Space logistics

Why rules matter for safety, security and sustainability

RAJESWARI PILLAI RAJAGOPALAN

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About the author

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Executive summary

With space activities expanding at an unprecedented rate, driven in part by a growing number of commercial players, space logistics is becoming increasingly critical to ensure the sustainable use of space. Space logistics encompasses a range of activities, including the remote maintenance of satellites in orbit, delivering supplies to space stations and satellites—possibly in the future to lunar and Martian habitats—and efforts to address the growing problem of space debris. The key issues that need to be addressed related to space logistics are the dual-use nature of rendezvous and proximity operations (RPOs), their consequences in terms of space debris, and the sustainability and governance of the arena.

RPOs, which are civilian and peaceful, form a critical component of space logistics, but they also raise new challenges. Given the current geopolitical context, security concerns regarding RPOs have been growing. States don't feel confident that technologies designed to remove space debris could not also be used in disruptive ways, such as damaging or interfering with satellites that belong to others. Such dual-use capabilities raise questions about intent: are they solely for peaceful purposes, or could they be employed with malicious intent? For example, the manner in which China has used its fishing fleet and maritime militia can be expected to be replicated in outer space activities in which civilian activities are used as a cover for offensive and aggressive behaviour.

There are currently no internationally agreed upon rules of engagement governing RPOs. This is a gap that will be exploited by various space actors if not addressed. Developing norms and even adopting an ethical approach to RPOs in order to beef up the safety, security and sustainability of space should become a priority for all stakeholders, including commercial actors, who stand to lose even more than state actors. And developing norms or rules before major incidents occur would also reduce the likelihood of governments lurching the other way, from no rules to complete constraint.

Setting the context

A day without access to outer space is unimaginable, given its centrality to daily life, from weather forecasting to internet access. Yet that could very well become a reality in the near future if space isn't used in a safe, secure and sustainable manner. Such disruption of space is a very real prospect not merely for a day but for weeks or months, due to either war or accident. This is partly due to the lack of acknowledgement and appreciation of the criticality of outer space in our daily lives.

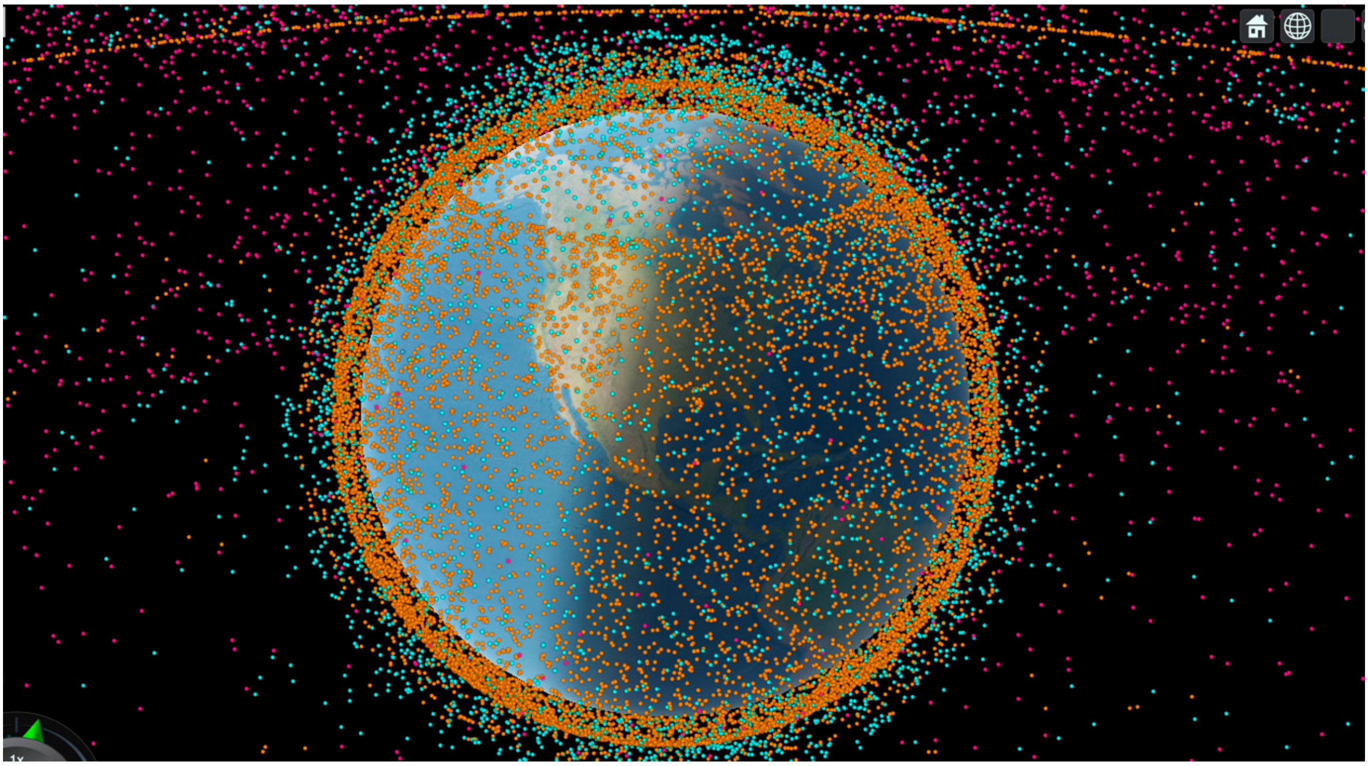
The competition in space has heightened, and the weaponisation of space is picking up momentum. In addition to many new challenges, the Russian plan to put in orbit either a nuclear-powered military satellite or even a nuclear explosive device will further worsen the situation.[1] Further, recent reports of NASA's plans to build a nuclear power plant on the Moon by 2030 to be a steady source of power for lunar bases and habitats can trigger more competition in space.[2]

