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Evolving Shifts in Outer Space Geopolitics: Locating India's Space Programme

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India has a space programme which is now completing six decades. India started developingits space programme in little more than a decade after its independence. It took nearly two decades for India to achieve indigenous launch capability into the LEO (Low Earth Orbit), and another two decades to venture by itself into GEO (Geostationary Orbit). Another two decades hence, India is attempting to send Indian nationals to outer space and has already achieved several remarkable feats in interplanetary exploration as well as in the commercial and military sphere. Even with this solid foundation, India faces a huge challenge in light of an intensified major power rivalry, which has been building up for the past few years. This paper attempts to explore where India is located amidst the evolving shifts in outer space geopolitics. The paper deals with this enquiry by examining the major areas of human space activities, identifying the key trends underway and looking at where India is placed at crucial junctures in these areas.

Rapid Advances in Space Technology

Technology has come a long way since the advent of the Space Age. The advances in technology over the past several decades have led to phenomenal growth in the diversity of space applications. Accordingly, human activities in outer space have diversified. From traditional use in remote sensing and communication, satellites have emerged as paramount and unavoidable entities in navigation. Satellites in the remote sensing domain have evolved from films which can provide only daytime imagery and recovered only after re-entry, to sensors providing real-time digital transmission of high-resolution imagery. Communication satellites have transitioned from their traditional Geostationary

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Orbit (GEO) base to the Low Earth Orbit (LEO) with the evolution of small satellite mega-constellations. Launch vehicles have evolved from single-use rockets to reusable ones, which can be salvaged multiple times for launching missions. The rise of the Fourth Industrial Revolution and the need for sustainable development is also having a marked influence on space technology and its various applications.

The capabilities of remote-sensing satellites are getting increasingly advanced with the emergence of technologies like Synthetic Aperture Radar (SAR), which can provide extremely high-resolution day and night-time imagery, irrespective of the weather conditions.[1] It is getting translated from a niche technology to a mainstream one, as a growing number of satellites are utilizing this technology. The capabilities of communication satellites have certainly grown; however, a major revolution is underway in the sector with quantum technologies emerging to radically transform space-based communication. Quantum communication satellites ensure high secrecy communication which is impossible to decrypt using current-day technologies. They achieve this by exploiting the principles of quantum entanglement from the field of quantum mechanics for encrypting data flows. As of now, only China launched a satellite called Micius in 2016 meant for demonstration of the technology.[2] The Fourth Industrial Revolution is increasingly penetrating into the space domain, with Artificial Intelligence (AI), robotics and autonomous systems, and Big Data analytics getting integrated into space programmes.

Robotics is finding applications in space exploration, from the use of robotic arms to robotic probes to even humanoid robots. These are ideal for replacing human effort in an inhospitable environment like outer space. Other technologies such as 3D printing are gaining growing salience in outer space, which has only very restricted access to terrestrial supply chains. This will become especially relevant as human colonies are envisaged in other heavenly bodies and mining activities are planned in space. The need to enable green, sustainable and uninterrupted energy supplies on Earth is leading to proposals like harnessing solar energy from space. The Space Based Solar Power (SBSP) concept envisions the collection of solar energy directly from space based solar panels and transmitting it wirelessly to terrestrial stations.[3]

Technological shifts are also underway in the more upstream segments of the space sector. There is an increasing effort being put to develop reusable launch vehicles by governmental and corporate launch service providers which brings down the cost and increases the frequency of launches in case of

sustained demand. Reusable launchers have been developed at various levels – from the reusability of only stages of the rocket to the reusability of the launcher as a whole. New actors in the space domain like SpaceX have become successful in not just developing such rockets, but also operating them frequently on a commercial basis. In the case of the Falcon-9 launcher of SpaceX, the first stage is retrieved. This stage lands in a controlled manner vertically on a floating barge at sea and is not recovered traditionally like manned space capsules which have an unguided re-entry.[4] Technology now seems to be heading in a direction where even concepts like space elevators are being considered, which does away with rockets completely. Rather, it seeks to lift payloads via carbon nanotube cables into transfer orbits.[5]

