ORBITAL CONGESTION REPORT

This document has been prepared by the authors
for the Space Situational Awareness Datathon facilitated by Women in Data (WiD) and United States Space Force to provide information, insights, and
data based on available research and analysis at the time of
publication. It reflects the authors' commitment to addressing limited access to space data and participation in space-focused innovation, especially for women and underrepresented groups.

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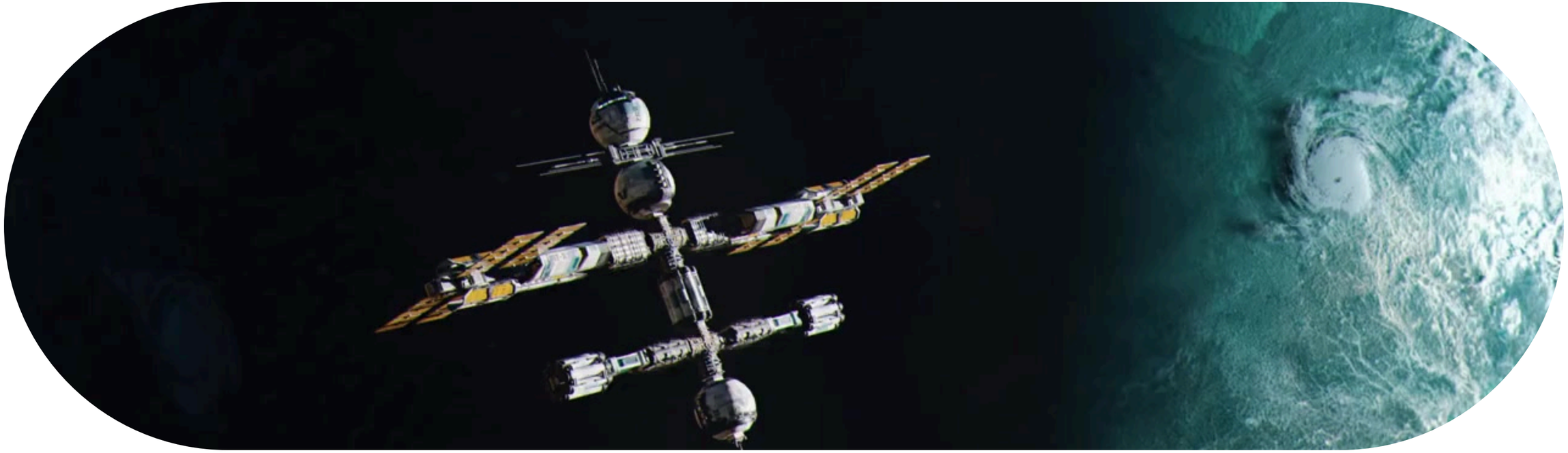

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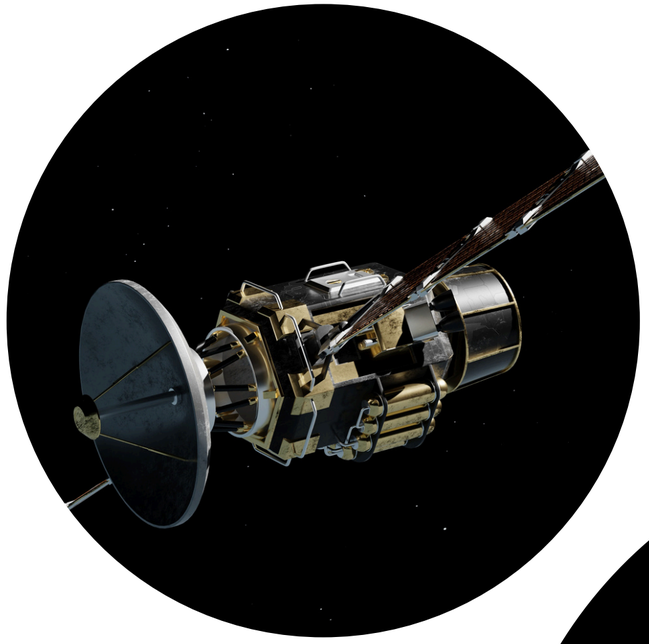


CHALLENGE

Enhance Space Situational Awareness (SSA) using open data

PROBLEM STATEMENT

The launch of thousands of satellites every year by governments, commercial companies, and private actors has led to increasing congestion of the Earth's orbital environment. This rapid growth, especially in Low Earth Orbit (LEO), poses rising risk of collisions, debris generation, and long-term sustainability challenges. Without clear monitoring tools, stakeholders struggle to identify altitude ranges and inclination bands with the highest object density.