Space is a fundamentally different environment now from what it was just a few decades ago. From being dominated by a handful of states, today there are more than 100 active players—from start-ups and small and medium-sized enterprises to major industry actors. That growth has complicated our ability to access and operate in space in a safe, secure and sustainable manner. The democratisation of space has shifted the traditional model, in which space was the exclusive domain of government space agencies.

A growing number of satellites and the amount of debris in orbit has made space increasingly dense and congested, leading to problems such as radiofrequency interference and the need for space traffic management (Figure 1).[3] Those issues have direct implications for continued access to space. They underscore the urgent need to promote the sustainable use of space in order to preserve it for future generations. But challenges in space are only partly technical;

the biggest impediments are political in nature, leading to lack of consensus among the major powers about both threats and solutions. The key issues that need to be addressed related to space logistics are the dual-use nature of RPOs (rendezvous and proximity operations), their consequences in terms of space debris, and sustainability and governance of the arena.

Figure 1: The near-Earth space environment—active satellites in orange; the rest are inactive satellites, debris and rocket bodies



Source: AstriaGraph, University of Texas, online.

Recognising that space is truly a global common is essential because outer space is shared by all of humanity and all have equal right to access and utilise it. Thus, framing some shared global space rules, even as differences in national space priorities and technological maturity and sophistication among states persist, is in everyone's interest.

While all the major space powers acknowledge this, great power politics has hampered efforts at rule-making, including reviewing the existing mechanisms. The Outer Space Treaty (OST) of 1967 continues to be the foundational treaty governing outer space activities but, given that the treaty is almost six decades old, it has some critical gaps, including not considering threats in outer space that are unrelated to weapons of mass destruction. There are four additional treaties that build on the principles contained in the OST:

- The Rescue Agreement (1968) deals with the safe return of astronauts and objects back to Earth.
- The Liability Convention (1972) holds countries liable for damage caused by their space objects.
- The Registration Convention (1976) requires states to register space objects with the UN.
- The Moon Agreement (1984) governs the use of lunar resources, although it has limited support.

The five treaties together constitute the international space regime that governs activities in outer space.

In recent years, there have been multiple efforts at framing new rules, including: the EU's International Code of Conduct for Outer Space Activities, proposed in the early 2010s;[4] the Russia–China co-sponsored draft 'Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects' (2008, 2014)[5] and several groups of governmental experts and open-ended working groups in the past decade that have focused on space security, none of which has produced any meaningful outcome.[6]

Given that those multilateral efforts haven't been fruitful, minilaterals such as the Quad could play a useful role because all four Quad members are space actors with important stakes in the sustainability of space.

