SMART INDIA HACKATHON 2025

- **Problem Statement ID -** 25142
- **Problem Statement Title -** Student Innovation: Swadeshi for Atmanirbhar Bharat - Space Technology
- **Theme -** Space Technology
- **PS Category -** Software
- **Team ID -** 102815
- **Team Name -** Neelkantvarni

NEELKANTVARNI

PROPOSED SOLUTION

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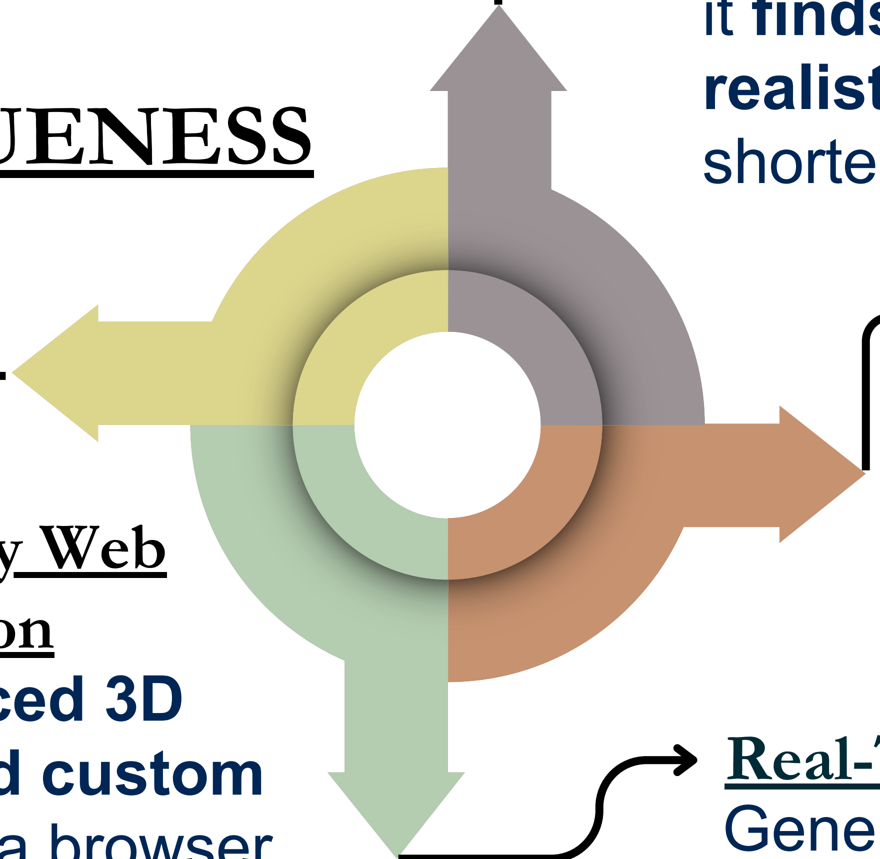
Planetary Rover Pathfinding Simulator: An **interactive 3D web simulator** designed to visualize rover navigation across unique, procedurally generated planetary landscapes. Its core innovation is a **slope-aware A* algorithm** that calculates the safest paths by **considering terrain difficulty, not just distance**. This **provides a crucial, risk-free virtual environment** for pre-mission analysis and optimization of autonomous navigation strategies.

INNOVATION & UNIQUENESS



Slope-Aware A Algorithm*
Incorporating slope and elevation, it **finds smarter, safer, and more realistic paths** than standard shortest-route pathfinders.

Seamless Dual-Control Mode
Switch instantly between autonomous AI and manual control to test decisions and explore alternative routes.

High-Fidelity Web Simulation
Runs **advanced 3D graphics and custom AI** directly in a browser, making it accessible for education, research, and hobbyists.

Real-Time Procedural Terrain
Generates vast, unique planetary landscapes on-the-fly, offering an **infinite testing ground for navigation AI.**

KEY FEATURES

Pathfinding Engine | Rover Control | Live Analytics | 3D Simulation

HOW IT ADDRESSES THE PROBLEM

OPTIMIZE EFFICIENCY

By selecting **slope-aware, power-saving paths** instead of just shortest ones, the rover can conserve energy and extend its mission.

LOWER MISSION RISK

Virtual terrain simulations help **identify and avoid dangerous routes before deployment**, reducing the chance of costly rover failures.

OPTIMIZE ROUTING

Endless procedurally generated terrains provide a tough training ground that makes the rover's autonomous **navigation more reliable.**

FAST INNOVATION

Rapid virtual testing **speeds up** software **improvement** while **reducing reliance** on expensive prototypes and testing facilities.

