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ORF SPECIAL REPORT

JANUARY 2020

India in the Final Frontier: Strategy, Policy and Industry

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Attribution: Rajeswari Pillai Rajagopalan, Pulkit Mohan and Rahul Krishna, 'India in the Final Frontier: Strategy, Policy and Industry', *ORF Special Report No. 100*, January 2020, Observer Research Foundation.

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ISBN: 978-93-89622-36-2
ISBN Digital: 978-93-89622-37-9

ABSTRACT

This report builds on the discussions during the 5th ORF Kalpana Chawla Space Policy Dialogue 2019 organised by ORF. The report has three sections: the first covers questions of strategy in space; the second discusses policy dimensions; and the final one explores the role of private enterprises in the space domain. While some sections may include global perspectives, the report views the various challenges in space primarily from an Indian standpoint. The section on strategy focuses on the militarisation and weaponisation of space and India's own position on these issues. The section on policy covers questions of both internal and global policy matters for India, looking at the need to revamp the Indian Satellite Communications policy and explaining the prudence in documenting a comprehensive space policy for India. Finally, the report outlines the role that the private sector can play in various sectors in the space arena.

INTRODUCTION

The space community has been at the centrestage of ground-breaking innovations and the conversations at every iteration of the space dialogue have become bigger, better and more rigorous. India has had its fair share of achievements in the domain, including the launch of the country's heaviest satellite, the GSAT-11 which will boost India's broadband services by enabling 16 Gbps datalinks across the country; the launch of GSAT-7A, the military communication satellite; and the launch of the GSLV Mk III-D2, the GSAT 29, and the Anti-Satellite (ASAT) test.

Even as these achievements are important, the responsibility and the challenges faced by the space community have also grown, especially as security requirements in the space frontier have increased in recent years. The Conference on Disarmament (CD) in Geneva continues to be deadlocked, discussions on measures to prevent the weaponisation of outer space is on the verge of a breakdown, and the guidelines prepared by the United Nations Committee on the Peaceful Uses of Outer Space has garnered little support. The failure of the UN Groups of Governmental Experts on the Prevention of Arms Race in Outer Space (PAROS) in 2019 is a case in point.

In the 20th century, competition over strengthened space capabilities was only a prerogative enjoyed by the two global superpowers, the United States (US) and the Soviet Union. With the democratisation of space technology and the entry of new players into the sector, including private players, the challenges have become more complicated. Outer space has become an intrinsic part of today's geopolitics as well as in the national security context of all the major spacefaring powers. The advancements being made in the domain either through state entities or

commercial players are posing serious questions in the area of international security, global governance, and ethics of war.

I. STRATEGY

Significant efforts were made to reach outer space in the 1950s with the aim of creating an edge in warfighting using exo-atmospheric rocketry. In the next few decades, space was largely used as a domain to fulfil security ambitions or as a medium to gain national prestige by outshining rival countries. Since then, the strategic importance of space has become a given especially for countries aiming to assert military dominance. The use of space-based assets during the Gulf War by the US displayed the immense potential for force multiplication through infrastructure in-orbit. The world took notice of the achievements of the US through these assets, sparking a renewed race to achieve supremacy in space. Today, nations differ in their view of the strategic nature of space. Some fear space will soon be a warfighting domain while others view space as a medium to obtain an edge in terrestrial conflict through 'informationalisation' and missile early-warning and defence. There is little doubt that space as a domain will have a significant role in how terrestrial conflicts play out in the future.

Assessing and arresting the growth in weaponisation of space

Over the last several decades, space has become an increasingly important aspect in the national security calculus. From the first satellite launched by the Soviet Union in 1957, to the current capabilities possessed by several other countries, space has moved from an isolated domain to one that connects the operational capabilities of a nation in the traditional domains of land, air and sea. The use of space assets as an effective force multiplier has also been an important factor for countries with a space programme, with many of them actively taking steps to ensure their space assets are not only functional, but also well protected. With space assets becoming increasingly crucial to terrestrial military operations, countries have also developed offensive assets in space and have begun to view space as a warfighting domain.

In the years since the launch in 1957 of the first satellite, Sputnik I, by the Soviet Union, both the US and the Soviet Union were embroiled in a space race during the Cold War era, which led to the US sending the first man to the Moon in 1969. The emphasis on developing technological prowess in space and its potential to augment military operations pushed several other nations to start developing their own space programmes. India and China were amongst the first countries in Asia to establish active space programmes, albeit with different objectives. In today's world, any country having space-based assets of their own is

considered to have a tactical advantage over other countries that are unable to counter those assets. To that end, China, the US, and Russia have all been major players in the development of space-based capabilities for military purposes. These capabilities ensure that their militaries have superior information and communication coverage, while deterring the adversary from using their space-based assets effectively. This has resulted in China becoming a major player in the launching of satellites for the People's Liberation Army, with as many as 39 separate launches containing satellite payloads in 2018 alone.

These assets, however, do not necessarily mean that a country has placed weapons in the domain of space. While several kinds of counterspace technology that a country may possess can be covert, such as signal jamming and spoofing of signals, ground-based assets have the potential to be just as disruptive to an asset in space. Therefore, the world is also seeing the emergence of Anti-Satellite (ASAT) technologies being developed by the major space powers, with the most recent test being conducted by India in March 2019. While this has signalled India's capabilities to disrupt a country's space capabilities, India was only matching a capability that already existed in the region. In addition, India's ASAT test appears to send some contradictory message about its approach to the use of space. Before it successfully conducted the ASAT test, India had stated that they did not intend to weaponise space. Instead, New Delhi intended to use the domain of space for the acquisition of knowledge and as a platform for advanced scientific development. However, recent developments made by China in the field of space technologies, along with the idea that the weaponisation of space has become inevitable, have forced India to develop the necessary capabilities required for the defence of their space assets. Yet, despite the development of a counterspace capability, India remains firm on its stance of using the domain of space only for peaceful purposes and does not support any form of weaponisation of outer space.

