EUROPEAN ROVER CHALLENGE 2023

PRELIMINARY REPORT

TEAM NAME: Team Anveshak

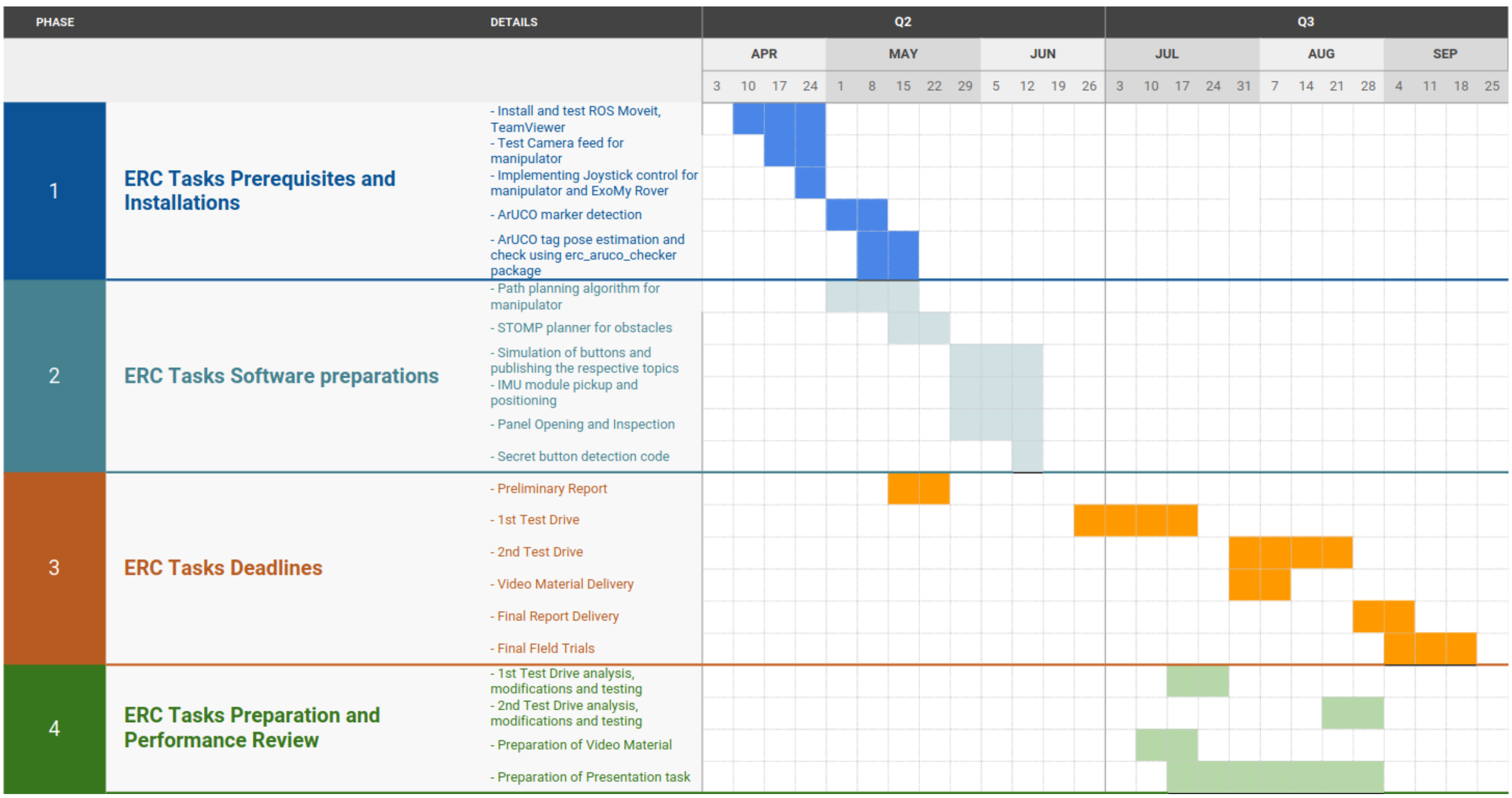
PROJECT NAME: Galilleo

AFFILIATION: Indian Institute of Technology Madras

INDEX

PROJECT PLANNING

The team has been organized into two distinct modules: manipulator and navigation The allocation of team members to these modules is based on the difficulty and complexity of the respective tasks. Additionally, a dedicated project management team is responsible for creating a comprehensive schedule spanning the entire year, ensuring timely completion of tasks, managing finances, securing sponsorships, and handling public relations.

