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Need for Regulating Satellite Mega-Constellation Populations in Earth's Orbit

Chaitanya Giri*

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Introduction: UN Resolution against the testing of Direct-Ascent Anti-satellite Weapons

The world is moving towards commercialization of the Earth's orbits, especially the low-Earth-orbit (LEO) at a pace faster than ever. Commercial earth-observation (EO), communication satellite constellations, singular satellites, co-orbiting ones, active debris removal technologies, space stations, space capsules, and spacecraft awaiting slingshots into interplanetary space, the diversity of objects functioning in Earth's orbits is increasing tremendously. Diverse operators – commercial companies, space agencies, militaries, plurilateral space-based assets – are making orbital operations an economic opportunity, a regulatory challenge and a security risk all at the same time. In December 2022, a necessary global confidence-building measure that aims to assuage some of the security risks was initiated. This measure is the United Nations' resolution to voluntarily abandon testing of kinetic-kill, direct-ascent anti-satellite (DA-ASAT) weapons in the low-Earth orbit (LEO).

This history of ASAT testing by the United States, Soviet Union (later Russia), China, and India, among others, has been well documented.[1] Most of these have been DA-ASAT missiles launched from air-, sea- and land-based platforms. These DA-ASAT tests were often demonstrated to deter an adversary with critical satellites in the LEO. The DA-ASAT has never been used for warfare, but targets predominantly are command, control, computers, communications, intelligence,

*Consultant, RIS. He holds a PhD degree in Astrochemistry from the Max Planck Institute for Solar System in Germany and the University of Nice in France.

surveillance, and reconnaissance (C4ISR) satellites. In a classical 20th-century ASAT use case, the target for these tests would have been an adversarial military satellite and its use scenario would primarily be a hot conflict. Contrariwise, in the 21st century, the adversarial target can be commercial or dual-use C4ISR satellites, and the ASAT could be used even during protracted cold wars.

The last set of DA-ASAT tests happened in the 2018-20 timeframe, with Russian, Chinese and Indian agencies demonstrating their prowess, India demonstrating it for the first time, and China and Russia showcasing upgrades to their DA-ASAT systems. DA-ASAT has also been symbolic of extremely high-precision striking. This is due to its ability to intercept an object moving at high-hypersonic speeds in the LEO.

This was the same period when numerous military space entities cropped up worldwide. These include the Russian Space Forces (established in 2015), China's People's Liberation Army Strategic Support Force (2015), German Bundeswehr's Cyber and Information Domain Service (2017), the Indian Defence Space Agency (2018), the US Space Force (2019), the French Air and Space Force (2020), The Iranian Revolutionary Guard Corps Aerospace Force (2020), the Italian Space Operations Command (2020), Japan's Space Operations Squadron (2020), and the British Space Command (2021). All these military space entities depend heavily on LEO satellites for their C4ISR needs, and the use of DA-ASAT does not suit their C4ISR operations. This is why many militaries now focus on developing non–kinetic electronic and cyber warfare capabilities, even for ASAT weapons. For instance, the PLASSF operates[2] the Network Systems Department and the Space Systems Department under its umbrella. The US Space Force's Space Operations Command has given equitable weightage[3] to space (C4ISR, satellite navigation, space situational awareness, and electronic warfare) and cyber operations. Military space entities are cognizant of the vast possibilities on the lower escalatory ranks of conflict via non-kinetic means. And that being so, none of them are 'trigger happy' about DA-ASAT.

They are ready to stop DA-ASAT testing on reaching specific preparedness with non-kinetic weapon systems. However, the militaries of democratic countries are not entrusted with responsibilities for setting international governance codes. The same is the responsibility of a government's executive arm, and in some countries, both are taking cognizance of the orbital regulation challenge.

No Global Consensus on Long-Lived Orbital Space Debris

On 6th October 2020, the United Nations General Assembly received a draft resolution titled "Prevention of an Arms Race in Outer Space.[4]" The draft resolution, among many propositions, called upon all states, particularly those with outstanding space capabilities, to contribute to the global objective of peaceful use of outer space, promote international cooperation, stand by the existing treaties, and abstain from activities antagonistic to these expected contributions.

This draft received extensive support and eventually led the UN to adopt it as the resolution on "Reducing Space Threats through Norms, Rules, and Principles of Responsible Behaviours[5]" in December 2021. This adopted resolution made a pertinent mention of the issue of orbital debris. It emphasized that 'long-lived orbital debris' created by the deliberate destruction of space systems, ASAT to be precise, not only heightens the risk of in-orbit collisions but also creates misinterpretation and missteps that could eventually lead to conflicts.