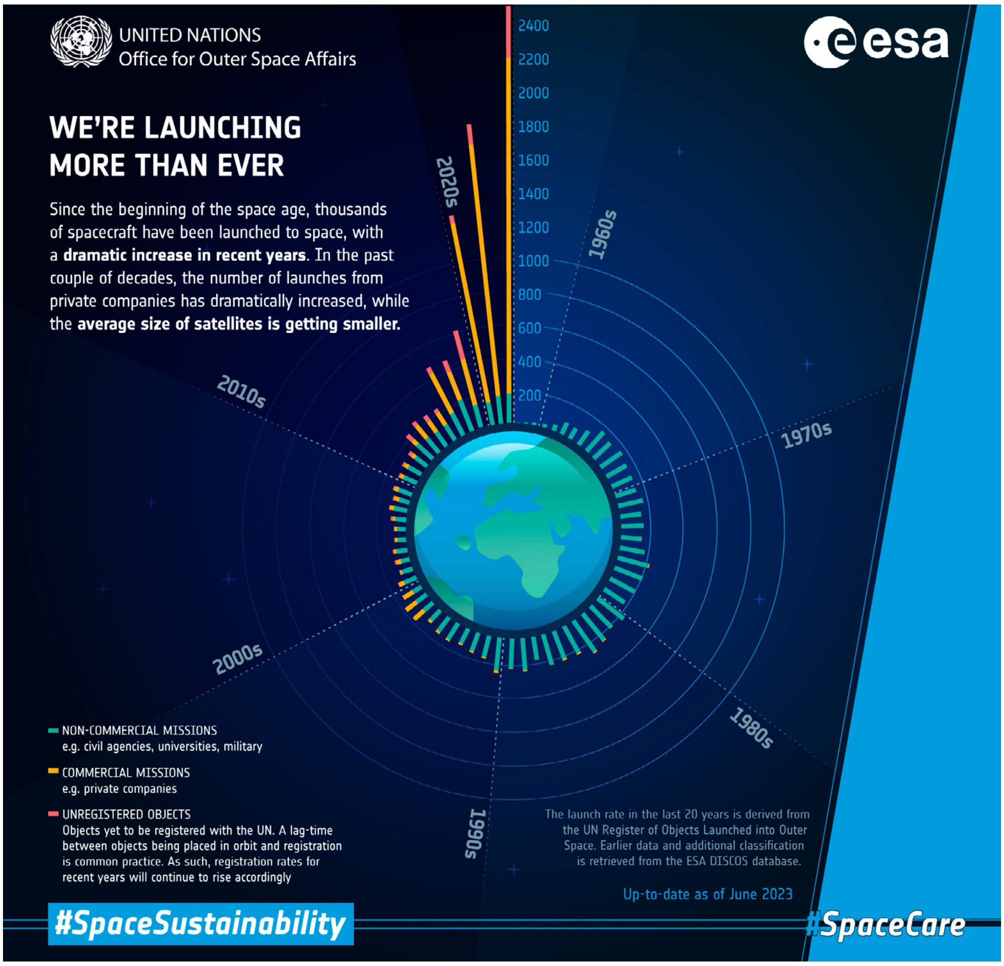
Meanwhile, newer technologies such as on-orbit satellite servicing and active debris removal are being developed, but with no rules governing their use. Problematically, those activities are fraught with suspicion, given the current state of global politics and the highly contested relationships among the great powers. For instance, a spacecraft that can be used to repair a satellite can also be used to interfere with the normal functioning of a satellite. Such possibilities have raised suspicions about those technologies. There have been no discussions yet on what the rules of engagement should be for these new technologies and how they might be used, and it seems increasingly unlikely that we'll see progress on that front in the near term. However, without an agreement on some basic norms or rules, safe and sustainable use of space will remain empty rhetoric.

Within this larger context of space governance, this report examines the increasing challenges of space logistics. It lays out the emerging space logistics capabilities and how they are transforming our traditional understanding of space operations. In particular, it outlines the challenges posed by RPOs because those technologies carry huge potential to mitigate some of the risks posed by space debris while opening new options to extend the lives of satellites in orbit, but they also represent dangers of malicious behaviour if not properly regulated. The report then highlights the need for rules as well as transparency and confidence building measures, while making a case for an ethical approach to space logistics.

Why space sustainability is critical

Space has become critical to our lives in numerous ways, yet very little is being done to preserve the sanctity of the space environment. Unless space sustainability is integrated into every stage of space operations, the already limited crowded usable orbits could soon become unusable (Figure 2).

Figure 2: Who's launching, and how many?