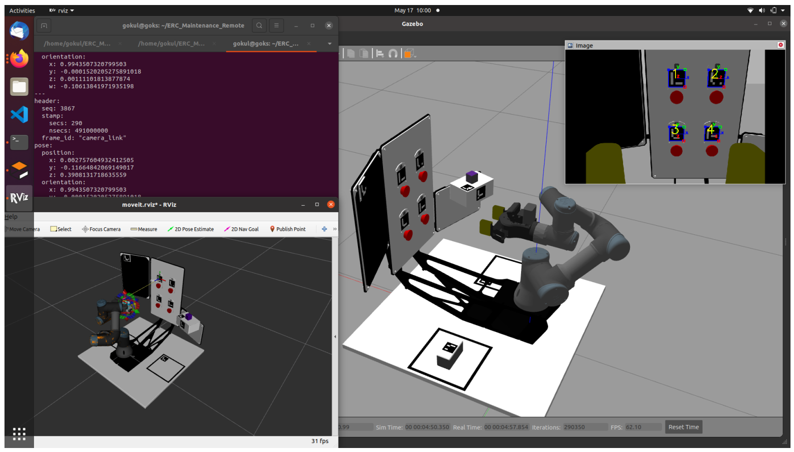


MISSION PLANNING

SIMULATION TASK

1. Software used

Freedom robotics, Gazebo, TeamViewer and RViz will be used to visualize the rover, arm and various camera/sensor feeds.



2. Use and Improvement

We plan to use the simulation of the UR3 manipulator for testing our path planning, object detection and collision avoidance algorithms and also to prepare ourselves to perform the tasks required by the competition. Training for the manual control of the ExoMy rover and the UR3 manipulator will be done using an Xbox controller.

NAVIGATION TASK

1. Software used

We will use the OpenCV module, aruco to detect the Aruco markers. We use Rviz for visualization and Gazebo to simulate the rover in Moonyard terrain. We also make use of Freedom Robotics for long distance manual control. Python and C++ scripts are used for easy control of the rover. We will use an Xbox controller for manual operation of the rover.

2. Approach

Since the RGB camera is the only sensor that has been provided, our goal is to make the manual operation of the robot as precise as possible. There will be two main subtasks that we will focus on - accurate detection of Aruco markers and their IDs from the camera feed, and controlling the robot accurately by using the three steering mechanisms - ackermann, spot turn and crabbing. Additionally, we will also focus on accurate probe deployment at the correct landmark.

3. Aruco Detection

The OpenCV package aruco gives us the ability to detect aruco markers and recognize their IDs very accurately. Given camera calibration parameters, it also gives us a pose estimate of the marker from the camera. We can get a rough estimate of where our rover is as we reach the given waypoints and use this for pose estimation of our rover.

4. Locomotion

The ExoMy rover has three locomotion modes - Ackermann, Spot turn and Crabbing. Ackermann will be the primary mode used, and Spot turn will be used to look for the aruco markers in case they are not visible. Crabbing will be used only if the rover has to navigate between closely spaced obstacles.

If the aruco marker is detected and has ID between 1-7 (i.e. it is a landmark), and there is no visible large obstacle, a script will be deployed to operate in ackermann mode to move towards the marker. Once it has reached close to the marker, we will switch to manual mode to bring the rover within 50 cm of the marker.

We will also be recording the messages on the /motor_commands topic and using it to generate the path traversed by the robot so that we can come back to any location easily, if required.