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TECHNICAL APPROACH

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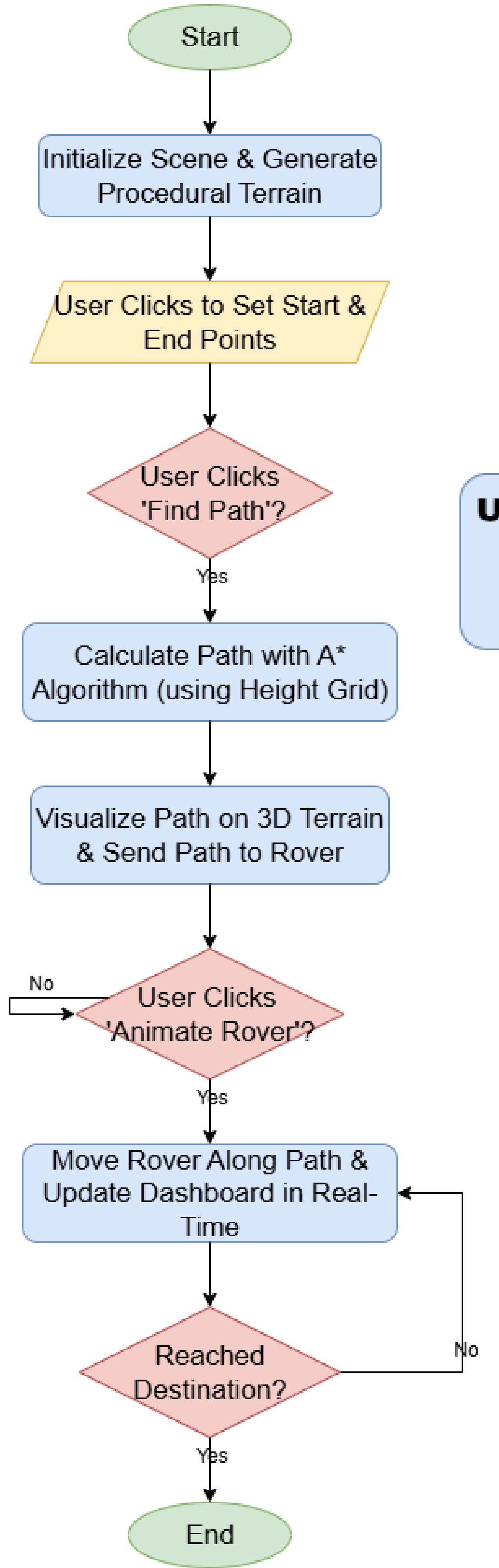
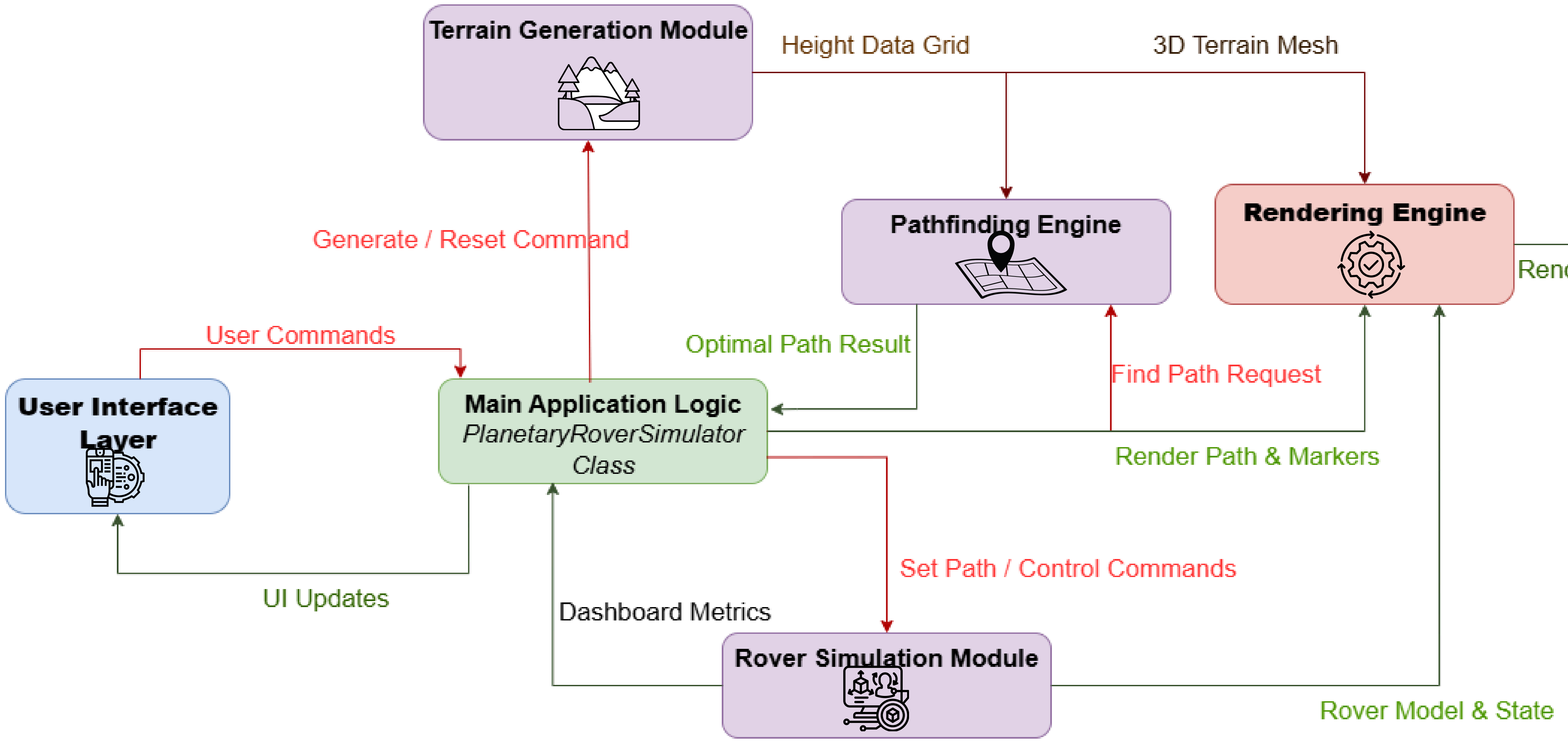
WORKFLOW