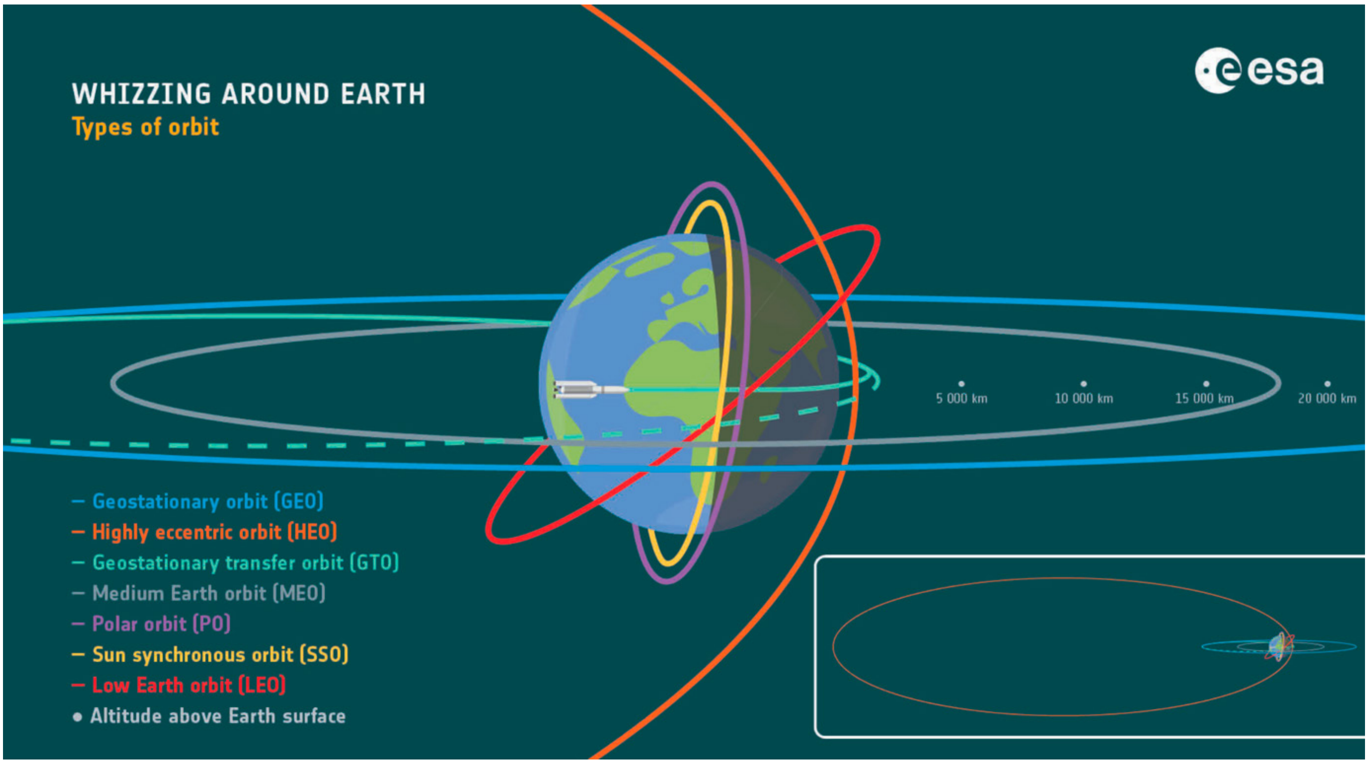


Source: European Space Agency and UN Office of Outer Space Affairs, online.

It should also be noted that discussion of space operations and other activities isn't a luxury. Our modern lives depend on them. Downstream applications and services that rely on space-based data and infrastructure have gown greatly in recent decades, affecting the state of the economy and society today. From the use of GPS for navigational purposes and the growing broadcasting, broadband and communication requirements to military communications and intelligence, surveillance and reconnaissance, as well as weather forecasting and agriculture, space permeates our lives. If access to space were to be disrupted, the effects will be felt immediately, from failure in navigation services affecting driving, air travel and delivery services to ride-hailing apps, or disruptions in communication systems resulting in cutting off internet and other broadcasting services such as live news and satellite TV. Disruptions in supply chains, remote work, online education and military operations could all be real if space were to become unavailable.

Major destruction of orbital space can affect space utilisation for several decades. Therefore, all stakeholders engaged in space need to adopt sustainable practices from the time of the design of a satellite and plan for debris-mitigation practices accordingly, such as de-orbiting satellites at the end of their lives. De-orbiting is undertaken through a controlled re-entry process, so that the defunct or inoperable satellite can be guided to fall on a remote part of Earth's atmosphere where it can burn up safely. There are also some satellites that end up in uncontrolled re-entry, when a satellite decays naturally in orbit, but those are mostly small satellites and CubeSats that generally burn up in the Earth's atmosphere before posing a risk to terrestrial activities. An increasingly used alternative practice for geostationary satellites is for them to be pushed out to a space graveyard—a less crowded orbit, which is around 300 kilometres above the operational geosynchronous equatorial orbit (GEO; Figure 3).

Figure 3: Earth's orbits



Note: Geostationary orbit = geosynchronous equatorial orbit. Source: European Space Agency, online.

On the regulatory side, different rules have come into effect in recent years. The Inter-Agency Space Debris Coordination Committee (IADC) recommends a 25-years rule, meaning that a satellite should be de-orbited within 25 years of the end of its mission, but the US Federal Communication Commission requires satellites to be de-orbited within five years of the end of their lives. Many institutions, including NASA and the European Space Agency, require end-of-life de-orbit plans to be built in at the time of mission planning and approval.[7] Even the IADC's 25-year rule, which was endorsed by the UN Committee on the Peaceful Uses of Outer Space (COPUOS) in 2007 and adopted by the UN General Assembly in 2008—which should have given it stronger international legitimacy—is still not legally binding on states and other parties.

The significance of space logistics capabilities

Space has witnessed several technological advances in the past decade. There are new capabilities in the form of space logistics that contribute usefully to the concept of space sustainability. RPOs are growing in importance, transforming how we engage with space. The newer technologies come with enormous benefits on the one hand, but they also carry risks, especially in the context of current geopolitical flux and great power rivalry. Unless we put in place pragmatic and practical protocols that can balance the strategic benefits of space logistics and RPOs while mitigating associated national security risks, our ability to use space even in our generation could be at risk.

The challenge with RPOs

RPOs are processes that facilitate one spacecraft undertaking a close approach and manoeuvres near another space object for a variety of functions, such as docking, inspection and servicing of a satellite or the removal of space debris. RPOs remain critical for a number of major contemporary space missions, including supporting and sustaining the International Space Station. They're also necessary for on-orbit satellite servicing, which includes extending the life of a satellite. Of course, remotely undertaking such tasks creates enormous challenges in the technological, operational and policy space. However, given the current state of international politics, it's the policy aspects that have gained most attention.