One of the main concerns for the space powers of Europe, on the other hand, is the increasingly crowded and congested outer space that could make secure access to outer space a bigger challenge in the coming years. The fact that outer space is also contested compounds the challenge. While defence against an adversary's attack is a vital part of a country's national security, space debris and the risk of collision with other satellites is also shaping up to be potential threats to space-based assets. This, along with the blurring of lines between civilian and military technologies in space, are some of the major concerns which the spacefaring countries in Europe are working to mitigate in the near future. Part of the solution lies in clearly defining what is meant for civilian purposes and what is for military utility. Additionally, several countries are also looking at methods to further involve the private sector in this industry, given the fact that state entities will continue to face an uphill challenge in their ability to keep pace with the rapid technological advancements in the domain of space.

Fostering Indo-European collaboration in space technology

The European space programme, akin to India's, has its roots in using space for peaceful purposes and for development. This similarity between the two programmes creates an ideal atmosphere for partnership. Unlike most major spacefaring nations, whose space programmes were created largely to serve the military, India and Europe have remained committed to advancing space technology for the benefit of humanity. India and Europe have several potential areas for cooperation such as navigation, remote sensing, and space debris mitigation. India has collaborated with the European Space Agency on a number of projects and has recently begun collaborating with individual European countries such as France and Germany as well.

There is immense scope for cooperation between India and Europe. The diversification of the Indian space programme offers multiple opportunities to strengthen cooperation with Europe. India and Europe are important stakeholders in addressing international issues of common concern including space security, safety, and sustainability.

Apart from government-to-government cooperation, it is also vital to have individual states collaborate and cooperate on the space programme by involving other stakeholders such as private sector actors which can contribute in the sustainable use of outer space. Indo-European collaboration needs to be aggregated to create alliances which can add value to space technology and cooperation. Europe has and continues to play a crucial role in the advancement of India's space programme by identifying specific areas of cooperation such as sharing of earth observation satellite data. The two are moving towards a deeper cooperation in the space domain. India proves to be an example of how developing countries' sustained investments in space technology can create a multidimensional scientific institution that can accelerate the local economy and pay long-term dividends. The number of collaborative ventures over the past 50 years have been remarkable, proving to be of utmost importance for the emergence of India as a mature spacefaring nation. The Indo-French space cooperation, for example, has spanned almost 60 years, making the two countries among the oldest space partners in the world. India's first sounding rocket launch in 1963 used a payload of French design and subsequently, all Indian launchers are fitted with the Vikas engine (also known as Ariane Viking), which was initially developed with the contribution of French engineers. Both countries have shared a long history of utilising space centres in France and India for launches – most recently India's GSAT31 was launched by Ariane, a French facility, and the Spot 6 and Spot 7 satellites of France were launched on the Indian PSLV.

However, some argue that Indo-European space relations have been strong on agreements but fallen short on actual implementation. The growing concerns regarding space debris after India's ASAT test are legitimate and thus India and European countries will need to make joint efforts in addressing the issue. Both entities share similar values regarding the peaceful use of outer space. Responsible behaviour needs to be promoted and the full applicability of international law must be ensured. However, any discussion on space-related issues should be framed with a pragmatic approach. Going forward, both India and Europe must sustain a deep and longstanding space cooperation focusing on capacity building to address a range of emerging space security challenges including the global governance aspects. Enhancing policy dialogue, creating institutionalised mechanisms, and a strong political commitment could prove to be viable options for the actual implementation of agreements. The diversification of the Indian space programme could provide new pivots to enhance cooperation and share common objectives, particularly in high-technology space science.

Militarising space to maintain a strategic edge

India is a major spacefaring nation. At its inception, the Indian space programme was focused primarily on societal and developmental utilities. Today the imperatives behind the Indian space programme have evolved. Like many other countries, India is compelled to use space for a number of military requirements such as for intelligence, surveillance and reconnaissance. India is turning to space to gain operational and informational advantages. Space is the fourth dimension of warfare other than sea, air, and land. Nations are increasingly reorienting militaries to exploit the space domain.

Space has several applications. Satellite communications, satellite imagery and reconnaissance, and satellite navigation perform numerous functions. For instance, satellite imagery enables damage assessment following an air strike and satellite navigation guides precision missiles to their targets. The global debate has moved from utilisation of space for military purposes towards one of weaponising outer space.

China's space programme is militarily oriented and controlled by the People's Liberation Army (PLA). In 2015, China undertook major institutional reforms and created the PLA Strategic Support Force (PLASSF), integrating cyber, electronic, and space capabilities into a single unified service. With the support of its space assets, China has created a potent Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR). These measures are the result of China identifying space as the new strategic high ground. The establishment of the PLASSF is indicative of Beijing's intention to exploit space as a pivotal asset for the conduct of military operations.

India is confronted with a range of national security threats including proxy wars perpetrated by inimical neighbours, domestic insurgencies, left-wing extremism, natural disasters and dangers along the Sea Lines of Communication (SLOCs). Space will play a critical role for India in addressing these threats. Given the sheer geographic spread of India's defence forces, space will be vital in helping them meet the threats the country faces. Space is vital for sustaining communications, logistics, missiles launch and guidance, weapons systems, and Unmanned Aerial Vehicles (UAVs) across the Indian Armed Forces.

At the same time, opportunities for developing a space nexus also exist in India's neighbourhood. Pakistan is seen as a proxy space power of China. Military collusion between the two will extend to increasing battlefield awareness and transparency, assist in acquiring precision coordinates, and prioritising targets. China's Anti-Satellite test (ASAT) in January 2007 demonstrated the intent behind China's moves to acquire a potent space weapons capability. India conducted its own ASAT test on 27 March 2019 but as mentioned earlier, New Delhi could not have ignored the trends of space weaponisatin including in the Indian neighbourhood.