OUR PROPOSED SYSTEM



TECHNOLOGIES USED

WebGPU

VITE

WA WEBASSEMBLY

TS

WebGL

three.js

CSS

HTML

Rust

METHODOLOGIES

PHASE 1 : TERRAIN GENERATION

Establish the **3D environment** and implement procedural terrain generation using Perlin noise.

PHASE 2 : PATHFINDING LOGIC

The **slope-aware A* algorithm** to intelligently calculate paths based on terrain difficulty.

PHASE 3 : ROVER & UI

Create **the 3D rover model**, its movement physics, and the interactive mission control dashboard.

PHASE 4 : INTEGRATION & REFINEMENT

Integrate all systems, add **dual-control modes**, and refine the **user experience** with advanced features.

FEASIBILITY AND VIABILITY

CHALLENGES AND RISK

PERFORMANCE OPTIMIZATION

Heavy terrain and pathfinding can slow or freeze browsers.

ALGORITHMIC INTEGRATION

Integrating 3D, noise, and AI creates tricky bugs.

CROSS-PLATFORM SUPPORT

Different browsers and devices handle graphics inconsistently.

UX FOR COMPLEXITY

Balancing simplicity with advanced features is difficult.

STRATEGIES FOR OVERCOMING CHALLENGES

MITIGATING PERFORMANCE ISSUES

Run A* in a **Web Worker with a binary heap** for smooth, responsive pathfinding.

MANAGING INTEGRATION COMPLEXITY

Use modular architecture and TypeScript to isolate systems and prevent bugs.

ENSURING BROAD COMPATIBILITY

Leverage Three.js and test across major browsers for consistent performance.

DESIGNING AN INTUITIVE UX

Streamlined **UI with visual** feedback, tooltips, and a Quick Start guide.

FEASIBILITY ANALYSIS

TECHNICAL FEASIBILITY: HIGH

Mature tools like **Three.js, TypeScript**, and **A*** make development reliable.

RESOURCE FEASIBILITY: HIGH

Uses open-source software and **runs on any modern browser.**

ECONOMIC FEASIBILITY: HIGH

Free tools and no distribution costs **minimize financial risk.**

IMPACT AND BENEFITS

POTENTIAL IMPACT ON TARGET AUDIENCE

SPACE EXPLORATION COMMUNITY

Low-cost tool for testing paths and de-risking navigation before real missions.

DISASTER RESPONSE PLANNERS

Simulate and plan UGV routes in **hazardous, GPS-denied areas** for safer, more effective relief missions.

STEM EDUCATION

Interactive platform making robotics, algorithms, and procedural generation tangible for students.

BROADER BENEFITS

ECONOMIC BENEFIT

Cuts mission **risk** and pre-deployment **costs.**

SOCIAL BENEFIT

Makes space **navigation** fun and **accessible to everyone.**

TECHNOLOGICAL BENEFIT

Open-source platform driving robotics and simulation innovation.

EDUCATIONAL BENEFIT

Shows algorithms in action for **hands-on learning.**

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RESEARCH AND REFRENCES

Live Deployment: https://sih-2025-neelkantvarni.vercel.app/

Demo Video: https://youtu.be/EaWfp8M-nYg

Source Code: https://github.com/manojCodes77/SIH_2025_NEELKANTVARNI

Research Papers & Algorithms:

Pathfinding Algorithms (A & Dijkstra)*

- Hart, P. E.; Nilsson, N. J.; Raphael, B. (1968). "A Formal Basis for the Heuristic Determination of Minimum Cost Paths". IEEE Transactions on Systems Science and Cybernetics.
- Resource: The Algorithms

Procedural Terrain Generation

- d'Oliveira, F., & Apolinario, A. (2018). "Procedural Planet Generation based on derivate fBm noise". Proceedings of SBGames.
- Dewey, B., & Wang, H. (2021). "Procedural Generation of Planetary-Scale Terrains in Virtual Reality". CalState ScholarWorks.

Validation & Training Data

- NASA JPL Machine Learning Datasets: https://ml.jpl.nasa.gov/datasets.html
- NASA Mars Reconnaissance Orbiter (MRO) Mission Data: Used as reference for realistic Martian terrain characteristics.

Core Technology

- Three.js Library: https://threejs.org/