Technical Document and Presentation Outline: AstroView

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github.com/trifida/AstroView

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Abstract

Despite extensive data on Near-Earth Objects (NEOs), a gap remains between scientific knowledge and public understanding of asteroid impact risks. This paper introduces **AstroView**, an intelligent platform developed for the NASA International Space Apps Challenge 2025 to visualize and assess asteroid impact risks. AstroView integrates physics-based models, geospatial visualization, and artificial intelligence to translate complex astronomical data into accessible insights. The system simulates impact effects, estimates population exposure, and generates natural language risk reports through hybrid AI. Built with Next.js, React, Python, and FastAPI, AstroView aims to democratize impact risk analysis, raising public awareness and supporting data-driven planetary defense strategies.

Contents

1 Introduction

1.1 Problem Statement

The threat of asteroid impacts, although statistically rare, represents one of the most significant existential risks to life on Earth. Space agencies such as NASA and the USGS collect vast amounts of data on Near-Earth Objects (NEOs) and our planet's geology. However, these data are often complex, scattered, and inaccessible to non-specialists, policymakers, and even the general public. There is a critical gap between the collection of scientific data and the ability to clearly and actionably communicate the consequences of a potential impact, hindering preparedness efforts and public awareness [Gisler et al., 2004, Collins et al., 2005, Robertson and Gisler, 2019, Fudali, 1989].

1.2 Objectives and Target Audience

The primary objective of AstroView is to bridge this gap by translating complex astronomical and geological data into a powerful, accessible, and interactive visualization and simulation tool [Wheeler et al., 2023]. Our platform is designed to serve multiple audiences:

- General Public, Students, and Enthusiasts: Provide an educational and visually captivating tool to learn about asteroid risks in an interactive way.
- Decision-makers and Civil Defense Agencies: Offer a clear, data-driven risk analysis dashboard that quantifies human and economic impact to support decision-making and contingency planning.
- Scientists and Researchers: Provide a "sandbox" to rapidly simulate impact scenarios, validate hypotheses, and communicate results effectively.

1.3 Project Context

This project was developed as part of the NASA International Space Apps Challenge 2025, responding to the "Meteor Madness" challenge. The challenge premise is to develop a tool that integrates NASA and USGS data to model, predict, and communicate the risks associated with the impact of a hypothetical asteroid, "Impactor-2025" [NASA, 2025, Survey, 2025].

2 Methodology and Development

We adopted an agile development approach, focused on building a modular and robust system within a 48-hour timeframe. The methodology was divided into three parallel work streams:

- Data Engineering and Machine Learning: Focus on collecting, cleaning, and analyzing data from NASA's NEO API, culminating in the training of a risk classification model.
- Backend Development: Building a centralized Python API that serves as the "brain" of the application, orchestrating impact physics, AI predictions, and geographic analysis.

- UI/UX Design and Frontend Development: Creating a modern, intuitive, and responsive user interface, with a focus on information clarity and immersive user experience.

3 Theoretical Framework

Our simulation is not based on assumptions, but rather on established scientific models. The core of our physics engine was inspired by the PAIR (Probabilistic Asteroid Impact Risk) model, documented in papers such as "A probabilistic asteroid impact risk model". We implemented the scaling equations from this model to calculate blast overpressure and thermal radiation damage, which are the dominant effects for sub-kilometer asteroids [Chomette et al., 2024]. For human impact analysis, we used population density data from the Gridded Population of the World (GPW) v4, provided by NASA's SEDAC.

4 Technologies Used

Table 1: Technologies Used in AstroView Development

Category	Technologies
Frontend	Next.js (React), TypeScript, Tailwind CSS Shadcn/UI, react-leaflet, react-three-fiber, recharts
Backend	Python, FastAPI, Pandas, NumPy
Machine Learning	Scikit-learn, Joblib
Generative AI	Google Gemini API
Geospatial Data	rasterio, geopandas
Version Control	Git, GitHub
Project Management	Trello

5 AI Functionality

Artificial Intelligence is a central pillar of AstroView, operating on two fronts:

- Predictive AI (Machine Learning): We trained a RandomForestClassifier model with real NASA data to automatically classify whether a simulated asteroid possesses characteristics of a "Potentially Hazardous Asteroid" (PHA). This model is part of a robust hybrid system that also uses physics-based safety rules to ensure reliability in extreme energy scenarios [Chomette et al., 2024].

- Generative AI (LLM): After each simulation, the numerical results (energy, damage radius, affected population) are sent to the Gemini API. The AI acts as a "Senior Risk Analyst," translating these numbers into a natural language report, with summary, risk analysis, and recommendations, making complex data immediately understandable to a decision-maker.

6 Dashboard and Application Differentiators

AstroView distinguishes itself from other tools through its user-centered approach and information clarity. As illustrated in Figure 1, the main dashboard provides immediate situational awareness through key performance indicators.