As will be discussed further in the paper, the resurgence of major power rivalry has brought in more competitive elements into the space sector in all dimensions. The major space faring nations want their space programmes to be commercially competitive, have a military edge over others, and stay ahead of others when it comes to prestigious projects. India already has SAR capability – it deployed its first indigenous radar imaging satellite with such a capability in 2012 with its RISAT-1.[6] As far as communication satellites are concerned, India is also developing Satellite Based Quantum Communication (SBQC), with the Indian Space Research Organization (ISRO) successfully achieving terrestrial quantum communication across a distance of 300 m in free space twice – in 2021 and in 2022. These achievements have paved the way for realizing satellite-based quantum communication in the near future.[7] The ISRO has also been actively incorporating AI into its space programmes. For instance, the Pragyan rover of the Chandrayaan-2 lunar mission was AI-powered since it requires autonomy owing to lack of direct contact with Earth. ISRO is also involved in the process of developing "Vyomnoids" – humanoid robotic assistants, which can provide services in manned and unmanned missions.[8] India is also working towards deploying reusable launchers through its Reusable Launch VehicleTechnology Demonstration (RLV-TD) programme in which testing has been underway since 2016. India is also developing a reusable launch vehicle like Falcon-9 called ADMIRE.[9] Innovations in space technology will contribute not just to India's space programme, but will also have cascading impact on multiple other domains – from military to developmental to commercial. It is essential that India keep up with the evolving technologies so that its space programme can remain competitive.

Growing Commercial Uses of Space

At the beginning of the Space Age, human activities in outer space have largely been carried out from the perspective of national security, competition for scientific and technological leadership and the superpower prestige driven by Cold War geopolitics. Subsequently, as the neoliberal wave swept over the world, the commercial dimensions of the few existing space programmes became increasingly significant. As the multifold benefits of space activities started getting visible in all possible sectors, the demand for space services grew. Subsequently, commercial interests started asserting themselves in the space sector, giving it an industrial identity. The age of commercialization of space evolved and got further impetus in the post-Cold War era. The countries in the developing world started recognizing the promising role of space activities in catering to their developmental aspirations and security interests. Not all such countries have the capability to develop satellites and launch facilities. Therefore, the countries which already possessed established infrastructure had the edge in delivering space services – building of satellites, satellite/payload launch and provisioning of satellite imagery, leasing of transponders in communication satellites, satellite-based navigation services, and sharing of scientific data, among others. As globalization deepened, the global commercial space market also grew, leading to the expansion of the global space services market. The global commercial space industry is today nearly $300 billion and constitutes around two-thirds of the global space economy.[10] All major spacefaring nations today offer such services as this is a market too attractive to stay away from, and they are certainly competing among themselves to get the bigger share of the pie. China has emerged as one of the most preferred space services providers, especially with its cheap end-to-end services, and the rollout of its Belt and Road Initiative (BRI), which has a space component.

The building of satellites and launching them has been around for some time. However, its intensity has increased of late, as more and more countries want to establish their presence in outer space and derive benefits from it. When it comes to launch services, one relatively new trend which seems to have caught up is the use of a sea launch platform. Commercial space launches are all about the economical launch costs. The cost of launches depends on a number of factors including the location of the launch site – being close to the equator imparts a reduced fuel cost advantage than if the same launcher was fired off from higher latitude sites. This is because the launcher gets an additional thrust when being launched from lower latitudes. Since not all

countries have the geographical fortune of being proximate to the equator, the less fortunate ones can use the seas to offset this inherent constraint of theirs. The concept of sea launch involves a country with launch bases at higher latitudes (or with none at all) utilizing a ship to carry its launcher to a floating platform positioned as much near the equator as feasible so that it accrues the equatorial cost advantage. Until recently, there has been only one such initiative called Sea Launch, which was a multi-stakeholder project and is currently redundant. Lately, China has entered into the picture and has established its own sea launch infrastructure based in its north-eastern province of Shandong.[11] This has certainly boosted China's commercial satellite launch credentials.