On the technological side of RPOs, the challenges are in terms of the high levels of precision that's required in orbital mechanics, guidance, navigation and control systems. The complexity of this is captured succinctly by Chris Shaw, CEO and co-founder of Advanced Navigation, a Sydney-based Australian company that has specialised in advanced navigation and autonomous systems, when he talked about extending support to Gilmour Space to have Australian-made launch vehicles. He remarked that:

> In the vast emptiness of space, without external guides, rockets rely on a sophisticated suite of navigation, guidance, and control (GNC) systems. The onboard navigation system must withstand dynamic conditions, gravitational forces, and the intricate physics of orbital mechanics, while providing a reliable flight path. Put simply, the system must be indestructible.[8]

The problem is that even a minor error or the slightest departure in navigation or thrust application can push major orbital trajectory deviations that can result in collisions and cause mission failures.

Missions involving autonomous navigation and guidance will become even more compelling in the future because of the new and fresh impetus and drive with which states and other stakeholders are pursuing deep space and interplanetary missions that can't rely on human Earth-based communication and guidance due to the great distances and the resulting lag in command and control. However, as in other domains, the introduction of artificial intelligence (AI) into decision-making in RPOs brings its own complications around predictability and failure management. For such high-stakes operations, ensuring that AI decision-making is transparent and interoperable by human operators is essential for maintaining operational integrity and accountability. Building that explainability into the AI systems used for RPOs will be essential to future operational safety, predictability and accountability.[9]

When considering safety, collision avoidance or controlling a contingency, RPOs come with a number of challenges. Most obviously, given the close-proximity manoeuvres involved in RPOs, there are always inherent risks. As mentioned above, even the slightest deviation in navigation can result in a collision, which can create a significant amount of space debris and the added risk of cascading collisions. This is referred to as the Kessler syndrome[10] or mission failure, both of which can be disastrous for space sustainability. Stakeholders engaged in RPOs urgently need to consider and develop collision-avoidance protocols, abort scenarios and fail-safe mechanisms as part of mission planning. For complex missions, such as handling damaged satellites or satellites that may be spinning out of control, rather than routine docking missions, one may need to develop newer technologies such as robotic arms, nets or harpoons, all of which are being explored currently by a number of space actors, and can be seen on satellites such as SJ-17 and SJ-21, both of which have undertaken RPOs.[11] None of those is foolproof technology, and all come with their own technological and safety challenges. A major challenge is to prove that systems are safe in order to reassure all other space actors.

Of course, a bigger concern is about the fact that RPO technologies are inherently dual-use and that they can be used in an ASAT (anti-satellite) role, with disruptive effect. Satellites that conduct RPOs and on-orbit satellite servicing functions aren't demonstrating entirely novel capabilities. Some of those capabilities could be found in co-orbital anti-satellite weapons from an earlier generation.[12] Some of the specific capabilities that have applicability in the RPO context are manoeuvrability, close approach, rendezvous and proximity operations, as well as imaging and docking.[13]

Given its potential ASAT role and the current international security circumstances, RPO technology is looked at with a lot of understandable suspicion. The absence of any effective multilateral discussions on RPOs adds to the suspicion and sense of wariness among space actors. But the benefits of those technologies in removing space junk or extending the life of a satellite means that the technologies are crucial for sustainable space operations. Those technologies are likely to see continued growth because of such benefits, which in turn means that there's an urgent need for international discussions on RPOs.

However, the most significant challenge comes from a rules and regulatory perspective. Undertaking RPOs creates both geopolitical and legal issues. In fact, the current state of geopolitics has clouded any efforts at conversations about RPOs. The fact that RPO capabilities exist among a few stakeholders makes those states that don't have RPO capabilities feel particularly vulnerable. But the challenge also extends to states that have RPO technologies because the worry is also driven by suspicion and wariness that an adversary might interfere with their space assets. The legal issues around RPOs are equally complicated. Article VI of the OST clearly states that:

> States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space … shall require authorization and continuing supervision by the appropriate State Party to the Treaty.[14]

That states have complete authority over their space activities complicates endeavours such as satellite servicing or the removal of a piece of debris. There's minimal clarity on questions such as ownership of space debris (such as inactive satellites) and who determines which piece of space debris can be removed or which space asset is coming too close so that it needs to be manoeuvred. There are also questions about the right of a private sector actor to 'mitigate space debris' through RPOs without approval of the state that built the vehicle or satellite. Article VII of the OST, which lays out the liability aspects, is relevant in this context.

Despite the benefits that RPO technologies bring, they also introduce new threats to national security. Because an RPO is inherently dual-use, verifying the intent of a mission is most challenging.[15] In a geopolitically supercharged environment, misinterpretation of intent is a potential problem, given the absence of openness and transparency measures among states and other stakeholders involved in RPOs. This means that states are going to assume worst-case scenarios and build up their own defences to counter any technological advances in the RPO arena. As with the risk of inadvertent nuclear escalation, miscalculations about RPOs can be a significant risk during times of international crises and tensions.

Therefore, the policy and technical communities need to consider practical steps that need to be instituted in order to avoid mishaps in space. Without genuine efforts to address those, miscalculation, miscommunication and intensified space weaponisation will all be realities.