The adopted resolution in its next iteration, which came out in December 2021, decided to convene an open-ended working group (OEWG) on the same issue with the attendance of civil society, commercial entities, and international organizations. Since then, two UN OEWG on Reducing Space Threats sessions, in May and September 2022, have convened in Geneva[6]. These OEWG sessions have been concurrent with a few other unilateral steps on reducing space threats taken in consonance with commercial entities. But what brings so many countries to conclude similarly when geopolitical consensus-building has become difficult? The answer is simple – the rapid commercialization of LEO and all of them seek crucial stakes in it.

The upper (600 to 2000 km) and lower (100-600 km) LEO have become a gateway for numerous economic undertakings that are both outbound – towards what is known as cis-lunar (between Earth and Moon) or interplanetary activities – and inbound – civilian, commercial, and military C4ISR activities. All the contemporary prefixes to the global economy – digital economy, circular economy, blue economy, agriculture economy, environmental economy, solutions to climate change, domestic governance, banking, insurance and finances, maritime trade, land management, water resource management, global Sustainable Development Goals, and fulfilment of net-zero commitments – are all intimately linked with C4ISR platforms fixated in LEO. Each of these applications has at least two or more competing satellite constellations, each consisting of 100s to 1000s of satellites, vying to offer commercial services to various end users. These end-users are governmental agencies, militaries, and businesses. The modality of trade of data and services is happening on government-to-government, business-to-government, and business-to-business tracks. Most constellations are coming up in the satellite-communications domain and aim to add tens of thousands of satellites unsustainably in the LEO.

Uncontrolled growth of the satellite

population, due to mega constellations, in LEO has been long articulated to lead to Kessler Syndrome[7]. The syndrome is a scenario where the Earth's orbit gets overpopulated with satellites, their active payloads, spent launch vehicle stages and adapters, defunct payloads, empty propellant tanks, and collision fragments, rendering the orbits inoperable. Commercial space players do acknowledge the challenge at hand. They now find opportunities to mitigate the orbital debris challenge through technological solutions.

More recently, commercial space players and governments with influential commercial players to serve have begun to self-regulate. This self-regulation can be seen as a correction to make space activities more sustainable and economically rewarding. The concern for economic rewards did not exist earlier, before the surge of LEO commercialization activities, when the satellite populations were low, satellite constellations did not exist, space businesses were in their nascence, and orbital debris was not a pressing challenge.

Systemic and satellite-specific mechanisms to prevent runaway collision cascades have been in the works. Various satellite manufacturers and their operators have attempted to develop autonomous collision avoidance mechanisms to re-orient a pre-empting satellite collision from incoming objects. However, collision avoidance mechanisms are not full-proof[8]. For example, since they cannot enter and burn in the Earth's atmosphere, satellites from upper LEO may become susceptible to collisions if they lose their autonomy during their end-of-life, technical failure, or non-kinetic ASAT attack. In another scenario, satellites, while avoiding a collision autonomously, may fail to pre-empt other potential collision conjunctions with other objects or may even create new conjunction hazards.

Systemic mechanisms, like SSA and space traffic management (STM), are also gaining prominence in preventing collisions. But they, too, have limitations. For instance, the SSA, currently developed by various private space companies and governmental agencies, is preparing to offer rapid and detailed intelligence about the compositions and dimensions of objects and pre-empt conjunctions. But an over-populated LEO may wane SSA's accuracy in forecasting collisions and mitigating them in a timely manner. Crowding in the LEO is becoming a hazard with on-demand, cost-effective space launches, easy deployment of small satellites, and growing defunct objects and fragments created by collisions in LEO. This crowding needs to be quickly attended to with high international priority.

'Sustainable Development' and 'Net Zero' in Earth's Orbits

In November 2021, the Paris Peace Forum, a newly-established French not-for-profit institution, commenced the Net Zero Space Initiative[9]. With support from the French space agency CNES, the initiative has gathered several commercial satellite operators, space launch companies, consulting firms, downstream service providers, and space agencies worldwide. Together, they pledged to take concrete actions to reduce orbital debris and achieve sustainable use of outer space.

After that, in April 2022, US Vice-President Kamala Harris announced from the Vandenburg Space Force Base US' voluntary commitment to discontinue testing of DA-ASAT[10]. This decision could not have been taken without discussions with US's commercial space industry and international partners. The semantics in the announcement demonstrates the US' emphasis on ensuring permanency, well-being, protection, and a sustainable environment for maintaining the global

primacy of the US commercial space activities in LEO. The lines between commercial space enterprises and conventional military space operators have blurred while ensuring what Vice President Harris mentioned in her April 2022 announcement. In September 2022, the US Department of Commerce and the Department of Defense signed an agreement on basic SSA and space traffic management[11]. In the near term, a resolution could be tabled in the UN General Assembly calling all nations to prevent testing DA-ASAT weapons.

