Slipping Through Celestial Bars

How the Prisoner's Dilemma Can Help Us Avoid Earthly Confinement

Abstract

Access to reliable space traffic data is a prerequisite to most proposed orbital sustainability solutions, including collision avoidance systems and active debris removal. A global space traffic database would empower this by aggregating information from governmental and commercial actors, ground stations, tracking satellites, and AI-enabled cross-referencing. International disagreements over data sovereignty, proprietary information, sensitivity, and the free rider problem threaten to stall the development of this essential system. This essay explores how an orbital data repository could leverage data governance practices to foster international trust and makes the case for a multilateral, transparent, and accountable system inclusive of developing countries.

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Introduction

Whizzing above our heads at several times the speed of a bullet, an ever-increasing number of space debris threaten to render our planets' orbits unusable and trap humanity in a celestial trash prison[1]. According to the European Space Agency, over 36500 debris larger than 10 cm were orbiting Earth by December 2023, in addition to an estimated one million splinters larger than 1 centimetre in diameter[2]. Most proposed solutions to mitigate[3] or remediate[4] high-velocity orbital debris require widespread access to the amount, position, and type of debris. As of writing, this key prerequisite is not met. The requisite information exists but is fragmented across a variety of government and private databases, stemming action and increasing the risk of further collisions.

In February 2023, the 60th session of the Scientific and Technical Committee of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) recommended that the United Nations Office for Outer Space Affairs (UNOOSA) facilitate free and non-discriminatory access to reliable space situational awareness data[5]. Such a project requires a robust international space data governance framework. Whereas the world would benefit from such an orbital database, individual institutional and private data owners are perversely incentivized to withhold information, as this would confer them an information advantage over commercial or geopolitical competitors. In all cases, they are incentivized to reject any course of action that could place them at an information disadvantage. This can be represented as a prisoner's dilemma.

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[1] Pultarova, Tereza. 2023. How many satellites can we safely fit in Earth orbit? February 27. Accessed July 02, 2023. https://www.space.com/how-many-satellites-fit-safely-earth-orbit.

[2] European Space Agency. (2023, December 06). Space Environment Statistics. Retrieved January 15, 2024, from https://sdup.esoc.esa.int/discosweb/statistics/.

[3] United Nations Office for Outer Space Affairs. (2007, December 22). Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space. Vienna, Austria.

[4] Colvin, T. J., Karcz, J., & Wusk, G. (2023). Cost and Benefit Analysis of Orbital Debris Remediation. Washington, D.C.: NASA Office of Technology, Policy, and Strategy.

[5] United Nations Office for Outer Space Affairs. (2007, December 22). Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space. Vienna, Austria. 197

		Actor A	
		Cooperate	Defect
Actor B	Cooperate	No actor has an information advantage. Optimal debris mitigation and remediation solutions are available.	Actor A has an information advantage over Actor B Partial debris mitigation and remediation solutions are available
	Defect	Actor B has an information advantage over Actor A Partial debris mitigation and remediation solutions are available	Less opportunity for information advantages Few debris mitigation and remediation solutions are available

In this Prisoners' Dilemma framework, cooperation means volunteering data in good faith, while defection refers to withholding or falsifying data. To prevent an information disadvantage relative to other players, actors are incentivized to defect, hindering international cooperation.

This essay contends that, with the right conditions, a global orbital traffic database including active and inactive space objects orbiting earth can solve the dilemma in favour of cooperation and lead to mutually beneficial outcomes. The database would begin by aggregating existing information into a transparent and freely accessible repository, augmented by data ownership rules enabling AI-powered modelling. A network of observation stations would provide verification and contribute to refining the model.

<u>Transparent source data</u>

Establishing an effective orbital debris database requires gathering data from a variety of sources, ranging from national satellite registries[6] to government[7] and commercial[8] debris trackers. Initial participants may hesitate to share data, but offering full database access can mitigate mistrust. The U.S.' decision in late 2023 to transfer military tracking data to civilian

[6] Jakhu, R. S., Jasani, B., & McDowell, J. C. (2018). Critical issues related to registration of space objects and transparency of space activities. Acta Astronautica, 406-420.

[7] Weeden, B. (2011). Overview of the legal and policy challenges of orbital debris removal. Space Policy, 38-43. p.41

[8] Garber, S. J., & Rand, L. R. (2022). A Montreal Protocol for Space Junk? Issues in Science and Technology, 20-22. p.21

control [9] signals political readiness to declassify and de-securitize orbital information, underscoring the feasibility of this endeavour.