OBJECTIVES

We aim to identify altitude & inclination hotspots, to assess if Low Earth Orbit (LEO) congestion is highly localized (especially around 550 km).

- Indicate where collision avoidance efforts or debris removal would have the most impact.
- Reinforce that mega-constellations dominate congestion patterns.
- Show key stakeholders exactly where the “traffic jams” are.

SPACE AWARE

STAKEHOLDERS

Space Agencies / Regulators such as FCC, UNOOSA, COPUOS, and even national agencies responsible for safe and sustainable space operations.

Satellite Operators at OneWeb, ESA, NASA, including commercial operators like SpaceX and Blue Origin in ensuring collision avoidance.

SSA Researchers at Lockheed Martin, LeoLabs, and NorthStar Earth & Space providing SSA data to enhance spaceflight safety.

Space Insurance Companies like AXA XL, Lockton, and Lloyd's for assessing liability and financial exposure from orbital collisions.

METHODOLOGY

Data Acquisition

combined datasets:
UDL (Elsets),
CelesTrak, SatCat

LEO Analysis

altitude bands,
inclination & RAAN
distributions, decay
candidates

Data Visualization

heat-map, density
plots, pie-chart,
growth trends

Filtering for LEO

<2000 KM Altitude

Orbital Bodies Classification

payloads vs rocket bodies vs debris

Presentation

insights,
recommendation,
and conclusion

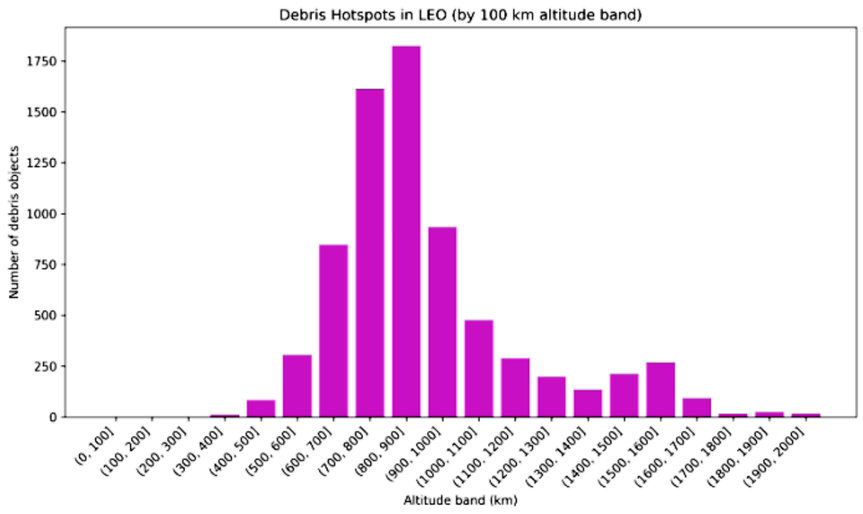
TOOLS

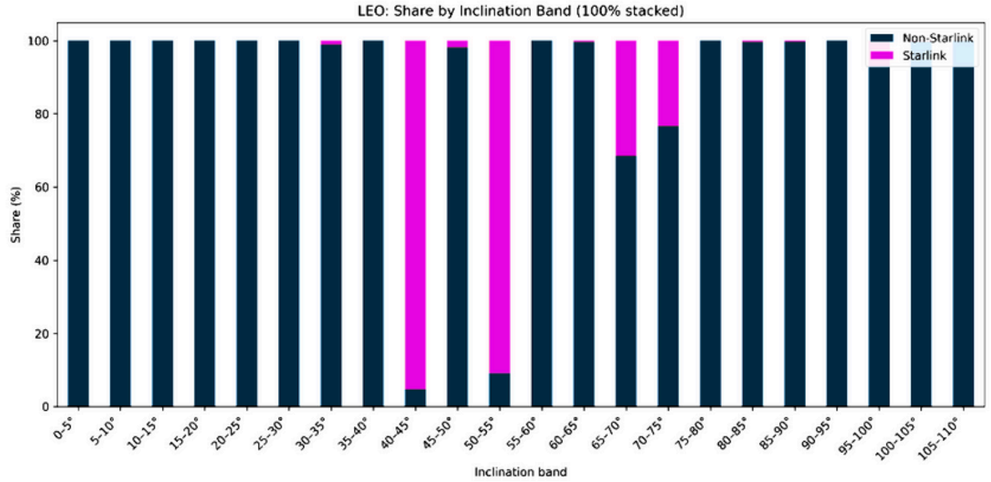
- Microsoft Teams
- Python Language
- Jupyter Notebook
- Google Docs
- Canva

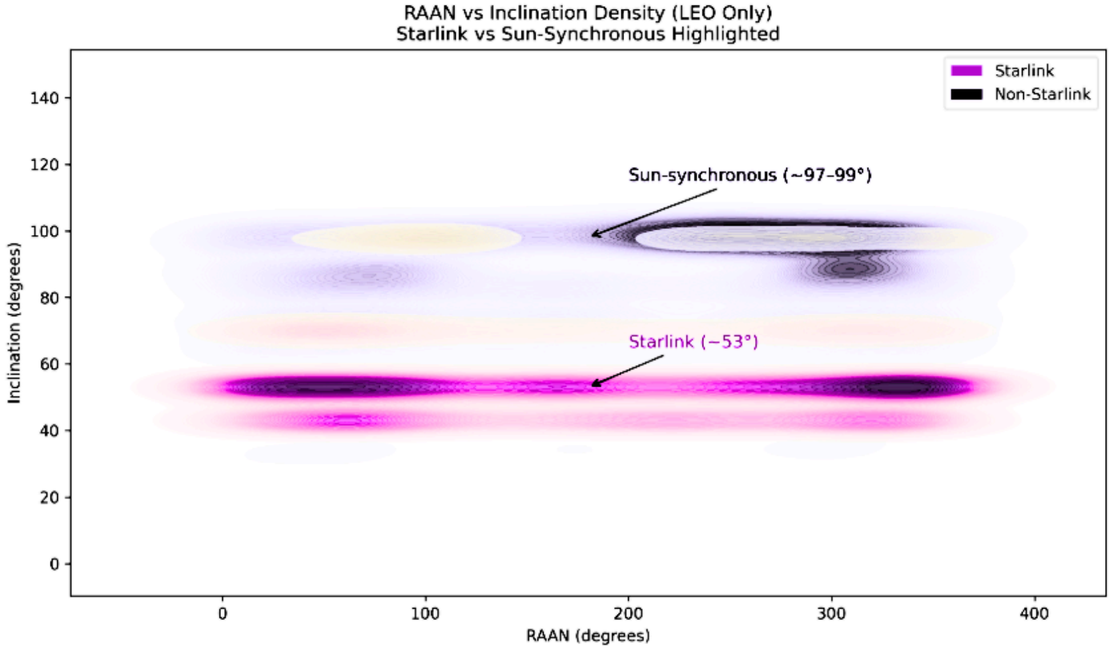
KEY FINDINGS

During our analysis, we discovered a **persistent debris belt**, the 700–1000 km band is the “graveyard” of long-lived debris which poses high risk for future collisions. Further analysis showed an overlap of active bodies and space debris at around 500–600 km.

Starlink & other constellations overlap with debris, raising conjunction concerns. Below 400 km of the LEO is the **natural decay region** where debris is short-lived. This represents an ongoing reentry stream, rather than permanent clutter.







