggarwal



Deepam Ameria

Bhaswanth Ayapilla



Simson D’Souza

Boxiang (William) Fu

Dr. William “Red” Whittaker

Goal: Resolve Arduino connection & reset issue

In Progress:

- Implementing a software-based auto-reset feature
- Using GPIO Pins on Jetson and Digital Pins on Arduino

Software Procedure:

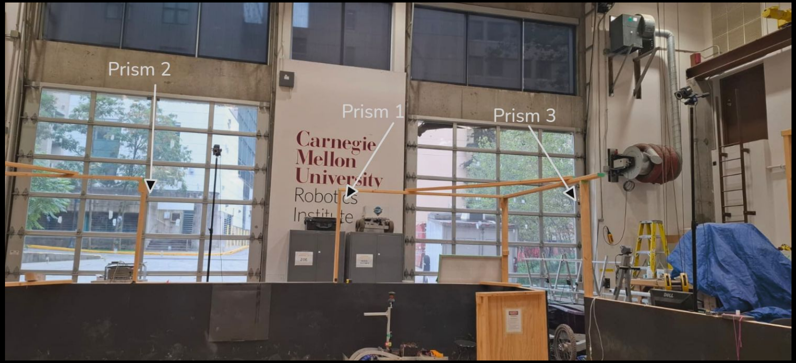
- Arduino (micro-ROS): Publishes /arduino_heartbeat
- Jetson (ROS 2 C++ node):
  - Subscribes to /arduino_heartbeat
  - On timeout (> 5 s): toggle GPIO via **libgpiod**
  - Pulse ~200 ms → reset Arduino

Goal: Implement new total station resection method

Resection: Uses three or more known reference points to solve both position and orientation of the total station (more accurate)

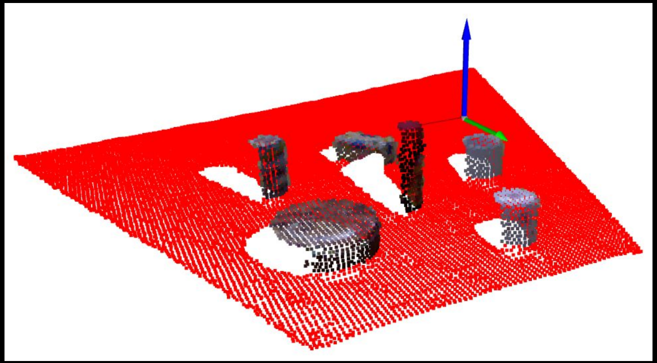
Key Motivation: Swapping batteries will not lead to total station offsets anymore

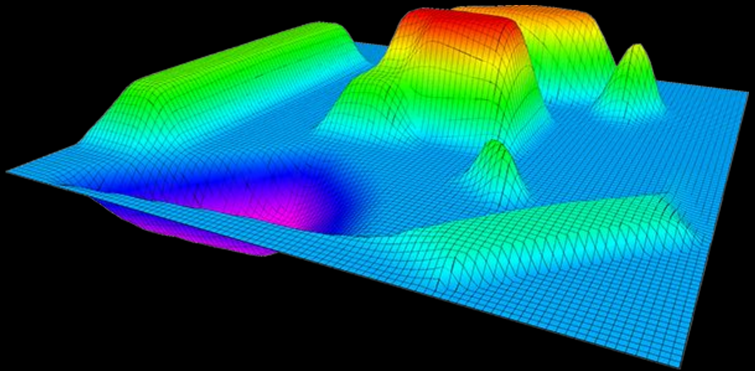
Validation: A fixed target measured from different total station setups yields consistent coordinates



Goal: Finalize validation stack code methodology

Step 1: Obtain point cloud from ZED camera FOV
Step 2: Use RANSAC to fit a plane
Step 3: Discretize map into grids and bin points in each cell
Step 4: Compute an elevation map relative to the RANSAC plane
Step 5: Compute gradients using finite differences
Step 6: Remove excessive gradients (walls)
Step 7: Compute maximum gradient





Goal: Finalize validation stack code methodology (PERCEPTION)

- **Device Used:** ZED 2i RGBD Stereo Camera
- **Methodology:** Train a Deep Learning Model (YOLO) on a custom Crater dataset to determine geometric data: centroid, diameter, distance to crater, etc.
- **Data collection** using ZED 2i and annotation to be done manually
- **Output:** Crater dimensions and position in robot frame which will be used by the planning stack to get robot poses

Goal: Finalize global path planner methodology

Inputs:
- Occupancy grid with crater classification
- Reference circular path (ring)
- Obstacles are large sized craters (>0.5m)
- Costmap with Ring Bias: adds extra cost for leaving the ring corridor

Planner:
- Hybrid-A* (lattice) search with Ackermann primitives
- Forward-only Dubins arcs (for minimum turn radius)
- g-cost: arc length + curvature penalty + obstacle cost + deviation from ring
- Heuristic: Dubins distance to goal + small penalty for ring misalignment

Directionality:
- Only Counter Clockwise motion
- Reverse moves allowed but heavily penalized

