DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College Of Engineering)
Shahbad Daulatpur, Main Bawana Road, Delhi - 110042

Critical Design Review Report

TEAM NAME: UGV-DTU

AGNI (Autonomous Ground-based Navigation Inspector)

Date: 24th May, 2024

Under the supervision of
Prof. S Indu
Faculty Advisor

Led by Team Captain
Lakshay
B.Tech (CSE) 3rd Year

ABSTRACT

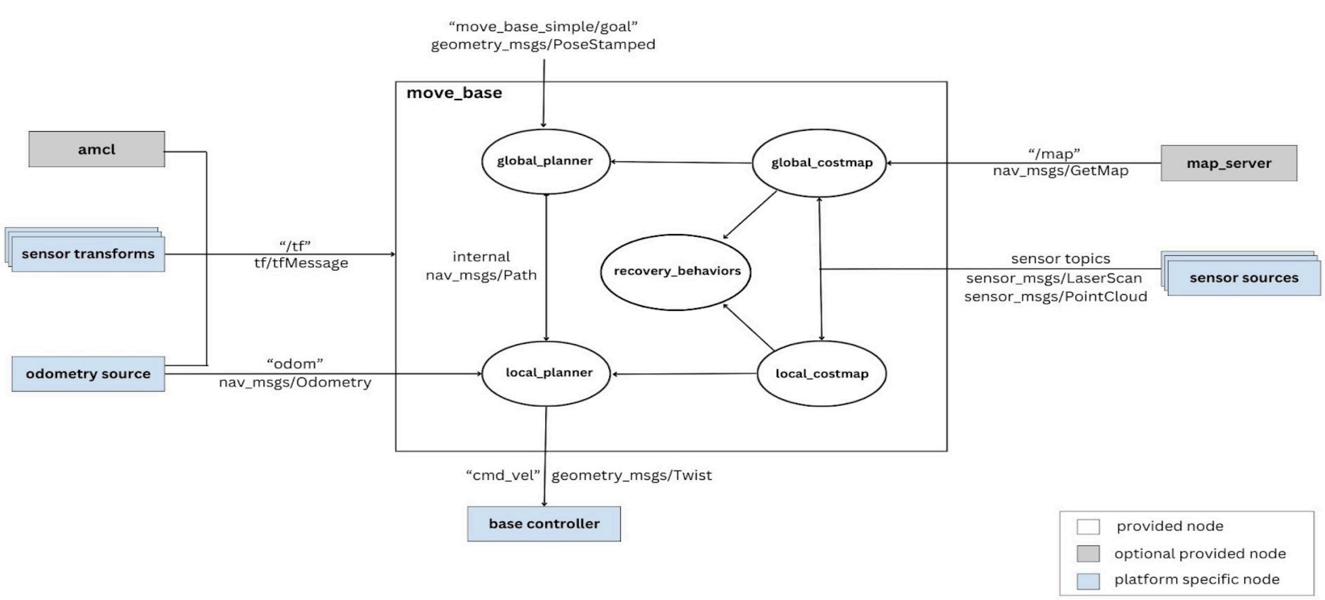
Our vehicle is named ‘AGNI’ - Autonomous Ground-based Navigation Inspector, symbolizing its dynamic and powerful capability to navigate and inspect autonomously with precision and efficiency, much like the elemental force of fire in its Sanskrit translation.

AGNI is engineered with a focus on traversing uneven terrain efficiently. Adopting a rocker double lambda bogie design balances stability and flexibility to traverse through the uneven terrains as mentioned in the problem statement. The control system uses a combination of hub motor controller and an Arduino Uno to control the six wheels (4 Hub motors + 2 dummy wheels) for better traction and handling, ensuring efficient traversal in difficult terrains. AGNI is equipped with the Minelabs 44 metal detection module, known for its capability to detect metal objects at depths ranging from 10 to 12 inches. Wireless communication is maintained through Xbee Pro transmitters and receivers, with 443MHz whip antennas facilitating reliable data transmission. AGNI leverages SLAM, Rviz with GPS and INS for precise localization, while also utilizing the DWA (Dynamic Window Approach) for efficient path planning, ensuring precise navigation through diverse terrains. Moreover, it employs RPLiDAR, enabling advanced environment perception and obstacle detection. For OCR, our rover utilizes ZEDCAM and employs a convolutional neural network (CNN) like Tesseract to accurately scan and interpret characters written on the black box.

