Space Weather & Satellite Anomaly Analysis

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Github:
https://github.com/AM-31/Guvi-Data-Analytics-Project-3.git

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Contents

Introduction

Space weather, driven by solar flares and geomagnetic storms, has a significant impact on satellite operations. These high-energy events can disrupt communication, navigation, and power systems in orbit, leading to anomalies or even failures. By analyzing solar flare intensity, geomagnetic indices, and recorded satellite anomalies, we can uncover meaningful patterns that explain these disruptions. This project develops an interactive dashboard to visualize the relationship between space weather and satellite risks, providing a foundation for better prediction and enhanced satellite resilience.

“ Objectives

- Identify patterns in solar flare intensity and frequency.
- Analyze the impact of geomagnetic indices (Kp/Ap) on satellite performance.
- Explore correlations between flare classes and satellite anomalies.
- Build an interactive, visually appealing dashboard with filters.
- Support future prediction models for satellite risk assessment.

Dataset Description

Solar Flare Dataset

- Fields: Date, Flare Class (C, M, X), Intensity
- Source: Simulated dataset based on NOAA structure

Geomagnetic Index Dataset

- Fields: Date, Kp Index, Ap Index
- Source: Simulated dataset modeled after geomagnetic activity records

Satellite Anomalies Dataset

- Fields: Satellite ID, Date, Anomaly Type, Status
- Source: Synthetic dataset inspired by ESA/NASA anomaly reports

Methodology

1.Data Collection

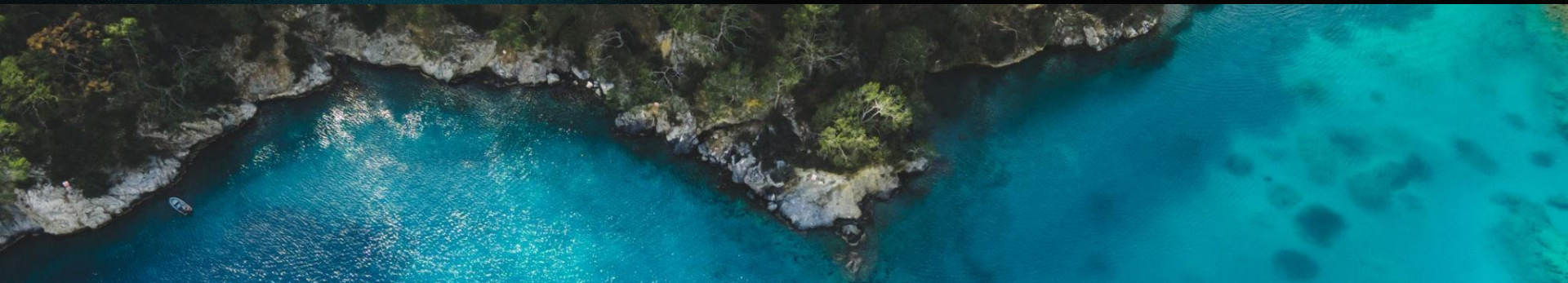
- Gathered datasets on solar flares, geomagnetic indices, and satellite anomalies.

2.Data Cleaning & Standardization

- Removed missing values and standardized timestamps into a unified format.

3.Data Integration

- Merged datasets into a single timeline to analyze relationships.