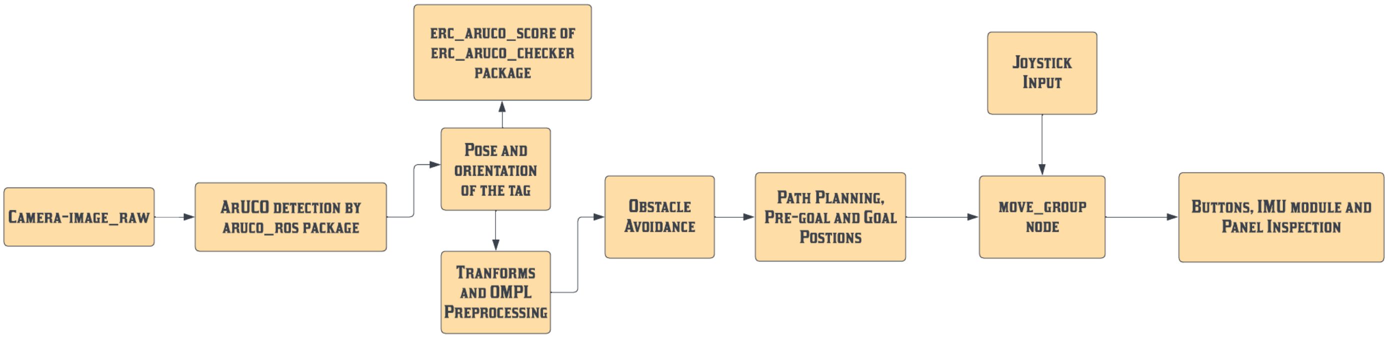
5. Test Drives

The following aspects will be tested during the test drives:

1. Manual control using a joystick
2. Navigation to marker
3. Testing how to stop within 50 cm of the aruco marker from camera feed only.
4. Testing accuracy of probe deployment
5. Exploring ease-of-use of Freedom Robotics

MAINTENANCE TASK

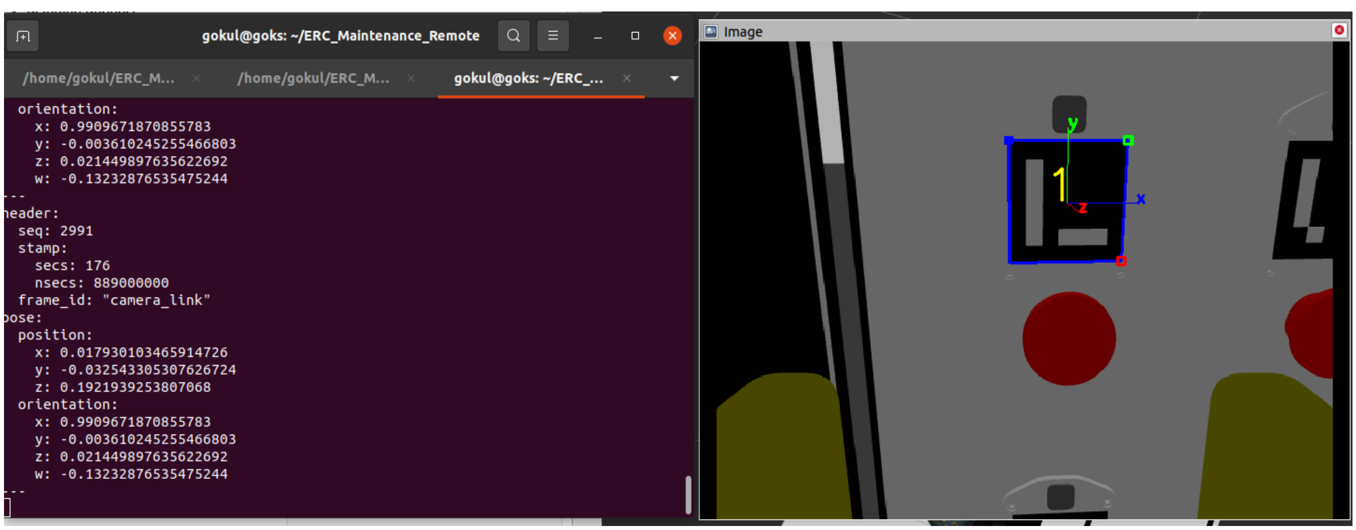
1. Software used



The UR3 Robotic Arm utilizes ArUco ROS tag detection and STOMP packages to execute path planning and trajectory tasks.