COMPETITION STRATEGY

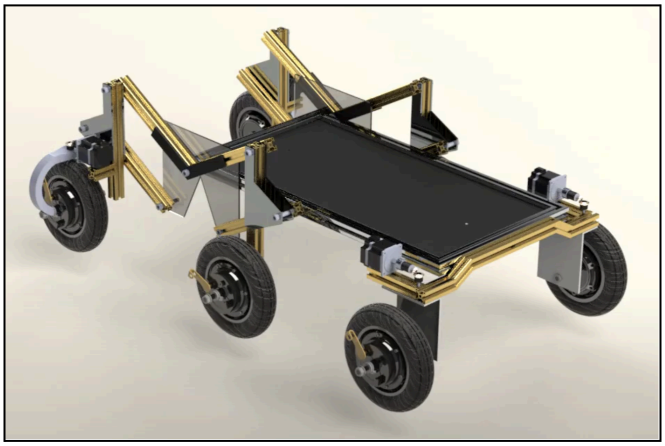
SOFTWARE STRATEGY

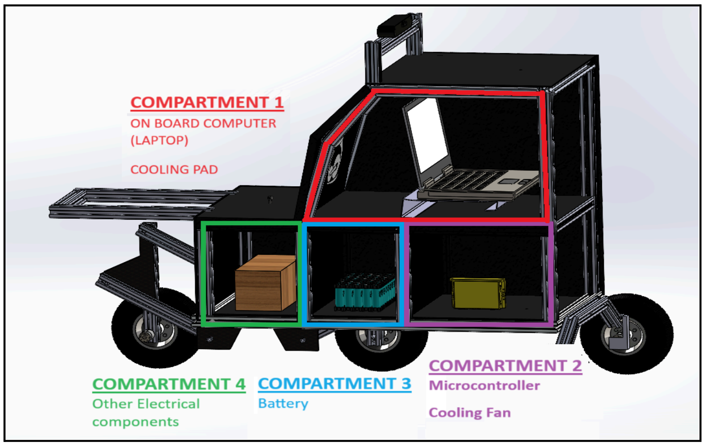
AGNI’s software strategy for the UGVC competition prioritizes autonomous navigation, obstacle detection, and waypoint navigation. It leverages advanced algorithms like DWA (Dynamic Window Approach) for path planning and SLAM for localization.



MECHANICAL STRATEGY

AGNI's design emphasizes on the traversing stability on uneven terrain and also on the heat and dust proofing of the components. Aluminum composite sheets are used due to their lightweight, strength and sleek design, and a rocker-double lambda bogie model for its stability and weight distribution. The polycarbonate sheets provide insulation from environmental heat. The "rocker" allows for side-to-side pivoting while navigating uneven terrain, and the "double lambda" refers to the inverted V-shaped structure that distributes weight evenly.

