**Title:** Prototype Tool for Space Traffic Visualization and Orbit Risk Classification using Live Satellite TLE Data  
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### Abstract

Understanding the complex orbital dynamics of artificial satellites is increasingly important in the modern era of space exploration and satellite communications. This project presents an interactive visualization and simple classification tool for Earth-orbiting satellites, using publicly available Two-Line Element (TLE) data. The project utilizes the Skyfield library in Python to process and visualize satellite positions in 3D space, and to classify satellites based on their orbital altitude and inclination. Satellites are categorized into Low Earth Orbit (LEO), Medium Earth Orbit (MEO), or Geostationary Orbit (GEO), with an additional "Risk Zone" label assigned to those at altitudes below 300 km. The visualization component, delivered as an interactive 3D plot, allows users to intuitively explore the spatial distribution of satellites around Earth. The goal of this project is to provide an educational tool that helps students and researchers better understand satellite orbits and the increasing density of objects in space. The entire project is implemented in an openly accessible Google Colab notebook and is provided under the MIT License for educational and research purposes.

**1. Introduction**

* Rapid increase in number of satellites (Starlink, OneWeb).
* Need for Space Situational Awareness (SSA) to avoid collisions.
* LEO becoming highly congested.
* Few tools available for intuitive visualization.
* Goal of this project: create a simple prototype tool that classifies and visualizes live satellite traffic.

**2. Methodology**

**2.1 Data Sources**

* Source: Celestrak (<https://celestrak.org>) → provides updated TLE data.
* TLE = Two Line Element → describes satellite orbit.

**2.2 Orbit Classification Tool**

* Python-based tool.
* Libraries used:
  + skyfield for orbit calculations.
  + pandas for data processing.
* Parameters extracted:
  + Altitude.
  + Inclination.
  + Orbit type:
    - LEO (<2000 km).
    - MEO (2000–35786 km).
    - GEO (>35786 km).
    - Polar (Inclination > 75°).
* Risk Zones defined:
  + <300 km → Drag risk zone.
  + 700–1000 km → Debris risk zone.
  + 35700–35850 km → GEO clutter zone.
  + Safe otherwise.
* Output saved as CSV.

**2.3 Visualization Tool**

* **3D Static Plot:**
  + Satellite positions shown around Earth.
  + Orbit type visualized by color.
  + Earth shown at center.
  + Interactive plot with rotation and zoom.
* Libraries used:
  + skyfield for position calculation.
  + plotly for visualization.

### 3. Results

#### 3.1 Overall Classification

A total of **11,757 satellites** were processed using the latest TLE (Two-Line Element) data.

The breakdown of orbit types is as follows:

| **Orbit Type** | **Number of Satellites** |
| --- | --- |
| LEO | 10,949 |
| MEO | 450 |
| GEO | 358 |

#### 3.2 Risk Zone Analysis

Out of the total satellites, **954** were classified in the **Risk Zone** (altitude < 300 km), representing satellites at increased risk of atmospheric re-entry or collision.

The remaining **10,803** satellites were classified as **Safe**.

**Sample of Risk Zone Satellites:**

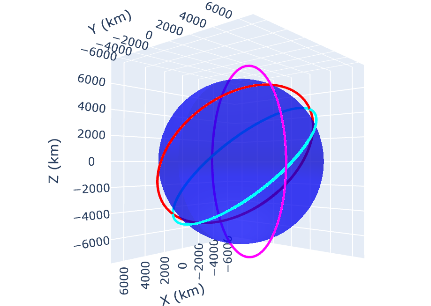
| **Satellite Name** | **Inclination (deg)** | **Altitude (km)** | **Orbit Type** | **Risk Zone** |
| --- | --- | --- | --- | --- |
| GENESIS 1 | 1.13 | 283.15 | LEO | Risk |
| GENESIS 2 | 1.13 | 344.40 | LEO | Risk |
| YAOGAN-6 | 1.70 | 227.66 | LEO | Risk |
| TELEOS-1 | 0.26 | 280.93 | LEO | Risk |
| CASSIOPE | 1.41 | 336.55 | LEO | Risk |
|  |  |  |  |  |
|  |  |  |  |  |
| ... |  |  |  |  |

## . Visualization

### 4.1 3D Visualization of Satellite Orbits

This figure shows a **3D interactive static visualization** of satellite orbits produced by the tool.

The visualization tool developed in this project is intended primarily for educational and awareness purposes. By providing an intuitive 3D interactive representation of satellite orbits, the tool enables students, educators, and general audiences to better understand the complex dynamics of Earth’s satellite population. It serves as an accessible entry point into topics such as orbital mechanics, satellite classification, and space traffic awareness, helping to bridge the gap between raw orbital data and visual understanding.



## 4

## 5. Conclusion

This project demonstrates a practical approach to classifying and visualizing satellite orbits using open-source tools and publicly available TLE data.

By providing an interactive 3D visualization along with automated classification of orbit types and risk zones, the tool enhances understanding of satellite distributions and supports greater public engagement with space data.

Such tools can be extended further to include real-time updates, collision risk assessment, or visualization of satellite constellations.

# **Visualization Tool**

The full project code and visualization tool are publicly available as a Google Colab notebook at: [https://colab.research.google.com/drive/1hwxmSmHoTvSP2ETFpvqwAS0gj5HNhksH?usp=sharing](https://colab.research.google.com/drive/1hwxmSmHoTvSP2ETFpvqwAS0gj5HNhksH?usp=sharing%20) provided under the MIT License.

# **Classification Tool**

<https://colab.research.google.com/drive/1fgkDKaTOB5PjZWVFaqB4sb7VQZCbbBC1?usp=sharing>

### Acknowledgments

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