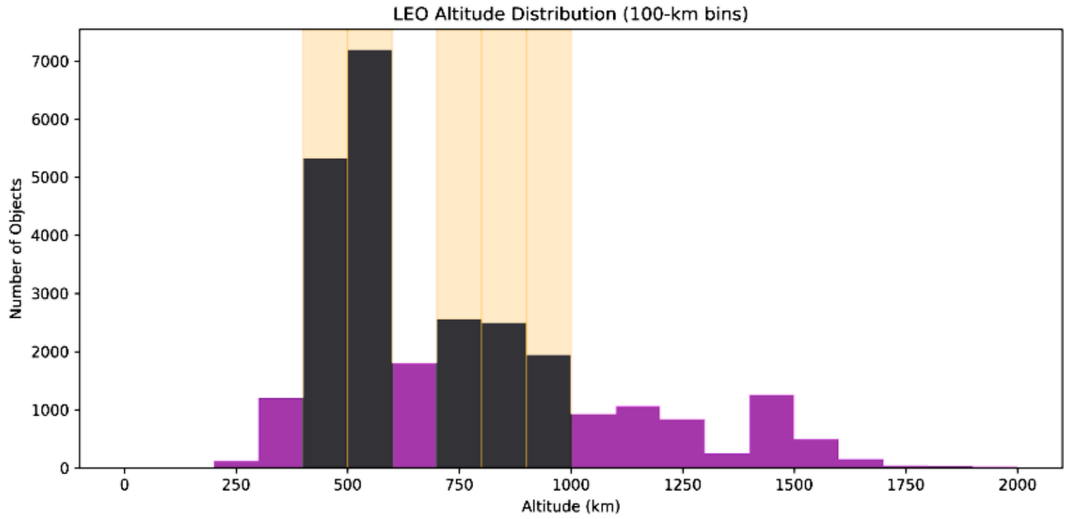
KEY FINDINGS

Altitude Hotspots:

- 500–600 km → Starlink shell
- 700–1000 km → legacy satellites + debris accumulation
- <300 km perigee: candidates for imminent decay

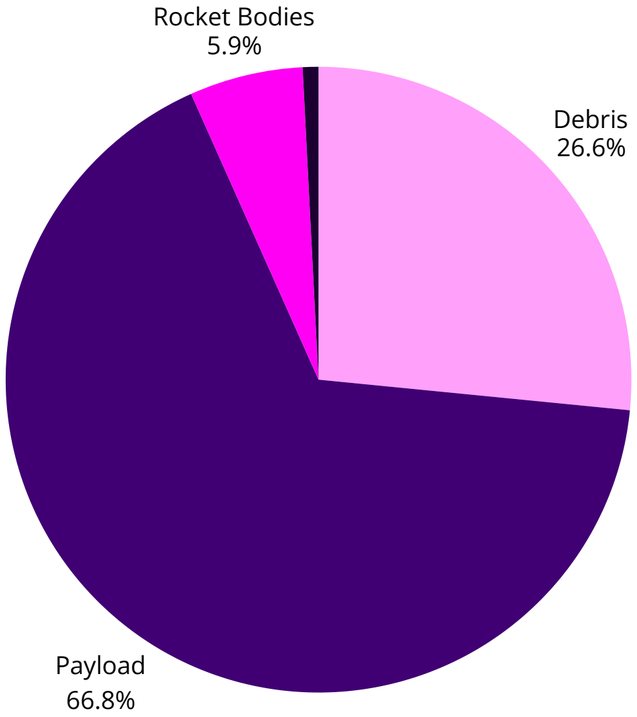
Inclination and RAAN:

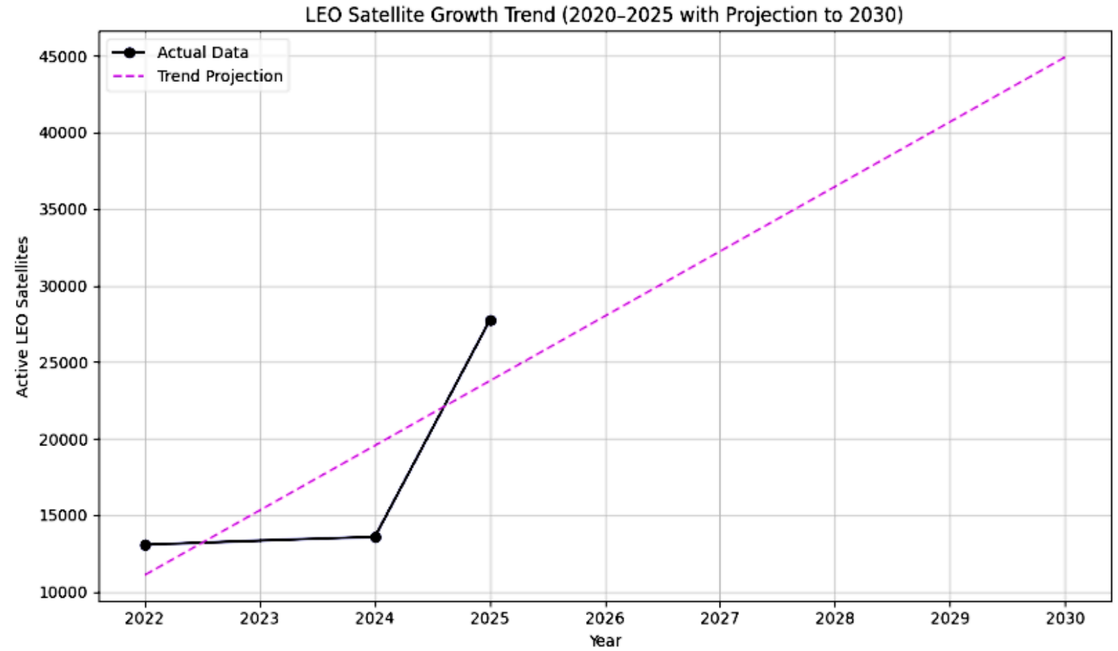
- 53° → Starlink planes
- 97–99° → Sun-synchronous orbits
- Congestion is clustered, not uniform