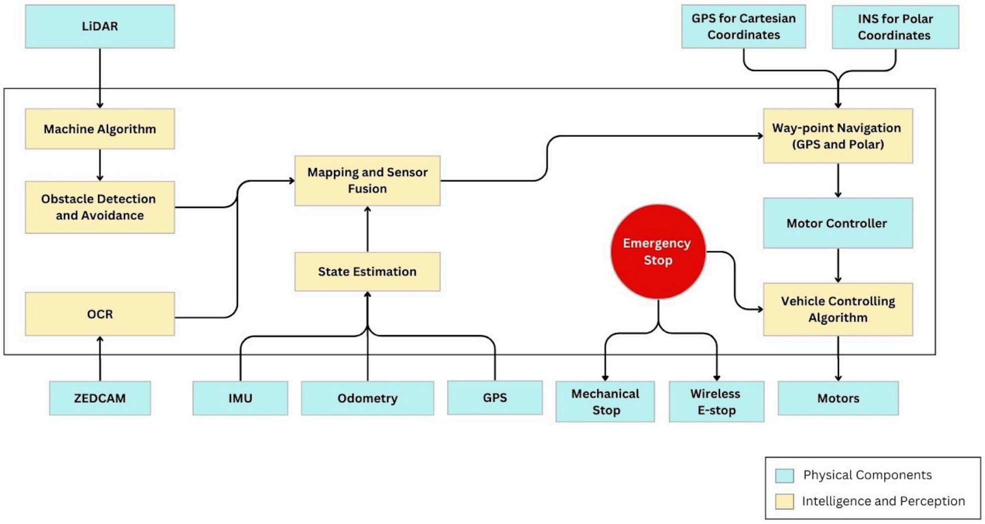




DESIGN CREATIVITY

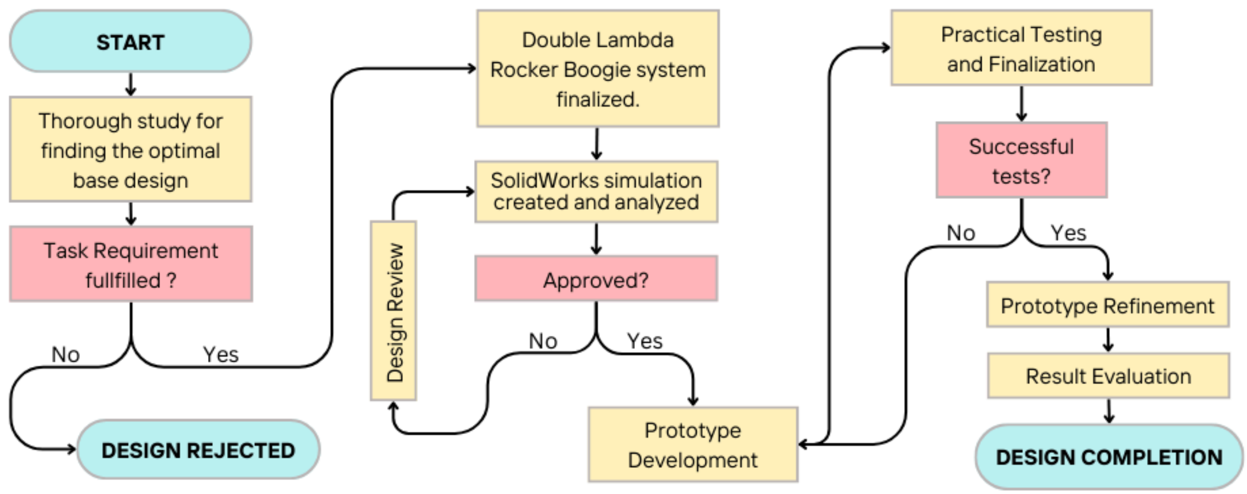
SOFTWARE

Instead of using 3D lidar, we are using 2D lidar and merging the ZEDCAM images to create a 3D costmap. Additionally, instead of using a high end GPS system, we are using two low-end GPS modules and configuring one as a rover and the other as home station to achieve the same high level accuracy.