The urgent need for rules, and transparency and confidence-building measures

While space might be infinite, the number of usable orbits around the Earth is very limited. The broader set of issues confronting space governance includes finding an agreement among key space powers on what the most significant challenges in space are, without which there's very little that can be achieved in addressing them. Traditionally, space debris was discussed in the COPUOS in Vienna, which is the multilateral UN platform for discussions on peaceful and civilian space issues. Typically, space debris has included defunct satellites, spent rocket stages and small fragments due to collisions and explosions. However, increasingly, space debris is a result of intentional ASAT tests, creating large numbers of debris objects, which, therefore, should be discussed in the Conference on Disarmament (CD) in Geneva, which is the UN's multilateral institution responsible for space security and arms control debates. But there's no agreement even on the venue for discussion, let alone advancing meaningful discussions for developing new rules of the road.

Meanwhile, the challenges around RPOs aren't fictional but a growing reality, underscoring the importance of rules, regulations and norms. There have been a number of incidents involving RPOs, when satellites from near-peer competitors have made unusually close manoeuvres near other satellites, raising concerns of espionage, or even ASAT capability testing.[16] We're therefore reaching a stage when we need to embrace these technologies because they come with enormous benefits, but without at the same time adopting rules to limit their hostile use in ways that degrade our common space environment.

There's an urgent need to develop good practices, establish useful norms and build up the necessary support base for further progress. Establishing clear channels of communication for when orbiting satellites come too close to each other, or if there's an accident involving RPOs, can't be more important. In July 2025, there was an incident involving a Malaysian and a North Korean satellite that came within 75 metres of each other. According to a South Korean space official, the United Nations Office of Outer Space Affairs (UNOOSA) 'received an emergency conjunction warning[17] from #Malaysia of a Malaysian satellite and a DPRK satellite.' It was expected that a collision would happen within 24 hours. UNOOSA, with the assistance of space environmental experts from the Space Data Association and Digantara, which is a space situational awareness (SSA) company, informed Malaysia and North Korea about the situation. A crisis was averted because, according to the Korean space official, 'the North Korean satellite operator performed the maneuver and the collision was avoided.'[18]

Under current international political circumstances, space global governance and rule-making exercises have become quite problematic. Despite the existing treaties and norms, there are several cases of noncompliance and violations. On-orbit satellite servicing and debris-removal technologies are relatively new, which is why they aren't even within the purview of the OST.

The need for an ethical approach

While it's essential to establish legal frameworks to ensure the safe and responsible conduct of RPOs, ethical and normative approaches can serve as valuable interim measures. Those approaches may help to promote responsible behaviour, especially in complex and congested orbital environments in which spacecraft interactions require heightened caution and coordination. Ethics in RPOs can be useful, practical, courtesy considerations such as collision-avoidance measures; having due regard for other space objects and ensuring that no harm is done to them and the broader space environment; making effective and responsible use of resources; and ensuring that the space environment remains environmentally sustainable.

Some of the key considerations while shaping an ethical approach to RPOs could include collision avoidance; using fuel-efficient measures; transparency and information sharing; and the establishment of keep-out zones.

Collision avoidance is particularly important in the context of RPOs. Given their close-proximity operations, RPOs need to pay significant attention to space objects to which they may come close, especially uncooperative space objects.[19] This means, therefore, that there needs to be meticulous planning, ISO-like standards and certifications (to ensure that the services and processes are up to agreed-upon, established standards), and compliance to avoid collisions. Meticulous planning in this regard should also include designing contingencies in terms of orbital deviations that might identify safety zones and/or outline pathways to minimise accidents and inadvertent incidents in orbit. Installing sensors and other forms of close surveillance to keep a constant vigil on areas around spacecraft and the means to modify their flight paths if the sensors detect a potential hazardous situation are also useful measures. It's also noteworthy how the Artemis Accords are similarly trying to establish a baseline norm for safety zones.

A range of other considerations could include employing fuel-efficient measures, such as Hohmann orbital raising manoeuvres, that are considered optimal options.[20] Utmost care must be taken to ensure that RPOs don't contribute to the growing space debris problem and, therefore, stakeholders need to include debris-removal and de-orbiting plans at the time of conceiving and planning RPO missions.

Encouraging stakeholders to act ethically while adhering to existing legal frameworks remains a surprisingly persistent challenge. Despite being signatories to international agreements, some states have fallen short of fully complying with their obligations. The Registration Convention is a notable example: some states fail to provide comprehensive information about their space missions, including the nature, purpose and timeline of the objects they launch. Enhancing transparency by ensuring full and timely disclosure under existing treaties would be a meaningful step forward. Simply honouring the commitments already in place could significantly strengthen trust, accountability and the overall governance of space activities. An example of noncompliance in the current maritime context would be the case of Iranian and Russian evasion of sanctions with their 'dark fleet'—the practice of turning off the automatic identification system transponders on their ships so that their locations and the origins of their cargo are hidden.[21]

In the context of RPOs, the existing treaty measures have a role to play, and states are bound by their regulatory commitments. For instance, the 'due regard' obligation contained in Article IX of the OST means that all states should be responsible for their RPOs and ensure that they be considerate of each other's space interests and rights while pursuing their own space activities. Further, the Liability Convention of 1972 also has direct relevance to RPOs in case of an incident or accident.[22] While the existing treaty measures have a role in the conduct of safe RPOs, there are several other regulatory issues that still need to be dealt with. For instance, who determines which piece of a space object can be removed? A lot of the defunct space objects are military satellites, which are sensitive in nature. Additionally, given the crowded and congested nature of space, space objects come close to each other and, unless manoeuvred to another orbit, they could end up in a collision. But who decides that a satellite needs to be moved to another orbit, and who conducts such an operation? There's no apparent standard operating procedure for such situations.