One of the leading trends in the commercialization of space today is the growing preference for using small satellites. The small satellite launch market is witnessing a palpable rise. Though currently, the small satellite market is worth around $3 billion, it is expected to grow ten times that size.[12] There are many benefits of utilizing small satellites – it is cost-effective, multiple satellites can be launched in one go, and they can be easily and economically replaced by another one in case of damage. A small satellite constellation can be more effective than a large satellite in the same orbit. The small satellite launch sector has also given rise to the trend of small satellite launchers coming to the fore. The rise of satellite mega constellations has opened up a wide pathway towards expanding the downstream satellite service sector possibilities in a radical manner. Even though the internet emerged three decades ago, there are various parts of the world, even in developed countries, where Internet connectivity is sparse or non-existent. Internet satellite mega constellations consist of constellations of a large number of small satellites, which are placed in the LEO. Multiple satellites are inserted into several orbits at a scale in which they can cover the entire world and deliver broadband Internet facilities globally. There are today such rival Internet mega constellations in existence and under development.

The most prominent among them is the Starlink mega constellation by SpaceX, whose services have helped Ukraine maintain its access to the Internet during the recent conflict.[13] Other players like Amazon, One Web and even China have been working on such massive projects. China, among other similar projects, is planning a 13,000-satellite mega constellation named Guowang, more than the number initially planned for Starlink.[14] The other important downstream service, which is increasingly provided by commercial satellites, isremote sensing. This is especially important as more and more countries and corporates are seeking to expand their natural resources more

effectively and sustainably. Moreover, the scourge of anthropogenic environmental change has raised the demand for remote sensing data. There is an increasing focus on developing Open Source Intelligence (OSINT) platforms, which can offer satellite imagery for analysis in times of growing geopolitical and geoeconomic risks.

The area of space-based navigation services is witnessing fast growing competition, especially in the current information era. The Beidou satellite-based navigation services provided by China is seeking to challenge the Global Positioning System (GPS) of the US, which pioneered the concept of the Global Navigation Satellite System (GNSS). This is happening at a time when there are already rivals to GPS like Russia's GLONASS and European Union's Galileo. The Beidou is now part of BRI's Digital Silk Road and is trying to cater its services to the developing world, and even parts of the developed world. Not everything related to space commerce is targeting the rising middle-class aspirations; there are niche areas in it which are by default is elitist in nature. Space tourism has emerged as an important avenue in commercial space services by the turn of the century. This activity can be afforded by only a very minute percentage of the human population, but it involves huge sums of money. Currently SpaceX, Virgin Galactic and Blue Origin provide space tourism operations with the latter two offering only suborbital flights.[15] There are also opportunities, which could be opened up for interplanetary excursions, which may not be realized in the near term. However, in the deeper parts of space, the prospect of mining heavenly bodies remains a very promising prospect – one which many nations and firms are currently pondering over. For instance, the Moon contains rich reserves of Helium-3, which is an isotope of Helium and can be used in nuclear fusion reactors. It has been estimated that just twenty-five metric tonnes of the isotope, which could be transported in one tranche to earth, has the capacity to power a country like the US for a year.[16]

When it comes to launch services, it is not just the cost which matters; reliability is also a very important factor which drives countries or corporations to opt for a particular launch service provider. India's workhorse launcher, the Polar Satellite Launch Vehicle (PSLV) is both cost-effective, as well as perhaps the most reliable and versatile launch vehicle which currently exists in the world. The launcher also helped India create records by launching the cheapest Mars mission as well as the maximum number of satellites (104) launched in one vehicle. However, India has one very serious drawback with regard to space launch services – the launch of heavy payloads into GEO. India has for long been depended on Arianespace for its own launches to the

GEO and has only recently developed the indigenous platform powered by cryogenic engine stages. Since the first developmental flight in 2001 using imported Russian cryogenic engines, India has successfully developed three successive versions of its Geosynchronous Satellite Launch Vehicle (GSLV). Though this has of late enhanced India's payload capacity up to four tonnes for GEO, it is only a fifth of what China can launch today to the same orbit.[17] India is currently seeking to develop a heavy lift vehicle capable of double the existing payload capacity for the GEO. On the other end of the spectrum, India has developed the Small Satellite Launch Vehicle (SSLV), which is meant for launching small satellites. As far as the downstream components are concerned, India has developed its own satellite navigation system called the NavIC (Navigation for Indian Constellation) through the seven Indian Regional Navigation Satellite System (IRNSS) satellites deployed for the purpose since 2013. The NavIC provides regional coverage of South Asia and the Indian Ocean neighbourhood of India with much more accuracy than the GPS.[18] Though it represents a successful first step, India is yet to come up with a full-fledged GNSS. India has also not yet broached niche sectors like space tourism, as its human spaceflight programme is still on the anvil.