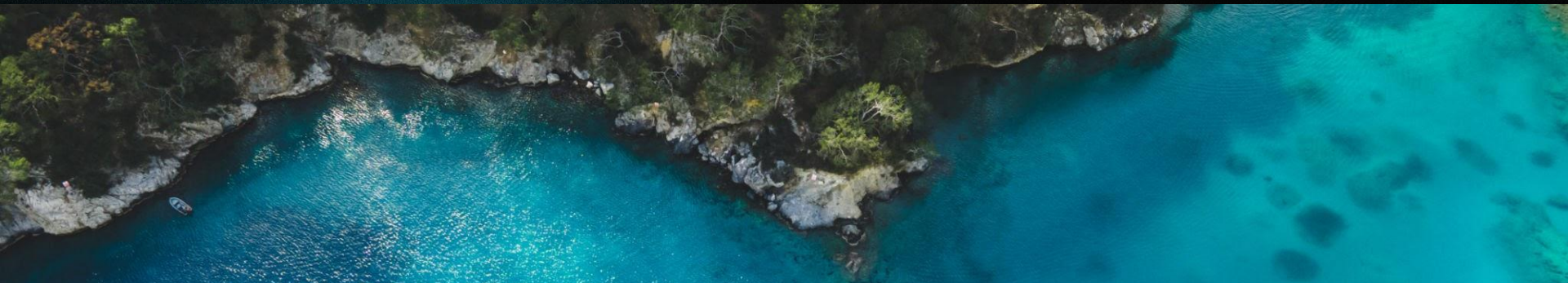
Methodology

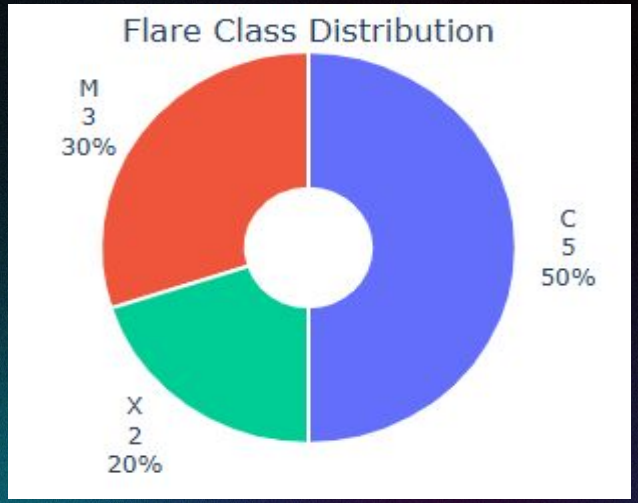
4.Feature Engineering

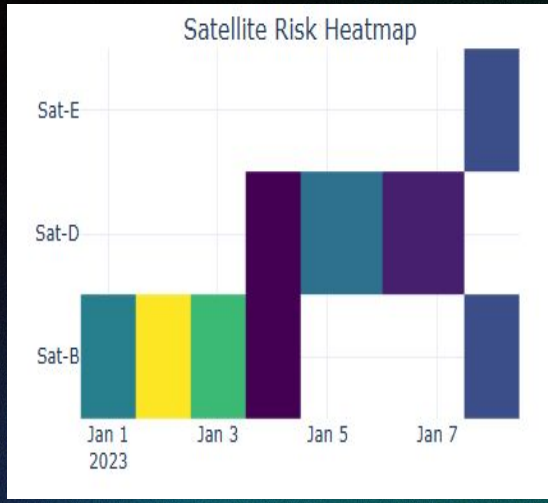
- Created derived features such as flare intensity levels and anomaly severity.

5.Exploratory Analysis & Visualisation

- Used charts, plots, and dashboards to identify correlations and trends.