It indeed makes sense for countries to engage in information sharing and transparency measures, especially in missions related to RPOs. Not knowing what a particular RPO mission is about can trigger misconceptions and drive countries to assume the worst and prepare countermeasures, making the space environment fragile and vulnerable. Sooner rather than later, states and other stakeholders must come together to establish certain basic parameters that will provide reasonable information on missions, including the purpose and duration, so as to avoid misgivings about the missions.

Identifying clear keep-out zones around a spacecraft, which one shouldn't violate, is particularly important to conduct safe RPOs. Crossing into keep-out zones shouldn't be done without explicit permission and coordination. The parameters of keep-out zones differ based on the risk tolerance associated with missions and the possible negative consequences of a keep-out zone violation as well as the nature of the satellites, some of which are particularly sensitive due to their missions. Establishing clear limits and restrictions can be enormously useful in avoiding accidents and collisions.

Going forward, a sensible way to address the problems listed here is not to try to deal with them all together but to follow a triage procedure to account for the more serious ones first and others later. This would suggest a layered, planned and sequential program. In the first-priority layer, to be handled in the first couple of years, we could look at establishing certain protocols for communication and notifications, as well as information sharing and transparency measures. Those could be helpful in removing some of the apprehensions that many states have, while laying out certain actionable steps in case of an incident. In the second-priority layer, which could be taken up in a five-year time frame, industry-led recommendations and solutions for some of these problems should be actively considered. Finally, a slightly longer term priority agenda could look at the establishment of joint space logistics hubs in a collaborative fashion. That phase should also prioritise the development of legal measures that guide RPOs and space logistics for a sustainable future in space.

Australia–India space cooperation under Space MAITRI

Australia and India have been stepping up space cooperation under the Space MAITRI (Mission for Australia–India's Technology, Research and Innovation) initiative. Space MAITRI is meant to take the bilateral space agenda to greater heights between 2024 and 2026. Its key activities involve multiple stakeholders across commercial sectors, as well as the policy communities and the governments of both countries. Under an arrangement between the two countries, NewSpace India Limited will launch Space Machines Company's (SMC's) 250-kilogram Optimus Viper spacecraft aboard the Indian Space Research Organisation's Small Satellite Launch Vehicle in 2026. This is the first dedicated launch agreement between the two countries. The SMC's Optimus Viper spacecraft is meant for on-orbit servicing functions such as inspection, propulsive manoeuvres and debris mitigation. This will be a tremendous step towards space sustainability because, as SMC says, it will be a novel 'roadside assistance' provided by the company.

A number of Australian and Indian entities are working under Space MAITRI. On the Australian side, there are SMC and relevant research departments of the University of Adelaide, the University of Sydney and the University of Technology Sydney, as well as Advanced Navigation, ASPI and LeoLabs. On the Indian side, there are Ananth Technologies (which is meant to handle assembly, integration, testing and logistics) and Digantara (providing space domain awareness and optical payloads).

Conclusion

Space logistics gives us the ability to inspect, refuel, repair and resupply, which is enormously beneficial in extending the life of a satellite and meeting its mission requirements in orbit. RPOs are economically important because they significantly reduce satellite replacement and launch costs, as well as provide clarity about and possible remedies for potential malfunctions. They also provide mission flexibility based on changed circumstances and cater to demands for both civilian and military functions.

Space logistics are also critical in the context of a long-term, sustainable presence in space, which is no longer a fictional idea. Industry players, in particular, are quite hopeful about achieving such feats in the near term.

But space logistics and RPOs are relatively new facets of space engagement and currently lack any rules, regulations and norms. It will be enormously beneficial if ethical and normative approaches are pursued as initial steps before arriving at legally binding regulations. Legal measures are ideal, but it's unlikely that we'll see progress on that front in today's competitive international political environment.

At the very least, countries need to pursue practical courtesy measures such as collision-avoidance practices, implement the due-regard principle while engaging in RPOs and establish keep-out zones that could ensure that space remains safe, secure and sustainable.

Glossary

Kessler syndrome: A phenomenon in which two space objects collide, resulting in many pieces of space debris, which can collide with other debris pieces and other objects, in a cascading fashion, making space extremely congested and cluttered.

RPOs (rendezvous and proximity operations): Manoeuvres that a spacecraft undertakes to perform a range of functions, including docking, on-orbit servicing and debris removal.