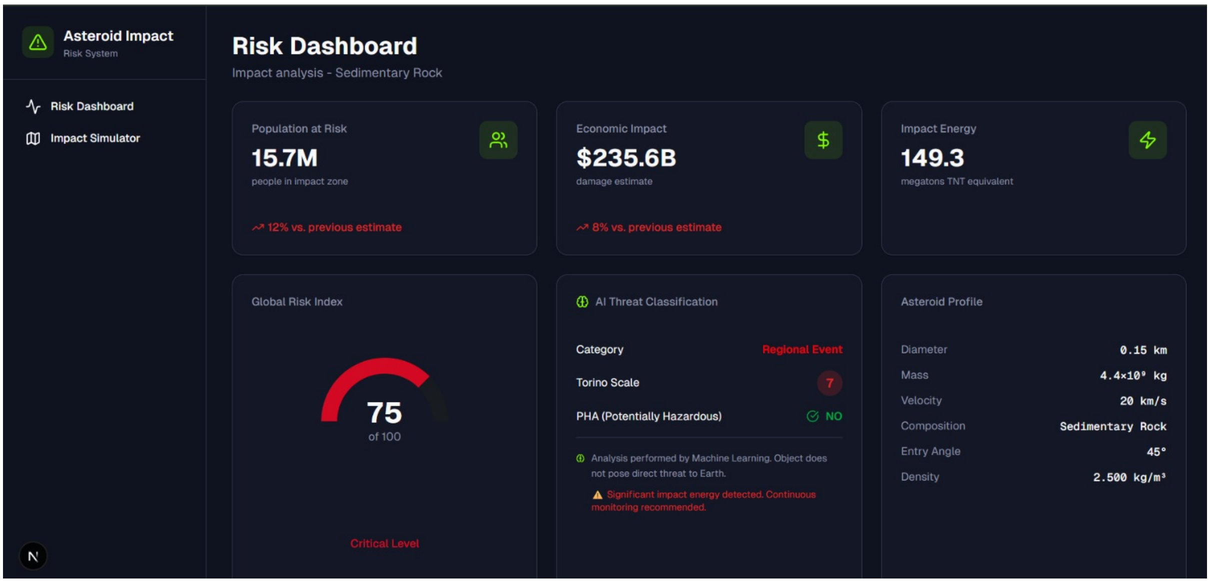

Figure 1: Main dashboard displaying Population at Risk, Economic Impact, and Risk Index

- Risk-Focused Dashboard: Instead of just showing physical data, our main dashboard translates everything into actionable KPIs: Population at Risk, Estimated Economic Impact, and Global Risk Index [Wheeler et al., 2023].
- Guided Experience (Wizard): Our simulator-wizard guides the user step-by-step through the complexity of configuring a simulation, making the process accessible to everyone.
- Hybrid AI System: The combination of a trained ML model with physics-based safety rules offers a superior level of reliability and sophistication.
- Effective Communication: The use of Generative AI to create narrative reports is a key differentiator, bridging the gap between data and action.
- Immersive Design: From the landing page with animated starfield background to the clean and professional dashboard design, the entire experience was designed to be captivating and credible.

7 Conclusion and Future Prospects

In just 48 hours, the team developed AstroView, a functional and robust platform that demonstrates it is possible to democratize access to asteroid impact risk analysis. We successfully integrated diverse data sources, implemented complex scientific models, and leveraged artificial intelligence to make the results both understandable and actionable.

Looking ahead, we plan to expand AstroView with several new features:

- Mitigation Simulation: Implement a "Test Deflection Strategies" tool that allows users to explore how a small "push" could alter an asteroid's trajectory.
- Gamification: Enhance the gamification component by introducing educational challenges to engage and inform users.
- Real-Time Data: Connect the 3D globe to NASA's API to display the real-time positions of known asteroids.
- Advanced Damage Analysis: Integrate infrastructure data (e.g., power plants, hospitals) to provide more detailed assessments of potential economic impacts.

8 Live Demonstration

A comprehensive video demonstration is available at:

https://youtube/System-Demo

The 5-minute demo showcases:

- Interactive simulation workflow
- 3D visualization capabilities
- AI-generated risk reports
- Dashboard analytics

Demo deployment: https://youtu.be/P89okHimy-8

References

[Chomette et al., 2024] Chomette, G., Wheeler, L., and Mathias, D. (2024). Machine learning for the prediction of local asteroid damages. *Acta Astronautica*, 219:250–263.

[Collins et al., 2005] Collins, G. S., Melosh, H. J., and Marcus, R. A. (2005). Earth impact effects program: A web-based computer program for calculating the regional environmental consequences of a meteoroid impact on earth. *Meteoritics & planetary science*, 40(6):817–840.

[Fudali, 1989] Fudali, R. (1989). : Impact cratering, a geologic process. *Journal of Geology*, 97(6):773–773.

[Gisler et al., 2004] Gisler, G. R., Weaver, R. P., Mader, C. L., and Gittings, M. L. (2004). Two-and three-dimensional asteroid impact simulations. *Computing in Science & Engineering*, 6(3):46–55.

[NASA, 2025] NASA (2025). Nasa open apis.

[Robertson and Gisler, 2019] Robertson, D. K. and Gisler, G. R. (2019). Near and far-field hazards of asteroid impacts in oceans. *Acta Astronautica*, 156:262–277.

[Survey, 2025] Survey, U. G. (2025). Search earthquake catalog. https://earthquake.usgs.gov/earthquakes/search/. Accessed: 2025-10-05.

[Wheeler et al., 2023] Wheeler, L., Dotson, J., Aftosmis, M., Stern, E., and Mathias, D. (2023). Introduction to asteroid impact risk assessment. In *8th IAA Planetary Defense Conference*.