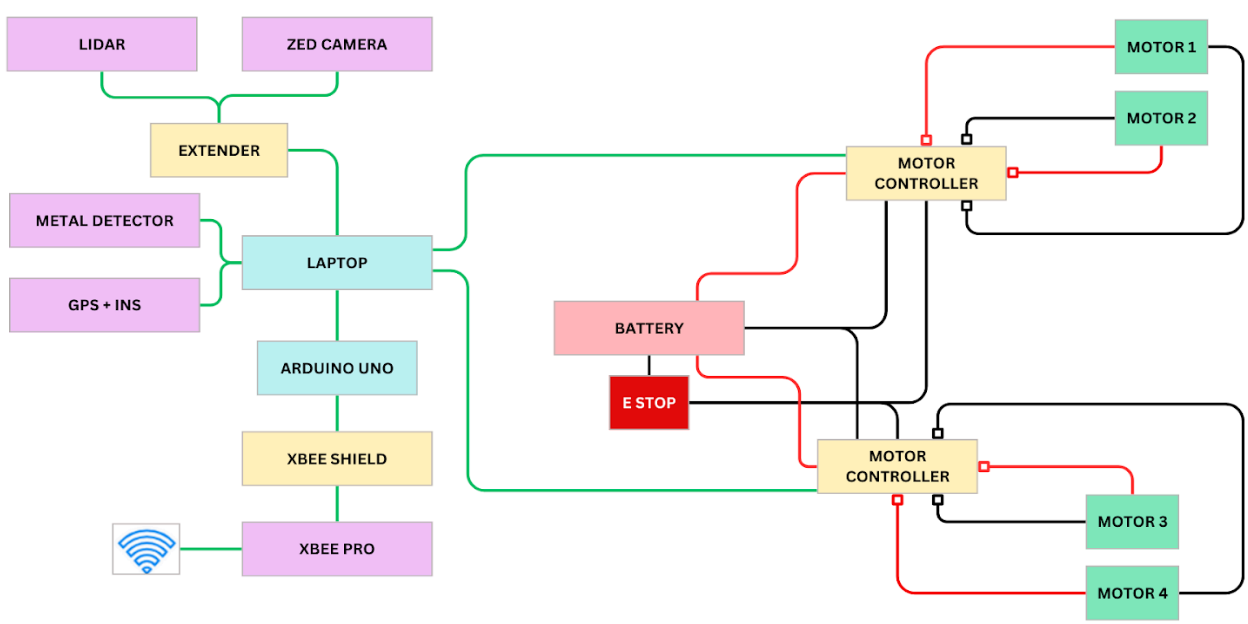
MECHANICAL

The design of AGNI uses 4-wheel drive along with pneumatic wheels to enhance the stability and increase the traction. The rocker double lambda bogie system is highly adaptable and suitable for a wide range of terrains, including rocky, sandy, or uneven surfaces. The smart use of light weight aluminum composite sheets and balanced weight distribution guarantees a smooth, stable journey.



ELECTRICAL

AGNI utilizes the XBee Pro communication module which handles wireless data transmission and reception based on pre-configured settings, forming a self-healing mesh network, which enhances communication robustness. Additionally, the Arduino Uno paired with a motor driver offers a cost-effective and efficient solution for motor control, making our robot both affordable and highly functional.

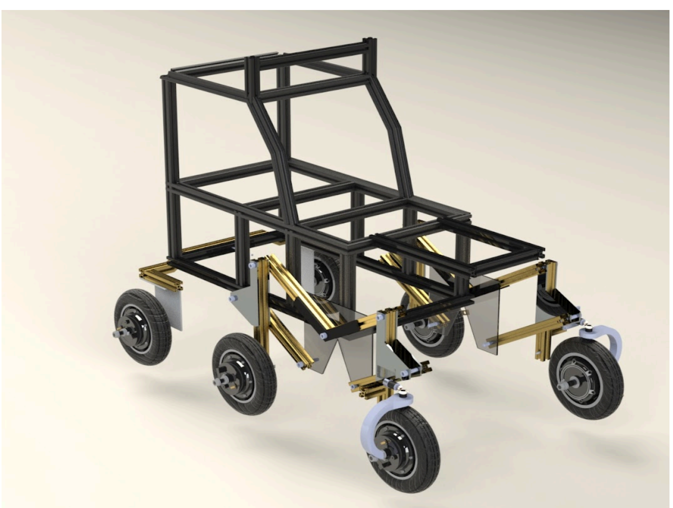


MANUFACTURING PLAN

For manufacturing the robot, we have used Aluminium T-slots for building the chassis because of their convenience of assembling and lightweight.