KEY FINDINGS

Distribution of orbital bodies in LEO



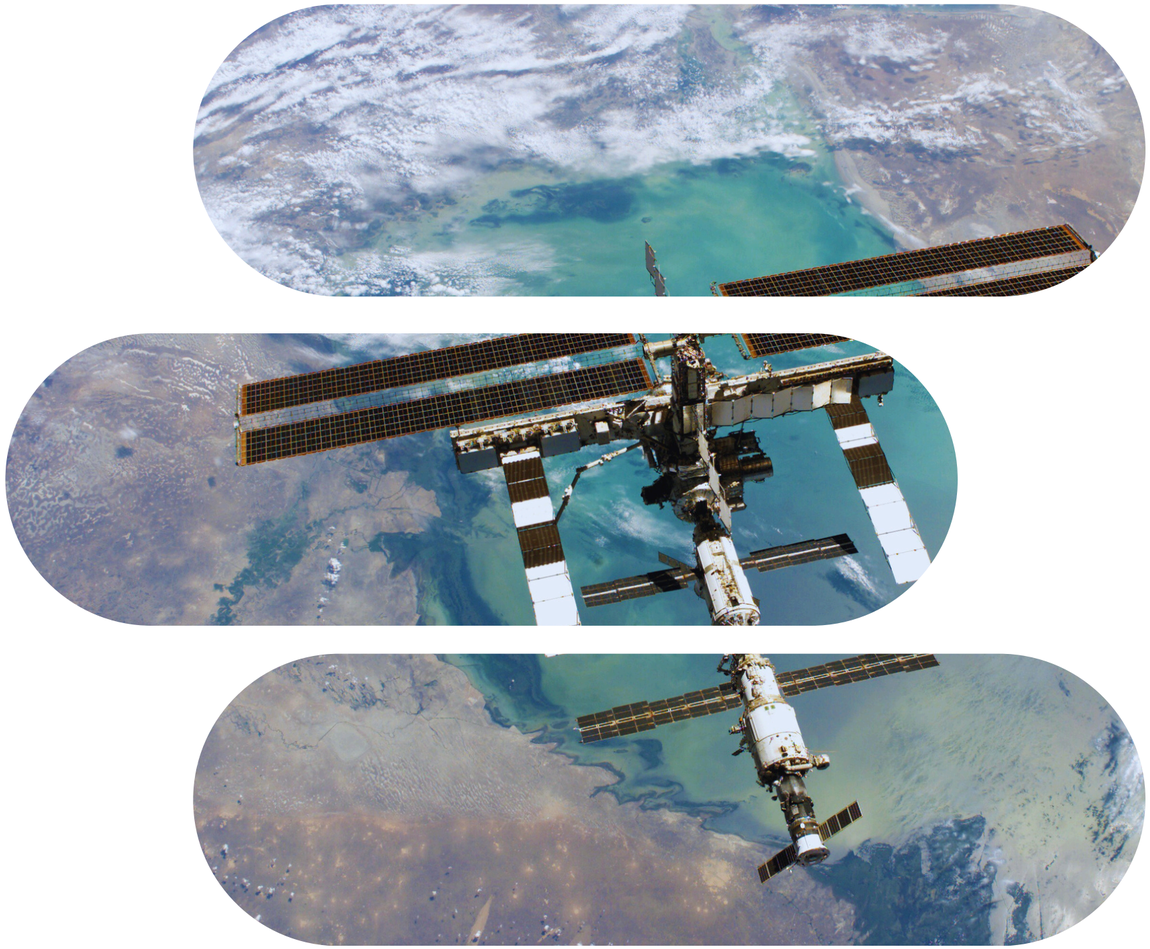


Approximate CAGR (2020–2025): 28.48%

- LEO satellites nearly doubled between 2022–2024
- CAGR ~28% → projection to >45,000 satellites by 2030
- Without debris mitigation, congestion will increase collision probability exponentially

SOLUTION HIGHLIGHTS

- This is a report on the analysis of merged UDL and SatCat datasets to identify altitude and inclination hotspots and assess orbital congestion in the Low Earth Orbit (LEO)
- The Orbital Congestion Report contributes to better space situational awareness by classifying orbital bodies, detecting hotspots, and flagging decay risks in LEO
- According to our prediction of LEO satellite growth—till 2030—the overlap of active bodies like Starlink with space debris at around 500–600 km poses significant operational and ethical considerations