For India, space for military applications has started to gain traction. India has a large constellation of communications satellites. INSAT and GSAT satellites meet India's communications requirements for now. Progress has also been made in the area of surveillance satellites. In addition, India also has Synthetic Aperture Radar (SAR) satellites, and high-resolution panchromatic satellites. With the completion of the Indian Regional Navigation Satellite System (IRNSS) a large part of navigation requirements has been met. Therefore, satellite dependency for military purposes has become a bigger reality. Nevertheless, gaps continue to exist in India's space capabilities.

For instance, China has made advances by launching an "unhackable" communications satellite based on quantum technology. It is a niche technology, which India still does not have and will need to develop on a priority basis. India also needs to match the advanced spacefaring states by developing a larger number of ELINT and Imagery Intelligence (IMINT) satellites to increase the number of revisit times and improve resolution. India will need more space-based SIGINT capabilities. India will have to go in for larger number of multi-tiered micro-satellites with multiple payloads rather than a large number of complex and expensive satellites, which are highly vulnerable to ASAT weapons strikes. Future applications of these satellites are in the area of Position, Navigation and Timing (PNT) which are used by the military and civilians for navigation. These are vital as India's indigenous navigation system needs to be expanded for it to be more

effective and competitive. In the future, India needs to step up its PNT capabilities as well as measures against jamming and spoofing of India's satellites. In the area of ground infrastructure for India's space segment, New Delhi will need to increase telemetry, tracking, downloading, and control ground stations to strengthen redundancy. Anti-jamming capabilities and space situational awareness are crucial for India to secure its space assets as it needs to be able to scan and survey the space environment effectively.

India needs to augment and reorganise its space organisational structure in order for the armed forces to take fuller advantage of the country's space assets. Training personnel for the military application of space technology will need investment for effective planning and conduct of military operations. While space is a global commons, there are states across the world seeking control and aiming to deny other countries use of space. Space plays an important role in meeting national security needs; however, a balance has to be found between meeting national security challenges and societal needs.

Competitiveness of India's space programme

Space is used extensively in India's social and development sector, with at least 60 departments using space services to pursue the country's developmental agenda. Space technology can affect the most fundamental change in the ground rules of economic competitiveness and development. Space technology applications have served national development well. India's space programme is self-reliant and has also been providing launch services to foreign countries. India is now capable of placing four tonnes in orbit. India has achieved self-reliance in launch vehicles and satellite technology. Furthermore, there is immense potential of lunar resources for energy generation and the possibility of lunar bases, which is also beginning to see competitive attempts in Asia and in other regions. Space-related assets are exceptionally useful for military purposes. For example, ballistic missile defence cannot function without space assets providing communications and navigation. Apart from these, disaster management and tackling natural calamities are also important applications of space assets. India's space policy should also energise competitive industries to participate in domestic and global markets with increased entrepreneurship in launch vehicles and satellite manufacturing segments. At the same time, efforts must be made to clean up space debris, which is already a huge challenge to keeping space safe, secure, and sustainable. Space assets need to be protected for supporting civil space functions and national security objectives.

II. POLICY

India has also faced similar issues with its conceptualisation of space. In the two decades since the SATCOM policy was passed, India has made little progress in formulating a comprehensive policy or law to regulate its space sector. There have been several calls for the creation of an all-encompassing framework that clarifies regulations so that the industry can grow and achieve its potential. With significant growth in space-based utilities, India must establish a policy framework that will enable a level playing field for the private sector through burden-sharing between the public and private actors.

As of November 2019, the US National Aeronautics and Space Administration (NASA) was tracking nearly 20,000 objects in space, with nearly 5,000 active payloads. The number of countries that have payloads in space has also grown over the last decade. With an increasing number of players and orbits getting more crowded, robust governance mechanisms are needed to ensure stability and avoid untoward incidents in outer space. There has been a lack of progress in establishing rules of the road for space since the late 1990s. Treaty-making exercises were a relatively easier effort in the 1960s and '70s with the two superpowers—the United States and the Soviet Union—driving much of the efforts. Today, despite efforts to create multilateral mechanisms to prevent weaponisation, regulate resource mining, and mitigate debris, the domain has relatively little by way of comprehensive governing mechanisms.

Establishing frameworks for multilateral governance in space

The number of spacefaring nations has grown rapidly over the last two decades. Outer space has come a long way from being a domain where a select few nations exhibited technological prowess and asserted military superiority, to a medium of growth and development for several nations. Space has become an area of importance not only for the nations that use it but also for the wealth of commercial enterprises who have forayed into the domain. As an increasing number of essential services and users grow more dependent on space-based systems, it has become essential to strengthen and establish mechanisms of governance for space.

The challenges to the governance of outer space can be broadly grouped in two categories. The first set of challenges concerns the regulation of the growing number of space objects and variety of traffic in space, and the second set concerns the space security challenges in outer space. There also exist multiple processes to build governance frameworks on each of these challenges, with difference of opinions between countries on whether treaty-based approaches are more effective than normative ones. Many argue that treaty-based approaches and traditional arms control mechanisms are no longer feasible in outer space due to

the multitude of objectives that countries have in space. They believe that normative approaches must be emphasised. The impasse and the lack of consensus among major spacefaring powers has led to a crisis in decision-making on outer space affairs. In such a scenario, normative tools may help to make progress in the short term and serve the potential to create an environment for legally binding verifiable measures in the future.