Proliferation of New Actors in Space

The number of space faring nations is currently on the rise, and the rate of such proliferation is also increasing. In the initial decade, there were only two active space faring nations – the US and the USSR. This went on to become half a dozen by the end of the Cold War with China, Japan, France/European Space Agency and Israel joining the club. The number has increased to ten by the twenty-first century, with the addition of North Korea, South Korea and Iran. However, it has to be noted that almost a third of the world's nations have established their own space programmes, not considering the level of their capability.[19] It is most likely that more nations will set up and develop their own indigenous space programme and capabilities in the future. It is also possible that some of them might adopt the easier alternative by relying on established players in the field. The latter could have been the most obvious scenario until just a few years back; however, the re-emergence of major power rivalry and the recent series of shocks to global supply chains and globalization might lead to more focus on indigenous space capability.

Space activities have long been primarily the domain of the governmental sector. Though it would be impossible not to have any private participation in the space programmes of liberal democratic states like the US, governments

had an outsized role in controlling and regulating space activities. One of the key aspects of this role of the government has been the control over access to outer space. It has hardly been the case that a private entity could independently access space, at least in the twentieth century. These entities acted largely as contractors and sub-contractors of government projects. However, this has changed as the commercial dimensions of outer space have witnessed massive growth in the twenty-first century, as mentioned earlier. This led to the private industry players getting mature and capable of effectively running space programmes of theirown – building satellites and launching them from their own sites, using their own launchers for multiple customers. The second decade of the twenty-first century saw the rise of what is known as a 'NewSpace' revolution, marked by the emergence of companies like SpaceX in the US and many smaller firms subsequently in other parts of the world.[20] Increasingly, these companies are competing with countries in their annual launches. Today, SpaceX contributes the most to launches from US soil, more than NASA. SpaceX is also competing with China in terms of launch numbers today. In 2021 itself, the highest number of launches was done by China, which conducted 56 missions. If treated separately, SpaceX could come second with its 31 launches, and it incidentally helped the US retain at least the second place with 51 launches.[21] The Starlink project has completely turned around the fortunes of SpaceX as well as the trajectory of space launches. SpaceX by itself may be responsible for launching at least half of the total number of satellites launched by humanity since 1957. Following the footsteps of SpaceX, other companies across the world have also come to the fore to reap the commercial dividends offered by the NewSpace revolution.

The rise in the number of private actors and their growing clout also brings in a lot of political and legal questions. Is it possible for the state to retain these firms under its control? And at the international level, do they represent a particular country which they belong to or an independent entity? For one, the rise of SpaceX would not have been possible without the patronage of the American state, which gave it the necessary support and lucrative contracts that has helped the company builds a formidable base for itself. However, its ambitious and assertive trajectory, going beyond satellites and launchers to interplanetary travel and colonization of heavenly bodies, has raised concerns on whether such playerscan be controlled under the existing legal frameworks. The answer so far has been negative, and it will certainly be a daunting task to control such entities once they become too large to handle, whether at the level of the state or at the global level.[22] Nevertheless,

their impact within a short time frame has been nothing short of transformative. Even India has not been immune to the rise of New Space actors. India currently has a vibrant set of New Space firms which deal with activities upstream and downstream, like satellite launch services, manufacturing, as well as space application services. Skyroot Aerospace, Agnikul, and Bellatrix are focused on launch and propulsion systems; Exseed Space has already launched its communication satellite through SpaceX, making it the first Indian private entity to deploy its own satellite; Pixxel India seeks to deploy a high-resolution remote sensing satellite constellation of global scope; Rebeam is developing the technology for wireless transmission of power in SBSP systems, and there are many more who are working on independent and joint projects.[23] India created a new organization called NewSpace India Limited in 2019 with the purpose of leveraging ISRO's capabilities in the commercial sector and boosting the role of India's private sector in the space domain.[24] In the following year, India established the Indian National Space Promotion and Authorisation Centre (IN-SPACe), which will act as a single window nodal agency for the private players to help utilize ISRO's technology, infrastructure and facilities for the development of their own projects.[25] Subsequently, in 2021, the government created the Indian Space Association (ISpA), an advocacy body consisting of prominent private players in India's space industry to boost India's self-reliance in space.[26] The commercialization of space and the NewSpace movement is interconnected. ISRO by itself will not be able to produce launchers and satellites to keep up with the pace of growth in space services demand. Therefore, it is imperative for India to facilitate the growth of the Newspace ecosystem in India to ensure that it could reap the maximum benefits of the commercial space prospects.