Space conjunction warnings: Alerts about potential collisions between two or more objects in space, either satellites or space debris. The warnings are issued if objects are expected to travel close enough to each other to raise the risk of collision.

SSA (space situational awareness): Awareness and understanding of the space environment, including the location of space objects such as satellites and debris, as well as space weather, that can ensure the safe, secure and sustainable use of space.

Space traffic management: Technical and regulatory measures to maintain safe and sustainable access to and operations in space, avoiding collisions and radiofrequency interference.

Uncooperative space objects: Typically, those space objects that don't have tracking, communication or control systems operating. They could include natural uncooperative objects such as asteroids, or defunct satellites and space debris.

Notes

1 Katie Bo Lillis, Jim Sciutto, Kristin Fisher, Natasha Bertrand, 'Exclusive: Russia attempting to develop nuclear space weapon to destroy satellites with massive energy wave, sources familiar with intel say', *CNN*, 17 February 2024, online; Rajeswari Pillai Rajagopalan, 'Why Russia's latest space weapon is so dangerous', *The Diplomat*, 17 February 2024, online.

2 'Analysis: Why NASA is planning to build a nuclear reactor on the Moon and what the law says', *PBS*, 9 August 2025, online.

3 Space traffic management (STM) involves a number of different technical and regulatory provisions in order to achieve the safe and sustainable use of space by tracking objects in space, avoiding collisions and managing radiofrequencies in a manner that ensures smooth operations in space. STM has gained greater traction in recent years because of the rapid increase in the number of satellites, including large constellations, which raises congestion in space and potentially the risk of collision and the creation of debris. Some of the crucial components of STM are space situational awareness (tracking and monitoring of the space environment), collision-avoidance manoeuvres, and the promotion of openness and transparency measures as well as norms and regulations to avoid physical collisions and radiofrequency interference.

4 'DRAFT International Code of Conduct for Outer Space Activities', European Union External Action Service, 31 March 2014, online.

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Acronyms and abbreviations

AI	artificial intelligence
ASAT	Anti-satellite
COPUOS	Committee on the Peaceful Uses of Outer Space (UN)
EU	European Union
GEO	geosynchronous equatorial orbit
GPS	Global Positioning System
IADC	Inter-Agency Space Debris Coordination Committee
NASA	National Aeronautics and Space Administration (US)
OST	Outer Space Treaty
RPOs	rendezvous and proximity operations
SMC	Space Machines Company
Space MAITRI	Mission for Australia–India's Technology, Research and Innovation
SSA	space situational awareness
UN	United Nations
UNOOSA	United Nations Office of Outer Space Affairs

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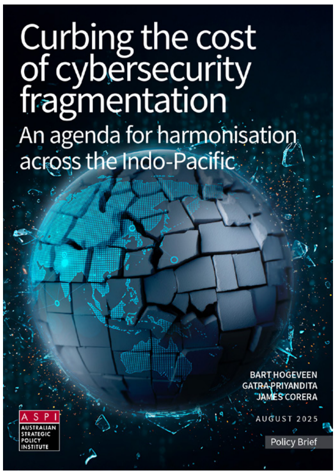

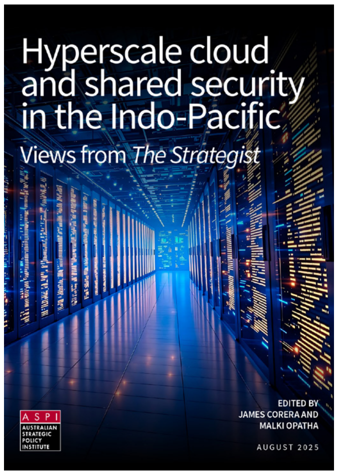

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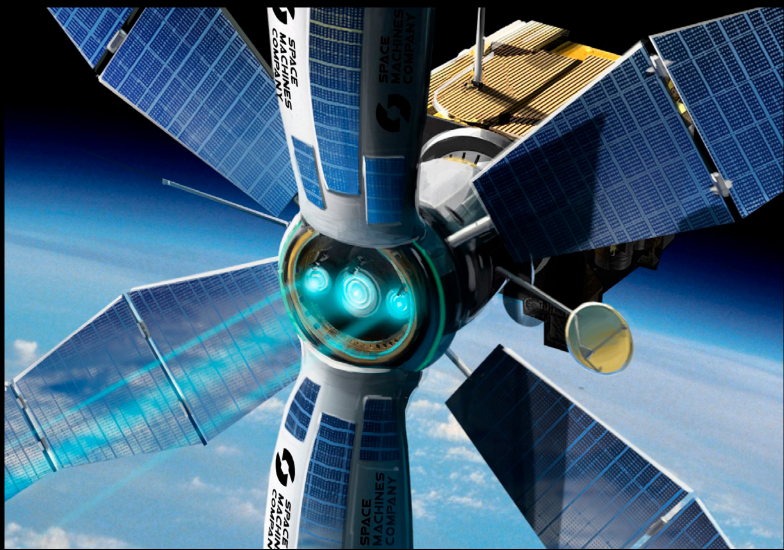

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