For the first set of challenges, the UN Committee on the Peaceful Uses of Outer Space (COPUOS) is considered the primary body for forming rules of the road. The body was established at the cusp of the space age and is vested with the responsibility to ensure the use of space for peaceful purposes and for coordination between spacefaring nations in their activities. Discussions at the COPUOS have resulted in the creation of much of the existing framework for the governance of space, and efforts continue to further this by exploring the possibility of cooperation and collective capacity building for outer space. There has been significant progress in building a body of norms for the use of outer space for development. Even though these norms are non-binding, they build on existing international law applicable to space to create a more stable environment to further growth in this field.

Space security has become the most pressing challenge in outer space, threatening the safe and sustained use of outer space in the future. The 2007 Chinese ASAT test broke the lull in the testing of space weapons since the Cold War era. The US and India have conducted their own ASAT tests since then and other countries are possibly contemplating such measures in the future, thereby heightening the insecurities in outer space. Despite several different efforts—the European Union-initiated International Code of Conduct for Outer Space Activities, to the Russia-China draft treaty on the prevention of the placement of weapons in outer space, the UN Group of Governmental Experts (GGE) on Prevention of Arms Race in Outer Space—over the last decade, there has been very little consensus that no consensus report was issued at the end of the UN GGE sessions. Treaty-based approaches have failed due to a lack of definitions on activities in space as well as few mechanisms for verification of compliance in an atmosphere of little trust and transparency between major players. The challenges of developing consensus has been fuelled by the fact that there is no definitional clarity on a number of important terms such as "space weapon", "defensive use of space", and "peaceful use of space". Also, getting the major powers to agree upon verification of compliance in an atmosphere of mistrust is a serious challenge. The norms-based approach seems to be the way forward in this scenario as well. Norms can lead to the creation of a stable and predictable environment in space due to a big stress on openness and transparency which reinforces continued accessibility of the domain to all. TCBMs can go a long way in creating an atmosphere of trust

and confidence in each other, which are important first steps in working towards a more comprehensive, legally binding instrument.

Space cooperation: The drive to deliver benefits from space to increasing number of countries

A key dimension of space cooperation lies in how established spacefaring nations can contribute towards fulfilling the aspirations of emerging players. As more countries seek their own satellites in earth's orbit and beyond, established powers can play a vital role in ensuring a well-coordinated effort in achieving this goal. The US has played an active role in strengthening emerging players in their capacity building exercise since the 1970s. The newly drafted US National Space Policy documents have the potential to contribute to outcomes that are more significant in the future. Key areas for capacity building exercise between established players and emerging actors are space commerce, bilateral research, and development projects. From an Indian perspective, space is a global commons that goes beyond national considerations and requires international collaboration to explore more meaningful ventures that can meet social and developmental goals and develop effective global governance mechanisms. The US has also been helping emerging actors in their capacity building by providing free data through the National Oceanic and Atmospheric Administration (NOAA) and the US Geological Survey (USGS). In its commitment towards capacity building for emerging players, NASA has entered into a joint venture with the United States Agency for International Development (USAID) to help improve environmental decision-making in developing countries.

The progress made by the Indian Space Research Organisation (ISRO) in outer space technologies has also benefitted other emerging nations. India has signed over 200 cooperation agreements with 51 countries and five international organisations, which provide effective collaborative mechanisms for peaceful use of outer space, data sharing, capacity building, and policy coordination. In the case of Brazil's space programme, international cooperation has been a priority, which includes upgrading the national space launch centre to an international space centre, which would be accessible to other countries and private actors. The Alcantara launch centre is important, as its proximity to the equator provides significant advantage for the launch of geo-satellites. The Brazilian Space Agency collaborates with various space powers with whom it has bilateral, multilateral, and regional agreements. The launch of the first 'made in Brazil' satellite through India's PSLV, is an example of deeper cooperation between key space actors. While emerging space actors share many commonalities such as lack of resources and space policy awareness, it is important for established nations to extend their

cooperation by promoting technology transfers and sharing best practices. A well-established mutual coordination is important in order to ensure space sustainability.

The role of a documented space policy for India

The strength of India's space programme lies in the effective use of its space assets in the service of its people. India has so far had 73 mission launch vehicles and has launched 104 satellites of its own since the beginning of its mission, out of which 48 are still active. The country is now making great strides in several advanced technology missions. Apart from serving domestic needs, ISRO has also launched more than 300 satellites for foreign countries through joint cooperation missions. India's space assets have played a significant role in the fields of telemedicine, planning, search and rescue, communication, education, geology and oceanology, among others.

India does not have an open space policy and the debate on the need for one has been growing. Developments including increasing militarisation of space and early trends towards weaponisation of space in recent years have sharpened the debate around concepts such as peaceful use. Such questions have driven the need for India to conceptualise its own response to these debates. What should India's space policy be capable of? There is a need for two different space policies – one that deals with civilian space activities catering to the ISRO, and the other that looks into military space activities outside the purview of ISRO. India's space policy needs to be an instrument that enables the rapid growth of the space industry. It needs to look into different sectors like communication, navigation, and remote sensing where space has been put to great use. The space policy should also explain how the space sector will contribute to the achievement of a national vision, articulate the government's aims and goals for the space sector, define the ecosystem for enabling the capabilities needed by the space sector, and establish a governance structure for the successful implementation of the policy. Currently, there is no clear framework for private actors in India's space sector. It is predicated upon government authorisation for specific involvement. The space industry requires a coordinated effort between the public and private sector in order to promote India's advancement in the space domain. The existing draft policy does not address many of these concerns. The space policy needs to be debated in Parliament and involve all stakeholders. In an ideal situation, there should be one comprehensive space policy document issued by the Prime Minister's Office or the Parliament which will involve all the different uses of outer space, including in the military space domain. This document should be also in line with the overall national objectives of where India should be in the near, medium and long term.