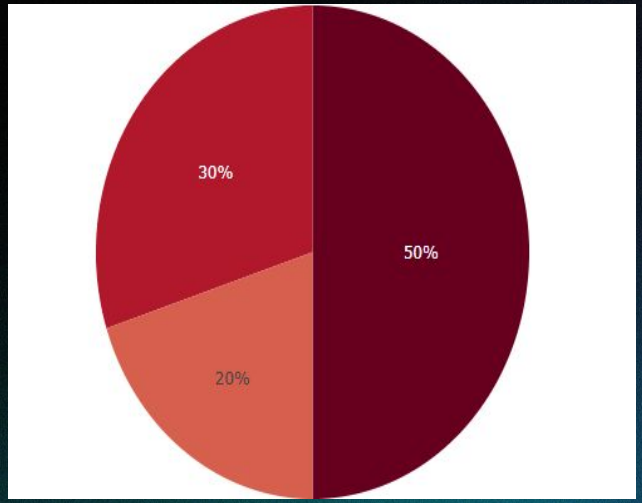


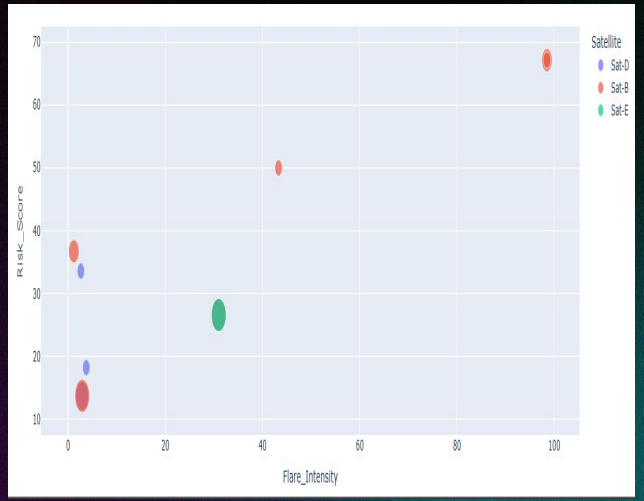
Trend Analysis
Solar flare frequency over time shows periodic peaks.

Flare Class Distribution
Majority of events are **C-class**, with fewer but more impactful **X-class** flares.

Geomagnetic Activity
High Kp/Ap values observed during flare peaks.

|Exploratory Data Analysis|





Satellite Anomalies

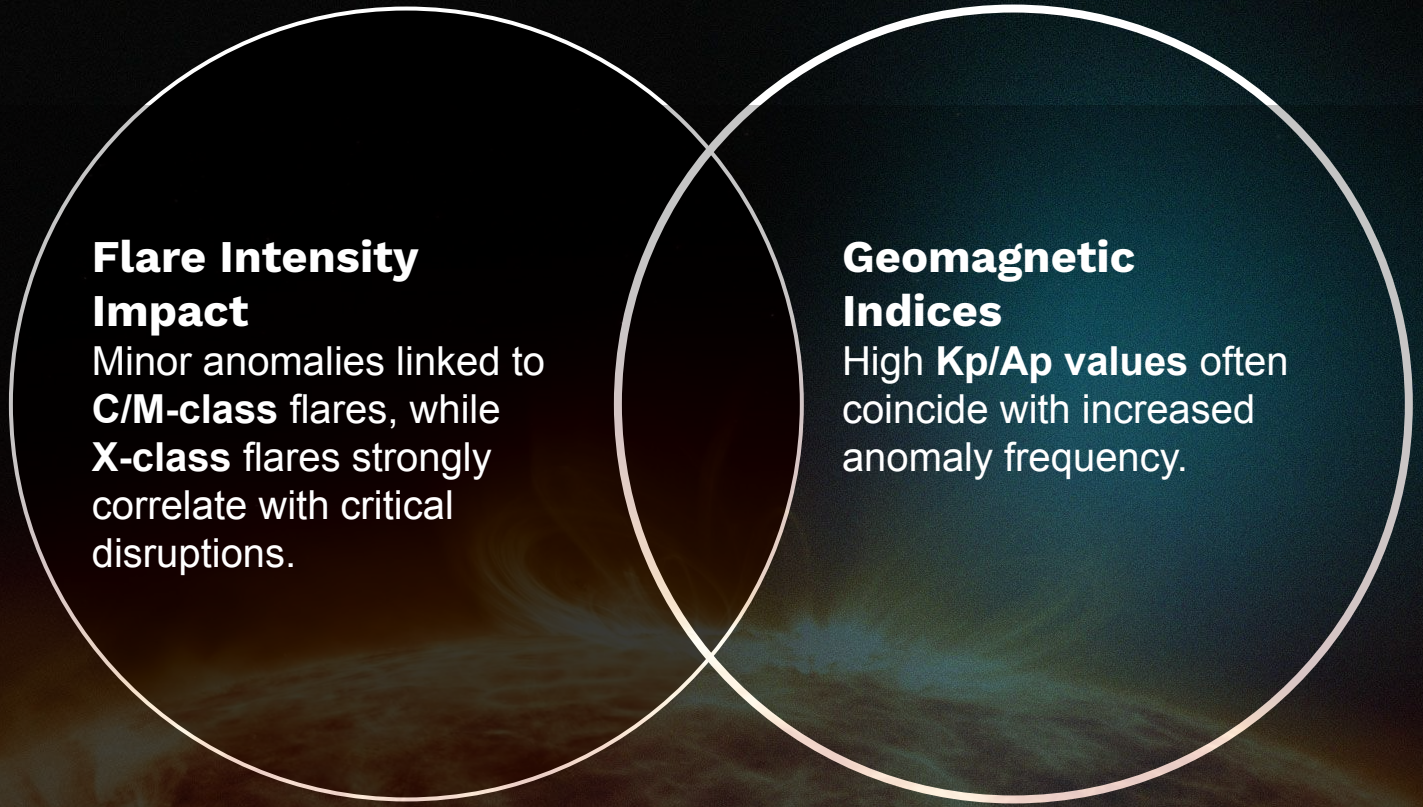
Noticeable spikes in anomalies following strong flares and high geomagnetic indices.