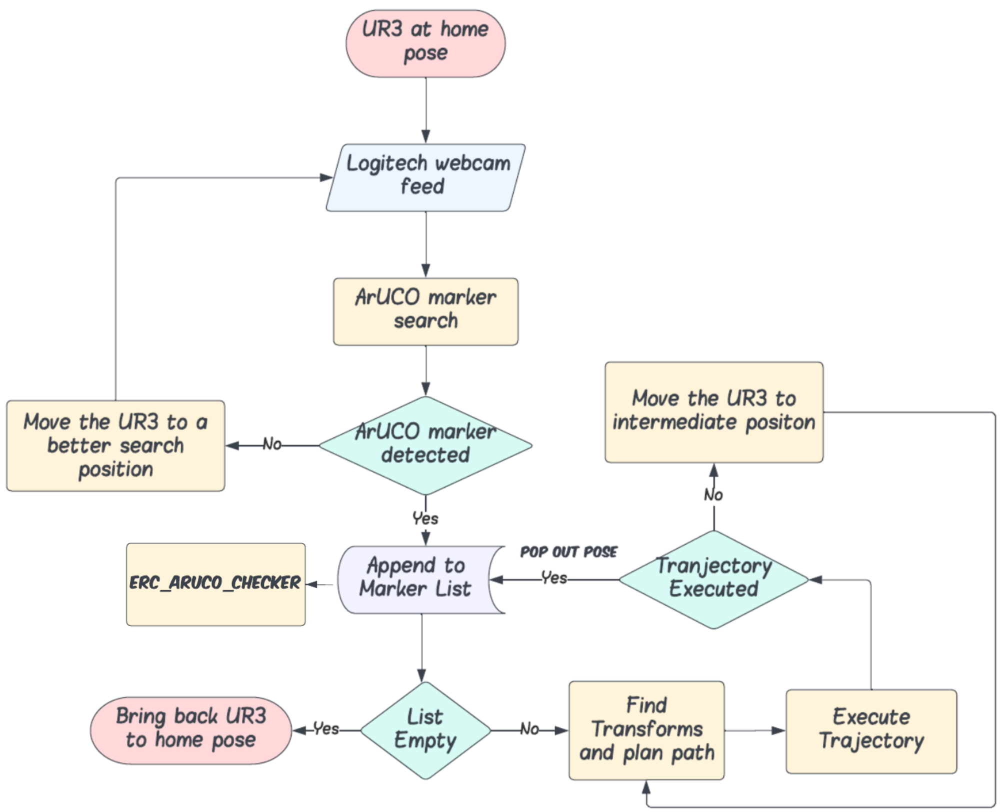
2. Approach

The Maintenance task has been divided into various modules. Maintenance tasks will be performed both manually and autonomously depending on the task at hand. By choosing multiple pre-goal positions and creating a trajectory with MoveIt, autonomous planning is carried out. These pre-goal positions are generated either manually or autonomously by analyzing the transforms and pose received by ArUco marker detection. In the event that the path planner is unable to locate a suitable trajectory, manual control will be used.