Creating mechanisms to bring gender parity in the global space race

The role and contributions made by women in the field of space and the need to encourage greater female participation is pertinent in cultivating a more diverse space community. Despite a relatively well-established education system in India, there is a dearth of women in mid to senior level managerial positions in the country. Female participation in the fields of space and aerospace has been limited, perhaps owing to the small number of female students focusing on these subjects in higher education.

In the Indian Air Force, for example, women are restricted to shorter service commissions, of up to 15 years. It is important to acknowledge that it is the prerogative of the individual – male or female – to choose a profession of their choice, and to make careful considerations of personal safety. Although the ground is not even for women in the space industry, women ought to focus on themselves, and collectively combat stereotypical perceptions that hinder their professional or personal growth as individuals. The future of gender narrative in the space community lies in the ability to articulate the doctrine of privacy in how gender stereotypes are viewed and perpetuated.

A significant measure of discrimination perpetuated against women comes from a unique concept of spatial luxuries. In the context of space exploration however, the luxuries of such kinds of stereotypes do not exist, making it crucial to look at the evolution of gender as a concept. In order to establish colonies on different planets, gender as a product of birth must be demolished once and for all, and ought to be understood as an exercise of choice. Despite the prevalent examples of women working as rocket scientists, payload experts, astronomers, pilots, geologists, engineers, doctors in space medicine, space entrepreneurs, the numbers as compared to that of men in the same fields, are lopsided. This disparity can be attributed to the general trend of fewer women taking up careers in science, technology, engineering and mathematics (STEM). In order to sustain human space exploration, it is imperative to embrace diversity and engage more and more women in the domain.

III. INDUSTRY

The nature of the space sector has changed drastically over the last two decades. What was previously a domain dominated by state-funded and state-run space programmes is now co-inhabited by a booming private industry. The industry has seen the inflow of significant capital and has made technological advancements which have often overshadowed those made by their state-run counterparts. Yet the nature of international space law requires nations to regulate and take

responsibility for spaceflight conducted by its private sector, which has required coordination between the two entities.

The role of the government in shaping and encouraging the private sector is yet to be determined with countries using different approaches. The Indian space programme has viewed itself as a regulator as well as a service provider. In areas such as remote sensing and communications particularly, ISRO has taken a lead in providing services, but it has encouraged the private sector to participate in these programs. Launch vehicles have been a focus area for developing public-private partnerships for ISRO, with the GSLV Mk-III having several components manufactured by private entities. However, there is still a long way to go for ISRO to ascertain its role in galvanising the private industry and remains an area which needs further attention.

Examining the rapid growth of the small satellite industry: future challenges and risks

From its rather humble origins in the 1960s, India's space programme has come a long way towards fulfilling the country's space aspirations, and there is no better proof of the same than India's satellite industry. Today, India stands among major world players in satellite launching technology, having launched a record 104 satellites in one mission in February 2014. The private sector has also seen growth in these industries, growing at a steady pace to meet India's growing demands for satellites. However, there are also significant problems in the current ecosystem which may hamper the emergence and growth of new private players in the industry.

India has seen a major evolution when it comes to the small satellite industry, with several companies setting up their infrastructure and developing launching capabilities for their small satellites. Companies such as Exseed Space, Pixxel and Azista have all shown great progress in the field of satellites, providing both space assets and the ground infrastructure required for these satellites to function. These companies and the satellites they provide come with a basic stipulation, and that is the cost of building a satellite. The world is currently seeing India move forward on a path to competent and affordable production of satellites, leading to foreign corporations such as Berlin Space Technologies (BST) partnering up with Azista in the establishment and operation of a satellite production facility, with everything from initial production to final testing to be done within India. These private companies are also investing heavily in the research and development of nanosatellites, as they believe the future of satellite technology will be its miniaturisation. ISRO also has projects related to nanosatellite technology, but its

main focus is on providing the launch capabilities to the growing customer base it is currently witnessing. The organisation is currently in the process of developing the required capabilities necessary to be able to launch satellites, especially nanosatellites as the primary payload, as all small and nanosatellites can only be launched as secondary payloads on a PSLV. The development of such capabilities will help ISRO capture a significant chunk of both the domestic and international market, once the world sees the affordable launch facilities India provides.

While ISRO and other organisations have exceeded expectations when it comes to the amount of work they have been able to achieve in such a short span of time, barriers exist due to the slow pace of India's space policy development in comparison to the capabilities of other major players in the space industry. It is no secret that companies want to work with ISRO at all stages of the satellite technology development process, but in many cases they are unable to secure simple launching facilities for satellites they have already built. The 2017 Draft Space Activities Bill, while deeply flawed provides a pathway to cutting out a lot of the bureaucratic red tape which currently sets these companies back. From infrastructure such as a test range, to a set of standards which apply to any satellite being launched in India, the country still lacks a lot of the basic infrastructure and general investment in its space programme, leading to ISRO not being able to provide a permit for the use of a particular bandwidth for the first mission of Exseed Space. Most players from the industry want the space sector to be opened up like the telecommunications sector and let private players in, as the current ecosystem greatly stifles the growth of the space industry as a whole and dissuades many start-ups and small enterprises from being a part of the satellite industry.

Ascertaining the role of policy for growth of the satellite communications industry

The satellite telecommunications (SATCOM) industry has been integral to the growth of communication networks throughout India. The SATCOM technology has a number of applications that complement the agenda of socio-economic development and inclusion. The industry forms the backbone of several essential services such as ATMs, distance learning, and mobile network backhauls. It has experienced several changes over the past few years with the arrival of new companies such as Blue Origin as well as new investors. Major satellite communication providers have begun vertical integration – attempting to own the service and all of the equipment required to provide it including the satellite capacity. The industry has made rapid advancements in reducing the cost per bit of data and have started launching Middle Earth Orbit constellations to augment

Geosynchronous Equatorial Orbit (GEO) constellations for low-latency, high-throughput applications.