Intensifying Militarization and Weaponization

Space is known as the "ultimate high ground". During the Cold War era, the military dimension was very much part of the space activities of the superpowers. The very act of launching Sputnik was essentially a political one spawned by geopolitical rivalry, and some of the earliest satellites placed in orbit were meant to take stock of the adversary's arsenal. Satellite-based reconnaissance, military communication and subsequently military navigation became an integral part of the militaries of either of the superpowers and subsequently, their allies during the period. With the end of the Cold War, the practice did not stop – rather it diffused into the space programmes of the relatively newer spacefaring nations. The American Intervention in the Second

Persian Gulf War by the end of the Cold War displayed the inevitable role that space will play in future conflicts. The countries which already had military components in their space programmes upped their modernization efforts, those who have not had it till then started considering their option, and those who did not have a space programme started working on it. The re-emergence of major power rivalry by the second decade of the twenty-first century has resulted in an increased build-up of military capabilities as well as their deployments. This is reflected not just in terms of deployment of capabilities, but also in terms of restructuring of the militaries themselves.

One of the major developments in outer space in the second half of the last decade, when the major power rivalry became apparent, was the creation of a Space Force by the US. The Space Force became the sixth branch of the US armed forces in 2019, with three missions – "protect the interests of the United States in space; deter aggression in, from, and to space; and conduct space operations".[27] This led to other countries like France and Japan taking similar moves. The French plan outlined in 2019 of a Space Command within its Air Force even involves deploying weapon systems, both kinetic and directed energy types, on satellites for their defence.[28] Japan launched a Space Operations Squadron as the first space domain mission unit of the Japan Self-Defense Forces in 2020.[29] The fact that Japan, which has a pacifist constitution has taken this move, and that too with regard to outer space, is a clear demonstration of the heightened level of militarization in outer space. However, it has to be noted that Russia and China had established their own versions of the Space Force in 2015 prior to the US in the form of Russian Aerospace Forces[30] and the Strategic Support Force,[31] respectively.

The technological advances in the space sector are also reflected in the military capabilities of major spacefaring nations. Reconnaissance satellites are getting more adept at noticing even minor moves of their adversaries on the ground anytime, with the introduction of advanced sensor technologies like the SAR. China's experimental deployment of its quantum communication satellite has opened the doors to establishing hack-proof military communications capabilities via space. This has significantly added to China's relative power with regard to its long-term rivalry with the US, aiding its superpower ambitions. This will certainly urge more countries to work on similar projects. Even on the navigation front, the major powers can be seen developing their own navigation systems, primarily because they won't have to depend on the American GPS in times of conflict. The military capabilities which are getting developed go beyond force support and penetrate into the realm of weaponization as well. Though outer space could be said to have

been weaponized even before the launch of Sputnik through the transit of ballistic missiles, it was during the Space Age that it broke new grounds for weaponization. Both the US and the Soviet Union tested Anti-Satellite (ASAT) weapons, which attempted to bring down deployed satellites during the Cold War. Though the concept of space weapons eludes a clear definition, the superpowers worked on several unrealized projects which included hard and soft skill options – from tungsten rods to high-power lasers based in space to attack ground targets as in the case of theUS in the 1980s.

Attempts were also made by the Soviet Union to target orbital assets from the orbits themselves using co-orbital satellites. Currently, such types of projects are witnessing possibilities of revival. The US withdrawal from the Anti-Ballistic Missile Treaty in 2002 to work on its Ballistic Missile Defence systems raised alarms in Russia and China and made them rethink their post-Cold War strategic equations with the US. China as a result conducted its first ASAT test in 2007, and the US conducted a retaliatory test in 2008.[32] Russia of late seems to have also rehashed the Soviet co-orbital as well as direct ascent ASAT tests. Meanwhile possibilities of electronic and cyber-attacks on satellite systems may turn out to be more realistic and affordable possibilities when it comes to weaponization. The growing utilization of the electromagnetic spectrum and cyberspace connectivity in the orbits brings out novel weaponizing options not just for nation-states but also for violent non-state actors.