Aluminium composite plates have been used for the outer body of the robot due to their lightweight durability, corrosion resistance, and thermal stability. They're easy to fabricate, reducing production costs, while providing excellent strength-to-weight ratio, enhancing efficiency and maneuverability. In-wheel motors have been used in our bot because of their compactness, design simplicity and installation. The direct drive improves efficiency by reducing energy loss in transmission. They enhance maneuverability and agility since each wheel can be controlled independently, enabling precise and stable movements.

Pneumatic wheels have been chosen due to their enhanced shock absorption, improved traction on uneven surfaces, allowing our bot to traverse more smoothly while minimizing vibration and impact on internal components. Additionally, their flexibility and ability to deform slightly under load help distribute weight more evenly, reducing strain on the bot's chassis and prolonging its lifespan.
We have also employed a metal detector which is attached to the bot through a lateral hinge which will allow for lateral movement thus increasing the range of the metal detector and hence improving the bot’s performance in the metal detection round. Carbon fiber sheets for our bot's outer chassis offer lightweight durability, high strength, sleek aesthetics, and design flexibility. They provide excellent protection from dust and heat while keeping the overall weight low, enhancing the bot's agility and performance.



EXPERIMENTAL RESULTS

MECHANICAL DESIGN SELECTION

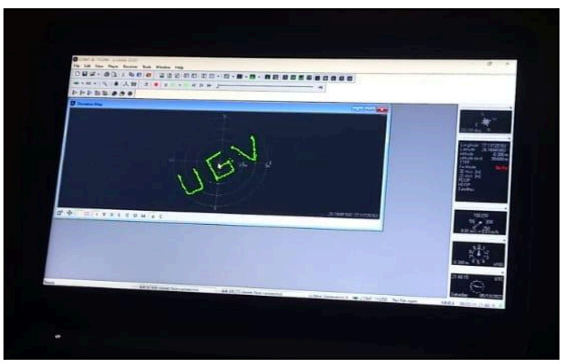
The competition required the robot to traverse a wide variety of terrain and detect underground metal objects. This task demanded a stable maneuver capability from the robot, which led to the finalization of the rocker double lambda bogie mechanism. Polycarbonate sheets are utilized for the protection of critical components and onboard computer from the high surrounding temperature.

TERRAIN TRAVERSING TASK

Traversing diverse terrains with a UGV (Unmanned Ground Vehicle) involves employing GPS data from which the UGV can pinpoint its precise location on Earth's surface, providing essential coordinates for navigation and use of an algorithm named DWA (Dynamic Window Approach) Which works by finding the optimal path from the vehicle's current position to the target destination. DWA (Dynamic Window Approach) evaluates potential paths based on a combination of two cost functions which are actual cost function and heuristic cost function.

WAYPOINT NAVIGATION

Rover leverages several advanced technologies to achieve autonomous waypoint navigation.
1. SLAM (Simultaneous Localization and Mapping): SLAM is employed for constructing and updating a map of the environment while simultaneously determining the rover's position within it which is crucial for autonomous navigation in unknown environments.
2. Rviz: Rviz plays a vital role in displaying sensor data and state information from ROS Noetic. It provides real-time visual feedback, aiding in monitoring the rover's behavior.



OBSTACLE DETECTION & AVOIDANCE

Obstacle avoidance and detection is one of the core objectives to be achieved by our rover. We fulfill this task using **RPLiDAR A1M3**. LiDAR is a device with 360 degrees rotation capabilities that emits laser pulses, measures their reflection time, and calculates distances, thereby gauging the distance of various objects from the vehicle. This data is then generated into a 2-D costmap of the surroundings at a given time frame. Additionally, we integrate the **Dynamic Window Approach (DWA)** with NAV-YOLO for advanced obstacle detection and avoidance. [2]

OCR - OPTICAL CHARACTER RECOGNITION

AGNI utilizes **ZEDCAM** for OCR, employing a convolution neural network (CNN) like Tesseract to accurately scan and interpret written characters in its environment. The image capture process begins with the **ZEDCAM** capturing images of the black box. These images undergo image processing using **ESRGAN** to enhance visibility and remove noise. Subsequently, Tesseract employs its neural network models to detect text regions within the processed images, followed by analyzing these regions to recognise characters.