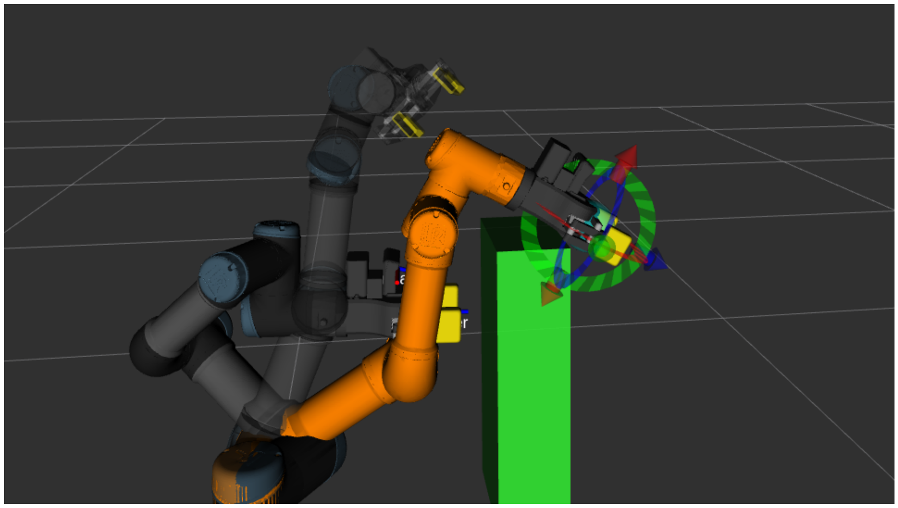
3. Autonomous navigation

An algorithm is being developed to control the arm in autonomous mode to the maximum extent possible. The current scenario allows path-planning, sensor pickup, positioning, panel operations and pressing of buttons using autonomous operation. The detected ArUco Markers on the switchboard are utilized as a reference for autonomous navigation. The aruco_ros package is used to detect the ArUCO markers on the button panel, IMU panel and Inspection panel. The package provides us with the exact pose and orientation of the detected ArUCO marker which is then sent to MoveIt for autonomous path planning to reach the pose.



4. Collision avoidance and Path planning

STOMP (Stochastic Trajectory Optimization for Motion Planning) is being used for motion planning and obstacle avoidance. The OMPL is a powerful collection of state-of-the-art sampling-based motion planning algorithms and is the default planner in MoveIt. STOMP was chosen over CHOMP as STOMP's stochastic nature produces non-jerky trajectories. CHOMP on the other hand produces jerky paths to avoid obstacles. An algorithm to detect obstacles post planning is being developed. This shall be useful in case the arm has dynamic or static obstacles in the planned path which were not detected or known during planning.



5. Task planner

The objective of our task planner is to create a comprehensive log of recognized positions and orientations of all 14 ArUCO markers and check it using the erc_aruco_checker package . Once the UR3 arm autonomously detects an ArUCO tag and fulfills the corresponding task associated with that tag, such as pressing buttons, picking up IMU module, or inspecting panels, the corresponding topics like /button1 and others will be published for scoring purposes

6. Test drives

The following aspects are to be tested during the test drives:

1. The installation and configuration of external packages and custom scripts on the rover and arm
2. Manual control utilizing a joystick
3. Verification of functionality for externally installed ROS packages
4. Navigating to ArUco marker locations
5. Manual testing of individual tasks
6. Testing autonomous execution of tasks
7. Evaluation of path planning and task planning algorithms
8. Assessing the user-friendliness of Freedom Robotics platform
9. Recording sensor feeds for future analysis and inspection purpose

PRESENTATION TASK

Our approach for the presentation task is as follows:

- During the initial phases of the competition, we will draft the slides for the presentation task. These slides will be continually edited and refined as our team progresses through the different stages of the competition. This approach allows us to have a clearer understanding of the slide contents and saves valuable time during the critical stages of the competition, enabling us to focus more on testing our algorithms and refining the software for the UR3 Arm and ExoMy Rover.

- Before the presentation task, we will organize practice sessions during which we will deliver presentations to our faculty advisor. This will enable us to gather valuable feedback and ensure that we are well-prepared for the actual presentation.

- Our plan for the presentation is to incorporate various forms of data, including graphs and tables, as well as visual elements such as flowcharts and diagrams. This will enhance the overall appeal and provide a deeper level of insight, making the presentation more engaging and informative.