Satellite communication also serves as a naturally good fit for areas such as in-flight connectivity and maritime communication which are expected to be growth areas for the industry. Far-flung areas have seen a renewed interest in using satellite connectivity for either terrestrial backhaul of mobile networks or community deployed Very Small Aperture Terminal (VSATs) to ensure these areas have connectivity despite a lack of other infrastructure. The Government of India along with ISRO has made efforts to ensure the growth of the industry in this sphere, bringing new bands and technologies on their satellites while also improving Ease of Business and compliance mechanisms.

The rapid growth of the industry has also led to questions about ISRO and the Department of Space's (DoS) role in the industry. They currently serve as a service provider, aggregator, licensor as well as regulator to this industry. A number of private players believe that the multiplicity of roles played by the DoS causes a conflict of interest and hinders growth in the industry. The administration, however, is of the opinion that DoS shares the same vision for the growth of the private sector that these players do. ISRO has claimed that they are encouraging the private sector to take a larger role and would be willing to depute the private sector some commercial applications that are of societal importance. This would have the added benefit of freeing up ISRO resources to focus on research and development in areas that are too expensive or technically challenging for private industry, a philosophy NASA has followed as well. There has been an emphasis from the government that while the private sector is to be encouraged, the industry should be indigenous, and all vertical integration should take place within India itself with minimal dependence on foreign capabilities throughout the supply chain.

While the official policy includes measures to allow for more privatisation in the space sector, these have not led to the expected level of growth in the industry. Despite the SATCOM policy having provisions for private satellite system launches, there has been only a single approval for such a system which came nearly two decades after the release of the policy. Several experts have questioned the reluctance on behalf of the DoS to give such licenses and implied that this may be a product of the conflict of interest they have due to the multiple roles they are currently playing.

There are a number of agencies within the government which need to approve a private satellite system, and some have complained of a lack of clarity and transparency on licensing within this system which has deterred the industry from launching a private satellite system. A single window clearance system, which ISRO claims it is already working on, might solve such issues and allow for

transparent and efficient granting of licenses. Another vital concern from the industry is the push towards indigenous manufacturing. Under the Make in India initiative, the DoS has pushed for any potential private satellite systems to be manufactured in India as well. Questions arise on how much of the satellite needs to be manufactured indigenously and whether that may be a criterion for licensing in the future. The industry would like for manufacturing of the satellites be a commercial decision, considering the globalisation of supply chains in several other industries, which has led to the need for clarification of these policies. It has also been suggested that instead of forcing operators to manufacture in India, an incentive-based approach could be used to encourage local manufacturing.

Overall, there are still a number of issues surrounding the role of private players in the satellite communications sector that are yet to be solved. Most of these concerns are not with the policy itself but with its implementation. There is a need to have consultations with stakeholders and develop implementation mechanisms to ensure that industry growth is not stifled.

Propelling innovation in India's launch capabilities through private sector involvement

India's dependence on space technology and satellite derived products has been increasing in line with the country's economic growth. As a leading spacefaring nation, India's future agenda is aimed at developing its own space assets for socio-economic as well as strategic purposes. However, the pioneering story of India's space programme has in recent times been beset with a private sector facing problems in setting up research and development facilities, and creating new products and services in both rocket and space propulsion.

Propulsion systems in general are the heart and soul of rockets and satellites. Space propulsion systems are installed on satellites to help them move around once they are in orbit. In-space propulsion enables satellites to maintain the right position and attitude so that they can do their assigned tasks. It enables satellites to stay in orbit and change locations so that they can remain above specific locations on the Earth's surface. As the space race heats up, this capability will increasingly be used to manoeuvre satellites being threatened by a number of threats including Anti-Satellite (ASAT) capabilities of certain countries.

The development of an Indian propulsion system has been active for half a century. It started with early sounding rockets which are small-scale rockets and after a few years, India developed its own rockets and currently is at a place where they are well developed – it has tri-genic technologies, good liquid technologies and is well within the stage of developing semi-tri-genic technologies. India so far has done a commendable job but if there is this one area where it is lacking, it is in

linking the propulsion industry to the private sector. At the moment, ISRO uses a few manufacturing companies like Godrej, MTR and L&T Space to manufacture certain sub-systems for bigger propulsion systems. It is only in the last five years that India has come to possess the expertise, the services, and the test facilities required to make propulsion systems. However, a decade ago all these options were not commercially viable even after ISRO opened its doors to the private sector.

The question that needs to be addressed is where private industries fit into an organisation such as ISRO. One possibility in the future is that a big private company can take up the launch of a vehicle all by itself, but the system is not equipped to do so at the moment. In order to generate more demand and make privatisation more commercially viable, ISRO has taken a few steps such as launching more satellites and doubling the number of space missions. Private companies can take small steps to fit into these efforts. ISRO's aim is to focus on the manufacturing side of the technology, which makes it a laboratory and not a factory. The Indian propulsion industry is expected to grow by US$ 10 billion by 2023 with the help of electric propulsion, which has resulted in a drastic dip in the weight of the satellite launched. Propulsion is a small sub-system in a big system of a satellite, but the technology is so complex and the investment which is needed to develop is also niche. A specialised industry can help in growing propulsion systems, however, currently India relies on imports for all its propulsion needs. India needs a vibrant debate around the issue of dual-use technologies. For instance, the UK is allowing start-ups from other countries to set up in the UK and launch satellites from their islands. Lockheed Martin has the ability to develop electrical propulsion, but instead they are investing in start-ups and acquiring them.

Private manufacturing industries are entering the business of electrical propulsion and there are certain rules and regulations framed by the Department of Petroleum and Explosives Safety Organisation which have eight clauses that private manufacturing industries have to abide by. The process, as it stands today, is complex and involves getting No-objection certificates from 11 different departments of various governments, and new entrepreneurs find it difficult to obtain a licence. It can be concluded that while ISRO is mainly focused on the manufacturing aspect of technology, India needs to learn from other countries in order to become a holistic and self-sufficient force to reckon with when it comes to propulsion technologies. Creating a more robust and resilient Indian space posture will depend on creating strong collaborative linkages between the private and public sector.