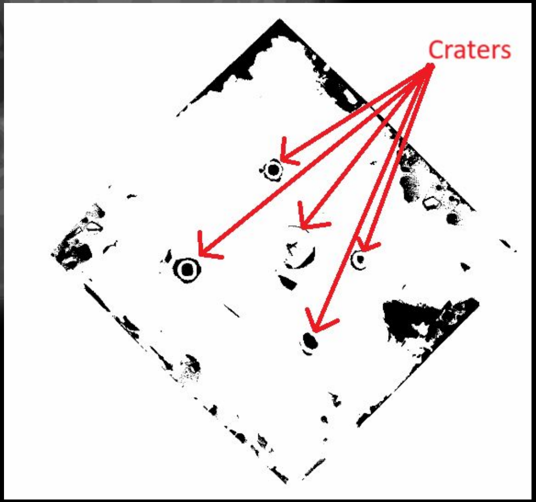
Outputs:
- Collision-free, curvature-feasible path hugging the latitude
- Path naturally passes through crater centers on the ring
- Smooth detours around large craters, rejoining the ring

Goal: Finalize global navigation controller methodology

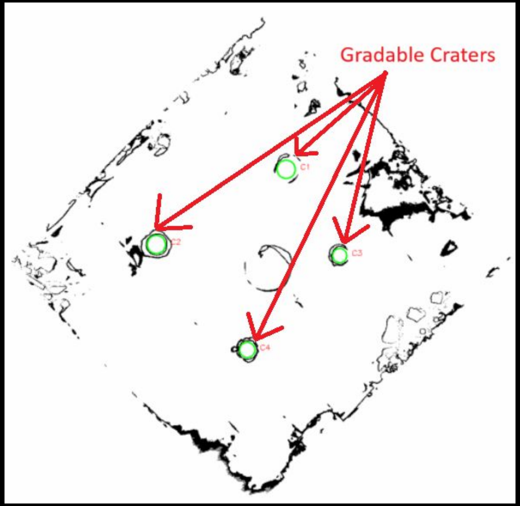
Pure Pursuit Controller Workflow

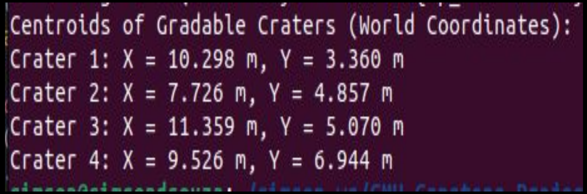
1. Receive global path (list of waypoints)
2. Get current robot pose from localization
3. Select lookahead point at distance L along path
4. Transform lookahead point to robot frame
5. Compute curvature and steering angle
6. Send steering & velocity commands to actuators
7. Repeat steps 2 - 6 until goal is reached

Goal: Finish implementing selection of gradable craters from global map generated from FARO scanner



Global Cost Map




Centroids of Gradable Craters (World Coordinates):
Crater 1: X = 10.298 m, Y = 3.360 m
Crater 2: X = 7.726 m, Y = 4.857 m
Crater 3: X = 11.359 m, Y = 5.070 m
Crater 4: X = 9.526 m, Y = 6.944 m

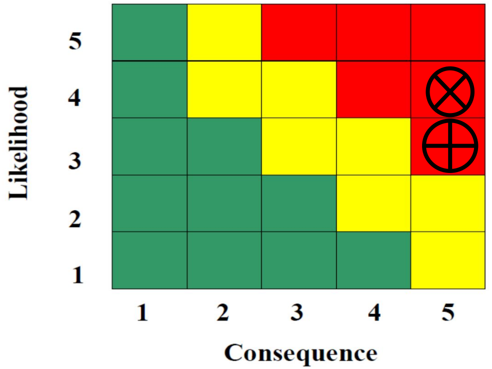
Identified gradable craters based on diameter and depth, extracting their coordinates which will be used for navigation

Risk Management

Risk ID	Risk Title	Risk Owner	Risk Type:	Logistics
R30	No spares available	Team		

Description	Date Added
Discontinued model, spare parts unavailable	3/4/2025
	Date Updated
	8/30/2025

Consequence
The whole project falling through, or redo almost all subsystems on a different rover.

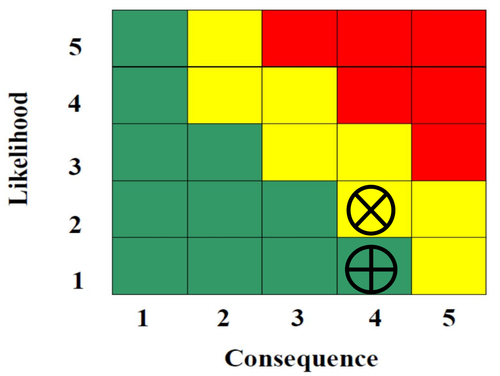


Action/Milestone	Success Criteria	Date Planned	Date Implemented
Check out eBay and other similar platforms for spares	Successfully find exact spares on these platforms	3/6/2025	9/22/2025
Check out and stock similar parts if not same	Successfully find and stock similar parts	3/6/2025	9/22/2025
Find a twin rover that was used by a previous team on campus	Successfully find the twin rover and scavenge parts	3/6/2025	3/7/2025
Find similar parts - a slightly smaller pinion and motor set	Spares problem will be solved	9/10/2025	9/22/2025

