ASTROSHIELD

TRACK: TECH FOR SOCIAL GOOD

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Team & Acknowledgement

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Acknowledgements:

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Overview

- AstroShield is a powerful tool designed to predict and prevent satellite collisions.
- It is intended for satellite operators, researchers, space enthusiasts, and anyone involved in satellite tracking and management.
- The app uses real-time data to simulate satellite orbits, detect potential collisions, and offer maneuver suggestions to avoid them.
- If two satellites come within 25 km, the system alerts potential collisions via an interactive Streamlit dashboard.
- Raise awareness about rising orbital congestion and risks.
- Provide a simple, interactive tool for early collision detection.

Problem

- Space is becoming dangerously crowded.
- Over 1,00,000 active satellites and space debris orbit Earth.
- Risks of satellite collision is rising, threatening communications, navigation, astronaut safety, global connectivity.
- It also causes orbital pollution, endangering future space operations.

Solution

- ASTROSHIELD – a real-time collision prediction tool.
- Fetches live satellite data from Celestrak.
- Displays results on a clean Streamlit interface.
- Predicts potential collisions using:
  - SGP4 orbital model
  - Euclidean distance calculations
  - Time to closest approach
- Allows threshold adjustment for fine-tuned collision sensitivity.
- Simulates secondary collisions and maneuver suggestions.

Tech Stack

- Frontend: Streamlit and plotly
- Data source: Celestrak’s GPS-OPS TLE set
- Backend:
  - sgp4: Orbital propagation using TLE data
  - requests: To fetch TLEs
  - numpy: For vector calculation
  - Pandas
  - Date and time
  - Random

Key Features

- •Real-Time Collision Detection using SGP4 and live TLE data
- • Secondary Collision Prediction after maneuver suggestions
- • 3D Orbit Visualization for multiple satellites using Plotly
- • Smart Maneuver Suggestions to avoid detected collisions
- • Live & Demo Modes for real and simulated scenarios
- • Interactive Streamlit UI with sidebar configuration
- • Threshold slider for Collision Risk Evaluation (customizable by user)
- • Relative Velocity and Time of Closest Approach computation

Future Scope

- Audio alerts and real-time notifications
- ML-Based Debris Pattern Forecasting:
  Use machine learning to identify future high-risk zones based on historical debris patterns.
- Machine Learning-based Maneuver Optimization: Smarter, fuel-efficient collision avoidance planning.
- User Authentication & Custom Dashboards: For organization-specific monitoring.
- Mobile App Interface: Expand accessibility for on-the-go tracking and alerts.

Business Viability

- Freemium SaaS Model: Offers basic collision alerts for free; premium plans for real-time monitoring, advanced analytics, and custom maneuver planning.
- Target Customers: Space agencies, satellite operators, private aerospace firms, defence organizations, universities, colleges and academic research centres.
- Revenue Channels: Subscriptions, API access, data insights services, integration with satellite fleet management tools.
- Market Need: With thousands of satellites in orbit and increasing space traffic, collision risk mitigation is critical for operational and financial sustainability.

Impact

- Enhances satellite traffic awareness
- Supports sustainability in space
- Helps reduce risk of orbital collisions and pollution
- Protects High-Value Missions like GPS, weather, and communication satellites.
- Reduces Space Debris by predicting and preventing satellite collisions

FEATURES OF ASTROSHIELD

1. Data Collection and TLE Fetching

What is TLE?

•TLE (Two-Line Element) sets are used to represent the orbital parameters of satellites.

How It Works:

•AstroShield fetches TLE data from CelesTrak.

•The app uses TLEs to propagate satellite orbits forward in time and detect potential collisions.

2. Satellite Orbit Propagation with SGP4

•SGP4 is an orbital model used to calculate the positions and velocities of satellites based on TLE data.

How It Works:

•The app uses the SGP4 model to propagate satellite positions and generate a trajectory over time. The model computes satellite positions at different time intervals (e.g., every minute) and predicts their movement for the next 90 minutes (or as specified).

•The satellite paths are displayed in a 3D orbit visualization, which helps users understand the movement of each satellite.

3. Collision Detection

•Collision detection involves calculating the distance between pairs of satellites to determine if they are on a collision course.

•If two satellites come within a specified threshold distance (e.g., 25 km), there is a potential risk of collision.

How It Works:

•The system checks the distance between all pairs of satellites.

•If the distance between any two satellites is smaller than the defined threshold (25 km by default), a collision risk warning is triggered.

•It calculates the closest approach time relative position and relative velocity between satellites to predict the likelihood of a collision.

•The system also accounts for **secondary collisions**, which may occur after a maneuver is applied.

4. Maneuver Suggestions

•A maneuver suggestion is a recommendation on how to adjust a satellite's orbit to avoid a collision.

•The suggestion is based on the relative velocities and positions of the two satellites at risk.

How It Works:

•Once a collision risk is detected, the app calculates the necessary velocity change to adjust the orbit of the satellite and avoid the collision.

•The system suggests a maneuver based on the relative positions and velocities of the two satellites involved.

5. Secondary Collision Prediction

What is Secondary Collision?

•Secondary collision refers to potential collisions that could occur as a result of maneuvering one or both of the satellites involved in the primary collision.

How It Works:

•After the maneuver is applied, the system re-checks satellite trajectories to detect new collision risks that may arise due to the changes in their orbits.

•This process helps simulate and predict the consequences of satellite maneuvers.

Step-by-Step Guide to Using AstroShield:

1. **Select Data Mode**:
   - Choose between Live Data or Demo Mode in the sidebar.
   - For Live Data, select the satellite group (e.g., GPS OPS, Starlink, ISS).
   - For Demo Mode, the app will automatically load predefined TLE data.
2. **Set Collision Threshold**:
   - Adjust the Collision Threshold slider (1 to 100 km) to define the distance at which a potential collision is flagged.
3. **View Satellite Orbits in 3D**:
   - Go to the 3D Orbit Visualization tab to view the satellite trajectories.
   - Rotate and zoom the 3D plot to track the movement of satellites(Due to network issues 3D plot may take longer time to load, view plot on full screen for better experience).

3. Check Collision Reports:

- Go to the Collision Reports tab to view any detected collision risks.
- If a collision is imminent, the app will show an alert box.

4. Review Maneuver Suggestions:

- The app will provide maneuver suggestions to avoid the collision.
- Check the recommended velocity change for each satellite to implement the maneuver.

5. Monitor Secondary Collisions:

- After applying a maneuver, re-check the satellite trajectories for any new collision risks (secondary collisions).

Thank you