India has also come a long way in developing its military capabilities in space – both on the capability front as well as on the organizational front. In the wake of the establishment of the US Space Force and the cascade of responses from major powers, India in 2019 set up a Defence Space Agency (DSA) and a Defence Space Research Organization (DSRO). The former is to focus on controlling and coordinating all of India's military space assets and the latter is to conduct research on the country's military space capabilities.[33] India has become increasingly bold in pursuing military projects in space, whereas it had been rather reluctant to bring in the military dimension into its space activities earlier. One key aspect of this trend is that India is deploying dedicated military satellites, which it previously did not pursue. This highlights the growing focus of India on exploiting the military potential of outer space. Today, India has high-resolution reconnaissance capabilities matching the best in the world, especially with the acquisition of SAR ability. However, its military communications and navigation capabilities are only shaping up of late.[34]

As far as weaponization is concerned, India had always stood up against space weaponization through its vocal support of a legally binding treaty at the negotiations on Prevention of an Arms Race in Outer Space (PAROS) at the UN Conference on Disarmament ever since the beginning of such talks in the early 1980s.[35] However, India realized that just like the case of nuclear weapon, it was forced to develop ASAT capabilities, as the major powers went ahead and conducted ASAT tests after a brief lull after the end of the Cold War. India finally conducted its first ASAT test in 2019 through its Mission Shakti, which involved a direct ascent kinetic attack on a pre-launched target satellite.[36] Through this "better late than never"act, India set up its deterrent against any adversarial power attempting to target its space assets. The next major milestone in this regard could be the testing and fielding of non-kinetic weapons.

Quest for Space Science and Sustainability

Outer space can be seen through the lens of commercial and military interests; however, it is also a domain of science and technology because it is the 'final frontier'. Only with more knowledge and capabilities to use the outer space, can its potentialities be fully utilized. In this respect, there has been sustained cooperation between countries, when it comes to the scientific exploration of outer space. Even in the era of renewed major power rivalry, it is important to note that long-established cooperative mechanisms continue, albeit not without hiccups – the International Space Station (ISS) itself can be seen as a case in point. Starting as a multinational effort, it heralded a new era in space science and exploration, especially since the US and Russia were members cooperating with each other in this partnership project. Of late, however, even such a partnership has been subjected to much strain, as witnessed in the recent Russian threats of withdrawal from the project in light of the Russo-Ukrainian conflict.[37] However, in addition to science, there is an added emphasis on national pride and stature, which has re-entered the spirit of spacefaring after a brief interlude.

The multitude of human spaceflight and interplanetary/deep space exploration projects being initiated in the past few years bear witness to this evolving trend. The US initiated the Artemis project in the wake of previous US President Donald Trump's 2017 call for the return of Americans to the Moon.[38] However, it is not doing it alone; rather it is partnering with its allies, facing the reality of its receding economic profile and in the face of growing geopolitical competition with rivals like Russia and China. On the other hand, China is charting its own independent course both in terms of manned and

unmanned space exploration. China debuted its "Taikonaut" in 2003, and followed it up with multiple manned missions, leading to the current construction of its own space station in the orbit. By this act, it is rivalling the ISS led by the US, out of which it was kept out, and which will expire by the end of the decade. The race for interplanetary exploration is also heating up, with China reaching out to the Moon and Mars in the past decade. It is also coordinating with Russia for a joint lunar base in the near future,[39] reflecting the geopolitical play on Earth.

Apart from science, the question of sustainable use of outer space is also something which has the potential to bring countries together. The threat of space debris – the remains of satellite and rocket components and their fragmentation – is a shared concern for all humanity and is quite an existential one for its spacefaring ambitions and the dream to make humans an interplanetary species. The biggest threat coming from space debris is not its ability to harm individual satellites, but its potential to turn entire orbits into satellite graveyards and thereby deny humanity access to space. According to what is known as the Kessler Syndrome, a runaway process of generation of space debris would exactly bring about such a consequence. As a result, all major stakeholders in outer space, the numbers of which are on the increase, are very much concerned about the sustainability of space activities and their future access to space. With the possibility of a Kessler Syndrome kicking in, humanity may not even be able to leave earth's orbit, let alone become a planet-hopping species.