Risk Management

Risk ID	Risk Title	Risk Owner	Risk Type:	Logistics
R36	PRL Moonyard Access	William		

Description	Date Added
Securing Moonyard access for testing/demos will be restricted and challenging	8/29/2025
	Date Updated
	8/29/2025



Consequence
No testbed available for testing and/or FVD

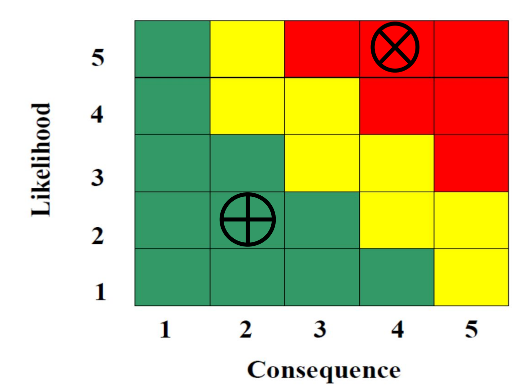
Action/Milestone	Success Criteria	Date Planned	Date Implemented
Devise and discuss a testing and demo plan with Prof. Red and Prof. David Wettergreen beforehand and reserve slots	Successfully meet and discuss the schedule of high priority projects	9/11/2025	9/11/2025
Complete Medical Evaluation to get unrestricted but controlled access	Successfully complete the Medical Evaluation and get unrestricted access to the Moonyard	9/5/2025	9/11/2025
Respirator Training	Complete training and get custom masks	9/30/2025	

Risk Management

Risk ID	Risk Title	Risk Owner	Risk Type:	Technical
R34	Arduino requires reset before operation	Bhaswanth		

Description	Date Added
Arduino needs to be manually reset each time before starting autonomy or switching between autonomy and teleoperation modes.	3/4/2025
	Date Updated
	4/10/2025

Consequence
Slows down setup time and impacts operational readiness, delaying mission start and mode transitions.



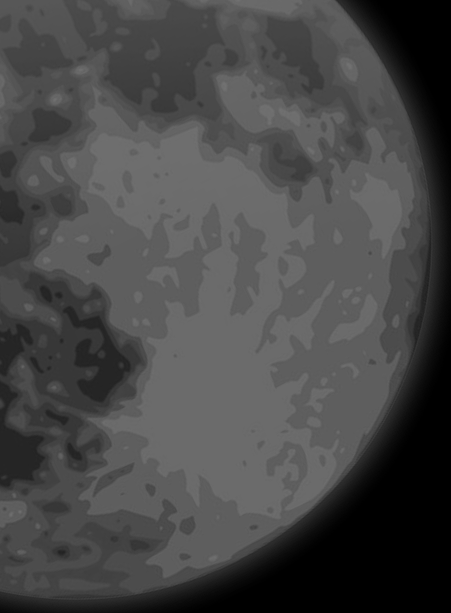
Action/Milestone	Success Criteria	Date Planned	Date Implemented
Check USB port permissions and drivers issues on Jetson	Successfully establish consistent serial connection without reset	4/26/2025	9/5/2025
Verify that Arduino is connected via USB 3.0 instead of USB 2.0 port	Ensure stable high-speed communication	4/26/2025	9/5/2025
Check for ROS node frequency mismatches causing packet loss to Arduino	Match ROS publish/subscribe rates	4/26/2025	9/5/2025
Implement a software reset trigger	Reset can be called from the operations terminal	9/7/2025	

Issues Log

I12	08/29/2025	09/12/2025	**Bhaswanth Ayapilla**	Localization frame shift after total station battery swap	1. Implement resection method using three known prism locations instead of orientate-to-line 2. Explore and test alternative localization methods (using SkyCam)	Learned and implemented resection method for localization using total station	Quick solution to implement first before exploring alternatives
I13	09/08/2025	09/14/2025	**Team**	Compute unit (Orin & Jetson) unable to communicate with Arduino	1. Replace old Arduino with new one 2. Find code workarounds to force communication 3. Retrace wiring to make sure everything is wired correctly	MicroROS versions between Orin and Arduino were incompatible. Reinstalled MicroROS resolved the problem	This allows Orin to communicate with the Arduino, which is used to send motor commands
I14	09/14/2025		**Team**	Steer pinion tooth chipped and worn-out due to wear-and-tear. Unable to find exact replacement for the pinion	1. Replace with similar pinion that has different tooth count 2. Switch to using another chassis		
I15	09/14/2025		**Ankit Aggarwal** **Deepam Ameria** **Simson D'Souza**	Wires keep on coming loose during operations due to bad soldering	1. Re-solder every wire 2. Switch to plug connectors and buy adaptors for the RoboClaws and motors		

Future Work

- Tuned validation stack - perception and verification separately
- Local navigation controller ready
- Navigation stack tested and tuned
- Methodology for integration
- Hardware finalized



THANKS!

Team Lunar ROADSTER