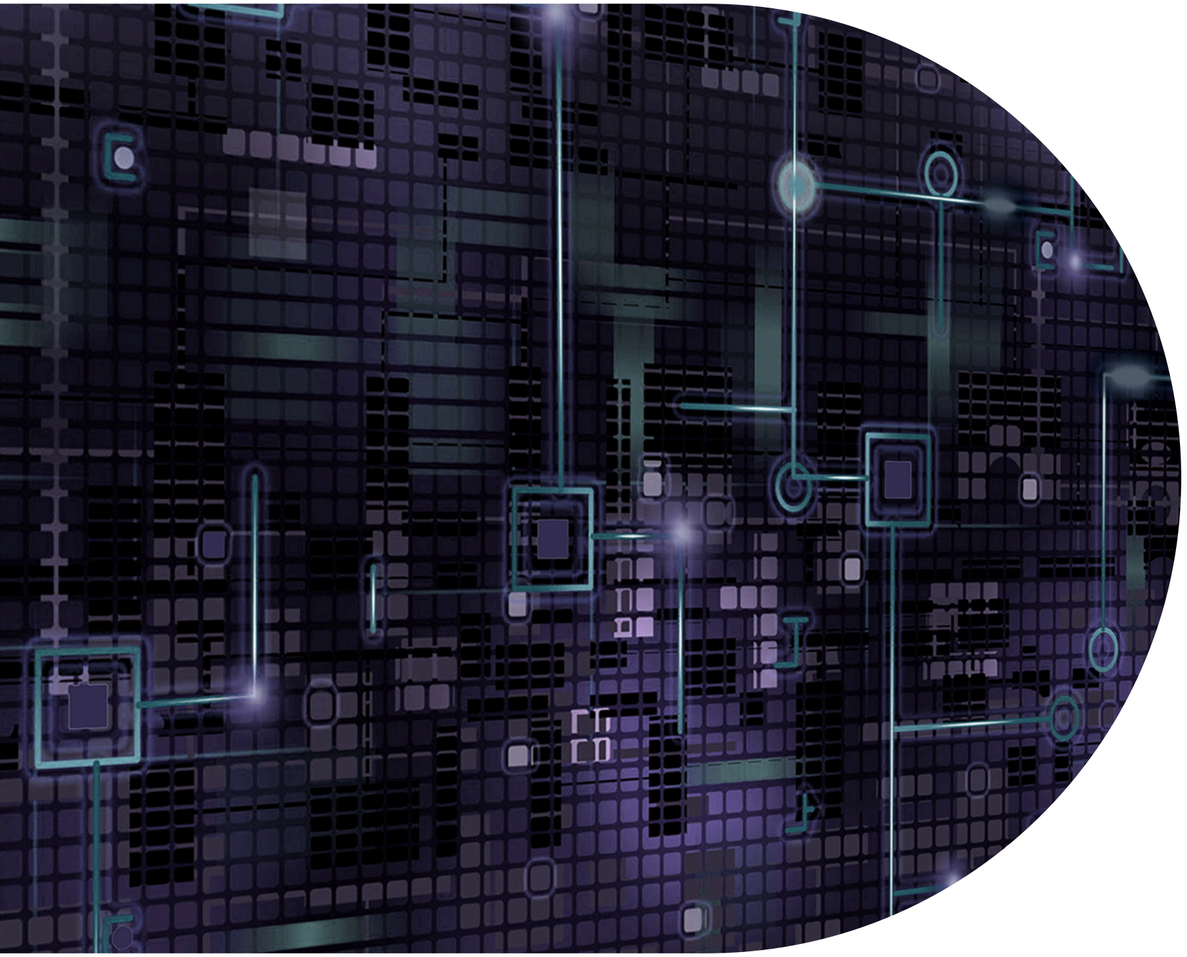


RECOMMENDATIONS

- Space Agencies/Regulators should champion policies that require satellite operators to register space objects, enforce debris mitigation, proper coordination of payloads, and post-mission disposal of rocket bodies to ensure long-term space sustainability.

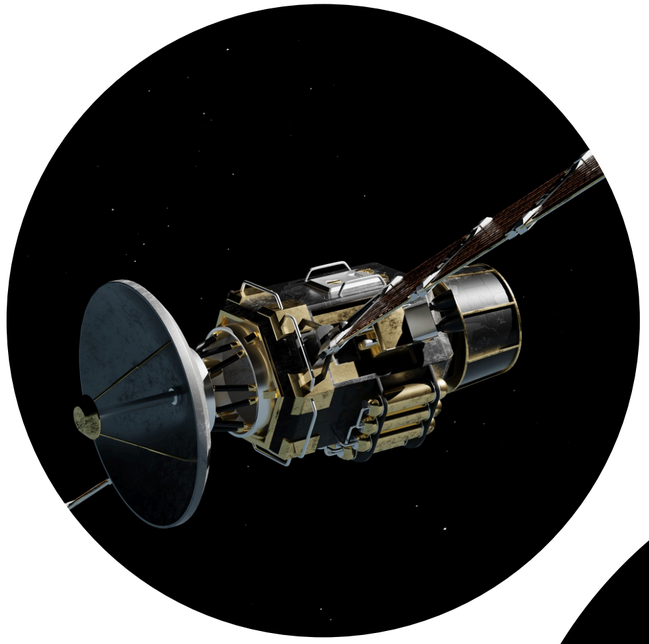
- Satellite Operators should implement automated systems for risk assessment and response that help strengthen collision avoidance, and adhere to established norms of behavior for space traffic management.

- SSA Researchers should integrate open space catalogs, participate in data-sharing agreements, and adhere to standard SSA data formats for cohesive workflows that enhance global space situational awareness and accessibility.



NEXT STEPS

Apply forecasting methods like ARIMA and Prophet to predict future congestion trends and support proactive planning to keep orbital growth sustainable.



CONCLUSION

In conclusion, collision avoidance efforts or debris removal would have the most impact where debris overlaps with active constellations, thus reinforcing that mega-constellations dominate congestion patterns as indicated in our findings.

The Orbital Congestion Report is highly valuable to the future of space data, particularly in the mitigation of orbital collisions that pose great risk to orbital safety.

CURIOUS?

You can access the full analysis, codes, and report at
https://github.com/kayeneii/OrbitalCongestionReport

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