# P.R.A.H.A.R. Project Report

## Planetary Risk Assessment for Hazardous Asteroid Reentry

*A Scientific Initiative*

**Submitted By:**

NAME: Ishan Shrivas
REGISTRATION NUMBER: 25BAI10966

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### Abstract

The **P.R.A.H.A.R.** simulator is a command-line utility developed to model the physical impact and catastrophic effects of an asteroid strike. The project successfully translates simple physical inputs (diameter, density, velocity) into critical, real-world metrics (kinetic energy, TNT equivalent, and crater size). This report details the theoretical approach, implementation of core physics, rule-based hazard classification, and analysis of simulation results. The final application provides a scientifically grounded yet highly engaging, narrative framework for planetary defense assessment.

## Contents

# 1  Project Overview

The primary objective of the **P.R.A.H.A.R.** project was to create an accurate yet accessible simulation tool that highlights the devastating non-linear relationship between an asteroid's parameters and its impact energy.

## 1.1  Core Objectives

- **Physics Simulation:** Accurately calculate the Kinetic Energy ($KE$) of an impacting body.

- **Comparative Analysis:** Convert energy to Megatons (MT) of TNT equivalent and benchmark against major historical impact events.

- **Hazard Assessment:** Employ rule-based logic to categorize the threat level (Local, Regional, Global, Extinction).

- **Narrative Interface:** Provide a professional, phased workflow (Detection, Analysis, Trajectory) for user interaction.

# 2  Technical Approach and Implementation

The simulator was implemented using Python, structured around a modular design to ensure separation of concerns between input handling, physical calculations, and report generation.

## 2.1  Physical Constants and Data

Critical constants and reference data were defined upfront:

- The TNT energy equivalent: $1$ MT $\approx 4.184 \times 10^{15}$ Joules.

- **Density Presets (`Dens`):** Asteroid types (C-type: $1500$ kg/m$^3$, S-type: $3000$ kg/m$^3$, M-type: $7800$ kg/m$^3$) are used to simplify density input.

- **Historical Events (`Historical`):** Key events like Tunguska and Chicxulub serve as direct energy benchmarks.

## 2.2  Core Physics Functions

The simulation's accuracy relies on the implementation of classical mechanics formulas.

1. **Volume (`vol_sphere`):** Calculated assuming a spherical body based on the diameter $D$:
$$V = \frac{4}{3}\pi \left(\frac{D}{2}\right)^3$$

2. **Mass (`mass_from`):** Derived from the chosen density $\rho$ and calculated volume $V$: $m = \rho \times V$.

3. **Kinetic Energy (`ke`):** The fundamental measure of impact energy, where $v$ is the velocity in m/s:

$$KE = \frac{1}{2}mv^2$$

This function highlights the critical role of velocity in determining $KE$ due to its quadratic dependence.

4. **Crater Estimation (`crater_est`):** A simplified scaling rule is used to estimate the transient crater diameter $D_c$ (in meters) based on the Megatons yield ($E_{TNT}$): $D_c \propto 1000 \times \sqrt[3]{E_{TNT}}$.

## 2.3 Rule-Based Analysis and Comparison

**Hazard Classification**

The `hazard_level(mt)` function implements a conditional structure to categorize the threat based on $E_{TNT}$ (Megatons):

– **Local Event:** $E_{TNT} < 1$ MT

– **Regional Threat:** $1 \leq E_{TNT} < 100$ MT

– **Global Catastrophe:** $100 \leq E_{TNT} < 10,000$ MT

– **Extinction Level Event:** $E_{TNT} \geq 10,000$ MT

**Historical Similarity**

The `find_similar(mt)` function calculates the distance between the simulation's energy and historical event energies using logarithmic scaling ($\log_{10}(E)$). This prevents small differences in huge numbers from obscuring the genuine closest comparison across a vast energy spectrum.

# 3 Results and Analysis

The simulator provides quantitative proof of the disproportionate increase in destructive power as diameter and velocity rise.

## 3.1 Key Findings from Sample Runs

Table 1: Impact Simulation Results Table

| Scenario | Diameter (m) | Velocity (km/s) | $E_{TNT}$ (MT) | Crater Dia. (km) | Hazard L |
|---|---|---|---|---|---|
| Chelyabinsk (S-Type) | 20 | 18 | $\approx 0.72$ | 0.89 | LOCAL EV |
| Regional Test (M-Type) | 100 | 15 | $\approx 140$ | 5.20 | GLOBAL |
| Extinction Test (C-Type) | 10,000 | 20 | $\approx 3.1 \times 10^7$ | 314 | EXTINCTI |

## 3.2 Analysis of Implementation

**Velocity Dominance**

The tests confirmed the exponential effect of velocity. Doubling the velocity, while keeping mass constant, quadruples the $KE$, demonstrating the extreme difficulty of intercepting high-speed asteroids.

**Narrative Integration**

The inclusion of Indian names (e.g., *Vajra*) and ISRO references in the original program enhances project identity. The web application derived from this code retains the core physics while presenting the results in a clear, modern dashboard, providing a professional and engaging user experience. The color-coded hazard levels in the web interface provide immediate visual feedback, significantly improving the interpretation of results.

# 4 Conclusion and Future Work

The **P.R.A.H.A.R.** tool is a successful implementation of a physics-based simulation in a user-friendly format. It effectively communicates complex concepts like kinetic energy and Megatons equivalents. The project fulfills all original objectives, translating the terminal application's core logic into a professional, graphically styled report and a responsive web interface.

## 4.1 Future Enhancements

- **Atmospheric Modeling:** Introduce a basic model for atmospheric drag and airburst effects, which significantly alter the ground-level damage for smaller objects.

- **Target Material Consideration:** Allow selection of target type (e.g., ocean impact, granite, porous soil) to use more specialized crater scaling equations.

- **Visualization:** Integrate the web application with a library (like `d3.js`) to visually plot the blast radius and crater size relative to a geographical map.