PROJECT MANAGEMENT

We believe that teamwork is at the heart of any great achievement. Our goal was not just to develop an autonomous vehicle but to build an environment which nurtures team and individual's growth simultaneously. Without the leadership of our team leader, the dedication of team members, and the diligent oversight by our treasurer, it would have been impossible to manage all departments and finances effectively.

Name	Major/Year	Software	Mechanical	Electrical	Hours
Lakshay Singh	CSE/3rd	✔			550+
Lakshya Kumar Sinha	AE/3rd		✔		500+
Aaryan Agarwal	EE/2nd	✔			400+
Kartik Walia	CSE/2nd	✔			500+
Darshan Solanki	AE/1st	✔			500+
Krishna Sharma	ME/1st		✔		200+
Mitesh Sati	ME/1st		✔		250+
Parth Salunkhe	CSE/1st			✔	400+
Vedant Singh	ME/1st	✔			500+
Yuvraj Gupta	EE/1st		✔		250+

BUDGET AND COST ACCOUNTING

Funding Sources:

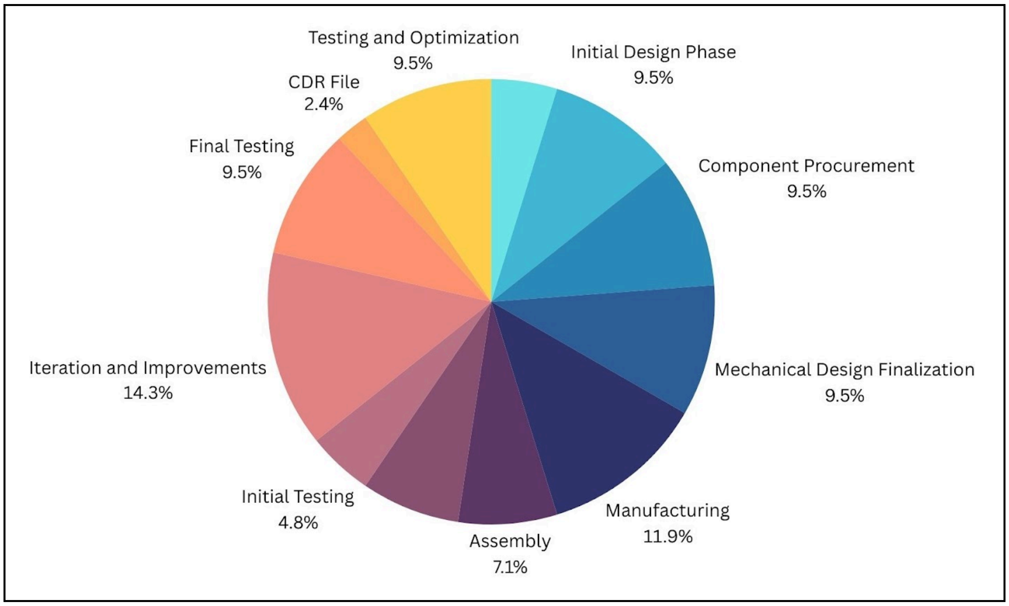
- **Delhi Technological University:** Our college has been a significant source of funding. We have raised around 7 lakh INR from the college to support our project. Additionally, an extra 1 lakh INR will be sanctioned after our demonstration event.
- **Sponsors:** We have received activation keys and software licenses from our sponsors Ansys and SolidWorks, which have been invaluable in our design and simulation processes.

Expenses:

- **Manufacturing Costs:** A substantial portion of our budget has been allocated to manufacturing the robot. This includes the cost of materials, parts, and technologies.
- **Testing Environment:** Creating a suitable testing environment to ensure the robot performs as expected under competition conditions has also incurred significant expenses.

- **Registration and Travel:** We have allocated funds for registration fees, cargo expenses for shipping our robot, and travel costs for team members to attend the competition abroad this year.