The advent of satellite mega constellations may have just fast forwarded the orbital fate towards such an eventuality, as the possibility of space debris generation increases with the rise in the number of space assets deployed. With such a dystopian future awaiting the orbits, there is a rising concern about the threat from space debris and a growing pursuit for the means to mitigate the threat. Of late, there have been several solutions suggested to both eliminate debris as well as to prevent them from being generated in the future. The mitigation measures include solutions like degrading their orbits so that earth's gravity will pull them into the atmosphere where they will be incinerated; as well as transporting them to 'graveyard' orbits where they will not interfere with regular space activities; among many others. There are also prevention measures being floated and implemented to some degree, by which satellites are provided built-in capacity to do the above actions by themselves in the future when their life comes to an end. Better monitoring and control of orbital traffic can also avoid accidental collisions leading to debris.[40]

India's track record in space science and exploration has been largely consistent with the keystones of indigenous development and cooperation with partners wherever essential. India will have to continue treading its own path in line with its *Atmanirbharta* or self-reliance imperative when it comes to space exploration, manned and unmanned. India has already kickstarted its human spaceflight programme with the Gaganyaan project announced in 2018.[41] If it succeeds, India will become the fourth country to do so and will become part of yet another elite club of nations having select high-end capabilities in outer space. India may also have to follow its geopolitical imperatives when it comes to space science and exploration missions like the space station. India already has expressed its ambition to set up a space station.[42] This is likely to come up as a rival to that of China, which is already under construction. It may also feature a high level of cooperation and compatibility with the QUAD and Western partners, and not so much as with the Russian side.

India also cannot remain on the sidelines and be left out as the major powers consider establishing their bases in heavenly bodies. Space debris management is an area where India can contribute so that it can provide a solution to the menace which could be beneficial not just for the world but also for India's space interests. At the same time, it can reap diplomatic benefits in line with its ambition to be recognized as a major world power capable of delivering global goods and develop a scaled-up version of its capability as a first responder in the Indo-Pacific region. India has the right ecosystem for startups, which can work in this area, provided there is more governmental thrust towards such a direction. India also needs to take a leadership position at the global level to drive multilateral coordination and action toward the prevention and mitigation of space debris.

Conclusion

There have been fast-paced advances happening in all major areas of the global space sector. This is especially so in the area of space technology, which India will have to catch up with as the overall geopolitical settings are transforming. There are new trends emerging today in the area of the commercial space sector as well as the private sector, which were taken far less seriously during the previous century. The space security scenario has become significantly complex with new actors emerging, as well as with older actors enmeshed in high levels of competition which could precipitate conflicts. The sustainable use of space is also getting increased attention,

albeit without solid actions from the side of the old and new actors, either individually or collectively. In such a flux, India's space programme is situated at a pivotal point where crucial decisions have to be made in charting the way ahead.

India has finally showcased its intent to boost the participation of the commercial and private sector so that the entire space industry can be elevated to the next level where it can stand and compete with global giants. But much will depend on whether the reforms unleashed in the past few years will be followed through, and on the development of a mature and healthy industry ecosystem. The support of ISRO is crucial for the private sector as they could compensate for their nascent level of growth with the governmental organization's vast infrastructure, know-how and experience. ISRO stands to gain a lot from this collaboration as well because it can now focus its efforts on core research and development areas in the scientific and technological field. These reforms will have cascading impacts, when it comes to space technology, as a higher level of innovation is expected in the space industry with the strengthening of private actors, the market forces as well as a reduced burden on ISRO. These advances in technology can then be channelized to further develop and elevate the commercial, scientific and military capabilities of India's space programme. Only then, India can gain significantly in the context of the emerging geopolitical scenario in outer space.

Notes:

[1] "What is SAR?", *NASA Earthdata*, at https://www.earthdata.nasa.gov/learn/backgrounders/what-is-sar.

[2] Harun Siljak, "China's quantum satellite enables first totally secure long-range messages", *The Conversation*, 16 June 2020, at https://theconversation.com/chinas-quantum-satellite-enables-first-totally-secure-long-range-messages-140803.

[3] Amanda Jane Hughes and Stefania Soldini, "Solar power stations in space could be the answer to our energy needs", *The Conversation*, 19 November 2020, at https://theconversation.com/solar-power-stations-in-space-could-be-the-answer-to-our-energy-needs-150007.

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