The changing face of space exploration and technology: Understanding the role that small and medium private enterprises play in the growth of the space industry

The private sector for space systems as well as services is increasingly opening space economy to new players and leading to new market layers. Commercial players such as BlueOrigin, SpaceX, and Rocket Lab are leading the fourth industrial revolution within the domain of space, namely NewSpace, with their visionary exploration and innovative earth-focused downstream commercial ventures.

Indeed, the space sector has changed drastically over the last few decades, with governments no longer being the sole actors with the resources to foray into space. Today, the private sector in space has made significant technological advancements and can monetise their prowess to ensure large-scale societal impact. However, to ensure that such impact is maximised, there needs to be engagement with policymakers and lawyers to ensure that space research has commercial viability. Next Big Innovation Labs is an example of such a company, conducting research on space technologies for maximising societal impact. They use 3D bioprinting to test methods that ensure space flight is not a health risk for the astronauts who undertake it. They are also using new technologies that focus on delaying the decay of skin and other organs in space to reduce the damage caused by spaceflight to the human body. This may eventually allow humans to inhabit other planets that do not have the same characteristics as Earth. Several other companies are also utilising the extra space on commercial resupply vehicles to the International Space Station (ISS) to transport hardware for experimentation.

Commercialisation has also led to an increase in cooperation between countries in developing space technologies, that were earlier siloed due to the largely confidential nature of governmental space programmes. The internet boom in the consumer industry has greatly benefitted cooperation in space and enabled a global supply chain in the space technology development ecosystem. Due to this, the cost of essential resources has decreased and the accessibility to these resources for a wide range of enterprises has significantly increased in recent years. The growth of the commercial space sector has also ensured that access to space technology becomes more equitable and allows countries whose governments may not want to invest in a space programme to benefit from space-based systems.

The development of space technology can be broken down into two major phases. The first phase involved the creation and use of new materials that are lighter, stronger, and more radiation resistant. The second phase dealt with the creation of products using these materials and ensuring availability to a large

consumer base. Companies such as NoPo Nanotechnologies have been working on improving the material used in space systems and creating material that can resist failure even at extreme temperatures and pressure. They have collaborated with ISRO in the past to create super black coatings for star trackers as well as advanced carbon nanotubes. Larger companies such as L&T have also partnered with ISRO on many projects, including components for most ISRO launchers as well as manufacturing of a deep space networking antenna. This ecosystem has been further encouraged by the 2017 Draft Space Activities Bill which stipulates a role for the non-governmental and private sector in space. ISRO itself has embarked upon a five-step programme that is set to culminate in newly developed technology being put to commercial use in partnership with the private sector.

There are some issues, however, that need to be addressed before private industry can be fully integrated into all aspects of space exploration and technology development. One such issue is the definition and scope of private involvement in the space sector given that governments still consider some domains in space too crucial for national interest to allow private participation. While the private sector is necessary for the growth of the ecosystem, reducing the development cost of space systems and launchers, ensuring simplicity and reliability is a challenge that the private sector needs to overcome.

Advancements in space technology for a more connected India

In the 1980s, Vikram Sarabhai, the father of the Indian space programme, realised that India had to stay abreast with the latest space technologies, not just to have an equal footing in the world but also to improve the quality of life of its citizens. The ISRO had humble beginnings with the initial material being manufactured outside India. The Indian space programme began providing services, even before indigenous manufacturing of related equipment began. Since then, the Indian space programme has grown in leaps and bounds, especially in the realm of rocketry, communications satellites, navigation satellites, remote sensing and science streams. Presently, India manufactures its own equipment like GSAT Mk III with developments in the pipeline such as semi-cryogenic engines. India is taking a lead in developing hyperspectral imagery which is the latest development in remote sensing technology. India has joined the quest to explore other celestial bodies through missions such as Chandrayaan-I, Chandrayaan-II, Mangalyaan, and Aditya. In the decade spanning 2010 – 2020, ISRO has launched 22 satellites. Currently, there are 18 communication satellites, 21 conservation satellites, and eight navigation satellites in orbit. These achievements display the rapid advancements made by the Indian space programme in manufacturing indigenous equipment to fuel its ambitions.

India is moving towards integrated application of different space technologies, the best example of which is the combined use of satellite communication, navigation, and imaging. These technologies are still being used for social welfare purposes. This is evident through advancements in tele-medicine, tele-education, disaster monitoring, and search and rescue. Ventures like village resource centres and e-governance have become relevant for large populations, providing connection to the most remote places while ensuring transparency.

The commercial uses of space technology are also in popular demand. Around 850 to 900 television channels are available to viewers through Direct-to-Home (DTH) services, teleports, and digital satellite news gathering (DSNG) which are made possible through this technology. Communication technology has even made inflight connectivity and maritime connectivity a convenient reality. However, in commercial use of space technology, India is lagging behind in the provision of services. For example, Indian transponders are fulfilling only 40 percent of India's DTH requirements, with the rest being leased. Only a third of the requirements of teleports are being met in-house by India. The ISRO is trying to shore this gap through the launch of new satellites to make Digital India a success. GSAT 11, 19, 20, 29, when fully functional together by the end of 2019, will raise the capacity to 75 gbps of data which will augment the already existing bandwidth on ISRO's satellites. GSAT 22, 23, 24 which are in the pipeline, will help meet the growing demand for more DTH capacity in India.