Task ID	Task Name	Start Date	End Date	Duration	Status
1	Project Planning	1-Dec-2023	15-Dec-2023	2 weeks	Completed
2	Design and Requirements	16-Dec-2023	29-Dec-2023	2 weeks	Completed
3	Component Procurement	30-Dec-2023	10-Jan-2024	2 weeks	Completed
4	Manufacturing and Assembly	15-Mar-2024	20-Mar-2024	1 week	Completed
5	Software Integration	20-Mar-2024	31-Mar-2024	1.5 weeks	Delayed
6	Initial Testing	1-Apr-2024	21-Apr-2024	3 weeks	Started
7	Iteration and Improvements	21-May-2024	10-Jun-2024	3 weeks	In progress
8	CDR File	17-May-2024	24-May-2024	1 weeks	Completed
9	Final Testing and Optimization	11-Jun-2024	08-Jul-2024	4 weeks	Planned



GANTT CHART & TABLE

ACKNOWLEDGEMENT

We would like to extend our sincere gratitude to our faculty advisor, **Prof. S Indu**, whose technical knowledge and unwavering support were invaluable throughout this project. Her guidance helped us navigate various hurdles and significantly contributed to the success of our robot.

We deeply appreciate the dedication and hard work of each team member. Bringing this project to completion required the team's unwavering efforts and cooperation. Special thanks to our team captain **Lakshay**, whose leadership and vision were instrumental in steering the team towards our goals.

We are also grateful to **Delhi Technological University** for providing the monetary funds necessary to complete this project. Additionally, we thank our team sponsors, including SolidWorks and Ansys, for their generous support. The access to advanced software and resources provided by these sponsors played a crucial role in the development of our robot.Moreover, we appreciate the facilities provided by the various laboratories of our college. The availability of these facilities (3D Printing, Welding, Cutting, etc.) allowed us to execute our ideas and bring our robot to life.

In conclusion, this project would not have been possible without the collective support and contributions from all these individuals and organizations. We are truly thankful for their assistance and encouragement.

I hereby certify that the design and development of the vehicle AGNI, described in this report, is significant and represents a substantial effort by the student team in preparation for this competition. This is prepared by the student team under my guidance.

Prof. S. Indu
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Dean Student Welfare
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[3] Minotaur - A Single Lane Navigation System
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[4] Waypoint Navigation System Implementation via a Mobile Robot Using Global Positioning System (GPS) and Global System for Mobile Communications (GSM) Modems
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[5]Robot Operating Systems (ROS): The fundamentals of ROS and its remarkable.
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APPENDIX

Component/Subsystem	Vendor	Model/Type	Specs	Cost (if new)
Chassis	Selfmade	-	-	42,000
Power system	Purchase	HP	HP OMEN Gaming Laptop	62,000
LIDAR	Robu.in	RPLiDAR A3M1	360° Laser Range	72,000
Camera(s)	Digikey	Zed 2i Camera	ZED 2i Stereo Camera 120° Wide-Angle FOV	62,000
SparkFun GPS Receiver Module + IMU	Digikey	C099-F9P-1	ZED-F9P EVAL ASIA AND ROW	50,000
XBee Pro	The engineer store	RP-SMA Antenna	1.5km Range	9,317
Metal Detector Sensor	Minelabs	Minelabs 44 Metal detector	10-12 Inch depth Detection	16,000
Li-ion Battery	Robu.in	Battery Pack	24 Volts	19,637
Motor + Motor Drivers	Robotics DNA	24V 350W 10 INCH BLDC TYRE HUB MOTOR FULL KIT	800-1000 Rpm	27,000
Misc Items	-	-	-	40,000
Outer Body Covering	Selfmade	-	-	92,400

Component/Subsystem	Description
Algorithms and Models	DWA, AO*, YOLOv4, Segmentation
Localization and mapping	SLAM & VLMAPS
Team Size (number of people)	20-25 Students
Expertise ratio (hardware vs software)	3:5
Testing time	3-4 weeks
Inter-vehicle communication	XBEE Pro modules (2.4GHz frequency)
Programming Language(s)	C++, Python