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TITLE PAGE

- **Problem Statement ID –** 25142
- **Problem Statement Title-** Student Innovation: Swadeshi for Atmanirbhar Bharat - Space Technology
- **Theme-** Space Technology
- **PS Category- Software/Hardware -** Software
- **Team ID-**
- **Team Name (Registered on portal) -** Neelkantvarni

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PLANETARY ROVER PATHFINDING SIMULATOR

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Detailed explanation of the proposed solution: A web-based 3D simulator that combines procedural terrain generation (using Perlin noise) with an A* pathfinding algorithm. It visualizes autonomous rover navigation on challenging planetary landscapes.

How it addresses the problem: Addresses the real-world challenge of autonomous navigation in unknown, difficult environments by providing a tool to simulate and optimize rover paths based on terrain difficulty and rover constraints before a mission is deployed.

Innovation and uniqueness of the solution:

- Slope-aware A* algorithm: Pathfinding considers not just distance, but also terrain elevation and slope, which is crucial for real rovers.
- Real-time procedural terrain generation: Creates infinite, unique environments on the fly.
- Dual control modes: Seamlessly switch between automatic pathfinding and manual driving.
- Interactive Mission Dashboard: Provides real-time metrics for mission control.

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TECHNICAL APPROACH

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Technologies: We will use Python and its libraries, including `Pygame` for rendering and `NumPy` for numerical processing. Our pathfinding will rely on the `A\*` or `Dijkstra's` algorithm.

Methodology:

a. **Terrain Generation:** We will generate a heightmap that is rendered as a 3D-like grid. This grid will include features like boulders and craters to mimic a realistic environment.
b. **Rover Model:** The rover's movement will be governed by a simple physics model that accounts for gravity, friction, and terrain slope.
c. **Pathfinding:** The `A\*` algorithm will be implemented to find the most efficient and safest path on the terrain grid, with a cost function that considers steep inclines.
d. **User Interface:** The UI will be a mission control dashboard that provides real-time visualization of the terrain, rover position, and the calculated path.

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FEASIBILITY AND VIABILITY

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Feasibility:

- **Technical:** Proven tools (Perlin noise, A*, Three.js), modular design
- **Resource:** Standard PC + internet, no expensive hardware
- **Time:** Prototype ready with core features

Challenges:

- Performance on large terrains
- Cross-browser/device compatibility
- Integration of 3D rendering + algorithms

Solutions:

- Use Web Workers & optimized A*
- Three.js + browser testing
- Modular architecture + TypeScript

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IMPACT AND BENEFITS

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- **Hackathon Alignment & Impact:**
  - Directly tackles autonomous navigation with an innovative, practical,
  - and technically sound solution demonstrating real-world application.
- **Target Audience & Social Impact:**
  - Low-cost simulator for students and space enthusiasts,
  - making robotics and AI tangible and engaging while inspiring future innovators.
- **Economic & Research Benefits:**
  - Open-source platform for rapid algorithm testing,
  - reducing the cost and risk of physical hardware development.
- **Safety & Risk Reduction:**
  - Enables engineers to visualize missions and identify hazards,
  - protecting equipment and improving mission success.

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RESEARCH AND REFERENCES

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Procedural Terrain Generation:

- "Procedural Planet Generation based on derivate fBm noise," by d'Oliveira & Apolinario. https://www.sbgames.org/sbgames2018/files/papers/ComputacaoShort/188242.pdf
- "Procedural Generation of Planetary-Scale Terrains in Virtual Reality," by Dewey & Wang. https://scholarworks.calstate.edu/concern/theses/5d86p3338?locale=en

Pathfinding Algorithms:

- **A* & Dijkstra's Algorithm**
- **Resource:** The Algorithms. https://the-algorithms.com/

Validation Data:

- **NASA Mars Reconnaissance Orbiter (MRO) Mission Data.**
- **NASA JPL Machine Learning Datasets:** Publicly available datasets, including rover images and terrain data, for training and validation. https://ml.jpl.nasa.gov/datasets.html