- Team Anveshak has organized numerous workshops for students in both online and offline formats. Additionally, we consistently hold orientation sessions and sponsorship drives where we elucidate our team's operations and research to industry professionals and members of the academic community. Consequently, the majority of our team members are confident in presenting to an online audience.

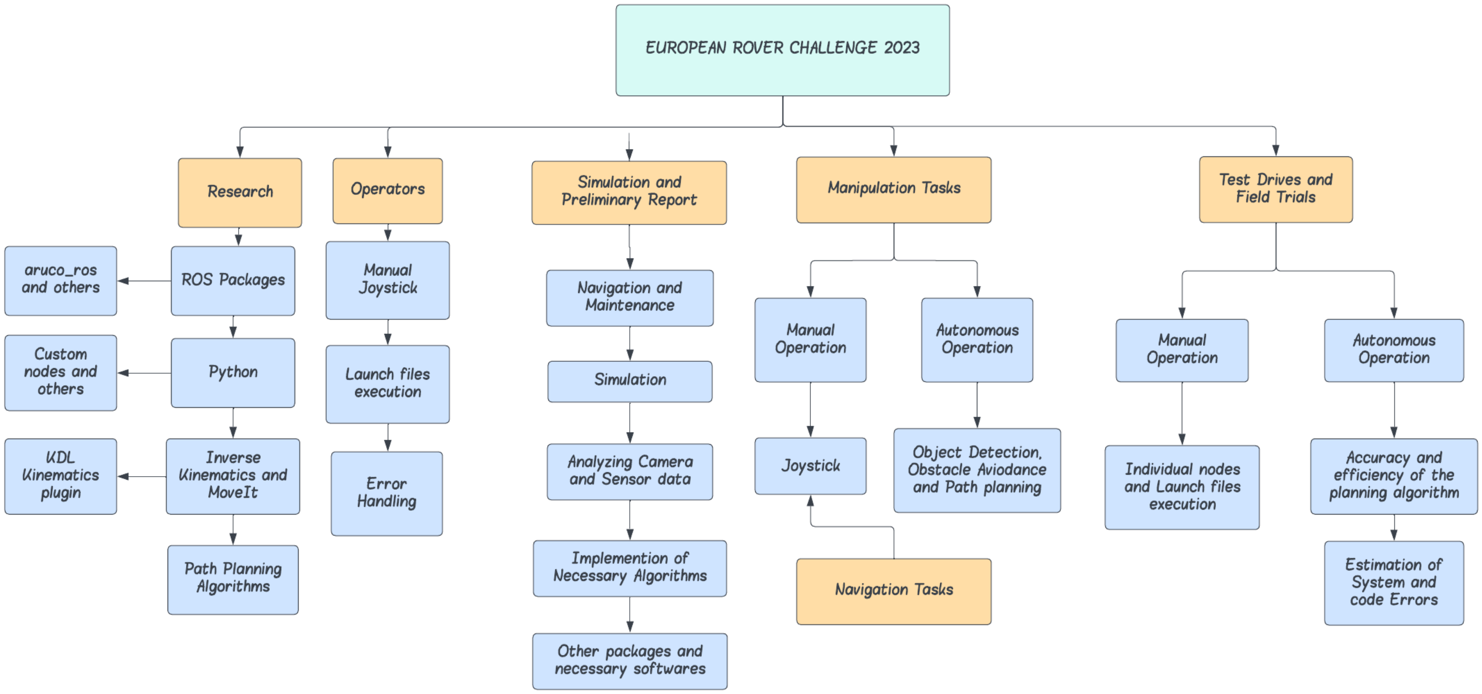
PROJECT ASSUMPTIONS

Technical Assumptions	Communication to and from the rover is assumed to be with minimum data lag and transmission loss
	The motors and actuators installed in both the rover and manipulator possess ample torque and force capabilities to successfully accomplish the tasks in the moonyard
	It is assumed that all sensors constantly transmit accurate information and are capable of providing continuous data throughout the entirety of the test drives and the competition.
Management Assumptions	The team's various sub-modules are anticipated to meet all deadlines, ensuring a smooth and seamless integration and testing of the algorithms.
	It is assumed that each team member's health and mental well-being will remain in a good condition throughout the duration of the competition.