Correlation Check

Positive relationship between flare intensity and anomaly count.

|Exploratory Data Analysis|

INSIGHTS & INTERPRETATIONS



INSIGHTS & INTERPRETATIONS

Lag Effect
Some anomalies occur **hours after flares**, suggesting delayed impacts.

Risk Zones Identified
Threshold levels in flare intensity and geomagnetic activity indicate **high-risk periods** for satellites.

Interpretation
Space weather acts as a **leading indicator** of satellite performance issues, making monitoring essential.

Challenges Faced

Data Availability: Limited access to publicly available, well-structured space weather datasets.

Data Quality: Missing records, inconsistent timestamps, and measurement gaps.

Complex Correlations: Satellite anomalies influenced by multiple factors, not just flares.

Small Sample Size: Simulated datasets restrict the depth of statistical conclusions.

Real-time Integration: Difficulty in connecting live feeds (NOAA, ESA) to dashboards for continuous monitoring.

Conclusion

Space weather plays a critical role in determining satellite performance, with solar flares and geomagnetic storms often triggering anomalies that disrupt operations. Through this project, we demonstrated how data analytics can uncover meaningful patterns between flare intensity, geomagnetic indices, and satellite disruptions. The interactive dashboard provides a foundation for monitoring risks and highlights the importance of predictive modeling in space-weather research. While the study used simulated datasets, it lays the groundwork for integrating real-time data to enhance satellite safety, reliability, and resilience.

References

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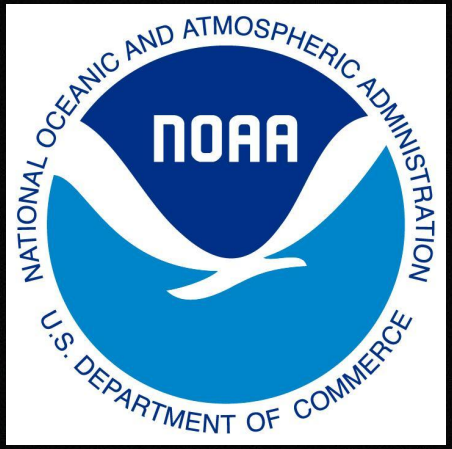
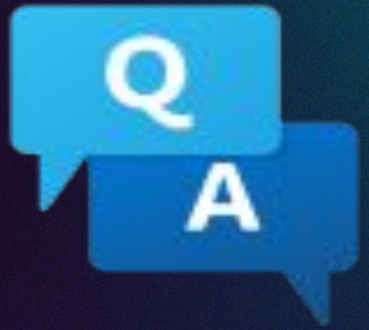


Q & A

- Feel free to ask any questions.
- Contact: arpita_2312res166@iitp.ac.in



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