Although the measured area remains identical, variations in resources, positions, and priorities lead to different observers tracking different objects. A large volume of redundant data can create a situation of "mutually assured transparency." Data aggregation widens coverage compared to individual sources, enhancing reliability through overlapping authenticity checks[10]. Redundancy also deters deceitful submissions by raising the chances of detection. Beyond a critical number of contributors to the database assumed to be cooperating, the calculus for each individual actor shifts in favour of maintaining cooperation.

		Actor A	
		Cooperate	**Defect**
All other actors	**Cooperate**	No actor has an information advantage.	Actor A has an information disadvantage relative to other actors

Actors defecting risk isolation from the database, losing access to valuable data worth more than what they withhold. Furthermore, misleading data would become harder to conceal, diminishing the database's potential as a disinformation tool.

<u>Data ownership</u>

Initial data contributors are likely to show reluctance at the prospect of surrendering ownership of their data[11], whether for commercial or sensitivity reasons. A space situational awareness database can address this challenge by leveraging blockchain technology to simultaneously enable data sharing while allowing contributors to maintain ownership over their

[9] Lopez, C. T. (2022, October 21). U.S. Space Command to Transfer Space Object Tracking to Department of Commerce . Washington, D.C., United States.
[10] Borowitz, M. (2019). Strategic Implications of the Proliferation of Space Situational Awareness Technology and Information: Lessons Learned from the Remote Sensing Sector. Space Policy, 18-27. p.23
[11] Raygan, R. E. (2017). The Ultimate Big Data Enterprise Initiative: Defining Functional Capabilities for an International Information System (IIS) for Orbital Space Data (OSD) . Proceedings of the Advanced Maui Optical and Space Surveillance (AMOS) Technologies Conference (pp. 1-9). Maui, Hawaii: The Maui Economic Development Board.

data. This can be accomplished by structuring the database across a blockchain. Storing orbital debris data from multiple providers on a blockchain ensures transparency, immutability[12], and decentralized control, safeguarding against data manipulation or tampering[13] while maintaining contributors' ownership rights. This approach fosters trust and collaboration among stakeholders while enabling secure and efficient data sharing.

An effective database would aggregate and process data using artificial intelligence to model orbits and predict collision[14]. Contributors retain ownership of contributed data, while data generated from it would become UNOOSA's property. Such a framework would enable the database to progressively reduce its reliance on proprietary data, ensuring open, free, non-discriminatory access, even in the event of contributors withholding data.

A robust verification system

A shared space debris database would be most effective if coupled with an autonomous network of ground-based orbital observation stations. This initiative would enhance resilience against dominant data providers and allow for an additional guarantee of data reliability. Furthermore, the collected data could serve to refine the AI-powered orbital tracking model.

Such a network would additionally promote inclusion of underrepresented developing states, who are otherwise underrepresented in orbital data ownership[15]. While resource-intensive, prioritizing centre construction in developing states ensures a valuable return on investment, fostering knowledge exchange, talent development, and domestic space industry growth, leading to orbits that are both more sustainable and more inclusive.

Conclusion

[12] Molesky, M. J., Cameron, E. A., Jones, J., Esposito, M., Cohen, L., & Beauregard, C. (2018). Blockchain Network for Space Object Location Gathering. . IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON) , (pp. 1226–1232). Vancouver, BC, Canada.
[13] Surdi, S. A. (2020). Space Situational Awareness through Blockchain technology. Journal of Space Safety Engineering, 295-301.
[14] Kyriakopoulos, G. D., Pazartzis, P., Koskina, A., & Bourcha, C. (2011). Artificial Intelligence and Space Situational Awareness: Data Processing and Sharing in Debris-crowded Areas. Proc. 8th European Conference on Space Debris (pp. 1-11). Darmstadt: ESA Space Debris Office.
[15] Ferreira-Snyman, A. (2013). The environmental responsibility of states for space debris and the implications for developing countries in Africa. The Comparative and International Law Journal of Southern Africa, 19-51. p.42

Although a space situational awareness database would likely face data sensitivity and geopolitical hurdles, scientific cooperation has a history of resilience to international tensions[16]. Recognising the situation of a prisoner's dilemma enables solutions based on mutual transparency, non-discriminatory access, built-in data reliability, and accountability. Technological advancements and the inclusion of a more diverse set of actors will cement an orbital debris database as a keystone for broader debris mitigation and remediation efforts, empowering humanity to reappropriate its planet's orbits.

[16] Mauduit, J-C. 2018. " Collaboration around the International Space Station: science for diplomacy and its implication for US-Russia and China relations." Proceedings of 7th Annual SAIS Asia Conference. Washington, D.C.: Secure World Foundation. 1-17.

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