Technology used and Confidence Level

1. Team Anveshak holds a combined experience of 7 years in ROS, encompassing expertise in interfacing ROS with hardware and participating in diverse rover building competitions, including the University Rover Challenge, the Indian Rover Challenge, and the Anatolian Rover Challenge.
2. Each member of our team possesses the confidence and adeptness to work with ROS in a flexible and comfortable manner.
3. In preparation for the current competition, we have successfully developed numerous software stacks and tailored planning algorithms for our manipulator arm and traversal systems.

SYSTEMS BREAKDOWN STRUCTURE



FINANCIAL PLANNING

Given below are the major expenditures that we anticipate in our planning for the remote edition of ERC 2023

Expenditure	ID	Name	Description
Technical Expenditure	**TE-1**	Controls	Joysticks for training controllers
	TE-2	Prototype (to test algorithms for autonomous tasks)	Electronic Components-microcontrollers, motors, drivers, soldering kits and wires
Management Expenditure	**ME-1**	Pizza Fund	Miscellaneous Team Expenses

Sponsorships and Fundings

Our income sources, including sponsorships and other software access licenses, are given in the table below.

Category	ID	Source
Funding	**F-1**	Institute Funding
Sponsorships	**S-1**	Pololu Electronics
	S-2	Progressive Automations
	S-3	PCB Power
Software Licenses	**L-1**	Freedom robotics through ERC organizers
	L-2	Zoom pro through parent institute

RISK ASSESSMENT

1) Technical Risks

Risk ID	Name	Description	Probability of Failure	Mitigation
TR-1	Weak Internet Connectivity	Connection Loss during testing or trials	2	Personal Wi-fi hotspots for backup Prolonged connection loss will allow the rover to go into a safe mode
TR-2	Power Outage	Power Failure from the Operator's Side	2	Having sufficient Power backups and power backup devices
TR-3	Emergency	Damage to the Rover due to obstacles	1	Autonomous detection and avoidance A kill switch has been incorporated on the operator’s side

TR-4	Node Failure	Node Errors while launching	2	A single launch file to reduce the clumsiness and provide higher error handling efficiency A custom GUI to launch terminals and nodes, monitor the status of each node
TR-5	Infinite Loop	Rover's or Arm's planning algorithm gets stuck in an infinite loop	3	A software kill switch on operator's side Improvement in the code to handle such situations, like repositioning the Rover and the Arm
TR-6	New Obstacle	Introducing a new obstacle to the planned space	3	Improved Camera detection and rerunning Planning if needed

2) Management Risks

Risk ID	**Name**	**Description**	**Probability of Failure**	**Mitigation**
MR-1	Schedule Conflicts	Team members having hard deadlines including exams, internship during the competition	4	Regular Team Meetings are being held to keep everyone on the same page A proper schedule is being maintained to balance academics, externalities and competition work
MR-2	Health and Wellness risks	Team members feeling unwell and stressed	3	Proper Schedule and Task Review ensures none of them are overworked Motivating and Energizing our team members by pizzas,

				eateries
MR-2	Inadequate Input	Pressure on and during competition week leading to inadequate performance	3	Regular meet with our faculty advisor and experts to assess our readiness Maintaining a tasklist on what we intend to accomplish during test drives
MR-4	COVID-19	Risk of team members contracting COVID-19	2	Every member will be trained with the tasks Team members will follow safety precautions to avoid exposure to COVID-19

REFERENCES

1) STOMP Planning Algorithm:

[1] M. Kalakrishnan, S. Chitta, E. Theodorou, P. Pastor and S. Schaal, "STOMP: Stochastic trajectory optimization for motion planning," 2011 IEEE International Conference on Robotics and Automation, Shanghai, China, 2011, pp. 4569-4574, doi: 10.1109/ICRA.2011.5980280.