US' Artemis Accords partners have quickly responded with similar relinquishing of DA-ASAT tests[12]. Canada took the pledge in May 2022, New Zealand in July 2022, Japan and Germany in September 2022, and the United Kingdom and South Korea in October 2022. The number of countries making the pledge will increase. Then again, it should be acknowledged that countries with ASAT capabilities have the most number of satellites, and any runaway collisional cascade does not distinguishingly keep their satellites safer. The voluntary decisions must be welcomed wholeheartedly, and so should be some accompanying questions.

Question 1: Is this end of ASAT weaponry for good, and will the world get divided into reasonable and unreasonable users?

Question 2: After giving up DA-ASAT testing, which offensive measures will the numerous newly established space military entities take in times of conflict?

Question 3: Does prohibition on DA-ASAT testing mitigate Kessler Syndrome?

Most of the pledges are on giving up 'testing' of DA-ASAT weapons in space. They cannot be construed as pledges to renunciate the use or also cannot be interpreted as 'no-first-use' pledges. The unrestricted use of DA-ASAT, in today's era of mega-constellations, in case of heightened bipolar geopolitical conflict will not have localized effects and will not remain in the realms of 'mutually assured destruction.' It will lead to a graver scenario akin to that seen in a 'nuclear exclusion zone' that can be deemed an orbital deterioration.[13] An orbital deterioration will be when the Earth's orbits are rendered useless for long periods, restricting humans from carrying out socio-economic, meteorological, communications, exploratory, and astronomical activities and pre-empt natural threats from outer space. Such deterioration will severely blow the global economy and security. Indeed most rational nations will try to keep their conflicts below the realms of such deterioration. Many incremental steps are being taken, including the shifting focus toward non-kinetic ASAT weapons.

Now to answer the second question. The wave of a self-imposed prohibition on DA-ASAT does not account for prohibiting the testing of directed energy, electronic warfare, or cyber-ASAT weapons, which could become a choice of offense for the newly-established military space entities. These non-kinetic ASAT weapon systems cannot be attributed easily, and the attacker remains camouflaged. Furthermore, these weapons do not create collisional fragments but still damage satellites, eliminating their functionality, including collisional avoidance and end-of-life de-orbiting. That non-kinetic ASAT does not generate a collisional cascade scenario is a wrong notion.

Now answering the third question. DA-ASAT or other ASAT acutely aggravates a chronic problem: the scaling likelihood of runaway collisional cascade due to the growing population of LEO satellites. The chronic problem is due to the misconstrued

and short-term business goal of filling up the orbits with as many satellites as possible, functional or defunct, and the over-emphasis on business models based on satellite constellations. The business model of satellite constellations commits to the end-user incessant C4ISR, continuous markets for satellite manufacturers, space launch companies, and numerous downstream service providers. Strong business interests in favour of mega-constellations and over-populating the LEO are the chronic contributors to the Kessler Syndrome than the acute ASATs. It has become imperative now, well before the LEO satellite population swells up to an unsustainable twenty and thirty thousand, to take necessary actions addressing the chronic contributors.

Super-Constellations would make LEO a Powder Keg

The Net Zero Space initiative and allowing private entities to participate in the OEWG are welcome steps for addressing the chronic challenge. On the scientific front, efforts are also being made in Europe[14] and Japan[15] to explore sustainable materials for building satellite buses, especially the use of wood. However, one cannot make electronics and payloads out of wood. Furthermore, wood-based satellites can be helpful only if the satellites can re-enter the Earth's atmosphere from lower LEO. The wood-based satellites in upper LEO will be unable to enter the atmosphere are burn themselves. Despite commendable solutions like collisional avoidance systems, wood-based satellites, better SSA, better STM, and space debris clean-up missions coming to the fore, these are, unfortunately, incremental solutions.

The international governance of outer space is taking small paces when space technologies and applications are progressing in leaps. This widening technology-regulation gap could eventually become detrimental to global cooperation in the LEO. Commercial satellites are now national and transnational critical infrastructure, and as the 2020 resolution aptly mentions, long-lived orbital debris created by premeditated destruction needs to be prevented. But can we only pinpoint the acute causal factor, DA-ASAT, as the only premeditated contributor? No. Overpopulating LEO with unsustainable mega-constellations is indeed a silent killer.

Giving up the DA-ASAT test is likely done to secure the short-term interests of the growing global space economy. This certainly does not mean the end-of-road of testing ASAT of other kinds and not the end of 'using' DA-ASAT. The next-generation weapons could target space businesses and may also become part of industrial warfare. These numerous advertent and inadvertent risks enumerated in this article demonstrate that every mega-constellation committed without review and analyses for sustainable use of LEO makes the LEO a 'powder keg.' This powder keg cannot be prevented from exploding without regulating the number of satellites that the LEO can harbor. The powder keg will remain explosive even if the world chooses to end the use of ASAT weapons of all types. The faster the world grows over the 20th-century notions of space weapons, satellites, and orbital environments, the better it is for the world.

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