Internationally, India is helping other countries boost their space technology and resultant services. Apart from hosting payloads and launching foreign satellites, India is also operating South Asian Satellite for the neighbourhood. Recently, India launched 31 replacement satellites with another 30 in the pipeline for other countries. In defence and security, S-band mobile services are being developed and improved, given the identified threat of interference from other countries. Data relay satellites are also being built which will help improve linkage between different satellites. These will act as a sky station by supporting lower orbit satellites, launch vehicles, and manned-missions such as the planned Gaganyaan.

Experts in India are coming up with new space technology in different fields like antenna design, where work is being done on size requirements and steering mechanisms. Another ongoing experiment is the installation of Q/V and optical bands in satellites, to adapt to future requirements. India is increasing its previously poor, indigenous components production with development of Traveling Wave Tube Amplifiers (TWTAs) and Solid State Power Amplifier (SSPAs). India is slowly making its way towards a self-reliant space programme, while continuing to serve both societal and commercial demands. Commercial

broadband application and in-flight and maritime connectivity (IFMC) demand are growing and will open avenues for entities entering the commercial satellite business. The Indian space programme intends to continue supporting a variety of applications even though most countries are following the trend of VSATs migrating to High-throughput satellite (HTS).

To aid in this, the government has created the Indian SATCOM Policy, which amongst other things clearly demarcates the scope of each sector and department. It also lays down the need for cooperation between ISRO, Department of Telecommunications, and the Ministry of Information and Broadcasting. Since Indian national policy heavily favours indigenous manufacturing, the policy while supporting private industries and investments, mandates basing the businesses in India. The implementation of the rules and regulations is effectively overseen by different, well-defined departmental bodies such as technical advisory groups and the INSAT Coordination Committee. While remaining the mainstay of Indian space technological development, ISRO has been flexible and visionary enough to encourage the development of private space industry and gradually include them in all spheres of Indian space technology.

Galvanising a self-reliant space ecosystem in India

There is a need to trace the evolution of India as an industrial capability power, and the need for a strategic partnership between space industry stakeholders and the government. Primarily due to the strategic relationships India has developed with about 30-35 countries in the recent past, it has evolved into a launch pad for global partnerships. Although Indian space missions were initially extremely frugal, the same frugality eventually became a characteristic for Indians to take pride in. Campaigns such as Make in India, and the increasingly popular trend of collaborating with global companies has helped India in gradually emerging not just as a low-cost destination for foreign investment, but a destination that has great engineering talent, great obsolescence support management systems, and engineering outsourcing services. India's space programme has been largely self-reliant, which is remarkable for a country that has never been a manufacturing or designing oriented nation. Apart from the automobile industry that grew in the last 15-18 years, and possibly the hospital equipment manufacturing industry that has also grown in the last few years, India has primarily been either an agrarian economy or an information technology oriented, back-end engineering support focused country. With that kind of background, emerging with its own space capabilities of launching and designing right from scratch has been commendable. In addition, rather than being driven by the changing political narratives in the country, India's space programme has been driven by scientists, who have largely functioned independent of political influence.

However, budgetary constraints have impeded the free functioning of the industry. Owing to the small budget, ISRO has been unable to create a supportive ecosystem for the private sector to engage with the organisation. Indeed, what exists today is not a strategic, forward-looking partnership but a contractual relationship between the private sector and the organisation. Moreover, since private sector companies are hugely dependent on the government for the framework within which they can operate along with a severe lack of state government support for technology manufacturing for Indian businesses, it is difficult to get banks to sanction funds for most projects in the aerospace or space dominated industry. Finally, there is an absence of a coherent policy framework at the national level, which could provide support and guidelines to technology manufacturing businesses, including tax rebates or other advantages of operating in a Special Economic Zone (SEZ). 'Make in India' will remain a rhetoric if ways of operationalising the rhetoric are not discussed and developed. A positive trend emerges through the capability of Indian industrial conglomerates as well as small businesses, and the unabashed rise of engineering outsourcing companies in India. Tech Mahindra, Wipro, and HAL – companies that started as back-end engineering outsourcing offices for global firms – are now billion-dollar businesses with flourishing verticals of aerospace. The biggest need in the space industry in India today is greater private sector participation, and for companies to hunt for the right opportunities, look for funding into gaps that have been identified, and cultivate the right talent to manufacture and run those projects.

CONCLUSION

The success of India's space policy, which continues to be grounded on using space in a sustainable manner and for peaceful purposes must be commended. India reaffirms that outer space is the 'common heritage of mankind' and it is the responsibility of all spacefaring nations to preserve and promote the benefits flowing from advancements in space technology. To ensure that space is used in a sustainable manner and for peaceful purposes, it is imperative that space activities are carried out in accordance with relevant international laws, rules, and regulations. India has been committed to the peaceful use of outer space and believes that space technology can help provide innovative solutions to developing countries for meeting their Sustainable Development Goals (SDGs). In order to advance space technology for development, India has concluded space cooperation programmes with 51 countries and five multilateral organisations, and has helped improve capacity building by training nearly 3,000 officials from some 109 countries.

With the present state of global politics entering a stage of regression, a new arms race in the form of military-oriented applications for space is increasingly

becoming dominant. Negotiations to develop global governance measures, be it legal instruments like the Prevention of Arms Race in Outer Space (PAROS) or political instruments such as the International Code of Conduct for Outer Space Activities (ICoC) have seen little progress over the years. In addition, the lines between nuclear, conventional, cyber and space are blurring and it makes little sense to discuss these domains in silos. Therefore, there is a need for collaboration and integrated conversations between various stakeholders who need to come together to help establish a suitable framework for space policy and governance. Furthermore, there is a need to formulate policies to expand the space economy, which will soon become the backbone of the fourth industrial revolution.

(This special report is a by-product of the discussions and deliberations that took place at the 5th ORF Kalpana Chawla Annual Space Policy Dialogue. The dialogue took place from 29 April to 1 May 2019 in New Delhi.)

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